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Human Ecodynamics in the Late Upper Pleistocene of Northern Spain: An Archeozoological Study of Ungulate Remains from the Lower Magdalenian and other Periods in El Mirón Cave (Cantabria)

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To my little family, which makes life wonderful.

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By

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ABSTRACT

Humans were mobile hunter-gatherers for more than two million years before the Neolithic Revolution, when agriculture and pastoralism led to sedentism. However, significant changes in human behavior and economic systems were accumulating long before. The mobile foraging lifeway developed for thousands of years, so why was it abruptly replaced among most human societies? One possibility is that impactful climate changes during the late Upper Pleistocene (Marine Isotope Stages 3 and 2) drastically reduced environmental viability in many human ecosystems, which were of lesser extent in refugia areas of relatively higher resources diversity. During the Last Glacial Maximum (LGM), about 23,000-19,000 years ago, climate impacted human populations sustained in refugia in southern European regions. Economic adaptations maintained the efficient extraction of resources by primary intensification, but followed by complex diversification processes accumulating with the post-LGM climate improvement and re-expansion from such refuge areas to central and northern Europe.

In this dissertation, changes in human economic strategies and their relationship to climate, demography, and social factors are evaluated based on a throughout archeozoological analysis of the macro-mammal assemblages from late Middle and early Upper Paleolithic, Solutrean, Initial and especially Lower Magdalenian levels of El Mirón Cave (Ramales de la Victoria, Cantabria, Spain) dating between circa 48,000, and 14,500 uncal. BP. Dominated by the ungulates red deer and Spanish ibex, the more than 200,000 faunal remains analyzed with classic and latest methods allow studying the foraging economic behavior in its contexts. This investigation emphasizes the local environmental conditions (by stable isotopes on ungulate teeth, phytoliths in ungulate dental calculus and chemical bone surface staining) and resource exploitation strategies (by archeozoological and taphonomic means to reveal diet breadth and butchering processes) through time and space. Further taphonomic-spatial studies provide the specific sequences of *chaînes opératoires* of animal exploitation, demonstrating multifaceted alterations of economic components by the inhabitants of the El Mirón Cave.

The El Mirón results combined with a meta-analysis of published late Middle and Upper Paleolithic (mainly the Magdalenian period) faunal studies from the Cantabrian region identify moments of dietary economic stress on these human-groups from a broader perspective. The overall results show that humans coped with resource instability through changes in annual mobility during unstable climate conditions. Notably, those

dominant large-game species subsistence strategies mainly increased the use of lower-ranked resources related to possible population growth and dietary stress. Economic adjustments were crucial to encounter the fluctuating distribution of food resources, diversity, and accessibility of the local environment, but varied according to demography and social dynamics. In particular, Cantabrian Lower Magdalenian groups intensified resource exploitation strategies during the harshest, but relatively stable climatic conditions, which is associated with complex (longer) site occupations. The dissertation provides a substantial corpus of detailed archeozoological data from one of the most important Stone Age sites, excavated with modern methods, in this region in recent decades. The work demonstrates how such well-dated, high-resolution insights of site use combined with structured collections of published faunal data improve human behavior analysis and understanding of the dynamics in prehistorical economic behaviors.

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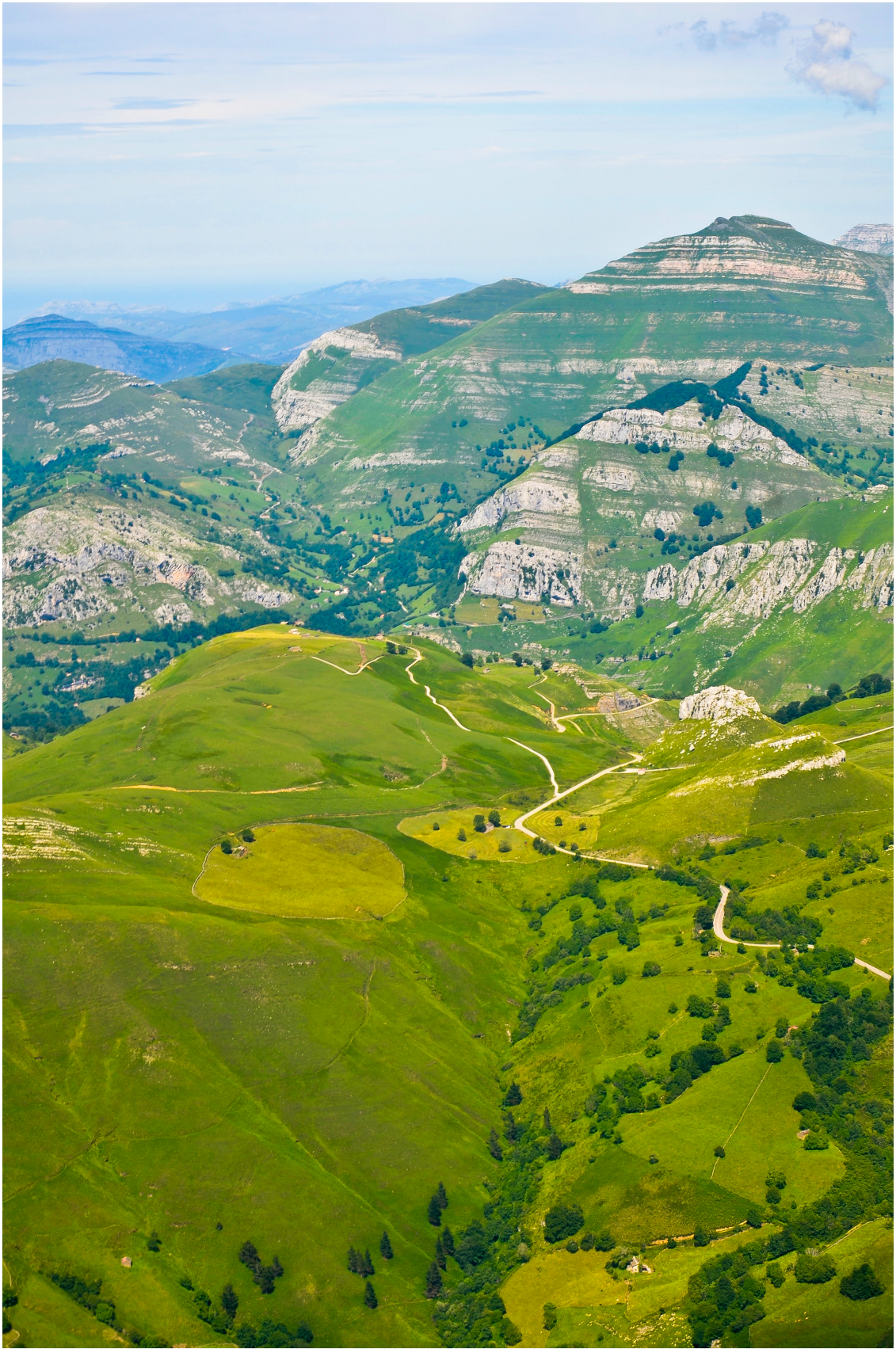
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1 INTRODUCTION

1.1 Human economies

During antiquity of humankind, starting c. 2.6Ma, a major dietary shift occurred from a more chimpanzee-like plant-based diet including large quantities of fruit, and smaller portions of leaves, flowers, bark, insects and some meat (ANDREWS & MARTIN 1991; MILTON 1999; KLEIN 2009) towards the incorporation of more meat, fat, and marrow from small to large animals into the food spectra. Ungulates, then, became a significant resource of early hominids (BUNN 1981), exploited with the earliest stone artifacts (DOMÍNGUEZ-RODRIGO ET AL. 2005; KLEIN 2009; BRAUN ET AL. 2010). They are associated with cut and percussion marks (BLUMENSHINE & SELVAGGIO 1988; DOMÍNGUEZ-RODRIGO ET AL. 2010) or human chewing marks on bones (SALADIÉ ET AL. 2013).

Around that same time, the human ancestor species started to convert natural objects (stones and presumably wood, bark, etc.) into simple tools (POTTS & SHIPMAN 1981; D'ERRICO & BACKWELL 2003; BACKWELL & D'ERRICO 2005; BARSKY ET AL. 2013). Toolmaking marks the beginning of the human ability to adapt and even control natural environments through technology and a significant step in the development of human culture. The definition of technology also incorporates a universal framework of processes or techniques; on 'how' environmental resources can be used (BARTON ET AL. 2011). The complexity and sequence of techniques to exploit local resources, influenced by both the environment and the social system, characterize the economic behavior of particular populations; it is their culture. One upshot of this combining technological, economic, social, and environmental factors should be the applied subsistence strategy of past humans, which enable archaeologists to characterize prehistoric adaptive regimes (QUESADA-LÓPEZ 1997a). The study of regime changes, in particular, gives insights into human response and resilience to environmental uncertainties, ecological risk, demographic shifts, and establishments of innovations (FOLKE 2006; BRADTMÖLLER ET AL. 2017).

Humans were mobile hunter-gatherers before sedentism started, and agriculture only recently led to the Neolithic revolution. Still, some significant changes in human behavior and economic systems had accumulated before that. This opportunistic mobile lifestyle had developed over hundreds of thousands of years, so why was it replaced? In light of significant climate changes that have drastically reduced biological viability in human settlements during the late Upper Pleistocene, but not in the refuge areas that maintained greater biodiversity under severe climatic conditions, some basic behaviors intrinsic to the human species are considerable.

Humans are extraordinarily versatile in adapting their lifestyles to occupy almost all the environmental zones on Earth (BINFORD 2001). While modern-day resilience and carrying capacity of populations often seem to be economically driven, the capability itself is the result of our socio-economic-technological system (KRUMME 2016). In this sense, contribute technological, economic, social, and environmental factors to any dynamic network equilibrium of a human ecosystem, a phenomenon also real when studying past human societies. Further contributes to this underlying assumption that in the context of adaptation to specific environmental changes, humans are flexible to change their behavior, adjust their settlement (mobility) pattern and modify their hunting strategy, i.e., their economy, relatively fast and more efficiently (KELLY 1995; BINFORD 2001; BETTINGER 2009). Adaptation is an essential human ability to be considered when studying the evolution of economic behavior among Paleolithic hunter-gatherers. In such a manner, the encoding of human behavior flexibility and resilience, i.e., ecological niche dynamics, will improve our understanding of what was driving cultural change during the Paleolithic (BANKS ET AL. 2012).

Here I will focus on human behavior studies on the economic system, where information on the context of the macro-mammal, more precisely ungulate, component of the diet will be pivotal. This procedure is feasible for three reasons. First, the evolutionary success of later Pleistocene populations of hunter-gatherers is widely agreed to have depended on a meat- or mammal protein-based nourishment. Such a diet was occasionally supplemented, in varied forms, by secondary dietary resources, such as plants, mushrooms, fish, shellfish, etc. (MILTON 1999). Second, while these other food resources mostly require gathering activity, the consumption of macro-mammal tissue always involves the performance of various tasks. From those tasks, a wide range of human behaviors can be deduced, i.e., weaponry production, game selection, manufacture of processing tools, creation of different storage options, transport, cooking, marrow extraction, etc. Thus, mammal bones provide crucial means to understanding subsistence behavior (PATOU-MATHIS 2000). Third, before farming and sedentism, the hunting economy served as a primary characteristic of hominids that also enabled in addition to that transcultural, diachronic, and spatial comparisons of human behavior (SHIPMAN & ROSE 1983; BRICKER ET AL. 1993). Especially, for reasons to understand cultural change, it is sensible to observe the variation of one component through time and space, where the hunting economy is considered vital for understanding past human behavior and its evolution.

Studying human-environmental interactions in the past encompasses a broad field of anthropological studies, also with an additional current interest since modern-day humans also have to challenge climate change, global warming, sea-level rise, and many more. How specifically can Archaeology contribute to the current debates on the effects of climate change on human life? They can provide observation, analysis, and deep understanding of human-environmental-interactions over the very long-time period of human evolution throughout the climate changes of the Quaternary. Archaeology's "strength is its ability to look at long-term processes, including long-term climate change" and its effect on human society whereby conclusions about human behavior can be derived (NAUDINOT & KELLY 2017: p. 1). Yet, correlating the timing of archaeological, demographical, and environmental phenomena is still a challenge, extensive cultural changes accumulated during the Middle and Upper Paleolithic. Despite the record of changes that took place, their causes and the role played by external factors, such as climate change and demography, are still hotly debated. This dissertation seeks to understand better how humans adapted their cultural behavior to challenging climate changes.

It is, therefore, essential to understanding climate processes. Since climate change profoundly influences the environment, it has varied effects on the ecosystems and its constituent species, too. Such climate changes also affect prey-predator interaction through abundance, disappearance, or geographical shifts of faunal species, including human populations and flora distributions (HOLLING 1959, 2001). Humans have long been predators with a generalist dietary tendency (KELLY 1995) with a subsistence relying on a variety of resources. Thus, the climate-driven collapse of one prey species would not necessarily directly influence the entire food supply. Humans will adapt their diet according to residential species diversity (STINER & MUNRO 2002: p. 186). If the availability of predator species in the faunal community changes, the hunted prey composition or their prey preferences will change (WINTERHALDER ET AL. 1988). Prey compositions changes in archaeological material can be the result of shifts in prey behavior (micro-habitat depressions) or exploitation depressions, according to optimization theory (MUNRO ET AL. 2004).

This opportunistic mobile lifestyle had developed in humans over hundreds of thousands of years, so why was it replaced? One possibility is that notable climate changes during the late MIS3 and MIS2 have drastically reduced viability in European human settlement areas, but not in southern refuge areas that maintained biodiversity under severe climatic conditions. In the context of the climatic fluctuations, the Last Glacial Maximum (LGM) was the coldest and driest period of harsh climatic conditions of the Last Ice Age. Despite that, the LGM also exhibited a long interval of relatively high environmental stable, but cold conditions during the Terminal Pleistocene. Such relative environmental stability gave time for ice age-hunter-gatherers to

adapt well to the open landscapes, also in southern Europe. From a broader perspective in human ecology, the end of the LGM period was probably ecologically traumatic. Environmental and large-game predictability faded as the world moved towards warming conditions of the Holocene interglacial.

The degree of successful economic behavior determines survival or extinction in animals during changing climate conditions, and this is reasonably true for humans, too. So, dealing with this topic is evolutionarily crucial, as un-economic behavior will lead in the long-term to extinction. But here we are still: *Homo sapiens*, the survivor of several glacial and interglacial cycles that involved several dramatic climatic shifts. Within ecology, the worsening of environmental conditions that limit the occupied ecological niche usually means that the niche occupiers either held on until the conditions improved again or a new strategy examined; this is called adaptation. Both tactics can involve varying degrees of behavior change. How this applies to human economic systems, is still in question. The study of Paleolithic hunter-gatherer economies explores how people obtain their material and nutritional needs from the surrounding environment. The field of human behavioral ecology helps to understand triggering factors involving human decision-making, e.g., to explore the optimality of the foraging system (SMITH ET AL. 1983; FOLEY 1985; KELLY 1995; WINTERHALDER & SMITH 2000). Lithic and faunal remains together, when the latter are preserved, can give manifold insights into different Paleolithic hunter-gatherer activities (STRAUS 2006), from which diet-related behaviors make up the bulk of daily activities. In the ethnographic present, hunter-gatherers cover circa 80% of daily nutritional needs with meat (BINFORD 1981), and a similar interpretation provide prehistoric evidence from stable isotopes and dental calculus analysis of a Lower Magdalenian human burial in El Mirón cave in Spain (GARCÍA-GONZÁLEZ ET AL. 2015; POWER ET AL. 2015). Some Neanderthals even had as much as a 100% carnivorous diet, at least in northern Europe (RICHARDS ET AL. 2000; JAOUEN ET AL. 2019). Thus, it is evident that quantified macro-mammalian remains from archaeological sites are a critical resource for interpretations of human daily activities and behavior.

Prehistoric human behavior is generally studied by its cultural remains (archaeological material), including, among others, the technology of stone tool products or the composition of stone and organic weaponry. The variation among assemblages may represent different cultural entities or site functionality—or even accidents of archeological sampling (STRAUS 2006). The dynamic character of change among these assemblages is, however, difficult to interpret in light of a static record. It is possible, however, to compare the differences in terms of quantitative, measurable data with other objective factors to determine the significance of any correlations, surely always after determining type and degree of taphonomic alterations. A multifactorial approach might allow researchers to test whether material/environmental/demographic changes coincide or certain factors interact. One method of how archaeologists explore hunter-gatherer behavior development and cultural change through time for gaining knowledge about past human life is by assessing the optimality in subsistence strategies. Changes in subsistence strategies might occur in interrupted fashion or spontaneously rather than gradually, as they might reflect economic responses to varying conditions in the habitat. Adapting different economic strategies might have several motifs, such as demographic, environmental, or cultural ones. These may be factors triggering the subsistence strategy applied by people. When periods are disadvantageous for the subsistence strategy employed, societies developed various risk-reduction strategies such as mobility, prey diversity, storage, and exchange (WILKINSON & STEVENS 2003).

Economic intensification or diversification trends and settlement reflect such risk strategies. For example, such changes in the technology of lithic assemblages, population turnovers, or modifications in settlement patterns indeed coincide with climatic changes (BRADTMÖLLER ET AL. 2012; SCHMIDT ET AL. 2012; MARREIROS & BICHO 2013). Nevertheless, when fully considering the ecodynamics acting in the background of these models, one should also include an in-detail subsistence reconstruction that backup the daily nutritional needs.

Discussions of the reasons behind past changes in human behavior, particularly in subsistence strategies, are ongoing, and concerning especially the period of the Middle-to-Upper Paleolithic transition and the Pleistocene- Holocene transition in the archaeologically rich Cantabrian region (Northern Spain), with its long research tradition (ALTUNA 1972; FREEMAN 1973; STRAUS & CLARK 1986; STRAUS 1992; QUESADA-LÓPEZ 1995; YRAVEDRA 2002; JONES 2007; GUTIÉRREZ-ZUGASTI 2010; MARÍN-ARROYO 2010; STRAUS ET AL. 2015d; ANDRÉS-HERRERO ET AL. 2018), as well as beyond that region along the continent (GRAYSON & DELPECH 2003; MÜNZEL & CONARD 2004; MARÍN-ARROYO 2011; RIEL-SALVATORE & NEGRINO 2018; RENDU ET AL. 2019), to mention a few examples. During Marine Isotope Stage (MIS) 3 and MIS2, global climate fluctuations marked by rapid temperature and humidity variations were manifested in the mid- and high-latitudes of Europe by marked environmental changes with dramatic effects on human populations (DANSGAARD ET AL. 1993; DOWDESWELL & WHITE 1995; VAN ANDEL & TZEDAKIS 1996; D'ERRICO & SÁNCHEZ-GOÑI 2003; NAUGHTON ET AL. 2009; HARRISON & SANCHEZ GOÑI 2010; MORENO ET AL. 2012).

Transitional industries are highly debated topics in archaeology, and indeed, characterize archaeologically often periods of regime change (i.e., compositionally mixed material culture). These periods may help reveal how human groups can react in a resilient fashion on an evolutionary timescale. For example, the so-called Middle-to-Upper Paleolithic transition encompassed the process of Neanderthal disappearance and Anatomical Modern Humans (AMH) arrival in Europe, wherein dates of both cultural phases (Mousterian and Early Upper Paleolithic) overlap for about 5000 years (MELLARS 2006; BENAZZI ET AL. 2011; HIGHAM ET AL. 2014; HUBLIN 2015). While the state of cultural development among the different hominin groups, their demographic interchanges, or subsistence competition (including AMH, Neanderthals, and now other archaic human species in Eurasia such as Denisovans) have been part of a long debate. In search for reasoning for the possible evolutionary success of one over the others (D'ERRICO ET AL. 1998; PÄÄBO 2015; ROEBROEKS & SORESSI 2016), our understanding of the dynamics of cultural development *per se* remains far from complete. On the Middle-to-Upper Paleolithic transition, initial arguments questioned the cultural and physical capacities of Neanderthals versus those of AMH (AIELLO & WHEELER 2003; SHEA 2008; KLEIN 2008; WYNN ET AL. 2016) to later argue for general differences on a behavioral level, often in terms of subsistence (DISCAMPS ET AL. 2011; EL ZAATARI ET AL. 2016). The decoded Neanderthal genome confirmed a sexual interaction of these two human groups, at least on the reproductive level; about 1-4% of Neanderthal DNA exists within the living non-African human population (GREEN ET AL. 2010). Cultural exchange by a measure of mobility and social interaction is not excluded entirely with the existence of so defined cultural transitional industries such are the Uluzzian (MORONI ET AL. 2013; VILLA ET AL. 2018) or the Châtelperronian (HARROLD 1981; ANDRÉS-HERRERO 2009), where only the latter is of Neanderthal origins (WELKER ET AL. 2016). How culture development, often connected with debates about climatic (BANKS ET AL. 2008; HOFFECKER 2009; NIGST ET AL. 2014), demographic or social reasons (STRAUS 1992; ZILHÃO ET AL. 2010; MELLARS & FRENCH 2011; WHALLON 2011; VILLA & ROEBROEKS 2014) is related to mobility is not solved. Different theories generally involve human migrations, invasions or displacement, and the evolution, adaptation, survival, or replacement of cultural-technological traditions. Further, in the recent focus of debates about cultural change are the Gravettian-Solutrean (RIPOLL LÓPEZ & RIPOLL-PERELLÓ 1990; RASILLA-VIVES & STRAUS 2004; CALVO & PRIETO 2013), Solutrean-Badegoulian-Initial-Lower Magdalenian (STRAUS 1975, 1990; BOSSELIN & DJINDJIAN 1999, 2000; STRAUS & CLARK 2000; TORTOSA 2007; CORCHÓN-RODRÍGUEZ 2009; ÁLVAREZ ALONSO & ARRIZABALAGA 2012; AURA-TORTOSA ET AL. 2012; FONTES 2016b) and Upper Magdalenian–Azilian-Epipaleolithic (QUESADA-LÓPEZ ET AL. 2001; FERNÁNDEZ-TRESGUERRES VELASCO 2006; MARÍN-ARROYO 2007; GONZÁLEZ-MORALES & STRAUS 2012) transition periods, with the Cantabrian region again a key area of inquiry.

In the last two decades, researchers increasingly investigated rapid climatic changes during the last glacial period and how these may have driven variation in cultural, economic and demographic processes (D'ERRICO & SÁNCHEZ-GOÑI 2003; SEPULCHRE ET AL. 2007; BRADTMÖLLER ET AL. 2012; SCHMIDT ET AL. 2012). Important

chronological information in the form of new radiocarbon dates from archaeological levels and climatic records provide progressive archaeological work and methodological updates. With more precise data, the possibility arises to build up a chronology of settlement and mobility patterns, through which economic behavioral changes of Paleolithic hunter-gatherers in possible relation to climatic alterations can be integrated and studied (STRAUS 2000; STRAUS ET AL. 2000a, 2000b; GAMBLE ET AL. 2005; CREMA ET AL. 2014; SILVA & STEELE 2014; FERNÁNDEZ-LÓPEZ DE PABLO 2016). Such an analysis is the research work at hand.

We need to elucidate further the dynamics behind human decision-making and to establish patterns of economic behavior in the past. This research approach here is summarized under the term 'Human ecodynamics' and explained further in what follows, but its primary material of study is archaeological macro-mammal remains. Since archeozoological data allow researchers to reconstruct the subsistence strategies followed by humans as reflecting economic practices, the viability of these practices is intrinsically linked to environment-climate factors, as well as to demographic factors (SPETH 2004). Faunal remains provide direct evidence of subsistence strategies, which, in consequence, can be used to test hypotheses about cultural or economic human behavior. The question of subsistence change and the dynamics behind economic decisions are, therefore, inherent as paramount characters, when attempting to learn about Paleolithic human behavioral change.

1.2 The Cantabrian Region

The importance of the Cantabrian research region (Figure 1.1) to realize such studies was already hinted above as for manifold reasons, but mainly some of which include a long research tradition, the existence of numerous caves in the region (many with archeological deposits), and distinctive regional topography. Within this context, the Cantabrian research region offers a wealth of archaeological data, including many archaeological sites dating to transitional periods on the Iberian Peninsula (e.g., Marín-Arroyo et al., 2018; Wood et al., 2014). The discussion of cultural relations (including competition) and its consequences significant in Iberia since Neanderthals may have survived much longer than in other parts of continental Europe (HIGHAM ET AL. 2014). The unique environment of the Cantabrian coast might have been a factor in all long-term human persistence due to its preferred habitat conditions. In particular, that includes high topographic relief with many short river valleys, coast and mountains nearby, and complex karstic bedrock in much of the region; it is the south-western-most part of the Euro-Siberian ecozone (FREEMAN 1973; STRAUS 1992). Various genetic-phylogeographical studies have shown how this situation led specifically the Cantabrian region, together with Southwest France, the Italian Peninsula and the Balkan region, to become refugia for animals and plants [in particular for brown bear (TABERLET & BOUVET 1994), red deer (SOMMER ET AL. 2008; MEIRI ET AL. 2013), Atlantic salmon (CONSUEGRA ET AL. 2002), common meadow grasshopper (COOPER ET AL. 1995), hedgehogs (SANTUCCI ET AL. 1998) and oak trees] from which they reoccupied European biota in Late Glacial times (HEWITT 1999, 2000). The Cantabrian region, during periods of severe climatic conditions and rapid climatic fluctuations consequently, seems to have also served for Paleolithic Anatomically Modern Humans as European Ice Age refugia (STRAUS 1991; STEWART & STRINGER 2012), although not as a refuge for Neanderthals past c. 42 kya (MARÍN-ARROYO ET AL. 2018b). Recently, several genetic analyses have demonstrated that the human repopulation of north-west Europe after the Last Glacial Maximum originated at least in part from here (POSTH ET AL. 2016; FU ET AL. 2016; VILLALBA-MOUCO ET AL. 2019; OLALDE ET AL. 2019) as long predicted by archeologists (e.g., JOCHIM 1987; STRAUS 1991).

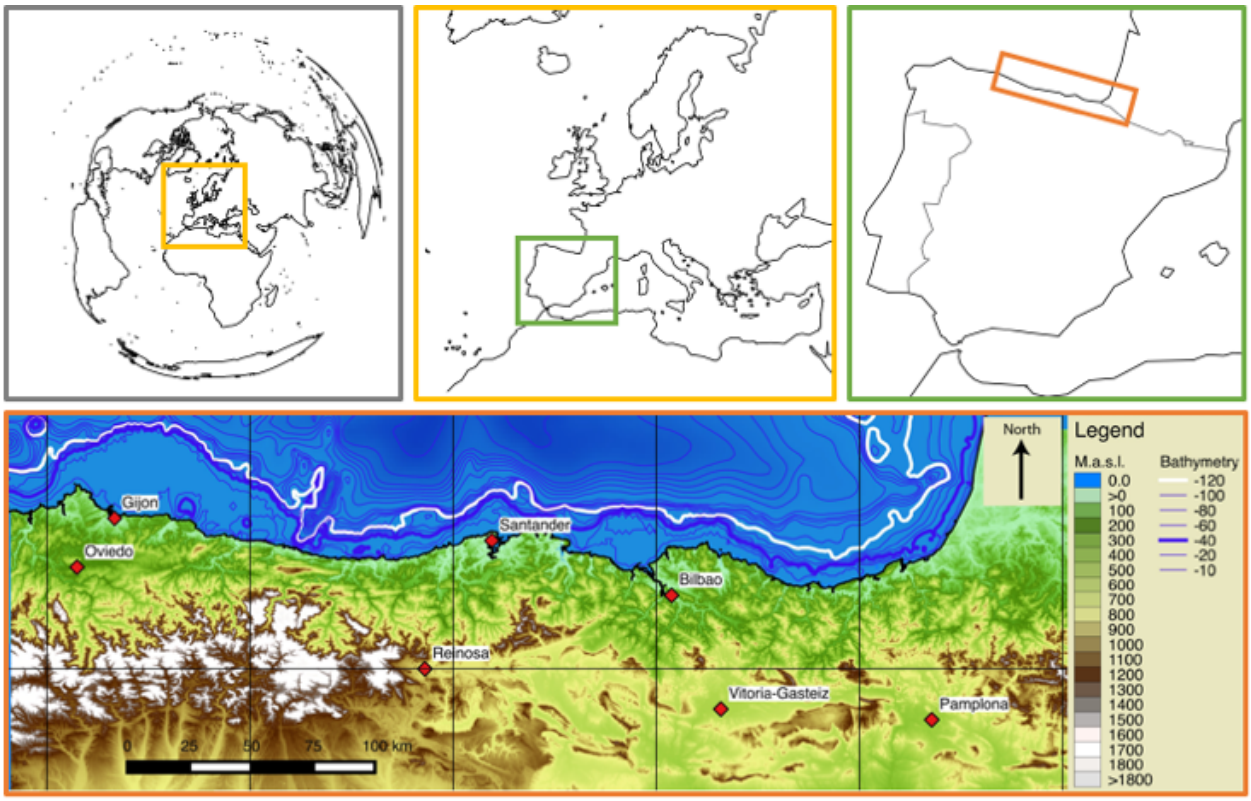


Figure 1.1: The Cantabrian region located in Northern Iberia, Spain. (Digital elevation model by JMG)

In the Cantabrian region, significant economic changes took place from the Late Middle Paleolithic and Early Upper Paleolithic (Aurignacian and Gravettian) with a relatively opportunistic diet, to more specialized and productive economic strategies employed during the Tardiglacial, corresponding to the Early Magdalenian, and to an again more diversified diet beginning with the Upper Magdalenian (17-11.5ka uncal BP approximated) (MARÍN-ARROYO 2008, 2009a). The Solutrean and the first moments of the Magdalenian represent a crucial transition period in the evolution of hunter-gatherer societies and their relationship with the environment (STRAUS 1977, 1983, 1992; STRAUS & CLARK 1986). Subsistence strategies indeed focused on the most productive animals (red deer and ibex) while maintaining the use of a variety of resources. While exploiting a broad spectrum of the capacity of the environment, some of these resources are notoriously lower in calories (YESNER ET AL. 1980) including harvesting of coastal mollusks and some fishing (notably salmon and trout) in rivers and estuaries (STRAUS 1977; STRAUS & CLARK 1986; QUESADA-LÓPEZ 1997b). Researchers believe that from the combination of a high carrying capacity of the exploited ecosystem, a variability of habitats involved, and a moderate competition for resources might have increased human occupations (STRAUS 1980, 1981). As a consequence, population packing leading for the first time to effects of territorial confinement, especially as the Magdalenian developed.

In this context, the Solutrean and early Magdalenian periods reveal critical moments of change in economic behavior towards intensified resource exploitation by hunter-gatherer societies and their relationship with the environment, at least in the Cantabrian region. Despite the implications of these changes, their causes are still not well-understood, and the exact role played by climate and demography is poorly known. The paleontological studies of Altuna and Castaños and the works of Freeman and Straus constitute fundamental starting points of faunal studies (ALTUNA 1972; FREEMAN 1973; STRAUS 1983; CASTAÑOS 1986; MARÍN-ARROYO 2010) as well as how the Paleolithic-Holocene transition impacted human economic studies (ARIAS-CABAL 1991, 1992; GONZÁLEZ-SAINZ & GONZÁLEZ-URQUIJO 2004), but they must be completed with more research. As

this period spans the end of the LGM and the Late Glacial, leading into post-glacial conditions, significant climatic changes had essential impacts on humans. At least reduced hunting territories due to advancing ice shields and areas of periglacial 'deserts' during glacial periods are known to have existed in northern and continental Europe. There is no Solutrean North of the Loire/Seine valleys due to harsh (cold and mainly dry) climatic conditions, during which the human range contracted to southern European refugia (STRAUS 1991; DJINDJIAN 2016). Early Magdalenian sites found in central Germany (KÜßNER & TERBERGER 2006; TALLER 2014), although, challenged the idea of an empty northern Europe. Researchers agree about at most limited occupations of north-central Europe during relatively moderate climatic fluctuations within the LGM. Possible human responses were manifested behaviorally by either changing land-use strategies, hunting practices, or demographic shifts, all of which must have left traces in the material culture (STRAUS 2015, 2016, 2019). Binford (1968) and Flannery (1969) first proposed demography as the crucial factor and primary driver of economic change referred to as *Broad Spectrum Revolution*, which also served explanatory for behavioral change in following studies (BETTINGER & BAUMHOFF 1982; GRAYSON & DELPECH 1998; STINER ET AL. 1999, 2000, 2008; BURGER ET AL. 2005; HILL 2007). Human demography is relevant not only in terms of modern human dispersal routes out of Africa, but especially during the initial occupation of Europe by modern humans, whereby extensive social networks were already being established during the Aurignacian, if not earlier. The dispersal of populations across Europe is vital for understanding demographic density and socio-spatial organization for specific periods. Still, it is challenging to obtain the necessary hard data on density from archeological materials (SCHMIDT & ZIMMERMANN 2019). Some socio-spatial information might be accessible to a certain degree through Paleolithic art, where similar artistic styles might infer group identities, human movements, idea exchange, or trade of objects within a social community (CONKEY ET AL. 1980; SAUVET 2019). Within demographic networks, however, local scale mobility patterns seem to be inherently linked to social organization and resource distribution (e.g., production of material culture).

However, archaeologists still know relatively little in detail about how Cantabrian hunter-gatherer groups endured and how resilient they must have been. New research involving spatial analysis of faunal materials studied under modern archaeozoological and taphonomic techniques, under the integration of climatic and paleoenvironmental reconstruction, build upon the study of stable isotopes in bones and teeth is needed to explore this subject further, and this is what this dissertation project seeks to do.

1.3 Objectives and structure

Studying how human-environment dynamics influence human behavior summarizes the main objective of this dissertation. Once obtained, our understanding will be improved as to how and why human populations adopted specific subsistence strategies and settlement systems by considering the influence of climatic, demographic, and social factors. Together, this information will enable us to assemble and produce an economic model for the site-locality, region, and time of the study, with broader, extra-regional implications on human behavior. Examining the role of the Cantabrian region as one of the critical European refugia under severe climatic conditions during the Terminal Pleistocene, contextualize subsequent the general results. Archeo-faunal data are particularly appropriate to make long-term observations of human behavior, and to study its evolution as some food acquisition from animal resources is present in most archeological site as bones are common objects in Paleolithic occupations.

Selected faunal materials from El Mirón cave (Figure 1.2) spanning a sequence covering the Late Middle Paleolithic, Early Upper Paleolithic (Gravettian), Solutrean, and Magdalenian, especially Lower Magdalenian, located in the eastern zone of Cantabria (STRAUS & GONZÁLEZ-MORALES 2012) were studied diachronically. These reconstructions of aspects of the paleoeconomic activities carried out by hunter-gatherer groups in

the Cantabrian region of Spain scrutinized archeological materials. Chronological speaking, this research concentrates on late MIS3 - MIS2 data (~48-10ka cal BP), centering on the evolving Solutrean and onset of the Magdalenian period, spanning the period before, during and after the LGM in a broader context.

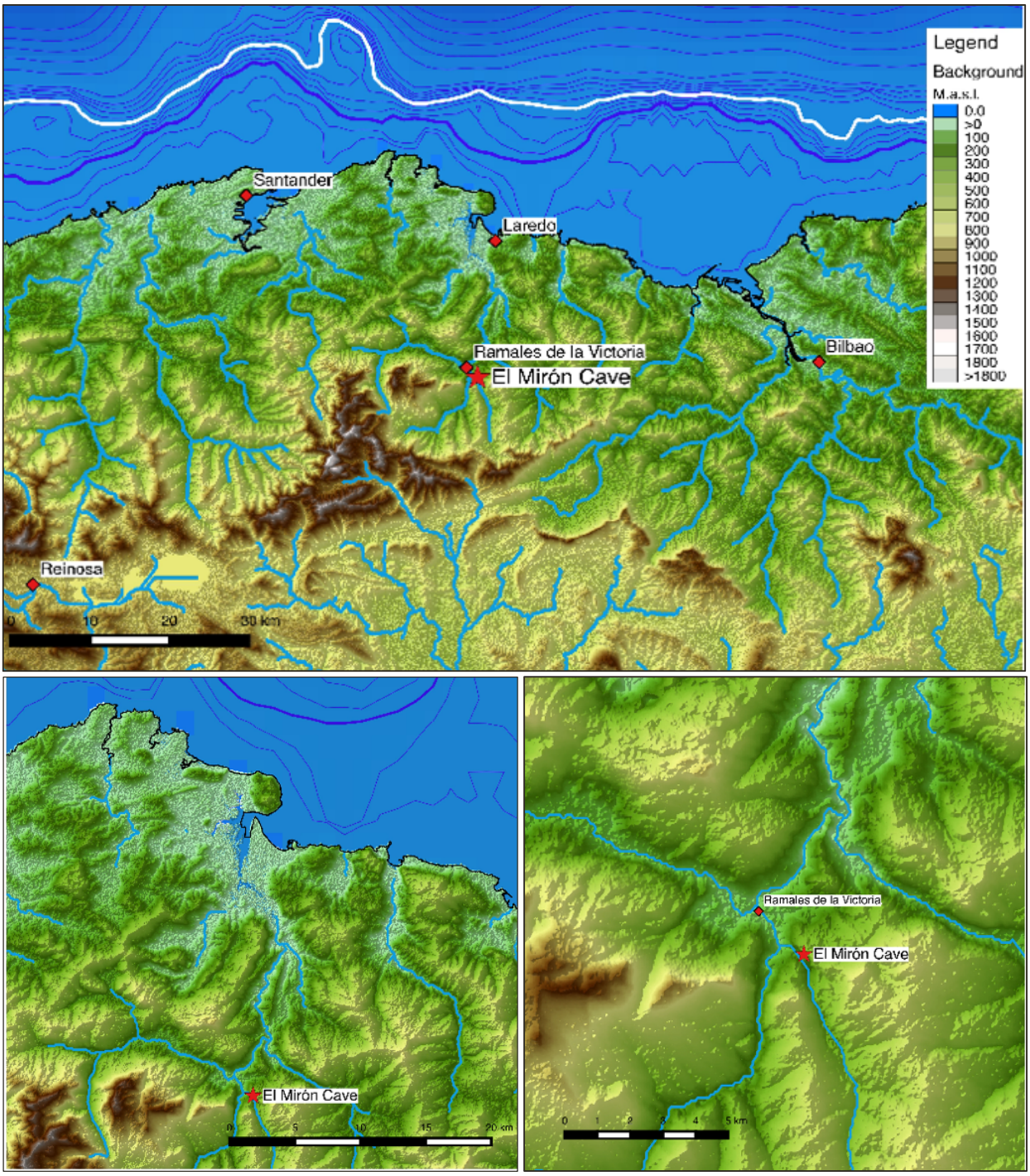


Figure 1.2: The Asón river valley is situated midway between Santander and Bilbao cities, on the Cantabrian mountain border, close to the town of Ramales de la Victoria. El Mirón Cave is located in the upper Asón valley. (Digital elevation model by JMG)

To accomplish the main objective, the author will reconstruct paleoeconomic and paleoenvironmental conditions for the addressed cultural period in El Mirón Cave, located in Ramales de la Victoria (Cantabria, Spain). With 92 radiocarbon dates, El Mirón cave holds deposits that attest long, frequent (semi-continuous),

and sometimes only ephemeral human use from the late Middle Paleolithic until the early Bronze Age, and even into the modern era (STRAUS & GONZÁLEZ-MORALES 2003, 2007, 2010, 2012, 2018; STRAUS ET AL. 2015c). The site was excavated between 1996 and 2013 under the direction of Lawrence G. Straus (University of New Mexico) and Manuel R. González Morales (Universidad de Cantabria), using modern excavation standards that included rigorous and up-to-date documentation and thorough collection of materials. A multidisciplinary team of researchers has conducted the research, including archeologists, geologists, micro-morphologists, archeozoologists (micro, macro, malacofauna), taphonomists, palynologists and lithic micro-wear analysts with the aid of modern geochemical, stable isotopes, ancient DNA (deer and salmon) techniques and Geographic Information Systems (GIS) (HERMOSO-BUXÁN Unpub.; ELLWOOD ET AL. 2001; STRAUS ET AL. 2001, 2008, 2014, 2015, 2016, 2018; COURTY & VALLVERDU 2001; CONSUEGRA ET AL. 2002; RISSETTO 2005; PEÑA-CHOCARRO ET AL. 2005a,2005b; NAKAZAWA 2007, 2007; STRAUS & GONZÁLEZ-MORALES 2007, 2012a, 2012b, 2012b, 2018, 2019, 2020; GONZÁLEZ-MORALES & STRAUS 2009; MARÍN-ARROYO 2010; ZURRO 2010; CUENCA-BESCÓS ET AL. 2012; CUENCA-BESCÓS & GARCÍA PIMIENTA 2012; FARRAND 2012; MEIRI ET AL. 2013; STEVENS ET AL. 2014; FONTES 2016; GEILING ET AL. 2016). All these factors ensure excellent contextualization for the dissertation project at hand, as demonstrated in previous doctoral theses and publications.

In El Mirón Cave, there are were Late Middle Paleolithic, Gravettian, Solutrean, and Initial-Lower-Middle-Upper Magdalenian deposits excavated in the Inner Vestibule (or Corral area), Lower-Middle-Upper Magdalenian and Azilian levels in the caves's Outer Vestibule (or Cabin area) and the connecting Mid-Vestibule trench. Many of the occupation horizons (especially those of the Initial and Lower Magdalenian) are extraordinarily rich and well-preserved (STRAUS ET AL. 2008). These conditions ensure that the obtained results will be meaningful for reconstructing human paleoeconomic activities. The cave located in the upper Asón valley, at a moderately high altitude (260 meters above the Holocene sea level) in the first chain of the Cantabrian Cordillera (summits ≤1000 m) and with easy access to the valley floor 150 m below, is also essential and will allow comparison not only with other contemporary montane sites in the region (e.g., Rascaño, Amalda) but also ones on the coastal plains (e.g., El Juyo, Morín, La Riera) or in-between (e.g., Las Caldas, El Castillo). It is the aim to characterize aspects of social organization, seasonality, the function of occupations, and the mobility pattern of the human groups that occupied the cave during the Late Upper Paleolithic (especially Lower Magdalenian period). Here are relevant aspects within site and the wider territory, notably the Asón Valley with several other Magdalenian sites in its upper, middle, and lower segments. The macro-mammal faunal remains (mainly ungulates) are analyzed from taphonomic, archaeozoological, spatial, and paleoenvironmental perspectives. By using a multifactorial approach, those various aspects of the faunal remains are studied in an accumulative way. Concerning the dynamic factors behind human subsistence strategies is investigated seasonality, human dietary preferences, resource exploitation, demography, changing environmental conditions, and other aspects of additional information regarding the use of the cave and the possible functional relationships of the faunal assemblages with the associated lithic industries. The inferences on human behavior resulting from the present study will enrich our understanding of human nature.

The research approach of this dissertation focuses on the study of subsistence strategies adopted before, during, and after the Last Glacial Maximum (LGM), to suggest the driving factors of Upper Paleolithic paleoeconomic behavior as carried out by hunter-gatherers during the Terminal Pleistocene. The extensive Paleolithic records of the Cantabrian region are useful for contextualization of the rich El Mirón records from contemporaneous archaeological remains and to establish a picture of the diachronic evolution of subsistence strategies. This study aims at reconstructing how global climate change affected (or not) landscapes and human ecological niches and, in consequence, human paleoeconomic behaviors. Ultimately this should lead to a better understanding of the role played by the Iberian refugium in European Paleoecodynamics.

Since human behavior change is not a single-cause model, to answer the central hypothesis of this project, several subordinate assumptions formulated covering the varied stimulus on economic adaptations according to the above-outlined matter of influence. They are as follows:

- Main hypothesis: Changes in human behavior are economically driven, directed by changes in resource availability. In the human past, significant climate changes have, at times, drastically reduced the environmental viability in human settlements, but not in the refuge areas that maintained biodiversity under severe climatic conditions. The past human groups that endured such times were those of hunter-gatherers who usually or ultimately adopted the strategy that maximized energy return regarding resource accessibility.
- Hypothesis 1 (H1): Dynamics in climate variability influenced directly past human behavior since many hunter-gatherer tasks were animal-related. When the climate changed diversity, access, and volume of animal resources in human-inhabited environments, human groups adapt their subsistence strategies accordingly.
- Hypothesis 2 (H2): Population dynamics influenced economic strategies. Increasing population sizes provoked resource stress, territorial confinement, and (conceivably) marked territoriality; all are lowering the local carrying capacity of the environment and leading subsistence strategies to adapt according to changes in demographic conditions.
- Hypothesis 3 (H3): Social networks are the common highways for exchanging knowledge and opportunities for cultural transmission of both new ideas and cultural restrictions. If social memory stored information on situationally better subsistence strategies, people often adopted new lifeways.

According to the current interest in the objectives, the importance of this thesis has multiple levels of significance, as it will be of local, over-regional, and overall value for European Paleolithic research.

On a local level, the project presented here complements the archaeozoological studies carried out in El Mirón cave by Altuna and Mariezkurrena and by Perez-Ripoll and Lopez Gila for the Holocene levels (ALTUNA ET AL. 2004; ALTUNA & MARIEZKURRENA 2012; PÉREZ-RIPOLL & LÓPEZ-GILA 2012; STRAUS & GONZÁLEZ-MORALES 2012) and by Marín-Arroyo for the Pleistocene/Holocene transition until the end of the Tardiglacial (MARÍN-ARROYO 2007, 2010). The results of this project will fill the gap in faunal studies conducted to date from the beginning of El Mirón occupations (dated to the Late Middle Paleolithic) until the Late Lower Magdalenian period. Furthermore, it will evaluate the role that local environments (micro-environments) played in the development of subsistence strategies at the site in contrast to the regional climate (macro-level). The results will allow reconstruction of aspects of changes in economic and social behavior for the periods under study, making it possible to explore potential chronological variations in site use and the human territorial organization of wider geographical areas. It will evaluate whether existing settlement-subsistence models for the Magdalenian of the Cantabrian region are applicable in the case of eastern Cantabria (STRAUS 1986; MARÍN-ARROYO 2009b).

On a regional level, in particular, this thesis will study how and why human populations adopted certain economic and spatial patterns in the Cantabrian region. Research focuses on the evolution of the Paleolithic environment, the influence of climate and demography in emerging economic changes, e.g., intensification processes; also recognized as dietary diversification vs. specialization (BINFORD 1968; STRAUS 1977, 1991, 1992; STRAUS & CLARK 1986; BROUGHTON 1994; GRAYSON & DELPECH 1998; STINER ET AL. 1999, 2000, 2008; CANNON 2000, 2003; GRAYSON 2001; WAGUESPACK & SUROVELL 2003; HILL 2007).

On an overall level, the thesis will focus on the verification of hypotheses about the determining factors of subsistence strategies and the influence of micro-environments and demography in significant economic changes. Furthermore, this project will examine the impact of climate in forager livelihood strategies. With the help of the analyses presented here, the author will formulate a general human behavior model *in sensu lato.* Such a model will constitute a theoretical update on the interpretational framework for understanding past foraging societies and changes therein, which is projectable to larger regions and over-regional useable. A whole set of complementary and newly developed methods is applied to improve the interpretational framework in archeozoology: they include bone micro-fragment analysis, stable isotope analyses (carbon and oxygen isotopes in carbonates, oxygen in phosphates, and strontium), analysis of phytoliths in the dental calculus of herbivores, GIS-based spatial analysis, Bayesian inference of skeletal profiles and chronological modeling. Correlating these separate lines of evidence is a crucial step forward to better understand past subsistence systems. The elaboration in methods highlighting specific archeological features has an overall benefit; while serving to examine varied ranges of activities and deciphering palimpsests, they represent significant access points for reconstructing past human behavior from archaeological records.

In a broader sense, this research seeks to unravel and understand how and why human populations adopted specific economic and spatial patterns. The multifactorial approach applied here will help to investigate the economic and social behavior of Late Pleistocene humans comprehensively.

In short, this dissertation advances knowledge about how human groups were able to react to environmental changes and variations in available resources, with the ultimate goal of identifying the evolutionary strategies that ensured the success of the human species over the long term despite reasonable periods of increased dietary stress.

Following this introduction (Chapter 1), Chapter 2 summarizes relevant aspects of the current knowledge on Upper Paleolithic subsistence strategies, the role of the northern Atlantic Iberian refugium, and provides the definitions and interpretational framework of paleoeconomic dynamics as used in this dissertation. Chapter 3 describes materials and methods. The results of the faunal analysis from El Mirón cave are presented in the 4th chapter, addressing taphonomic and archeozoological outcomes, an evaluation of the camp organization, site use, and results of stable isotope analysis accompanied with dental cementum phytolith analysis. Chapter 5 presents the paleoeconomic reconstructions from a diachronic viewpoint for El Mirón cave and the Cantabrian region. The synthesis of results and discussion of modeled human behavior are united in Chapter 6. Chapter 7 contains the trilingual summary of the dissertation. Finally, a critically important appendix provided the relevant datasets for the archeofaunal assemblages of several El Mirón levels.

CHAPTER 2: STATE OF THE ART



Edge of the Cantabrian Cordillera and Rio Asón Estuary

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2 STATE OF THE ART

This dissertation investigates past economies in the Cantabrian region (North-central Spain) and aims to perceive the driving factors of paleoeconomic adaptations. Therefore, the state of the art is organized accordingly. In order to contextualize the subsistence strategies carried out by Paleolithic hunter-gatherers in Northern Iberia and their evolution, this chapter reviews different subtopics related to the here proposed approach. The historiographic summary represents the relevant archaeological research on faunal remains, and a survey of the Late Pleistocene archaeological research in the Cantabrian region. The relevance of El Mirón Cave in the Cantabrian region follows a portrayal of the northern Iberian refugium; both build the archaeological case study to deciphering the primary question of interest showing the broader approach of studying human behavior change. Finally, a multidisciplinary approach proposes improving the understanding of human behavioral change that considers how subsistence strategies developed throughout time in this region. This chapter also highlights the potential of spatial analyses and the relevance of these regions' paleoclimate conditions.

2.1 Historiography of Cantabrian faunal investigations (late MIS3-MIS2)

To understand how economic studies developed in the Cantabrian region, first the scientific works contextualizing Paleolithic archaeological faunal remains found in this area will be considered. The initial fundamental scientific attention on the Cantabrian Paleolithic record was brought by Marcelino Sanz de Sautuola with his discovery of Altamira cave art and associated Upper Paleolithic artifacts (SAUTUOLA 1880) during the time of the early growth and dominance of French prehistory. Various works of Emile Cartailhac (finally recognizing the validity of Altamira art), Henri Breuil, Alcalde del Rio and Lorenzo Sierra (Paleolithic rock art discoveries and documentation at Altamira, Covalanas, La Haza, El Castillo, El Valle, etc.), Jesús Carballo (Morín, El Pendo; creation of Regional Museum of Prehistory and Archaeology of Cantabria in 1926), Hugo Obermaier (excavation of El Castillo in 1911-14 and Altamira in 1924-25), Jean Bouyssonie (El Valle 1909-11), E. Hernández Pacheco (La Paloma in 1914-15), T. Aranzadi, J.M. Barandiarán and E. Eguren (Santimamiñe 1918-22) and Vega del Sella (excavations in Cueto de la Mina, La Riera, Balmori, Morín, etc. mainly right before and during World War I) consolidated archaeological research interests by systematic excavations, comparative analyses, scientific publications of regional syntheses of cave art and artifacts made before the Spanish Civil War (CARTAILHAC 1902; ALCALDE DEL RÍO 1906; ALCALDE DEL RÍO ET AL. 1911; VEGA DEL SELLA 1916; OBERMAIER 1924; BREUIL & OBERMAIER 1935). Interrupted by the Spanish Civil War and impoverished post-war conditions, it was really not until the late 1950s and 60s that research return again on the Paleolithic Prehistory of Cantabrian Spain under J.M. Barandiarán, J. González-Echegaray and F. Jorda, finally achieving modern standards of excavation methods with the partnership of J.González-Echegaray and L.G. Freeman at Morín, El Juyo, and Altamira in the late 1960s-80s and the work of G.A. Clark and L.G. Straus at La Riera in the mid-late 70s (BARANDIARÁN 1953, 1967; GONZÁLEZ-ECHEGARAY & FREEMAN 1978; STRAUS & CLARK 1986).

The discovery of Lower Paleolithic sites, e.g. Sierra de Atapuerca and Orce-Spain, Dmanisi-Georgia, Monte Pioggolo and Ceprano-Italy, Korolevo-Ukrain, Vallonnet-France (CARBONELL ET AL. 1995; CARBONELL 1999; MUTTONI ET AL. 2011, 2013; TORO-MOYANO ET AL. 2013; MICHEL ET AL. 2017) and research into the first peopling of Eurasia by *Homo ergaster*, *Homo erectus* and *Homo antecessor*. It stimulated researchers to question the relationship between humans and animals in the past. Dietary practices, competition in shelters (carnivores) and in which environment the first pioneers settled (OBERMAIER 1924) are topics imbedded in debates about a long or short chronology for the hominin occupation of Europe (ROEBROEKS & KOLFSCHOTEN 1994; CARBONELL ET AL. 1996). Especially hunting activities and how they were elaborated are recurring aspects in human history, which enable to study animal-dietary activities under an evolutionary aspect (LEE & DEVORE 1987: p. 3).

In the Cantabrian region, archaeological research including economic aspects of Paleolithic human behavior have been advocated by J. Altuna, C. González-Sainz, J.A. Moure-Romanillo, J. González-Echegaray, V. Cabrera-Valdés, F. Bernaldo de Quiros, I. Barandiaran-Maetzu, L. Freeman, L.G. Straus, M.S. Corchón Rodriguez, P. Utrilla-Miranda, G.A. Clark, et al. (FREEMAN 1964, 1973, 1981; ALTUNA 1972, 1986, 1990, 1994, 1998; STRAUS 1977, 1983, 1992; GONZÁLEZ-ECHEGARAY & FREEMAN 1978; GONZÁLEZ-MORALES 1980; GONZÁLEZ-ECHEGARAY & BARANDIARÁN 1981; BERNALDO DE QUIRÓS 1982, 1992; CORCHÓN-RODRÍGUEZ 1986; STRAUS & CLARK 1986; MOURE-ROMANILLO & GONZÁLEZ-MORALES 1988; GONZÁLEZ-SAINZ 1989, 1989; MORALES MUÑIZ 1990; UTRILLA 1994; HOYOS GÓMEZ 1995; CABRERA-VALDÉS ET AL. 2006), while many economic aspects were summarized based on published, often more paleontologically- oriented, works such the dissertations of Jesus Altuna (ALTUNA 1972) and Pedro Castaños Ugarte (CASTAÑOS 1986). In the Cantabrian region, along with the paleontological studies by Altuna and Castaños and the works of Freeman and Straus constitute fundamental starting points for studying Paleolithic subsistence behavior and economies (FREEMAN 1973; STRAUS 1983, 1992; ALTUNA 1986). The need for a systematic consideration of faunal remains in Iberian archaeology was also stressed from other researchers who did not actually work in Spain (e.g., J. Boessneck, E. von den Driesch from the German veterinary school in Munich) in the early 70s, but Spanish archeozoological research continued to have a 'low impact' until the first decade of the new millennium (MORALES-MUÑIZ 2002: p. 111).

With chronometric methods improved and a comprehensive paleoeconomic approach to investigating subsistence strategies in the Cantabrian region, aspects of the dynamics behind economic changes and territoriality are beginning to be addressed (QUESADA-LÓPEZ 1997a).

Since early 2000s, studies of subsistence strategies and economic behavior are common aspects of research (MATEOS CACHORRO 2005), in parallel with lithic archaeological research, when considered under the aspects of technology and cultural transitions (RIOS-GARAIZAR 2007; SANTAMARÍA-ÁLVAREZ 2012), as well as mobility and settlement behavior (RISSETTO 2009; BRADTMÖLLER 2014; FONTES 2016a). Cultural trajectories of social connections are now being investigated through Paleolithic art (RIVERO VILÁ 2010; RUIZ-REDONDO 2014).

The idea of a new Archeozoology is mirrored within the context of new methods in contextual archaeology initiated by taphonomic studies differentiating anthropogenic from natural accumulation processes (YRAVEDRA 2005; MARÍN-ARROYO 2010; VILLALUENGA 2013; BEHRENSMEYER ET AL. 2018) following the lead of early taphonomic works that set the fundaments for this research direction applied in archaeological studies (NOE-NYGAARD 1977; BEHRENSMEYER 1978; ESTÉVEZ 1980; BRAIN 1981; SHIPMAN 1981; VILLA 1982; LYMAN 1987; FISHER 1995). It has been long realized that modification processes must be considered when subsistence information is to be retrieved from faunal remains (SCHIFFER 1983, 1996). Faunal as well as lithic analysis is increasingly accompanied by spatial distribution analysis (MARÍN-ARROYO 2003; NAKAZAWA 2007; GARCÍA-MORENO 2010; MALINSKY-BULLER ET AL. 2011) often to decipher site functionality/use.

Additional bioarcheological studies include non-macro-mammal remains as food sources and/or as paleoclimate proxies, e.g. fish (ADÁN ET AL. 2009; CONARD ET AL. 2013), shellfish (CLARK & STRAUS 1986; MORENO & MORALES 1987; ÁLVAREZ-FERNÁNDEZ 2001; GUTIÉRREZ-ZUGASTI 2010; COLONESE ET AL. 2011; GUTIÉRREZ-ZUGASTI & CUENCA-SOLANA 2015; GUTIÉRREZ-ZUGASTI ET AL. 2016), plants (POWER ET AL. 2015; CRISTIANI ET AL. 2018), phytolith studies (FOX ET AL. 1994; GOBETZ & BOZARTH 2001; ZURRO 2010) and micromammals (POKINES 1998a, 2000; CUENCA-BESCÓS ET AL. 2010a, 2010b).

The latest phase in the study of faunal remains from sites, with researchers centering in either microscopic structure and use–wear analysis (CUENCA SOLANA 2013), dating and environmental reconstructions via stable isotope analysis on shells and bones (HERMOSO-BUXÁN Unpub.; JONES ET AL. 2018, 2019, 2020; SUÁREZ REVILLA 2019; GARCÍA-ESCÁRZAGA 2020), constitutes an ongoing additional research direction for future work in Iberia.

2.2 Human presence and Cantabrian economies

A brief overview of the current state of the art on Late Pleistocene archaeological research in the Cantabrian region follows. Beginning with the transition from the Late Middle Paleolithic to the Aurignacian, Gravettian, Solutrean and Magdalenian bibliographic references will include mainly the most significant sites, recent syntheses and developments and will outline those aspects of the record that are most relevant to this thesis.

Cultural evolution in the Cantabrian region is compared to climate variation during the Late Pleistocene (see Figure 2.1), as by the oxygen isotope curve from the NGRIP ice core (RASMUSSEN ET AL. 2006; ANDERSEN ET AL. 2006; SVENSSON ET AL. 2006, 2008; NGRIP DATING GROUP 2008).

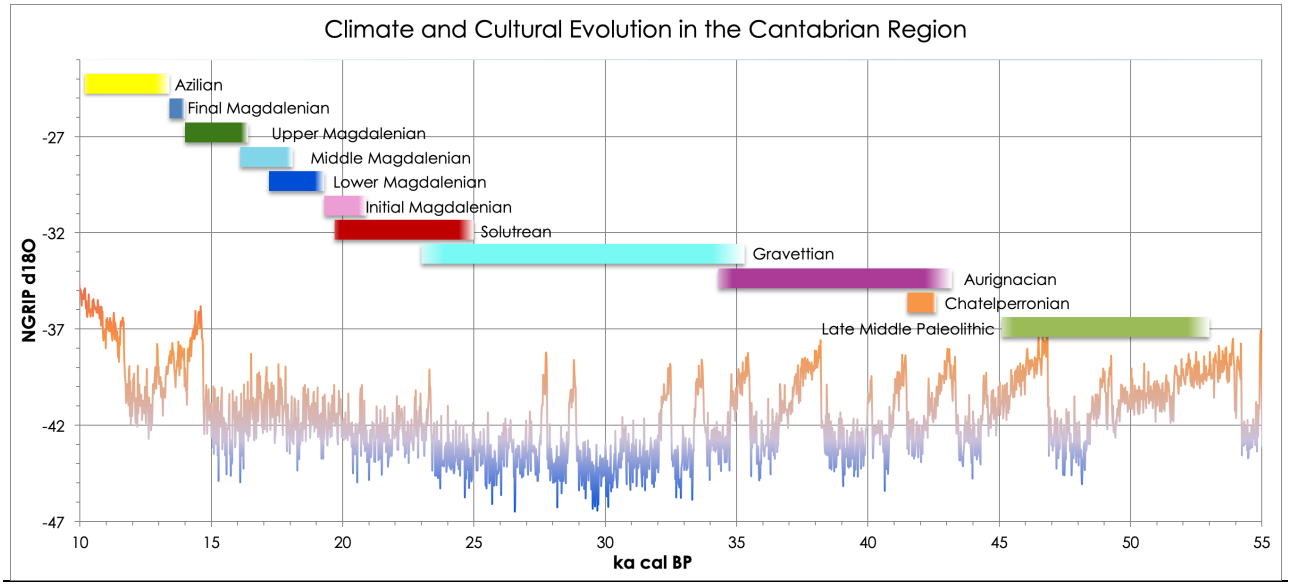


Figure 2.1: Major climate fluctuations and cultural sequences in the Cantabrian region. (NGRIP oxygen data obtained from *Greenland Ice Core Chronology 2005 (GICC05) released 10 September 2007*).

2.2.1 The Late Middle Paleolithic

The European Late Middle Paleolithic is characterized by Mousterian lithic industries, ranging in age from approximately 250,000 to 40,000 years ago, a period of continuous climatic fluctuations (TZEDAKIS ET AL. 2007), that witnessed emphases the emergence of Neanderthals in Eurasia and Anatomical Modern Humans in Africa, along with some significant technological developments. The presumed makers of all Middle Paleolithic industries in Europe were Neanderthals (KLEIN 2009). They changed their technologies to repeatedly adapt successfully to fluctuating environmental conditions during MIS3 (DAUJEARD & MONCEL 2010; DELAGNES & RENDU 2011; DISCAMPS ET AL. 2011; BAENA ET AL. 2012; SANCHIS ET AL. 2019) as well as before. In Europe, it is generally believed that Neanderthals had an opportunistic diet with a focus on large game. Neanderthals' subsistence behavior clearly was based on ungulate game hunting, but sometimes supplemented by low-yield, sedentary to slow-moving (e.g. tortoise, shellfish) and fast-moving (e.g. rabbit) food sources, when the circumstances required (STINER 1994, 2001, 2008; BLASCO ET AL. 2010; MORIN ET AL. 2019).

In the Cantabrian region, a degree of variability in settlement strategies, raw material procurement, lithic tool production and use was a major feature of this period (RIOS-GARAIZAR 2017). Relevant late Mousterian occupations are known from El Castillo, La Güelga, Esquilleu, Morín, Covalejos, El Mirón and Axlor all dated

between about 48-46ka cal BP (~44-41ka uncal BP) (MAROTO ET AL. 2012; HIGHAM ET AL. 2014; STRAUS & GONZÁLEZ-MORALES 2016). According to new carefully selected ultrafiltration samples, some of which date earlier to ~47.9-45.1ka cal BP (MARÍN-ARROYO ET AL. 2018b), it appears that late Middle Paleolithic occupations did not overlap in time with the first (and very rare) Châtelperronian in the region. Even though caution should be taken with dates so close to the radiocarbon dating limit and with normally large standard deviations, some of these new dates were obtained with up to date preparation methods (i.e. AMS and ultrafiltration AMS), improving result precision (HIGHAM ET AL. 2011).

While how much and in which ways late Neanderthal lifeways were influenced by the arrival of Anatomical Modern Humans (AMH) in Europe (just after HE4) is still debated (BERNALDO DE QUIRÓS & MAÍLLO-FERNÁNDEZ 2009). The successful adaptation of Neanderthals to climatic oscillations during MIS3 lead us to reject the idea of their inability to adapt 'one last time' in order to survive, with (contested) records of their survival in the southern refugium area of Iberia until 37.1 ka cal BP (32.6ka uncal BP) and maybe until 28.7ka cal BP (23.8ka uncal BP) (FINLAYSON ET AL. 2006; TZEDAKIS ET AL. 2007). Although mountain glacial extension reached its maximum in Iberia during MIS3 (contemporaneous of late Neanderthals) (HUGHES & WOODWARD 2008; SERRANO ET AL. 2013), cultural competition, as well population dynamics might have been a few of the multifactorial reasons for the demise of Neanderthals (BANKS ET AL. 2008). Across the Middle-to-Upper Paleolithic transition in Europe and, particularly, in Northern Spain several cultural changes are observed by archeologists. The Cantabrian region contains a wealth of sites that permit the study of this important period of time. Middle and Upper Paleolithic people occupied both the area of coastal low lands and the edges of the Cantabrian mountain range, displaying a certain continuity in their settlement strategies. However, a settlement intensification was observed during the latter period, e.g., with thick occupation layers in El Castillo and Cueva Morín (CABRERA-VALDÉS ET AL. 2006).

Despite the lack of diagnostic Aurignacian-age human remains in the region, it is still debated which human (sub)species were the producers of the different "transitional industries" of Europe [see a detailed discussion in (ZILHÃO ET AL. 2006; HIGHAM ET AL. 2010; MELLARS 2010; WELKER ET AL. 2016; STRAUS 2018)]. It has been demonstrated by means of ancient DNA analysis that before the demise of the Neanderthals and distribution by AMH, the two human types sometimes interbred (GREEN ET AL. 2010; TEIXEIRA & COOPER 2019). In addition, new transitional industries appeared such as the Châtelperronian in central-southwestern France and north-central Spain, the Leaf Point Industries of NW, Central and Eastern Europe, or the Uluzzian in Italy. The Cantabrian region has only a few minor Châtelperronian occupations: Morín (MAÍLLO-FERNÁNDEZ 2014) and Labeko Koba (ARRIZABALAGA ET AL. 2000), and the only open-air site in Iberia from this period Aranbaltza (RIOS-GARAIZAR 2012), first excavated in 2013. New ultrafiltration radiocarbon dates suggest a less than 1000-year coexistence of Châtelperronian (possibly made by Neanderthals, and ended 42.6-41.5ka cal BP) and Early Upper Paleolithic people (Aurignacian, appearing 43.3-40.5ka cal BP) at least in the region of Cantabrian Spain (MARÍN-ARROYO ET AL. 2018b). Ongoing research regarding this Middle-to-Upper-Paleolithic transitional period has created a wealth of new data relevant to the chronology (MAROTO ET AL. 2012; WOOD ET AL. 2014, 2018; HIGHAM ET AL. 2014), technology (RIOS-GARAIZAR 2007, 2012, 2017; ARRIZABALAGA ET AL. 2009; RIOS-GARAIZAR ET AL. 2012), subsistence (YRAVEDRA 2013; YRAVEDRA ET AL. 2016; MARÍN-ARROYO ET AL. 2018a) and environmental conditions (UZQUIANO 2006, 2008; CUENCA-BESCÓS ET AL. 2009; JONES ET AL. 2019).

2.2.2 The Aurignacian

Discussions are also ongoing about when exactly to date the Early Aurignacian occupations in Northern Spain at the end of MIS3. This cultural period is associated (albeit weakly in the beginning) with the appearance of Anatomically Modern Humans in Europe and characteristic toolkits that include rhomboidal/massive-base and split-base bone points, together with stone blades, bladelets, carinated scrapers/cores (CHURCHILL & SMITH 2000; TEJERO 2016). Important Early Upper Paleolithic Aurignacian technologies in the Cantabrian

region are attested at Aitzbitarte III, Ekain, La Viña, Labeko Koba, El Castillo, Covalejos, Morín and El Cuco, with new dates that suggest (that if they were the only makers of Aurignacian tools) the first Anatomically Modern Humans appeared as early as 40-43ka cal BP (36.5ka uncal BP) in the Cantabrian region (MAROTO ET AL. 2012; WOOD ET AL. 2014, 2018; MARÍN-ARROYO ET AL. 2018b; GUTIÉRREZ-ZUGASTI ET AL. 2018). Differences in subsistence strategies of early Upper Paleolithic people compared to those of late Neanderthals, have been difficult to determine with precision due to undeniable chrono-cultural uncertainties. Published subsistence syntheses (STRAUS 1982, 2013a; YRAVEDRA 2013; YRAVEDRA ET AL. 2016) that propose similar meat acquisition strategies, short-time occupations and alternating cave use with carnivores for both human groups must be reconsidered accordingly. The recent revision of the chronology by Marín-Arroyo et al. (2018) is an important step for further future faunal analysis. Although the earliest Aurignacian date (from Level 16 at El Castillo) is culturally clearly defined and was dated with an ultrafiltration method, it is the only evidence for pushing back the start of the Aurignacian in this region; without this one date, there would be a hiatus between the Châtelperronian and Aurignacian (MARÍN-ARROYO ET AL. 2018b).

An interesting fact is, however, that a few sites with important human occupations were repeatedly occupied across the Middle to Upper Paleolithic transition (MARÍN-ARROYO ET AL. 2018b), suggesting a general continuity in settlement choices (STRAUS 2018) and thus permit study of the trans-cultural (and trans-subspecies) use of the sites in question, e.g., at El Castillo, Morín or Covalejos (SANGUINO & MONTES 2005; BERNALDO DE QUIRÓS & MAÍLLO-FERNÁNDEZ 2009) in their surrounding environments (JONES ET AL. 2019).

2.2.3 The Gravettian

From a regional perspective, recent reconsideration of the transition from the final Aurignacian to the Gravettian has led some authors (RIOS-GARAIZAR ET AL. 2013) to suggest multiple origins, which may include an indigenous origin, rather than a solely exogenous one in Western or Eastern Europe. In the eastern Cantabrian region and the Pyrenees (eastern Cantabrian Gravettian or Noaillien sites), the beginning of the Gravettian is dated to 34-28ka cal BP and in central and western Cantabria to 28-23ka cal BP (DE LA PEÑA 2013), with a bottleneck of dates around HE3. However, a recent analysis of Gravettian levels by ultrafiltrated AMS dates suggests a start of the Gravettian between 36.8-35ka cal BP from the western (Asturias) sites of La Viña and Llonin, the central Cantabria site of Morín and the eastern (Basque Region) sites of Bolinkoba, Amalda, and Aitzbitarte III (MARÍN-ARROYO ET AL. 2018b). At this time, the beginning of MIS2 (beginning of the Last Glacial, Würm IV) is characterized by a general climatic downturn to the Cantabrian region and several drastic climatic changes took place during the circa 10,000-year duration of this cultural period (CACHO ET AL. 2001; FLETCHER ET AL. 2010). It witnessed changes in weaponry and other tools (appearance of Font-Robert and (micro-) Gravette stone points, Noailles burins, Isturitz bone points, etc.). The presumed development of social-networks with a pan-European common belief system (seen in red ochre burials and Venus figurines, the latter not found in Iberia and the former only represented by the Lagar Velho burial in Portugal) (DE LAS HERAS 2013) exemplifies cultural adaptations to these environmental deteriorations that still need to be understood. However, some authors propose that there is more than a coincidental correlation of technological and climatic changes (BRADTMÖLLER ET AL. 2012; SCHMIDT ET AL. 2012; BICHO ET AL. 2015, 2017; STRAUS 2018).

During the Gravettian, the number of sites increased in the archaeological record (STRAUS 2000; STRAUS ET AL. 2000a, 2000b), including more open air-sites (Irikaitz, Ametzagaina, Mugarduia, Pelbarte, Prado in the Basque country), with several major multi-layered cave occupations such are Aitzbitarte III V-VI, Antoliñako Lab-Lmbk sup, Bolinkoba V-VI, La Garma E-F, El Castillo 12-14, Cueto de la Mina G-H-VII, La Viña VII-VIII in the Cantabrian region (RASILLA-VIVES & SANTAMARÍA-ÁLVAREZ 2006; ÁLVAREZ-FERNANDEZ 2007; AGUIRRE 2012; ALTUNA ET AL. 2013; IRIARTE-CHIAPUSSO & ARRIZABALAGA 2013; BERNALDO DE QUIRÓS ET AL. 2015). It might be argued that

the origin of the above-mentioned chronological discontinuity in settlement patterns favored the preservation of occupations in cave sites above open-air dwellings (TAPIA ET AL. 2009; DE LA PEÑA 2013).

In the Cantabrian region, subsistence strategies were generally focused on the exploitation of red deer, sometimes with important supplements of ibex or chamois predictably in steep, rocky montane settings such as Antoliña, Amalda, Bolinkoba, Castillo Level 14. But others display more opportunistic diets with each of three species higher than 15% NISP of the total assemblage such as at Cueto de la Mina, La Riera, El Castillo 14, La Garma A, Antoliñako Koba, Aitzbitarte III (CASTAÑOS & ÁLVAREZ FERNÁNDEZ 2013). Bovines (*Bos/*Bison) and horse only occasionally dominate an assemblage during this period, for example in Aitzbitarte III Level IV outer cave or El Castillo Level 12 with generally rare carnivore presence in the archaeological layers (ALTUNA & MARIEZKURRENA 2011). Fish exploitation is only very exceptionally documented for the Aurignacian and Gravettian periods (ADÁN ET AL. 2009). In a general landscape mosaic with fluctuating arboreal vs. open vegetation and, consequently, varying animal resources, Gravettian people seem to have been better adapted to colder conditions than their human predecessors (but modern human populations with Gravettian culture also finally moved into southern Iberia under conditions of supposedly albeit temporarily milder climate) and seemed to have practiced a highly mobile lifeway, perhaps accelerated by an increase in human population density during that time.

Some of the most recent Gravettian occupations in the Cantabrian region date to 21ka cal BP (although some of these young dates need to be taken with caution) (CALVO & PRIETO 2013) and include Gravette and micro-Gravette points, backed blades and bladelets [e.g. La Garma, Altamira, Aitzbitarte, Amalda (DE LAS HERAS 2013).

2.2.4 The Solutrean

Contemporary with HE2 and before the onset of the Last Glacial Maximum (LGM), 23–18.4ka cal BP, the number of archaeological sites increased rapidly within a few thousand years in the Cantabrian region (STRAUS ET AL. 2000a, 2000b). Different definitions for the specific timing of the LGM *sensu stricto* and *sensu lato* still exist (MIX ET AL. 2001), but as a consequence of the maximum volume of water masses held in the global ice sheets, sea level regression reached its greatest extent of about -120m.b.s.l. (FLEMING ET AL. 1998; LAMBECK 2001; LAMBECK ET AL. 2002) between 19ka and 23ka cal BP during Greenland Stadial 2 (GS2). At that time, technologies appear that were often very elaborate, including large projectile points of standardized shapes (e.g., leaf and shouldered points), heat-pre-treatment of lithic raw materials, and also osseous sagaies, eyed bone needles and possibly spear throwers. The Solutrean culture developed out of local manifestation of Gravettian societies in southern France and Iberia with a continuous chronology. While in Mediterranean Iberia the Solutrean culture appeared earlier, the first Solutrean techno-complexes in Northern Iberia date to about 24.5-23.5ka cal BP (CALVO & PRIETO 2013). The most important sites in the Cantabrian region include Las Caldas, La Riera/Cueto de la Mina, Altamira, El Pendo, La Pasiega, Antoliña, Aitzbitarte IV, Amalda, albeit with occupations that are generally neither very large nor very long, depending on site function. Only a few exceptional sites in this region, such as Las Caldas, Cueto de la Mina, La Riera, El Mirón, (also Isturitz in the adjacent French Basque country) show multiple occupations for either substantial habitation or short-term visits. These seem to have been located in favored landscapes with varied relief and reliable water (also fuel and raw material outcrops), game and other food sources during these times of harsh climatic conditions (STRAUS 1983, 1992, 2018).

Settlement, therefore, seems to occur in regional clusters, which were separated by empty areas (according to the present state of knowledge, subject to needed survey in 'empty' areas). These clusters might indicate actual band territories (with their own identities), as stylistic differences exist among point types, e.g. various kinds of shouldered and tanged points or the typically Cantabrian concave base (STRAUS 2016). Very similar

artistic styles over large region, however, are hints of long-distance contacts, which were possibly part of a risk-reduction strategy during fluctuating, but often difficult, uncertain environmental conditions. By maintaining less extensive exchange networks during LGM conditions, however, these regional clusters might have been the origin of development of subsequent distinguishable cultures, such are the Badegoulian in Western France at 23.5-23ka cal BP (19.5-19ka uncal BP) (DUCASSE 2012)] and the Initial Magdalenian in France and Spain, respectively (STRAUS & CLARK 1986; DE LA RASILLA VIVES 1989; BANKS ET AL. 2009, 2011; AURA-TORTOSA ET AL. 2012).

The Solutrean subsistence systems in Iberia were mainly based on red deer and ibex (STRAUS 1983, 2018). Food management was specialized on these two ungulates, but within a general system diversification (STRAUS 1977a, 2000, 2013c), i.e. an 'early broad spectrum revolution' (STRAUS & CLARK 1986: p. 353). Marine resources were occasionally present, with a local abundance of marine mollusk evidence at La Riera and complements of fish species (there and at El Mirón). At some sites (but not La Riera), shells were perhaps more often collected from dead mollusks for decorative reasons along with perforated ungulate teeth (notably red deer canines) (ÁLVAREZ-FERNÁNDEZ & FERNÁNDEZ-GARCIA 2013). Mobile art of Solutrean age, with tick-marked ribs, and some decorated sagaies being probably the most 'common' ones, is scarily represented in Cantabrian Spain.

Evidence is interpreted in different ways by different researchers as to what characterizes the transition from the Solutrean to the Magdalenian in the Cantabrian region; especially as marked by changes in weapon technology. While some researchers argue that the French Badegoulian tradition (Magdalenian 0) was intrusive to the Cantabrian region and the "Badegoulien cantabrique" occurred (BOSSELIN & DJINDJIAN 1999, 2000); others argue that a "de-solutreanization" process was the result of progressive local adaptive shift i.e., the gradual loss of Solutrean foliate, shouldered and tanged points replaced by antler sagaies often armed with bladelets (STRAUS 1975, 1992, 2016; CLARK & STRAUS 1986; STRAUS & CLARK 2000; RASILLA-VIVES & STRAUS 2004; CORCHÓN-RODRÍGUEZ 2009, 2017). This is not only a discussion as to how to group archeo- cultural components, but also it is (in part) about a divergence of archeological schools of thought. Nonetheless, the chronological evidence shows a continued settlement of the region during which presumably varied human behavior changes led to a new cultural episode in European prehistory, the Magdalenian, preceded in France by the Badegoulian which was contemporaneous with the late Solutrean in Iberia.

2.2.5 The Magdalenian

The Magdalenian dates to ~20-13ka cal BP is the last major cultural phase of the Upper Paleolithic, before the general amelioration of climatic conditions that ended with the onset of the Holocene. Magdalenian cultural remains can be found from Portugal to Poland. These hunter-gatherer groups were already socially complex, exploring well known hunting grounds seasonally and during long periods, with exchange of information and goods (and possibly mates) over great distances in a vast social network. Hunting was efficiently adapted to local topographies with lithic and osseous weaponry of easily, low-cost, maintainable implements combining antler points and backed bladelets (STRAUS ET AL. 2000a, 2000b). In south-western Europe (especially in Iberian sites), the main game species hunted were red deer and Spanish ibex (STRAUS 1980, 1992), as opposed to specialized reindeer-hunting in north-western and central Europe such as Petersfels, Stellmoor, Meiendorf, Gönnersdorf, Hohle Fels (Germany), Pincevent and Verberie (France) Kesslerloch (Switzerland), and horse-hunting sites such as Ville St. Jacques (France), Champreveyres and Monruz (Switzerland), which suggest a general preference on the most abundant large game available in the local environment. This shows highly effective and successful hunter-gatherer subsistence strategies with flexible, but optimal resource usage.

After the Last Glacial Maximum, while the human expansion into the "upland and northerly regions of western and ultimately central Europe during the course of Greenland Stadial 2 and early Greenland Interstadial 1" (STRAUS 2013b: p. 247) developed a process associated with the Middle and Upper Magdalenian, which led to the stability and subsequent settlement of the Epipaleolithic groups (Azilian and Federmessergruppen). The initial phases of the Magdalenian can be traced back to the southern refugia of southern France and the Iberian Peninsula.

The Cantabrian region is one of the core areas of the European Magdalenian distribution (along with SW France). Approximately 60 sites dating from the Initial to the Final Magdalenian have been recorded across the coastal provinces of Asturias, Cantabria, Vizcaya and Guipúzcoa (plus the interior Basque provinces of Alava and Navarra) (STRAUS 2000, 2013b; STRAUS, N. BICHO, ET AL. 2000a; STRAUS, N. F. BICHO, ET AL. 2000). As such, this area has great potential for providing economic information within the greater Magdalenian chrono-cultural unit, with many of them including radiocarbon dates for the construction of an objective chronology (CORCHÓN-RODRÍGUEZ 1999; UTRILLA & GONZÁLEZ-SAINZ 2003; ALVAREZ-ALONSO 2007; ÁLVAREZ-ALONSO 2007). In this regard, more comprehensive information on the temporal extent of occupations is available. According to Straus & González Morales (2012a), it may be possible to subdivide the Magdalenian into four phases within the Cantabrian region: Initial, Lower, Middle, Upper and Final Magdalenian, beginning respectively at 20.3, 19.3, 17.7, 16.4 and 14 ka cal BP.

2.2.6 The Initial Magdalenian

With the transition from the Solutrean period, the Initial Magdalenian dating around 20.3ka cal BP marks the onset of the Cantabrian Magdalenian period. Though often described as having dry and cold climates, micro-mammal remains, as well as stable isotope studies have revealed some inconsistencies in temperature and humidity within that period, which need to be investigated further. It is unrealistic to imagine that the oceanic Cantabrian region was ever truly dry, for example, so that fluctuations in humidity were always relative.

While the discussion is ongoing about the connection of late Cantabrian Solutrean ending 19.5ka cal BP (21–17ka uncal BP) and French Bagdegoulian 23–20.5ka cal BP (dates to 18.2-16.5ka uncal BP), French Lower Magdalenian 20.5-18ka cal BP, or French Middle Magdalenian 18–16ka cal BP industries from precious regions (UTRILLA 1984; LANGLAIS ET AL. 2010), Initial Magdalenian occupations are poorly represented in archaeological sites making it hard to investigate this transitional industry further in Cantabrian Spain. Attributed to the Initial Magdalenian cultural trajectory are Level 5 in El Rascaño and nearby, El Mirón Levels 117–119.3 and possibly 19-21 (Cantabria) and Urtiaga Level F (Basque Country) (STRAUS & GONZÁLEZ-MORALES 2010; STRAUS ET AL. 2014; FONTES 2016b). However, some chronologically late Solutrean occupations date similarly, such are La Riera 17 and Las Caldas Pasillo 4 in Asturias, Chufín in Cantabria, Aitzbitarte IV and Arlanpe II in the Basque country. This transitional period occurred during GS 2-Würm IIIb of cold and dry climate and lasted through the Lascaux interstadial of gradual fluctuating climate to cool and humid conditions.

The Initial Magdalenian period, however, dates to 20.3-19.3ka cal BP (17-16ka uncal BP) is characterized by 'archaic' stone flake tool types, and the use of local non-flint raw materials, while raclettes are rare or absent (e.g. in El Mirón, Rascaño and La Riera) (STRAUS ET AL. 2014).

In the Cantabrian region, this transitional period is replaced by the appearance of a well-defined Paleolithic culture with very characteristic artifacts and works of portable art and subsistence evidence: the Cantabrian Lower Magdalenian.

2.2.7 The Cantabrian Lower Magdalenian

The classic Cantabrian Lower Magdalenian distribution, archaeologically characterized by a distinctive material culture, dates to 16-14.5ka uncal BP (19.3-18ka cal BP) after the LGM, GS2, early Oldest Dryas (GONZÁLEZ-SAINZ & UTRILLA 2005) and spans a coastal-montane territory of around 50km in N-S depth and 250km E-W width along the Northern Iberian coast. Caves with early recognition of this culture and key sites include El Castillo, Altamira, El Juyo, Rascaño, Morín (in Cantabria), La Lloseta, Cueto de la Mina, La Viña, La Riera, Las Caldas (in Asturias) and Aitzbitarte, Amalda, Ekain, Ermittia, Erralla, Santimamiñe (in the Basque Country) (JORDÁ-CERDÁ 1963; GONZÁLEZ-ECHEGARAY 1971, 2011; UTRILLA 2004).

The Lower Magdalenian has a typical, well-defined archaeological composition with scraper/cores [nucleiform endscrapers were in some {but not all} sites/levels used to scrape bone/antler or wood (STRAUS 1977b; KEELEY 1988; DOMINGO ET AL. 2012), but also simply as bladelet cores in other instances], low-investment, replaceable bladelets, resilient antler sagaies (often quadrangular-section, bevel-base and grooved), perforated teeth and shells. At many sites (e.g., Altamira, El Castillo, El Juyo, El Mirón) the levels are often extremely rich in lithic and osseous artifacts, portable art objects, personal adornments, hearths, fire-cracked rocks, constructions and massive amounts of intensively exploited faunal remains (notably red deer, ibex and salmon), as well as mollusk shells in sites along the coastal plain (UTRILLA-MIRANDA 1981; BARANDIARAN MAESTU ET AL. 1985; POKINES 1998b; STRAUS ET AL. 2016, 2018).

Lower Magdalenian subsistence practices are summarized as being a dual-game specialization of red deer and Spanish ibex, focused on prime age animals which were intensively exploited beyond their meat (e.g. bone/antler, bone marrow, bone grease and presumably skin, tendons, etc.) (FREEMAN 1973; STRAUS 1992). Direct evidence from human remains of the El Mirón burial have recently demonstrated, that the subsistence base was indeed diversified during the early Magdalenian with ungulate meat being supplemented in the diet by the consumption of some plants (tubers and seeds), mushrooms (boletus) and marine/aquatic foods such as shellfish and fish (notably salmon) (GARCÍA-GONZÁLEZ ET AL. 2015; POWER ET AL. 2015).

Occupations of the Lower Magdalenian are characterized by massive palimpsests, often with no sterile layers in between occupations, suggesting fairly continuous, repeated use of certain favored caves. These horizons are highly organic and probably represent longer inhabitation of caves than in previous cultural phases, with constructions of site furniture such as hearths, pits and even walls (FREEMAN & GONZÁLEZ-ECHEGARAY 1984; STRAUS & GONZÁLEZ-MORALES 2018). The prevalent regional settlement model based on seasonality data indicates that humans occupied lowland-coastal caves mainly during winter and interior, montane-zone caves mainly during summer months (POKINES 2000; STRAUS ET AL. 2015d: p. 118). New data of faunal analyses are available and these existing settlement model should be revised for its validity.

A group identity (and evidence of intensive regional cultural exchange) is symbolized by striated red deer hind engravings on red deer scapulae of very similar art style and chronometric dates, which can be found in different sites (El Castillo, Altamira, El Juyo, El Pendo, El Cierro, and El Mirón) throughout a limited area around the modern provinces of Cantabria and easternmost Asturias (ALMAGRO 1976; GONZÁLEZ-MORALES ET AL. 2006; GONZÁLEZ-MORALES & STRAUS 2009; DE LAS HERAS ET AL. 2012). Similar striated engravings of hinds are also found on the walls of caves in the same restricted region, which possible corresponded to the territory of a regional band (RIVERO ET AL. 2019).

More regular long-distance exploitation of resources, however, is exemplified by the raw material provenance of lithic tools that connect southwestern France, the Ebro basin and the Cantabrian region (FONTES ET AL. 2016, 2018). Excursions or (more likely) contacts with the Mediterranean coast are also exemplified by shells of *Homalopoma sanguineum* found in El Mirón Level 17 (n=1) (ÁLVAREZ-FERNANDEZ 2006) and *Cyclope* sp. in Level 503 (GUTIÉRREZ-ZUGASTI & CUENCA-SOLANA 2015). *Lussac-Angles* points found in El

Mirón cave (Levels 108, 114, 115 and 116 – the latter are Lower Magdalenian) might indicate long -distance social connections to contemporary early Middle Magdalenian (Magdalenian III) groups in southwestern France (GONZÁLEZ-MORALES & STRAUS 2005; SAUVET 2015; STRAUS & GONZÁLEZ MORALES 2019).

2.2.8 The Middle Magdalenian

As the Magdalenian culture progressed into its Middle phase, networking and intergroup relationships among hunter-gatherer bands intensified even more, especially between SW France and Cantabrian Spain. Small art works made on hyoid bones (*contours découpés)* and decorated flat bone discs *(rondelles)* are common objects known in sites of southwestern France (centering along the Pyrenees with the major site of Isturitz in the Basque Country) and northern Spain [e.g., Ekain, La Viña, Las Caldas, Tito Bustillo, El Juyo, La Garma for the former (BALBÍN-BEHRMANN ET AL. 2003; CORCHÓN-RODRÍGUEZ 2012) and Las Caldas, La Viña, Llonín X, Tito Bustillo, Linar, Las Aguas for the latter (CORCHÓN-RODRÍGUEZ & RIVERO VILÁ 2008; SCHWENDLER 2012)], indicating contacts beyond the Pyrenees region. Perforated *Homalopoma sanguineum* (n=11) and *Cyclope spec.* (n=4) shells found in Tito Bustillo (n=11) continued to appear and manifest long-distance contact far as the Mediterranean coast (ÁLVAREZ-FERNÁNDEZ 2002).

Magdalenians north of the Pyrenees were typically highly specialized reindeer hunters (but sometimes hunted many horses or saiga antelopes), while in southerly (i.e., Iberian) regions (including the Cantabrian region) the subsistence strategy was fundamentally based on the consumption of the (presumably) most abundant ungulate taxa in the region, red deer and Spanish ibex (MATEOS CACHORRO 2005; MARÍN-ARROYO 2010). A gradually changing picture of subsistence arose concerning the livelihood of these hunter-gatherers, who seem to have practiced ever greater coastal adaptations than before (PÉTILLON 2014). Food acquisition was once characterized by 'wild harvesting' (FREEMAN 1973), with a seasonal model of game management based on animal kills often in the montane areas during summer and in coastal-lowland ones during winter, with seasonal residential movements along the north-south oriented river valleys, referred to as the 'valley territory' hypothesis (FREEMAN 1973; STRAUS 1992; RISSETTO 2005; STRAUS ET AL. 2015d).

At this time, soon after the onset of HE1 (GS2a), climatic conditions stabilized and the environment was characterized by cold and humid environments with steppe landscape and a few trees (HOYOS GÓMEZ 1995). Within this period, between 14.5-13ka uncal BP (17.5-15.6ka cal BP), antler proto-harpoons appear occasionally (Ermittia, Las Caldas, etc.) and the characteristic osseous industry of antler points (split-based sagaies in Las Caldas) and wands (*varillas)* bone awls and eyed needles persisted. Significant continuity among the lithic assemblages (often heavily dominated by backed/retouched bladelet composite weapon elements) from the Lower to the Middle Magdalenian suggests a local development from previous cultural manifestations (STRAUS 2005). Site function and resource availability seem to be the root causes of inter-site variability of archaeological assemblages (STRAUS 2013b). This cultural period, however, is defined essentially by complex mobile art (e.g., bone figurines, some *bas relief* works of art, engraved stone plaquettes), cave art (some like rock art sanctuaries) and dense living floors together with possible structures in Cantabrian sites (e.g. Las Caldas, La Garma) (ONTAÑÓN & ARIAS CABAL 2010; ARIAS CABAL ET AL. 2011). After the LGM had provoked a demographic bottleneck, site density seemed to intensify in Northern Spain during the Middle Magdalenian; people recolonized higher altitudes as well as northerly latitudes throughout Europe (also manifested by DNA evidence) at times of glacier recession and incipient re-vegetation of formerly polar desert regions (POSTH ET AL. 2016; FU ET AL. 2016).

2.2.9 The Late/Epi- Magdalenian (Azilian) and transition to the Holocene

Still fluctuating, the global deglaciation phase continued in the final millennia of the Pleistocene and climate warming got especially dramatic at 14.5ka cal BP (16ka uncal BP) with the onset of Bölling (GI-1e or DO1-

event). This episode is followed by the short Older Dryas (GI-1d) cooling, with varying humidity during the still- cold Alleröd (Greenland Interstadial 1c-1a), then a more drastic, but <l,000-year-long, cold event, the Younger Dryas (GS1), and finally the warming of the Preboreal at the onset of the Holocene. The Final Magdalenian is placed within this period of dramatic environmental changes. In the Cantabrian region, the Late Magdalenian can reasonably be subdivided by the following chronological trajectory (STRAUS & GONZÁLEZ-MORALES 2012a):

- Upper Magdalenian 13.2-12ka uncal BP (16.4-14ka cal BP)
- Final Magdalenian/Transitional 12-11.5ka uncal BP (14-13.4ka cal BP)
- Epimagdalenian/Azilian 11.6-9ka uncal BP (13.4-10.2ka cal BP)

With the beginning of the Late Magdalenian, people established a stable pan- West European (i.e., beyond Iberia and France, to include Switzerland, Poland, Czechia and even England) network around 13.2-11.5ka uncal BP, which is reflected in a further "'internationalization of art" (BICHO ET AL. 2007: p. 93). These Late Magdalenian societies shared a cultural identity by means of similar art objects and parietal art, such are stone plaquettes found in El Horno, Abauntz (UTRILLA ET AL. 2009; FANO ET AL. 2010), or classic Late Magdalenian black outline 'Pyrenean-style' bison images found in Urdiales or El Castillo (SIEVEKING 1987; OCHOA & GARCÍA-DIEZ 2015) - so common in sites in southwestern France. Other important Late Magdalenian sites are Tito Bustillo, La Riera in Asturias; Rascaño, El Castillo, El Perro, La Fragua, La Chora, El Otero, El Valle in modern day Cantabria, and Santimamiñe, Ekain, Laminak II, Urtiaga, Berroberría in the Basque country.

The subsequent 'Epi-Magdalenian'/ Azilian occupations (whose diagnostic artifacts are flat section harpoons, thumbnail endscrapers, curve- backed points) existed very different landscapes from those of the Early Magdalenian in both coastal (La Riera, El Perro, La Pila, etc.) and inland sites (El Piélago, El Rascaño, Antón Koba, etc.), that latter of which reach up to the by then de-glaciated highland-subalpine zone (GONZÁLEZ-MORALES ET AL. 2004)

Archaic tool types on non-flint local raw-materials are decreasingly represented with the onset of the Upper Magdalenian, something which might signify better established trading/social networks. Cultural trajectories are characterized by composite tools made with backed bladelets and antler points and a lithic toolset regularly including endscrapers, knifes, perforators and burins. The osseous industry included true barbed antler harpoons (mainly unilaterally barbed in the Upper Magdalenian, sometimes bilaterally in the Final Magdalenian), often decorated sagaies of diverse cross-section and base types (including typical frontal- view engravings of ibex heads), wands, perforated antlers (*bastones de mando*), spatulae and needles. During the Azilian a simplification of both osseous and lithic tool inventories occurred: burins and perforator all but disappeared, more composite tools with micro-points and backed bladelets replace antler *sagaies*, and geometric micro-lithics begin to appear (e.g. El Valle, El Pielago) (STRAUS & GONZÁLEZ-MORALES 2012a).

Subsistence intensification continued; people exploited mainly red deer and ibex, but with a shift to more often include younger animals with less energetically valuable return rates and more dangerous species such as wild boar (FREEMAN 1973; STRAUS 1977a; MARÍN-ARROYO 2008). This coincided with a general trend towards further diversification in game management, e.g. incorporating more woodland species such as roe deer and wild boar, and significant supplements of aquatic resources, e.g., *limpets, topshells, other shellfish such as urchins and barnacles, and fish.* Increasing population density and higher levels of competition might be the reasons for this move towards the significant exploitation of lower energy resources; i.e., a radical change unfolded in the economic pattern during this period (STRAUS 1981; CLARK & STRAUS 1986; ALTUNA 1990). Seasonal indicators of cave occupation suggest a more complex system of human movements, including residential and logistical move and the existence of ritual sanctuary (plus aggregation) sites (STRAUS 1986; UTRILLA 1994; COSTAMAGNO & FANO 2005; MARÍN-ARROYO 2009a).

The beginning of the Cantabrian Mesolithic (9ka BP) saw the emergence of large shell middens (both in the Asturian and eastern Cantabro-Basque culture-areas of the region) that attest to full coastal adaptations being established with a final great rupture in longstanding Upper Paleolithic patterns of territoriality, subsistence and technology (GONZÁLEZ-MORALES & STRAUS 2012).

2.3 Paleo-environments as scenery of human behavior

Human activities cannot be untied from their surrounding settings, as such is the environment an important component to be considered when studying human behavior. What follows is a review of influence of global climate on the Northern Iberian terrain, as well as the environmental history of the region is presented. A short overview of some relevant methods for environmental studies is given at the end.

The period of study placed in the context of the Late Pleistocene was a period of severe climatic conditions, where the Cantabrian region seems to have taken a specially role during ice ages. The period of interest beginning in late MIS3 and MIS2 dating to 48.2-10ka cal BP with the MIS3/2 boundary at 27.8ka cal BP spans the last 50,000 years of the Late Pleistocene until the onset of the Holocene (Figure 2.2). The last half of the Last Glacial period was a period of strong and rapid oscillations including warm and extremely cold periods (DANSGAARD ET AL. 1993), some of which included particularly distinguishable general cold phases known as Heinrich stadials (here relevant H1 to H5) and the Last Glacial Maximum *sensu lato* (LGM, 23-18ka cal BP) are noted. The Tardiglacial or Late Glacial (19–10ka cal BP) frames the last period relevant to the current study.

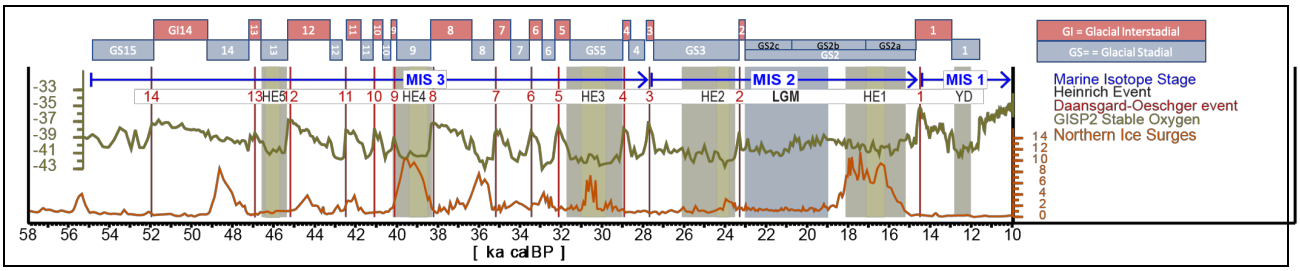


Figure 2.2: Global climate fluctuations during the MIS3 and MIS2. Age calibration using the Hulu curve with the program CalPal2016 (Weninger & Jöris 2008). Curves display global climatic changes from top to bottom: Marine Isotope stages (Sánchez-Goñi & Harrison 2010), red numbers mark Dansgaard-Oeschger high stands corresponding to warmer phases and the GISP2 stable oxygen record (Grootes et al. 1993; Meese et al. 1994; Steig et al. 1994; Stuiver et al. 1995; Grootes & Stuiver 1997) based on the Hulu atmospheric curve (Reimer et al. 2013) and Northern Ice Surges events from IBERIAN MARGIN C37_4 400 ka core data (Martrat et al. 2007). Light grey-shaded areas show particularly cold phases of Heinrich stadials (H1, H2 and H3). Blue marks the range of the Last Glacial Maximum (LGM).

Heinrich stadials (HS; i.e. cold ocean water stages) are climatic oscillations of irregular periodicity and highlighted to show significant climatic changes which coincide with cold phases in the western Iberian margin (SÁNCHEZ-GOÑI ET AL. 2008; FLETCHER & SÁNCHEZ-GOÑI 2008; SÁNCHEZ-GOÑI & HARRISON 2010). HS4, HS2, and HS1 are characterized by two phases. First, a substantial drop of annual and sea surface temperature, and virtual absence of Heinrich layers are recognized in marine cores, which are also known under the term Heinrich events (HE) (HEINRICH 1988). Naughton (2009) described relatively wet and very cold atmospheric conditions in the eastern Atlantic margin for this early phase of a Heinrich event, which can be explained by the southward displacement of the Gulf Stream and is associated with stormy conditions. The second phase in a Heinrich event is characterized by a high to moderate deposition of ice rafting debris, cool sea surface temperature and extreme continental dryness (HEMMING 2004). HS3 was different, it has in total remarkable

wet conditions. On the contrary, Daansgard-Oeschger events are examples of rapid climate changes marked by warmer climate followed by gradual cooling of temperatures (DANSGAARD ET AL. 1993; SÁNCHEZ-GOÑI & HARRISON 2010).

The location of maximum ice expansion differs in space and time throughout Europe, according to shifts in atmospheric circulation and hence varied sources of moisture in combination with varying elevation could be an explanation (IVY-OCHS ET AL. 2008). How different Europe might have looked under LGM conditions is shown in the following map (Figure 2.3). The map was compiled by Becker (2015), who used the LGM Paleoenvironment GIS data from published data sources (CLARK ET AL. 2001, 2009; KELSO & PATTERSON 2010; EHLERS ET AL. 2011; GENERAL BATHYMETRIC CHART OF THE OCEANS 2014; VERHEUL ET AL. 2015; WILLMES ET AL. 2017). The map shows major changes in the coastline and location of inland glaciers of the LGM landscape.

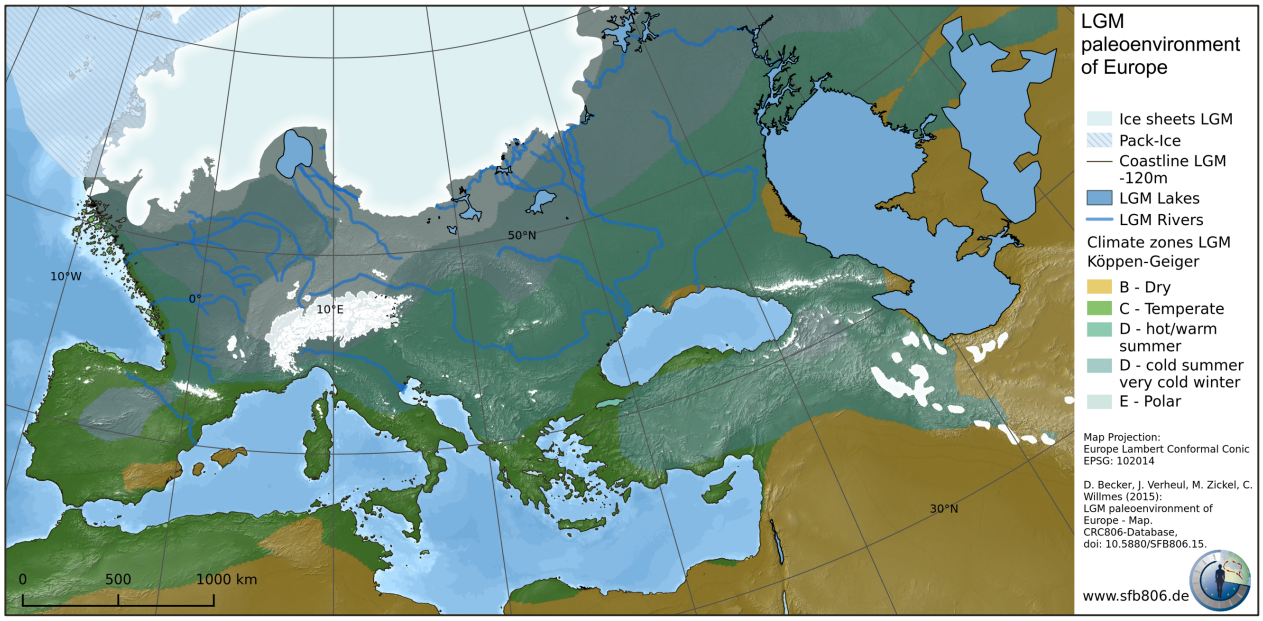


Figure 2.3: Europe during Late Glacial Maximum at 23-18ka cal BP (after Becker 2015).

Climate and weather are supposed to have varied under past glacial conditions. Currently, the Cantabrian region is under the influence of airflows from the north and north-west that create a sharp north to south rainfall gradient (ALLENDE ÁLVAREZ 2008).

Ignoring the vast impact of human-introduced modern eucalyptus and Monterrey pine plantations today, the primal vegetation diversity of Cantabrian Spain (mixed deciduous oak-hazel forest) seems to be related to its unique topography and researchers have been curious about how past environments evolved in the Cantabrian region. Significantly different types of climate are present across the Iberian Peninsula based on monthly average air temperature and precipitation, as well as the Köppen Climate classification provides information on how climate and topography influences the appearance of this vast subcontinental peninsula (AGENCIA ESTATAL DE METEOROLOGÍA, ESPAÑA 2011). Some key climate data (Köppen climate types, mean annual, minimum and maximum temperature) are summarized below (Figure 2.4).

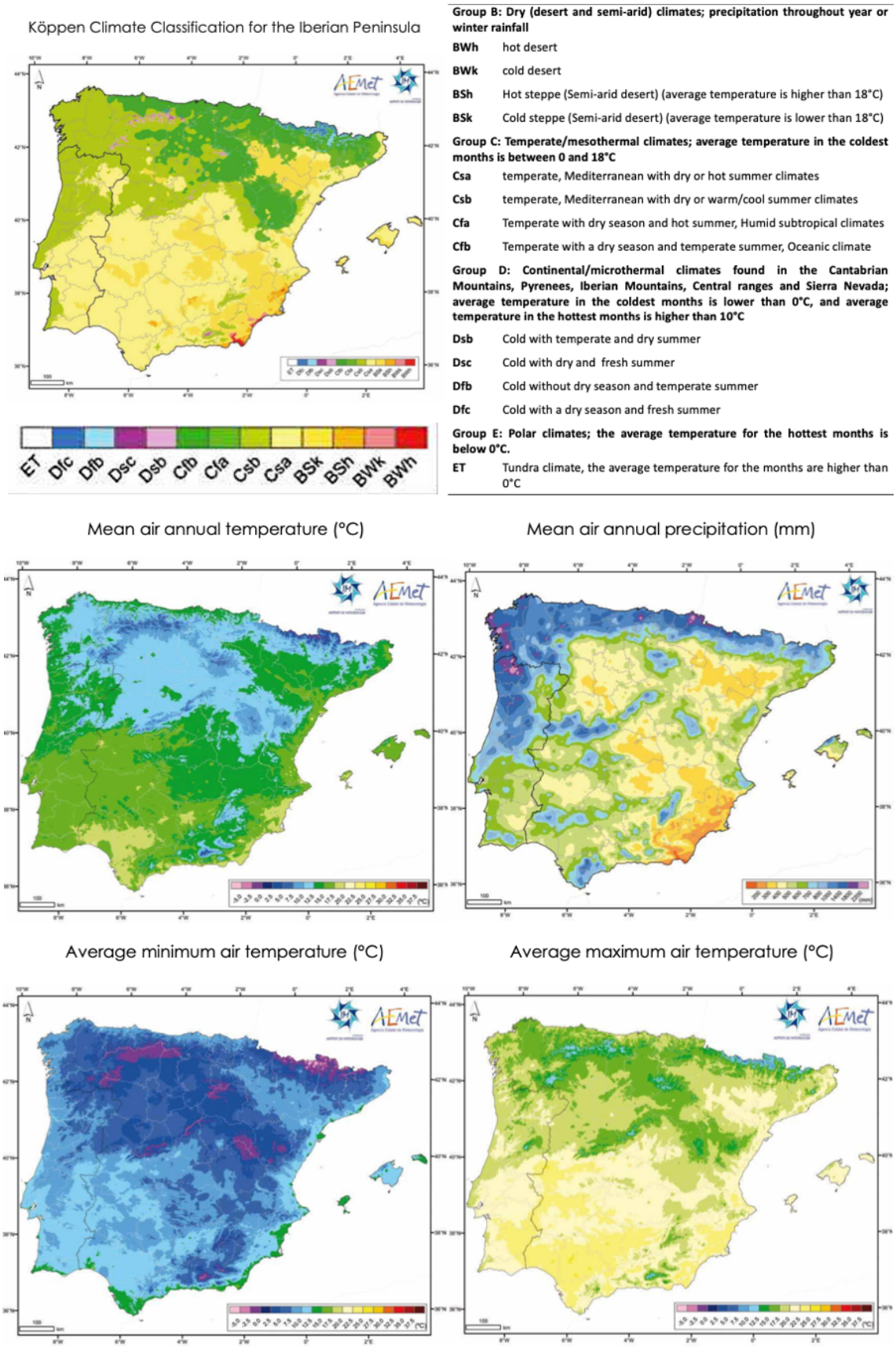


Figure 2.4: Köppen Climate Classification for the Iberian Peninsula, average temperature and precipitation values. Graphics obtained from the Iberian Climate Atlas. Atlas produced from climate normal concerning 1971-2000 period (Agencia Estatal de Meteorología, España 2011).

For the Cantabrian region during late MIS3-MIS2, in particular, there are environmental data available that are based on large and small mammal studies (CUENCA-BESCÓS ET AL. 2008, 2010a, 2010b; LÓPEZ-GARCÍA & CUENCA-BESCÓS 2010), pollen in lake sediments (MORENO ET AL. 2012), speleothem records from El Pindal Cave (MORENO ET AL. 2010), lake records Enol in the Cantabrian Mountains (MORENO ET AL. 2012), or mountainous glaciation events (SERRANO ET AL. 2013), etc.. Although, general environmental information is produced through these kinds of summaries and paleoecological syntheses (JALUT ET AL. 2010; IRIARTE-CHIAPUSSO ET AL. 2016) give useful insights into the complexity of the environmental history of the region, but it is also true that these kinds of studies mostly produce general environmental information. Ice-rafted debris and planktonic foraminifers in marine drilling cores (HEINRICH 1988), marine pollen (SÁNCHEZ-GOÑI ET AL. 2000, 2008; NAUGHTON ET AL. 2007), lake pollen (MUÑOZ-SOBRINO ET AL. 2001), cave sediment (LAVILLE 1986; HOYOS GÓMEZ 1995; FARRAND 2012) records, vegetation history (CARRIÓN ET AL. 2010) or climate models (RAMIL-REGO 2005) all do provide a broad understanding of the climate evolution for Iberia. Nonetheless, how pan-regional changes impacted local micro-environments is still not fully understood.

Marine core records show, according to pollen profiles, the vegetation change in the north-east of Iberia (CARRIÓN 2012: p. 6) (Figure 2.5). They show a gradual loss of the forest vegetation during MIS4, MIS3 and MIS2 and expansion of heathland and herbaceous vegetation, which indicate the steady increase of atmospheric and sea-surface temperatures during that period. This period is interrupted by warm spells with expansions of *Betula* (pioneer species) and *Quercus* (thermophile species). *Pinus* is a taxon which can withstand generally harsher climatic condition, *Betula* is a pioneer tree, *Quercus* prefer more temperate climates e.g. during Alleröd-Bölling. On the contrary, the reduction of these species and expansion of *Ericaceae* (flowering plants) y *Poaceae* (grasses) indicate an opening of the landscape and again cooling of temperatures with relatively dry conditions (NAUGHTON ET AL. 2007, 2009; SÁNCHEZ-GOÑI ET AL. 2008).

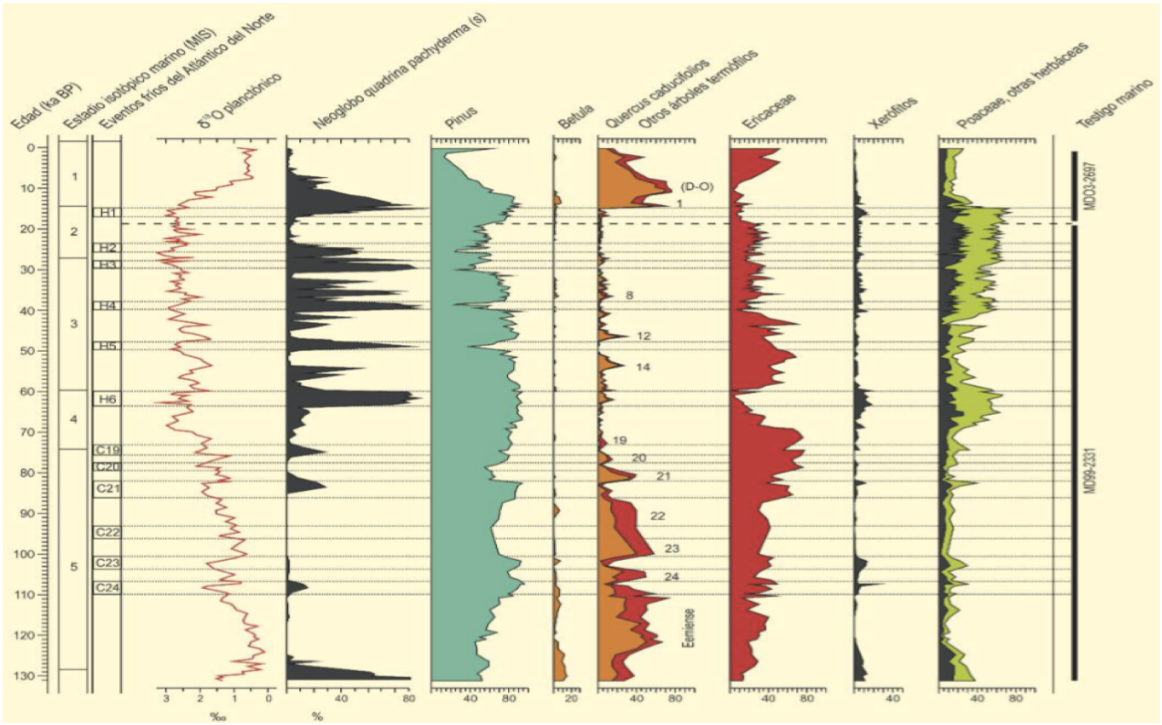


Figure 2.5: Late Pleistocene pollen from marine cores (MD99-2331/MD03-2697) in Galician Atlantic coast (Pleistoceno medio (330-280 Ka), Pleistoceno Superior-Holoceno (130 Ka-actualidad)). Figure from CARRIÓN (2012: p. 6).

During the Pleistocene, perpetual snows above 1500 m.a.s.l. and permanent ice fields covering the highest parts of the Cantabrian Mountains (with maximum glacier extensions above 1600-1700m.a.s.l., whose fronts reaches elevations between 490 and 1850m.a.s.l. (SERRANO ET AL. 2012)) are suggested. Three Pleistocene glacial stages (one during the Holocene attributed to the Little Ice Age and not further considered here) have been reconstructed for the Cantabrian region date to the MIS3, making them older than the LGM in central and northern Europe (MIS2) (a fact already noticed in the Pyrenees) (SERRANO ET AL. 2013). One glacial event of similar intensity, but briefer than the European LGM dates between 39 and 40ka, and for the Pyrenees and the Cantabrian Mountains a generalized glacier advance stage between 32 and 18ka is characterized by surge events (JALUT ET AL. 2010; SERRANO ET AL. 2015), compare Table 2.1.

Table 2.1: Cantabrian Glacial Stages after SERRANO (2015) with climatic and environmental context.

Cantabrian Glacial Stage	Glacier characteristics	Climate and environment
S-I Cantabrian Glacial Maximum (42-31ka, MIS3) (Mousterian-Aurignacian)	maximum extent of glaciers, longer and thinner glaciers than during LGM	cold, humid air masses from the N, NW and SW, and open landscapes in inner and coastal sites, easternmost mountains glaciers were generated at very low altitudes in favour of snowfall
Interglacial stage I/II 33 - 28ka	transition MIS3 to MIS2	Cold, abrupt climatic changes and brief warming
S-II - Glacial equilibrium, population increase of AMH	Cirque (short, thick) glaciers only in the high mountains; advance to similar positions prior to the LGM	cold, dry and more stable climate with air masses from the N - NW, similar temperatures, but significant change in snowfall
LGM, ~19ka	no glacial advance	cooling of the LGM is reflected
Interglacial stage II/III		Warming
S-III- Last retreat, (Magdalenian)-Tardiglacial (14–10ka).	a brief period; small sized glaciers at altitude and disappeared from the lower mountains, where the ice disappeared entirely at the end of this phase	related to the Younger Dryas and another AMH expansion into the Cantabrian Region, deglaciation processes

Specific questions addressing local climate conditions in the Cantabrian region before, during and after the LGM in contrast to human cultural appearances, however, remain unanswered. Stable isotope analysis combined with these records provide the mean to obtain environmental samples from Paleolithic remains which were directly accumulated by humans and they represent a direct record of the moment of living of the past humans. Principally have addressed a few projects stable isotope studies in the region so far. Only recent research include stable isotope analysis in the Cantabrian region and investigations are ongoing, while the focus often lye on the analysis of bones (STEVENS ET AL. 2014; ROFES ET AL. 2015; DOMINGO ET AL. 2015). Dental calculus analysis can also contribute further evidence on the environment and animal ecology. Plant particles, including silica phytolith, can be preserved within dental calculus adhering to animal or human teeth. They represent food remains that were consumed and accumulated during the animal's life. They accumulated on teeth during the process of chewing and plaque bacteria embedded them in the solid matrix of the dental calculus, from which paleodietary information can retrieved from and they are easy to extract (MIDDLETON & ROVNER 1994). Since the first record of the extraction of opal phytolith from herbivore teeth

(ARMITAGE 1975), studies on phytolith composition in dental calculus have been undertaken on different Pleistocene herbivore species for paleodietary reconstructions (CIOCHON ET AL. 1990; MIDDLETON & ROVNER 1994). Human dental calculus analysis is engaged for direct dietary inferences (FOX ET AL. 1994; HENRY & PIPERNO 2008; HENRY ET AL. 2011, 2014; LEONARD ET AL. 2015; POWER ET AL. 2015). Micro remains and tooth-wear analysis are often combined, as both are complementary within their interpretational framework (LUCAS ET AL. 2014; KAISER ET AL. 2018). The combination of such diverse analyses improve understanding of especially the environments of the catchment area around a site (a micro-environment) and contribute to understand Ice Age refugia.

The idea of the southern peninsulas of Europe acting as refugia during periods of Pleistocene glacial conditions has been developed by archeologists for some time (e.g., Jochim; Straus), it is referred to as the Northern Iberian Ice Age refugium.

A refugia where large mammals may have dwelled during glacial maxima (CARRIÓN ET AL. 2003; FORTEA-PÉREZ ET AL. 2007; MUÑOZ-SOBRINO ET AL. 2007) were specifically located on the Balkan peninsula, the Apennine peninsula, southern France, as well as the Iberian Peninsula (MEIRI ET AL. 2013; DJINDJIAN 2016). These southern European regions are characterized by milder climates and the Cantabrian region was a particularly favorable one. This region is part of the Eurosiberian ecozone, with a biotope and biocoenosis generally similar to the Central European ecosystem, but with attenuated temperature fluctuations (HAWS 2012). The evidence and relevance of Iberian refugia are explained in what follows.

Pleistocene climate (temperature and humidity) declines were extreme and had severe consequences in northern and central Europe, whilst in southern Europe refugia areas persisted and preserved biodiversity. These circumstances might have originated in the different timing of severe climatic conditions, which allowed population stability in some regions, while in other regions inhabitants might have suffered from extreme climate fluctuations. Under current climatic conditions, the Gulf Stream transports warmed waters from the equatorial waters of the Caribbean to the northern hemisphere, which includes the Cantabrian coast. During the Last Glacial, however, oxygen isotope studies on foraminifera from deep sea cores in the Bay of Biscay and off the coast of southern Portugal indicate that there was no influence of this phenomenon on local climate (STRAUS 1992: p. 199; EYNAUD ET AL. 2009; NAUGHTON ET AL. 2009). These records show that the Gulf Stream did not reach the Cantabrian region in the Late Pleistocene and instead hit the Iberian Peninsula much further south. These observations are supported by more recent regional studies in southwestern Iberia that have shown great differences between Heinrich Events H2 and H3 (BICHO & HAWS 2012; BICHO ET AL. 2013; CASCALHEIRA & BICHO 2013). These dynamic climatic processes led suggest a more complex picture existed, with different impacts locally.

It can be summarized that the southerly displacement of the Gulf Stream influenced airflows coming from the southwest bringing somewhat warmer and wetter conditions to the Cantabrian region, making the region a refugium during the glacial periods. However extreme (coldest, wettest) phases in the Cantabrian region were not always simultaneous with ones in northerly European areas (SERRANO ET AL. 2015).

2.4 Genetic evidence of climatic refugia

The Cantabrian Region includes a very great number and variety of habitable caves, a complex topography and vast ecological diversity, aspects that certainly favored Paleolithic hunter-gatherer life. Given this region's location in southern European latitudes, it has been suggested that smaller, less drastic climatic fluctuations provided a favorable habitat for animals, plant and humans during the Last Glacial Maximum (forthcoming LGM), but also during MIS3 and especially MIS2. In Europe, the LGM was a period with a unique suite of harsh (i.e., severely cold and dry conditions) climates (DANSGAARD ET AL. 1993; PEYRON ET AL. 1998; KAGEYAMA ET AL. 2005), for which reason in many regions gaps in occupation or only small numbers of sites

exit, with progressive reduction of available hunting territories due to the advancing ice sheets and periglacial ecozones across Northern and Central Europe occurred. This caused a contraction of human populations to the southern regions (STREET & TERBERGER 1999; STRAUS 2005). The high number of archaeological sites dated to the Solutrean and Early Magdalenian indicate the importance of the Iberian refugia (STRAUS 2000, 2005, 2013b; STRAUS ET AL. 2000a, 2000b; CASCALHEIRA & BICHO 2013).

Recent aDNA studies have confirmed the repopulation of central and northern Europe after the Late Glacial: not only red deer and salmon, but also humans, expanded out of an Iberian refugia. The human haplotype H had a wide geographic distribution with the highest diversity in Iberia. This would demonstrate their expansion from this region after the LGM (ACHILLI ET AL. 2004). Additional studies of historical and contemporary Atlantic salmon populations point to the Iberian Peninsula as the likely source of the most common haplotype within the current Atlantic lineage in Europe (CONSUEGRA ET AL. 2002). Further aDNA studies on red deer indicate that this species was restricted to the southern European refugia (Iberia, Italian and Balkan peninsulas) during the LGM, but later expanded from the Iberian southern refugia to central and northern Europe (SOMMER ET AL. 2008; MEIRI ET AL. 2013). Similar cases were observed for brown bear (TABERLET & BOUVET 1994), common meadow grasshopper (COOPER ET AL. 1995), hedgehogs (SANTUCCI ET AL. 1998) and oak trees (PETIT ET AL. 2002). All aDNA studies have established reasonable evidence that a combination of climatic and environmental factors allowed animal and human populations to persist along the Cantabrian coast during the LGM and then to re-expand northward afterwards. The Iberian refugia (together with southern France) hosted one of the richest mammalian species compositions during the LGM in Europe, including six-seven large ungulate species (horse, bison, aurochs, red deer, Spanish ibex, chamois, roe deer and, occasionally, reindeer). All these facts point to the Cantabrian region as a more favorable zone in terms of biodiversity in comparison with the far harsher environments of northern areas of Europe such as northern France, England, Switzerland, Germany, Poland, Slovakia and Czechia—all of which had seen significant Early Upper Paleolithic occupation before complete or substantial abandonment during the LGM.

The recent publication by Fu et al. (2016) compiling the genetic history of Ice Age Europe has shown that human population turnover and migration were recurrent during prehistory, especially the Upper Paleolithic. Early Aurignacian populations mark the emergence and manifestation of the Upper Paleolithic not only in the Cantabrian region, but in Europe – according to genetic evidence the founder population is associated with Kostenki 14 cluster (FU ET AL. 2016).

One branch of a founder population chronologically associated with the Aurignacian became predominant; the Gravettian cultural complex was mediated at least in part by population movements. Such population movements are inferred genetically by the Vestonice 16 cluster (FU ET AL. 2016). The Gravettian association with the Vestonice 16 cluster and its absence in Iberia represents at least one other European population alongside the local developments. While the genetically defined Goyet-116 cluster (Aurignacian) disappeared from central Europe between ~34-19ka, the El Mirón 'Red Lady' (Magdalenian) is in part associated to this ancient cluster (FU ET AL. 2016). This connection suggests a southward displacement/expansion/migration of groups ones settled at Goyet (Belgia) produced ancestors that lived in the Northern Iberian refugia as its descendants became widespread again at least by ~19ka cal BP in the form of the El Mirón Cluster. This genetic group was detected at El Mirón in northern Spain (from the 'Red Lady') and was associated with the Lower Magdalenian culture. It was involved in the post-Glacial Maximum expansion from southwestern Europe to northeastern France, Belgium and Germany. The expansion of the Magdalenian took place during its Lower, Middle and Upper phases as a direct, unbroken continuation of the rich Franco-Cantabrian culture of the Lower and Middle Magdalenian as outlined by Straus (2012). This is supported by another recent human mitochondrial genome studies identifying a Late Glacial population turnover in Europe (POSTH ET AL. 2016), where the European lineage persisted throughout and after the Last Glacial Maximum in the so called El Mirón cluster.

The genetic evidence supports the idea that Iberia was at least a Last Glacial Maxima refugia. A simplified summary of cultural development in the Cantabrian region and global climatic events can be found in the following Figure 2.6. The seemingly continuous settlement of humans in the region, but changing cultural manifestations let us question reasoning and dynamics of such cultural evolution.

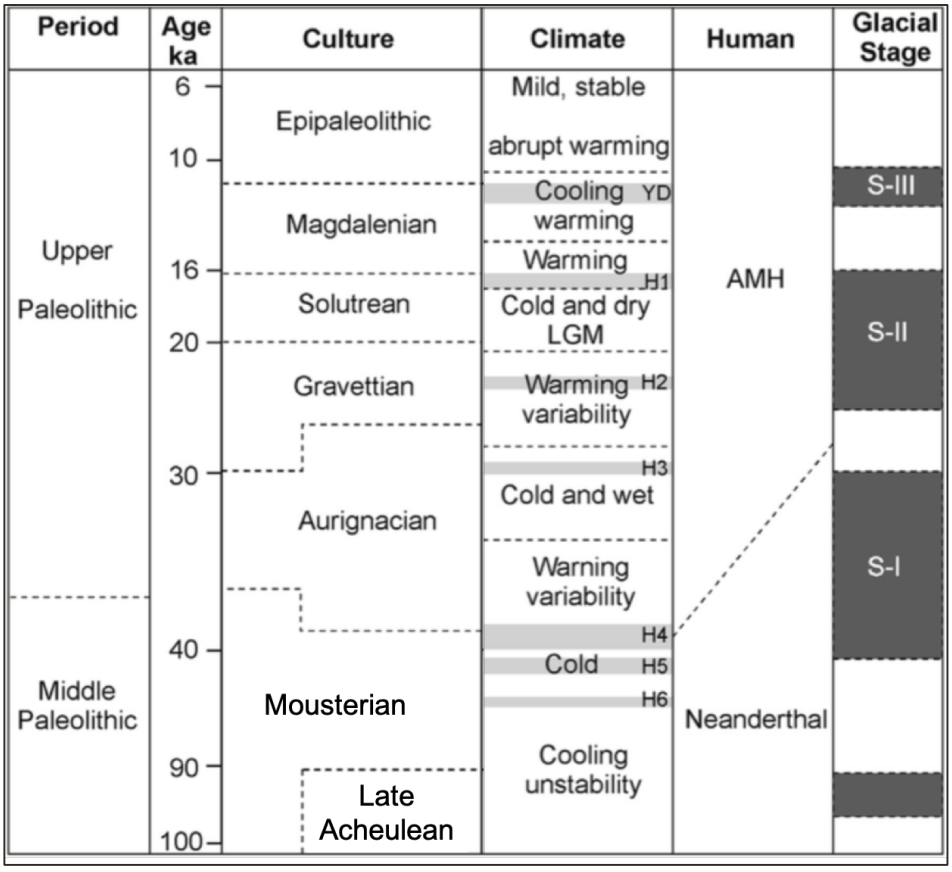


Figure 2.6: Glacial stages, cultural and climatic events in the Cantabrian region (modified from SERRANO 2015- synthesized from FINLAYSON AND GILES (2000); FINLAYSON (2004); STRAUS (2005); SEPULCHRE ET AL. (2007); SERRANO ET AL. (2012, 2013).

According to the current state of research, what is needed now is more detailed reconstruction of the effects of global climate events on the Cantabrian region in particular, as these are supposed to have varied to some degree from the north- and central-European ones to establish the refugia zone. For this reason, here and other future work should aim to reconstruct the development of the micro-environments around important Paleolithic sites in the Cantabrian region, which on a local scale are the conditions that hunter-gatherers confronted in their daily life as evidenced indirectly by archaeological remains found in such caves. With such a background on micro-environments, the role of human- environmental relationship dynamics obtain a new level of importance for studying human behavioral development during the Late Pleistocene and with which direct comparisons between change in local environments and culture can be carried out.

2.5 Questioning the dynamics behind cultural change

If we now recall the concluding question from the previous paragraphs, we basically want to know how can be explained cultural change: perhaps from a climatic, demographic or social perspective? “In order to

generate explanations of any sort, one must make some assumptions about how the world is put together." (SMITH ET AL. 1983: p. 626). So as to explain here how to explore the dynamics of such cultural change, the general dissertation hypothesis formulated in the introduction suggest focusing on the study of economies. For this reasoning is proposed that humans seek to exploit resources optimally to maximize their energy budget. It is quickly outlined such economic approach.

An economic approach applied in archaeology has a holistic perspective, because everyone needs to budget their energies; everybody needs to eat. And all anatomically modern humans have the same adaptive capacities; they are all equipped with the same brain (KLEIN 2009). Some might have cultural restrictions (such as food taboos). But would a society starve to death by ignoring an available or even abundant food source? Possibly not. In this sense, humans as omnivorous consumers use their humanly inherent transcultural adaptive capacities, wherein variability seems key. A society's capacity for change shows how resilient it can be. However, comparing to modern day human behavior where everything seems time-accelerated, constant change as a permanent adaptation to a changing world and its requirements seems to be a dynamic of human behavior (SIMONET 2010). Any examination of human economy should also consider the ecosystem carrying capacity in each particular case.

Especially in past societies, the bulk of human activities are related to food provisioning, processing, storage, consumption, etc. To enlighten the past human economies, human behavior studies can be employed, with which an interpretative framework is provided to study whether changes in human behavior are driven by changes in resource availability and if past humans always adapted the strategy that maximized energy budget (between consumption and production behavior). For example, when higher procurement costs might cause a greater risk of failure, humans might adapt a strategy that reduced risks of food shortage. Identifying these decision processes will provide a greater understanding of human behavior (MARÍN-ARROYO 2009b).

In archaeology, there is a specific research field for this; human palaeoeconomic behavior studies combine the study of Human Behavioral Ecology (HBE) (FOLEY 1985; WINTERHALDER & SMITH 2000) within evolutionary anthropology, while taking into account the development of adaptive behavior and optimality principles. According to these theories, the more efficient the feeding behaviors, the greater the overall reproductive fitness of a given population or group is (KELLY 1995). Optimality, then, is a set of observable behaviors resulting in fitness and reproductive success, archaeologically recognizable as the evolve, spread and consistence of cultures (FOLEY 1985). In archaeology theory, HBE research is often embedded in Optimal Foraging Theory (OFT), which synthesizes on prehistoric human adaptation for optimality in terms of species selection (Diet Breath Model, Central Place Foraging Prey Choice Model (HAMES & VICKERS 1982; GRAYSON & DELPECH 1998; RICHARDS ET AL. 2001; STINER & MUNRO 2002)), nomadic (Patch Choice Model, path choice (MACARTHUR & PIANKA 1966; GRAVEL-MIGUEL & WREN 2018)) or semi-sedentary (Central Place Patch Choice Model) economies, local dwelling time (marginal value theory (CHARNOV & ORIANS 1973; CHARNOV 1976)) and site catchment areas (VITA-FINZI & HIGGS 1970; ROPER 1979; MARÍN-ARROYO 2009; BECKER ET AL. 2017; ANDRÉS-HERRERO ET AL. 2017). Diet is an aspect of human behavior obviously reflected by animal remains from archaeological sites (LYMAN 2008: p. 41). This makes archaeological faunal remains an important resource with which to explore dietary preferences and decision- making through subsistence strategies to infer general past human behavior, when the optimality approach is applied.

Optimality modeling allows researchers to predict an organism's choice of behavior considering the costs and benefits of certain actions or decisions. It does not mean that optimality was always reached, but from a long-term view it is more likely that the evolutionarily successful human groups practice economies oriented towards optimality (even when they were temporary not doing so). This is meant in a balance of energies spend versus obtained. In terms of subsistence strategies, e.g. this evaluates how optimally animal

resources are accessed when considering expenses on time, people, weaponry, etc. An optimality model predicts that low-ranked food resources should or will be ignored as long as more profitable prey is available for justified costs, or how animal carcasses are transported according to body size (MARÍN-ARROYO 2009C).

Nevertheless, for any of these human behavioral analyses, a good set of data is the basis for further economic interpretations concerning technology, diet, wider settlement patterns, occupation densities and reliable chronological data. The archaeological site of El Mirón cave provides such good set of archaeological data making it a relevant site to be studied in detail to improve our understanding of economic dynamics within the Cantabrian region.

2.6 A multidisciplinary approach: human economic dynamics

Why are multidisciplinary methods necessary for studying human economic dynamics? Because each analysis can provide some sort of information that can either be better or sometimes only understand in context with other results, especially in archaeology where we mostly deal with relicts of evidence. It is here presented the dimension of a multidisciplinary approach that combines three analytical sets of techniques, each contributing important aspects to decipher paleo-economic dynamics in the Cantabrian region. First, Paleo-economy is employed for reconstruct site history, the context in the accumulation of faunal remains via taphonomy, and animal- human relationship is enlighten by archeozoological studies. Second, Paleo-space-use is applied as an extra source for information considering spatial distribution analysis on archaeological remains and GIS applications for reconstructing human activities, organization of working spaces and site function. Third, Paleo-environmental studies are applied for deciphering broader climatic impacts, their influence on local micro-environments and effects on ecoethology of animals during Late MIS3 and MIS2.

Within the next paragraphs, I will review the current state of all these three approaches to extract an overview on the arguments useful to study economic development in archaeological terms. It follows an evaluation of the multifactorial approach for human behavioral reconstructions, based on subsistence strategies. Also, is presented a point of view of the strength of using multiple parameters to study human economic behavior that include approaches of Environmental reconstructions, Spatial data, Taphonomy and Archeozoology.

2.6.1 Paleo-economy: Quantification, taphonomy and economic behavior

Archaeozoology refers to the study of animal remains of archaeological sites. These are interesting for both taphonomic and behavioral reasons: the accumulation contexts (human economy, carnivore activity, living communities) and reconstructing modification processes on site (paleo-environmental, taphonomy, chronology) (LYMAN 1994; REITZ & WING 2008). With the aim of understanding the relationship of humans and their environments, archeozoology particularly investigates the inherent interdisciplinary character of human-animal relationships.

It is feasible to study faunal remains, as they are often the most common objects in archaeological sites. Archeozoological research development, however, is highly entangled with the archaeological research history.

With a growing interest in faunal remains and their subsequent relationship to past living humans, researchers have amplified the desire to better define the study of biological archaeological remains. Various debates on the nomenclature of faunal studies followed (UERPMANN 1973; LEGGE 1978; OLSEN & OLSEN 1981; BOBROWSKY 1982; HESSE & WAPNISH 1985; MENGONI GOÑALONS 1988; LYMAN 1994; DAVIS 1995). Here it is asserted that zooarcheology (animal-human relationship) is a component of bioarcheology (inherently concerned with the biological aspect of the record) which is a subdiscipline within environmental

archaeology. Relevant for future studies, however, is the fact that the archeozoology (zooarcheology or osteoarcheology, etc.) was established for considering its own purposes and provide new line of evidences, which combine a series of research aims. These new directions in investigation can be summarized in three categories (REITZ & WING 2008):

First, a more methodological aspect that implements an extensive bone identification and contextualizing of remains to understand the formation processes of these accumulations. These comprise taphonomically-focused works (BRAIN 1981; LYMAN 1994; BEHRENSMEYER ET AL. 2018).

Second, a more derived aspect, according to the relationship of the faunal remains with the human societies, is to understand how subsistence is the biologically necessary part of human behavior, therewith are reconstructed the diet and processes that are involved in the general food requirements such as hunting strategy, transport decisions, dismembering techniques, carcass exploitation intensity, and meat preservation. These are supplemented by dietary reconstructions based on stable isotope composition, dental use- wear, dental calculus content, etc. The human involvement with animal products extended beyond food to include their use as raw material of osseous remains for tools or weaponry, as well as for fuel and artworks and ornaments, some of which had inherent symbolic, political or economic aspects. Within this broad field, a few examples from important works relevant to this thesis are the following books and dissertations (STINER 1994; MATEOS CACHORRO 2005; NIVEN 2006; BOCHERENS 2009; DUSSELDORP 2009; MORIN 2012).

The third category pertains to animal paleoecology in its biological, chronological and geographical aspects. Relevant are characteristics about environmental or dietary preferences, animal distribution in the landscape, social behavior and population plasticity, which is also connected with paleontological features of biometry, age, sex and the seasonal behavior of animals. The impacts of domestication on animals are included here and they are often summarized as Paleoecoethology, e.g. (WEINSTOCK 2000; GERMONPRÉ ET AL. 2009; DRUCKER ET AL. 2011; JULIEN ET AL. 2012; BRESLAWSKI & PLAYFORD 2017).

With the steady spread of 'Processual Archaeology' ideas, new generations of archeologist applied multidisciplinary methods in international projects on archaeological materials worldwide. Ethnographic aspects and experimental data were included into analysis for comparison (BINFORD 1981, 2012; GOULD & WATSON 1982; WENIGER 1982; LUPO 1995; O'CONNELL 1995). The economic aspects of prehistoric lifeways were brought into the focus of the archeological research interest, when considering settlement, subsistence strategies, environmental reconstruction, artifact and site function (UERPMANN 1973; HIGGS ET AL. 1975; HIETALA & LARSON 1984; ARIAS CABAL 1992; STRAUS 1992; OUTRAM 1998; BARTON & JOAN BERNABEU AUBÁN 1999).

L.R. Binford (1968) observed that, with the end of the Paleolithic, fundamental economic changes took place with diversifications in hunting, intensified use and fuller exploitation of habits, which were later summarized under the hypothesis of the post-Paleolithic 'Broad Spectrum revolution' by Flannery (1969). Demographic growth has been proposed quite early as driver of these economic changes and several subsequent researches were contributed thereto (COHEN 1977; STRAUS 1977a; BROUGHTON 1994; GRAYSON & DELPECH 1998; STINER ET AL. 2000; CANNON 2000; STINER 2001; BURGER ET AL. 2005), some of which were applied to the Cantabrian region (STRAUS & CLARK 1986; MARÍN-ARROYO 2009c).

So, how did economic strategies develop in the Cantabrian region before this post-Paleolithic scenario? For example, Neanderthals had already begun to exploit rabbits (and perhaps shellfish) in regions of southern Spain and Portugal (BLASCO ET AL. 2010; CARVALHO ET AL. 2018), where demographic pressure might not be the main factor driving the observed patterns of human hunting during the Middle Paleolithic (STRAUS 2013a). A number of important sites (among others La Riera, El Castillo, El Mirón, etc.) provide long stratigraphic sequences that allow for observing changes in the use of site locations through time, which are accompanied

by various faunal studies from other sites, enabling to draw a potential sequence in Paleolithic economic strategies applied in the Cantabrian region. In the Basque country were Neanderthal subsistence strategies defined (ALTUNA 1972) as opportunistic behavior, during the Middle Paleolithic. It involved a successful, unspecialized, non-selective exploitation of the territory, taking advantage of almost all the available faunal species, with a very mobile population that took advantage of local resources (ESTÉVEZ & VILA 2006: p. 262). This scenario might apply to the whole Cantabrian region. Early Upper Paleolithic diet still can be summarized as more opportunistic than what followed it in time. The Solutrean and the first moments of the Magdalenian are seen as a important transition period in the evolution of hunter-gatherer societies and their relationship with the environment. They show a certain focus on most productive animals, but maintaining a variety of resources of lower caloric values (YESNER ET AL. 1980), maybe a risk-reducing strategy incorporating some fish and shellfsih incorpation into the diet (STRAUS 1977a; STRAUS & CLARK 1986; QUESADA-LÓPEZ 1997b). This scenario may derive from the combination of a large carrying capacity of the exploited ecosystem, as a consequence of the relegating of ungulate populations and the variability of habitats involved, and a moderate competition for resources (STRAUS 1980, 1981). With the early Magdalenian, very specialized and highly productive economic strategies get established (FREEMAN 1973, 1981; FONTES ET AL. 2016). With the increase in human occupation density, Cantabrian populations were feeling for perhaps the first time the effects of territorial constraint, especially as the Magdalenian culture advances. A real diversification of resource usage and seasonal exploitation is well established with the Epi-Magdalenian/ Azilian transition seemingly associated with the Holocene warming trend (ALTUNA 1998b; FERNÁNDEZ-TRESGUERRES VELASCO 2006; MARÍN-ARROYO 2009c; GONZÁLEZ-MORALES & STRAUS 2012). All these economic changes have long been observed, but until today the driving forces triggering these phenomena are not well understood.

These studies must, however, be supplemented by new investigations that use modern techniques, improve archeozoological and taphonomic analyses, as well as climatic and paleoenvironmental reconstructions; a multidisciplinary approach should be applied such as presented in this dissertation work. Investigating dynamics in Paleoeconomic strategies will stimulate a holistic view of the past, these are ideas that actually already were seeded in early days of archaeological economic studies (the 'New' or 'Processual Archeology') in the United States (TAYLOR 1948; STEWARD 1955) and by the Cambridge School of Economic Prehistory in Britain (CLARK 1970; HIGGS ET AL. 1975)

Taphonomy is the scientific framework of how the living community is transformed into a certain fossil assemblage under study (EFREMOV 1940).

Researchers studying fossil materials for deciphering their depositional context subdivide fields of investigation into living, death and fossil assemblages, which are filtered and transformed by taphonomic processes (ISAAC 1967; CLARKE 1973; SCHIFFER 1976; BEHRENSMEYER 1978; BRAIN 1981; FOLEY 1981; BLASCO-SANCHO 1992; LYMAN 1994; FERNANDEZ-JALVO & ANDREWS 2016), compare also (Figure 2.7). The paleoecological context of the living animals defines the death assemblage by physical conditions of the populations, its structure, healthiness, predator activities, etc. As part of the biostratinomy, the death assemblage depends on carcass transport, scavenging and gnawing activities, trampling, etc. The fossil assemblage is subject to the diagenetic conditions of weathering and sedimentation processes, insect-fungi-microbial activity, root etching, chemical alterations, etc. A final loss of information from the original assemblage may happen according to the sampling technique of fossil assemblages and which ones are finally chosen for study.

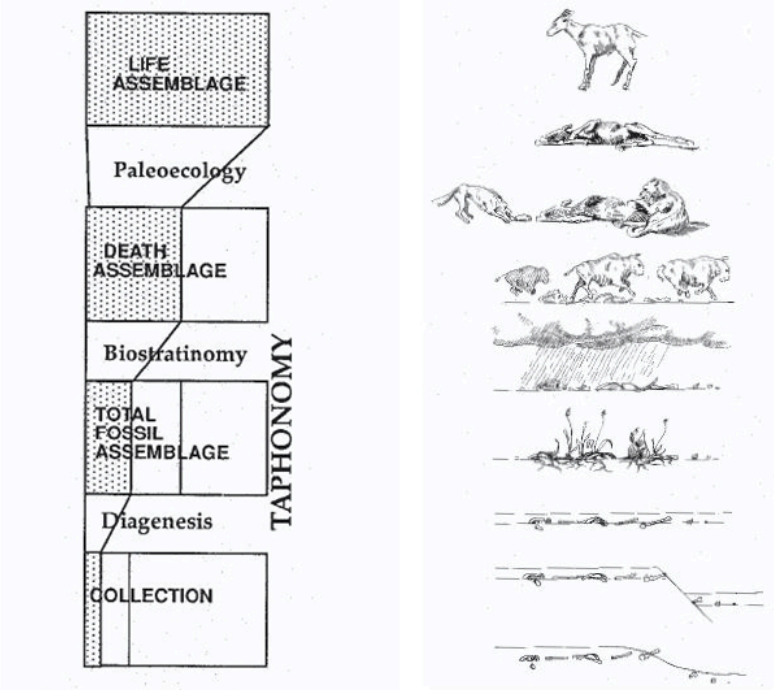


Figure 2.7: Life history of a fossil with loss of the original assemblage through taphonomic processes further (after Shipman 1981).

Taphonomic studies have been applied originally within Paleontological contexts where accumulation and fossilization processes were intended to be deciphered (O'CONNOR 2005; LYMAN 2010; PFRETZSCHNER & TÜTKEN 2011). Processes are generally subdivided into biostratinomy (pre-burial) and diagenesis (post-depositional) (WEIGELT 1927). Within early archaeological context, however, were often applied only paleontological works that not fully considered taphonomic formation processes; i.e (ALTUNA 1972). With further interest in the economic behavior of past human communities, archaeological faunal remains were investigated for human modifications that dedicate these remains as being the results of human activity (BLUMENSCHINE & SELVAGGIO 1988; CRUZ-URIBE 1991; BLUMENSCHINE ET AL. 1996; PICKERING 2002; COSTAMAGNO ET AL. 2005; KUHN ET AL. 2008; DOMÍNGUEZ-RODRIGO ET AL. 2009; SOULIER & COSTAMAGNO 2017) rather than natural accumulations. The influence of Processual ('New') Archaeology has also been reflected here in pushing forward the methodological applications that evolved to decipher human-carnivore alteration processes in archaeological assemblages (BLUMENSCHINE 1995; LUPO & O'CONNELL 2002; VILLA ET AL. 2004; SALA & ARSUAGA 2018) as well as post-depositional modifications (PRICE ET AL. 1992; HEDGES 2002; TÜTKEN 2003). Since then, this research direction is incorporating constantly new approaches on a methodological level in terms of techniques and objects of investigation, such are spatial, chemical, microscopic, etc. analyses (MARÍN-ARROYO ET AL. 2014; CAMARÓS ET AL. 2015).

The present dissertation work contributed already to the scientific method collection in deciphering Paleolithic palimpsests by combining faunal studies and spatial analyses (GEILING & MARÍN-ARROYO 2015; GEILING ET AL. 2016, 2018) and further work and publications will contribute towards diagenetic alterations and isotope biogeochemical analysis.

By reasonable arguments, an appropriate way to explore human behavioral development (on a regional level) is the analysis of ecology and the ecosystem where humans are living (BUTZER 1982); explicitly it involves investigating subjects such as subsistence strategies, social connections and, obviously, the paleoenvironment. The idea behind applying this analytical procedure derives when defining the cultural

system as “man’s extra-somatic mean of adaptation to his environment” (WHITE 1959; BINFORD 1962), which is agreed here. Culture reflects, then, an ‘extra’ ability to the human capacity to intervene with its environment, upon the somatic one; both compounds to complex human behavior. Human cultural flexibility and resilience encode human behavior with which drivers of cultural change might be identified.

Many activities of Paleolithic hunter-gatherers are animal-related; thus, suggesting that a high amount of human behavior can be inferred from archaeological mammalian faunal remains. A theoretical discourse about human-animal relationship can explore the nature of human ecology and its interpretational framework, where the concept of Optimality Foraging Modeling is considered for its potency of use within past economy and how it can be used to study past hunter-gatherer behavior. Human ecology is defined by its cultural and environmental contexts (BUTZER 1982). Accordingly, the role that is played by macro-mammalian remains they will be examined to enhances our understanding of paleoeconomies and paleoenvironmental context across time.

The nature of economies in advanced societies is defined by production and consumption. With the Neolithic revolution subsistence strategies evolved to concentrate on production strategies (productive societies) rather than collecting what is available in natural habitats (WILKINSON & STEVENS 2003). The form of collecting behavior, though, is a kind of foraging strategy, which was dominant during most of the Paleolithic time period; the longest time period in humankind existence. Economies are basically defined by the production sequences that a society uses to obtain their substantial needs. In Paleolithic economies, however, the concept of consumption is prior accessed to any production step. Thus, Paleolithic production of resources is controlled by nature itself, giving its natural supplies. Foragers consume a variety of materials for both food and other necessities: e.g. hunted or scavenged animals, gathering plants, fish, shellfish, nuts, seeds, mushrooms or collecting knappable lithic raw materials and wood for construction, tools and fuel. Economic decisions and dietary choices are made by hunter-gatherer themselves or they are imposed by the environment; they are reflected, however, within the subsistence strategy applied by people.

In a society of Paleolithic foragers, production is the process that follows consumption and is therefore the second criteria to characterize their behavior. It defines how products such as weaponry, clothes, personal adornments, or other symbolic objects were made from what was naturally available and how they are culturally transformed. How intensively varied raw materials were explored for weapon production or other tools (awls, needles, flakers, etc.) are possible questions to verify those people’s economic decisions making.

We can conclude so that Paleolithic societies can be described a by means of their consumption as well as their production behavior, i.e. their economy. The differences in consumption and production strategies allow researchers to define distinctive societies during the Paleolithic; these differences arrive from cultural change or developments.

2.6.2 Paleo-space-use: Spatial analysis and GIS application

The current state of art in Spatial Archaeology might be best summarized in terms of three key points: (A) objectives of Spatial Archaeology, (B) methodological developments, and (C) theoretical integration of spatial results into broader anthropological approaches. For El Mirón Cave were particularly applied methods deciphering (D) site formation processes and (E) intra-site spatial analysis.

(A) Within Paleolithic archaeology, researchers deal with societies that carry out a mobile economy and occupy camps on seasonal and temporary bass. With the objective to establish a settlement hierarchy, the necessity of distinguishing the major centers from more modest sites is important. Paleolithic human settlements can be subdivided into categorize of regional center, local center, aggregation site, hunting

camp, etc. with which the social territory (scale of human society) around centers and the organization of the landscape is accredited (FOLEY 1981; KENT 1991).

(B) Excavation by levels and squares is common and thus the basic levels of analysis are already equipped with at least rudimentary spatial data. Counts of specimens in each unit let archaeologists propose density estimations, which are unfortunately often subjective and should be standardized (GEILING ET AL. 2018). Computer-based and GIS methods are developed as key means of modeling the social-economic systems of human groups by aiming to reconstruct the annual food cycle of human groups in their circulation area. For deciphering site-use, i.e. function, intra-site analysis is stressed and ethnographic parallels are consulted (BAMFORTH ET AL. 2005; BINFORD 2012). The distribution of individual artefacts and site features supplemented by their individual characteristics (artefact type, animal species, degree of human modifications, etc.) seen on a diachronic level enabling the reconstruction of site histories and with it the evolution of societies (ISAAC 1978; HIETALA & LARSON 1984; DJINDJIAN 1988; KINTIGH 1990; BLANKHOLM 1991). Archaeological surveys are supposed to obtain the spatial dimension beyond a single site. For further studies on the socio-economic system, the implied site function based on artefacts and their distribution can be embedded within a regional model of settlement pattern with which Spatial Archaeology provide important insights into the organization of past human societies (RIEL-SALVATORE & BARTON 2004; BAMFORTH ET AL. 2005; BINFORD 2007; BARTON ET AL. 2010; GARCÍA-MORENO ET AL. 2013; RAYNAL ET AL. 2013).

The different scale of spatial activities relevant to study past human societies can be further described within the wider settlement and network systems (BUTZER 1982), important spatial levels are summarized below (Table 2.2).

Table 2.2: Spatial relation of human activities and analytical levels (modified after Butzer 1982, Table 13-1, p.231).

Spatial Level	Dimensions of Human Activity
Microscale	Intra-site activities in regard to animal, plant and tools processing; eating, sleeping; waste disposal; distribution and association of bone residues, plant remains, artifacts and related lithic debris, site structure (one-time or recurrent activities)
Semi-microscale	Site aggregation and function, limited or multiple activities of brief or protracted duration, during course of annual or multiannual group rounds, with repeated episodes of temporary group fragmentation
Limited activities	Quarry and/or workshop sites (few hours or days), located near or adjacent to lithic material source, specialized primary stone processing sites; large quantities of concentrated waste flakes/chips, hammer stones, uncompleted artifact raw forms and broken unused pieces; rare or no bone refuse, rare hearths
Limited activities	Kill and butchering sites (few hours or days) located near water or topographic trap/obstacle; preliminary meat processing sites with incomplete partly articulated skeletons of one or more animals (dominated by non-fleshy and cranial bones), with limited dispersal; small numbers of stone tools (heavy-duty chopping and cutting items), possible projectile points or microliths, but little or no stone- working debris
Multiple activities	Short-term, logistical camps (several days of residence), minor sites (open air or shelters) near special resources, subgroups of hunters or collectors, may include small animals or intermediate processing of larger animals and other food resources (plant, shell, etc.); moderate number and diversity of lithic artifacts, isolated hearth, temporary structures.

Multiple activities	Long-term camps (over several weeks or months), complex and major sites selected to be located close to water and food resources and suitable for shelter against extreme weather or hazards, often providing landscape overview; bone refuse abundant, disarticulated, highly fragmented, dispersed, representing many species and individuals, often charred or burnt; moderate to abundant lithic materials, high ratio of stone to bones, high tool kit variety, moderate proportion of stone debris (use-retouch, sharpening or refashioning); special activity areas (hide processing or woodworking by special tools, other special loci marked by carbonized plants, hearth, ash, rock arrangements).
Macroscale	Inter-site patterning, full network of activities (during the course of one or several years), operational area that comprise a topographic matrix with different degrees of biotic complexity. Depending on predictability and mobility of dispersed and concentrated resources, a variety of group movements, either seasonal or annual, define the mobility pattern. Linkages of operational areas of several adjacent groups favor different networks of non hierachical interactions.

(C) The theoretical integrity of Spatial analysis advances the construction of better economic hypotheses within the archaeological framework, i.e. optimal foraging theory applied from a central place represent a site catchment area as an adaptive relationship between subsistence strategy and resource distribution (CANNON 2003; MARÍN-ARROYO 2009b).

The combination of ethnographic studies and archaeological interpretations reveal different settlement models on a regional scale from which conclusion about the spatial organization of human groups can be drawn from; they have biological, demographic, and social dimensions (BUTZER 1982):

- Human groupings will tend to be more concentrated or dispersed if the spatial distributions of exploited resources are so.
- Mobility will be the fundamental factor in the survival of human groups living in environments with limited resources and low productivity, while the abundance of resources will favor sedentism.
- Human groups will tend to exercise territorial rights over areas of high productivity and predictability, while otherwise inter-group relations will become more flexible. Only when the energy effort needed to control a given area is compensated by its greater wealth will a marked territoriality be exercised.
- The size of the group will depend on the dispersion of the resources, increasing the more concentrated they appear.

(D) Archaeologist want to understand the activities that were involved in site formation. Modern archaeological excavation techniques, particularly in Paleolithic sites, encompass a variety of detailed steps including: piece-plotting of individual finds, collection of the smallest finds by sub-squares and thin spits during fieldwork, fine-mesh water-screening and, finally, sorting by material types (STRAUS & GONZÁLEZ-MORALES 2012c; MALLOL & HERNÁNDEZ 2016). All these procedures now aim accurately to recover all extant archaeological data, since archaeologist are aware of the importance to understand and decipher site formation processes (SCHIFFER 1996). During archaeological laboratory analysis, however, many aspects of these records are often overlooked or avoided because they are time-consuming. Especially the attention put to finds that are in average smaller than three centimeters is limited but essential to understand site formation processes.

Old excavations techniques (i.e., pre-World War II until quite recently) basically shoveled archeological sediments' out cave sites quite quickly of and only/mostly diagnostic finds were kept (MANNE 2010). According to L.G. Straus memos, when he dug with F. Bordes in 1969, Bordes would throw "non-diagnostic" bones out of the cave, exclaiming, "another goddamn bone". In these cases, mostly only larger remains of

bone fragments are available for research studies. Even during modern archeozoological laboratory analysis, small bone fragments from macromammals are often omitted or even overlooked. These bone micro-fragments we can define as normally less than ~3cm-long bone specimens that are often anatomically or taxonomically unidentifiable. They are usually set apart as 'indeterminate specimens' and then only 'identifiable' bones are studied (KLEIN & CRUZ-URIBE 1984; OUTRAM 2001). What needs to be taken into account is that these items represent often a class of ultimate end-products of the potentially long *chaîne opératoire* of animal carcass exploitation, i.e. taphonomic processes, and then should be considered if the whole economic process aims to be reconstructed, rather than only making a paleontological study of an archaeological site. This is especially important when working with Paleolithic archaeological sites. In Paleolithic human accumulations, bone-cracking for marrow extraction and grease-rendering commonly caused substantial fragmentation of bones (STINER 2002; CHURCH & LYMAN 2003; THÉRY-PARISOT ET AL. 2005; MARQUER ET AL. 2010; BINFORD 2012; JANZEN ET AL. 2014; MORIN & SOULIER 2017). The *chaîne opératoire* concept, pioneered in Paleolithic studies by André Leroi-Gourhan and normally applied to lithic analysis (see overview in BAR-YOSEF ET AL. 2009), is followed and used in this context to record the consequent steps of human actions within the continuum from food acquisition to waste abandonment as readable from faunal remains. Food procurement and butchering processes are frequently-performed tasks in hunter-gatherer lifeways that result in human-made bone accumulations, which in turn indicate the significant contribution of macromammal remains in the formation of archaeological sites (GEILING ET AL. 2016).

Archaeologists have a broad interest in the study of human activities for modeling behavior patterns, variability and adaptation to changing environments and climatic conditions among Paleolithic hunter-gatherers (BINFORD 1978; NAKAZAWA ET AL. 2009). Targeting specific activities can be used to understand Paleolithic human behavior; especially zooarchaeological remains provide the means to reconstruct Paleolithic behavior (BARTRAM ET AL. 1991) and campsite structures (O'CONNELL ET AL. 1991). According to plant-animal subsistence ratios among worldwide modern hunter-gatherers, diets include more than 50% animal-based foods (more in cold and high-latitude settings such as Oldest Dryas northern Spain) and therefore the exploitation of faunal remains is presumably a frequent activity (CORDAIN ET AL. 2000). Although plant foods play a role in the diet, under glacial conditions, the basis of subsistence is thought to be mainly fat and meat (FREEMAN 1973, 1981). A broad spectrum of activities based on animal remains and their subsequent spatial distribution can be used to define activity zones such as roasting, meat-, marrow- and grease-processing or discard (HENRY 2012). Distinct accumulating agents (humans versus raptors and terrestrial carnivores), anthropogenic modifications and preservation conditions can all be identified with the help of zooarchaeological investigations (STRAUS 1982; LYMAN 1994; VILLA ET AL. 2004; REITZ & WING 2008).

(E) Intra-site spatial analysis is the tool to tie together the varied human activities on-site. Activities of interest for the exploration of campsite organization include butchering, bone marrow extraction, grease rendering or bones used as fuel. Based on ethnographical studies, distributions of miniscule bone fragments in camps may reflect the location of activities generating bone refuse such are processing, consumption, and discard, while the intensity of secondary disposal activities, trampling, post occupational carnivore/scavenger activities give further insights into the depositional history (BARTRAM ET AL. 1991: p. 137).

Spatial distribution analysis is based on the three-dimensional relationships of archaeological remains (SCHIFFER 1996). Scrutiny of object distributions during human occupation layers is a useful tool for reconstructing intra-site spatial organization and use (CLARKE 1977). By using these methods archaeologists are able to reconstruct activity areas (FERRING 1984: p. 117). These are generally exemplified by hearth-centered models, where different types of activities are spatially distinguishable (LEROI-GOURHAN & BRÉZILLON 1966; AUDOUZE & ENLOE 1997; MÜLLER ET AL. 2006; NAKAZAWA ET AL. 2009; ALPERSON-AFIL ET AL. 2009; GOREN-INBAR & ALPERSON-AFIL 2010; FLADERER ET AL. 2014). According to Binford (1978) three main areas of bone distribution around a hearth are identifiable: a drop zone, a seating area and a toss zone. More recently these

basic categories have been widened to incorporate cooking, production, curation, walking or sleeping areas and multiple hearths, increasing the evidence for functional patterning of intra-site spatial use in the Paleolithic (see also HENRY (2012)).

Archaeological spatial analyses have to deal with the fact that recurring activities and long and/or repeated occupations of cave sites create often very thick palimpsest layers (STRAUS 1979, 1990). The term palimpsest refers to the superimposition of successive activities or traces of multiple, overlapping activities revealing time-averaged assemblages (HENRY 2012). The amalgamation of living surfaces with repeated or continues occupations overprinted by younger deposits and activities. The prevailing state of the art related to palimpsests is that stratigraphically distinguishing between single occupational events and activities is difficult or impossible (BAILEY 2007). Later, during interpretation, archaeologists tend to 'lump' the residues of multiple occupations together for creating more 'meaningful', on a broader scale interpretations (BAILEY 2007; STRAUS 2008; MACHADO & PÉREZ 2016). This procedure further contributes to the nature of palimpsests and from these time-averaged palimpsests researchers study substantial long-term characteristics of a cultural period, i.e. the broader context. After several decades of Paleolithic research in the Cantabrian region, these major cultural periods are fairly well understood. What is now coming into focus are questions about the transition between the various culture phenomena and what triggered their replacement. This seems to be outside the range of some methods used so far. As a necessity, depending on the type of research question addressed, these palimpsests need to be untangled or dissected to reconstruct individual human activities to reconstruct a more detailed human history.

Activities commonly are conditioned by the physical features of each cave such as walls, entrance and terrace, blocks, ceiling height, sunlit vs. dark areas (STRAUS 1979, 2008; SCHIFFER 1996; BAILEY 2007; HENRY 2012). Spatial analyses in palimpsest contexts can be guided by some spatially structured activities (such as those 'anchored' by hearths) and refits of artefacts or bones that help deciphering this kind of accumulations (FERRING 1984; MARÍN-ARROYO 2005; STRAUS 2008). In the absence of evident structures which segregate space in a tangible way, zooarchaeological studies may provide insights into spatial organization and site formation processes such as 'invisible hearths' features (O'CONNELL ET AL. 1991; GOREN-INBAR & ALPERSON-AFIL 2010). Significant natural post-depositional processes, such as water running through archaeological layers or reworking of the sediments, should be excluded as possible causes for altering or disturbing the levels under study. The intensity of visible anthropogenic modifications on each bone specimen depends on the type of economic activity carried out and on conservation of the anthropogenic marks. The combination of taphonomic features of faunal remains, as well as their spatial distributions, are useful indicators to understand past human activities related to subsistence behavior. Particularly, good bone preservation can indicate little post-depositional disturbance from natural agents and make it possible to investigate the evidence of human living floors.

Spatial analysis provides a useful tool for both, deciphering palimpsest and connecting activities, which are necessary steps to understand specific human activities in context of their economic system. The history of site occupation reveals varied aspects of Upper Paleolithic lifeways and economies. The economic systems definitely cannot be untied from their environmental context, which analytical framework will be outlined next.

2.6.3 Paleo-environments: Paleoclimate, stable isotopes and dental calculus studies

Until now, in Northern Iberia more work has been done on reconstructing over regional climate context to understand the broader environmental evolution, these circumstances leave many gaps to understand local climate impact and details of local environmental change in micro-habitats. For example, there emerged a

contrast of long-term climatic observations and short-term appearance of human cultural behavioral change. In this context remain subjects to discuss such as: What does the identification of a refugium mean: Shorter or milder winters? What infers 'a milder climate'? How drastically were seasonal changes? Does exist a change in seasonal duration? Have seasonal changes an influence on animal behavior, for example breeding seasons? Another debate is that the Cantabrian Lower Magdalenian a rather short appearance characterized by dense accumulations seems to not get explained by known general climatic shifts or long-term observations; or did they?

In order to reconstruct the paleoenvironmental conditions inhabitants of El Mirón faced during MIS2, an analysis of stable isotopic analysis on teeth has been achieved. Oxygen and carbon isotope signatures within red deer and ibex teeth enamel carbonate, to explore seasonal fluctuations in local environments during the Upper Paleolithic, was undertaken. Intra-tooth $\delta^{18}O$ and $\delta^{13}C$ bioapatite sampling provides an established method to study, amongst others, seasonal temperature and humidity variation, tooth formation duration and most recently social animal group identification (FRICKE ET AL. 1998; BALASSE 2002; READE ET AL. 2015; JULIEN ET AL. 2015).

Investigating the Iberian refugium local climate, influence of seasonality on humans and animals and on-site accumulation history contributes to a better understanding of past human behavior change in general, while aware of that Upper Paleolithic cultural periods formed and diversified under rapid climatic changes. Thus, a strategy to study these circumstances is to test the coincide of events in climate and cultural change: despite the fact that the Cantabrian region acted as a refugium and it was considered that climatic changes did not affect this region heavily, changes in cultural periods overlap with climatic changes anyway (BRADTMÖLLER ET AL. 2012).

For improving data for such reasoning, this dissertation study will include a broad, united analysis of stable isotopes in Spanish ibex and red deer tooth enamel for the Upper Paleolithic in the Cantabrian region. Despite that results can be correlated with previous, unpublished results of Middle Paleolithic tooth enamel studies from the same region made within the research group, it will provide a better understanding of local environmental conditions, prey species and Upper Paleolithic hunter-gatherers behavior. There are multiple reasons why this specific research is important for future interpretations: (1) There is a lack in the region of serial stable isotope analyses on herbivore teeth, instead stable isotope analysis on bones are more common, because bones are generally more abundant, sample extraction is easier and they are used for general environmental trends. (2) Most archaeological levels have not preserved enough animal teeth to compare several samples from one layer. (3) When comparing different cultural periods, it is beneficial to sample archaeological teeth from a long stratigraphy, at one site, to reduce changing parameters due to site locality (topography, etc.).

A few previous stable isotope studies were performed in the Cantabrian region as summarized here, and principle assumptions of such analysis will be explained for the interested reader.

Isotope studies on bones (commonly C/N) reveal an average signal from several years of the region's climate depending the species, while the bone matrix grows and rebuild during the whole life of every vertebrates. In bones, several stable isotopes (such as carbon and nitrogen) are studied as relative parameters for environmental conditions. Carbon and nitrogen isotopes in bone collagen reflect those of the dietary protein consumed and it is possible to extract paleo-environmental information from them. In $\delta^{13}C$ values water availability appears to be the most influential parameter. While corresponding to changing temperatures and soil activity, plant $\delta^{15}N$ is also often correlated with altitude (STEVENS ET AL. 2014).

Current stable isotope studies in the Cantabrian region propose according to general carbon and nitrogen trend that horse began to shift their ecological niche towards a more open vegetation on the Middle to Upper Paleolithic transition (JONES ET AL. 2018). The authors discuss whether high inter-individual nitrogen isotopic ranges in red deer and horse, observed during the Mousterian, Aurignacian and Gravettian, derive from procurement of preys in isotopically different environments/areas (and non-local animals were brought as 'trail-food' from different isozones) or rapid/short time climatic shifts contributed to isotopically different animals being accumulated within the same archaeological palimpsest deposit. They identified, however, a consistency in the exploration of the landscape from the Middle to Upper Paleolithic transition by exploiting similar isozones, but use of a variety of hunting locations (JONES ET AL. 2019). The mosaic landscape of the Cantabrian region may have buffered sharp environmental fluctuations and, thus, provide suitable habits for key prey species during the Last Glacial period (JONES ET AL. 2019). This niche separation might be also reflected within the stable isotope analysis from the paleontological site Kiputz IX, spanning a period of the Late Glacial. While the authors postulate a generally warmer environmental from about 22- 13ka BP in the Cantabrian region, they interpret that horse represent drier conditions and red deer show wetter conditions than continental Europe during the same period of time (CASTAÑOS ET AL. 2014). Bone collagen analysis were performed in a suite of herbivore bones at La Paloma cave (Asturias) covering the period from ~20.3–12.9ka cal BP. Isotopic signals indicate a C3 mixed woodland–mesic C3 grassland conditions, where large bovid seem to prefer more open environments. It is known from previous studies that red deer are considered to thrive in a variety of habitats, with browsing diets in open environments during the Paleolithic (STRAUS 1981; DELGADO HUERTAS ET AL. 1997; STEELE 2002). The match of horse and red deer values point to a mixed diet of both, but low $\delta^{15}N$ values in horses might infer a low protein diet. The authors summarize that isotope results did not show significant variations and likely indicate stable local conditions during this period, through either no major vegetation turnover, maintenance of hydrological conditions, or relatively constant soil activity (DOMINGO ET AL. 2015). According to a combined micromammal, marine and stable isotope data analysis from Antoliñako Koba (Bizkaia), the general climatic trend indicate that woodland areas decrease from the Aurignacian until the Upper Solutrean to then again increase until the Azilian period, accompanied with progressive raise in temperatures (begin of the Holocene) (ROFES ET AL. 2015).

Distinguishable are the information that can be obtained from studying carbon and oxygen isotopic compositions in animal tooth enamel. In wild herbivores, carbon reflects $\delta^{13}C$ values of the carbonate apatite in tooth enamel that is correlated with bulk diet (DENIRO & EPSTEIN 1978). The value varies within species according to following parameters: in Eurasia make C3 plants the decisive consumed input; according to consumed photosynthetic plant types C3 plants have an average $\delta^{13}C$ value of ~26‰; and $\delta^{13}C$ values get more negative when plants growing under closed canopy environments, low light intensity, or high humidity (DRUCKER ET AL. 2008). In general, appear in $\delta^{13}C$ values water availability as the most influential factor.

Water dependent herbivores obtain their oxygen isotope variations in the enamel phosphate fraction from drinking, which mean their $\delta^{18}O$ values are linked to those of environment water (precipitation/aridity) (LONGINELLI 1984; IACUMIN ET AL. 1996; FRICKE ET AL. 1998; LEVIN ET AL. 2006) and, in turn, reflect local average surface temperatures (DANSGAARD 1964). The animal's enamel $\delta^{18}O$ is closely related to plant water $\delta^{18}O$, though slightly enriched to local meteoric water $\delta^{18}O$, when water acquirements are mainly from ingested water.

Especially grazing species (e.g., horse diet exclusively relies on grasses), but also mixed feeders (e.g., red deer represent an intermediate browse – graze behavior), are obligate drinkers and obtain mainly their $\delta^{18}O$ from frequent drinking of surface waters, thus their $\delta^{18}O$ best represent precipitation and temperature (DANSGAARD 1964; LONGINELLI 1984). In contrast pure browsers, which are non-obligate drinkers, acquire their $\delta^{18}O$ mainly from dietary sources, plant and metabolic water (KOHN 1996; READE ET AL. 2016) which represent relative environmental humidity. Spanish ibex show tendencies for a more mixed diet (MOÇO ET AL. 2013).

The high topographical diversity at the Cantabria coast, including coastal plains and a mountain range of over 1500m within ~50km in close distances, might create a local-steep $\delta^{18}O$ gradient reaching from high $\delta^{18}O$ values at the coast to lighter ones along the montane area through fractionation (LONGINELLI 1984; BRYANT ET AL. 1996; CHENERY ET AL. 2012). When plotting the modern ten-year variation of $\delta^{18}O_{precipitation}$(‰) values of precipitation shows that further inland (locations of Valladolid, León, Zaragoza and Madrid) the $\delta^{18}O$ value ranges increase (with lower values) compared with coastal locations such are Coruña or Santander (Figure 2.8). Those data imply that less seasonality and warmer conditions exist along the coastal area of the Cantabrian region. Coastal areas show mean values of -4.97±1.51 (Santander) and smaller standard deviation compared with inland areas recording -7.79±2.38 (León) with higher standard deviation.

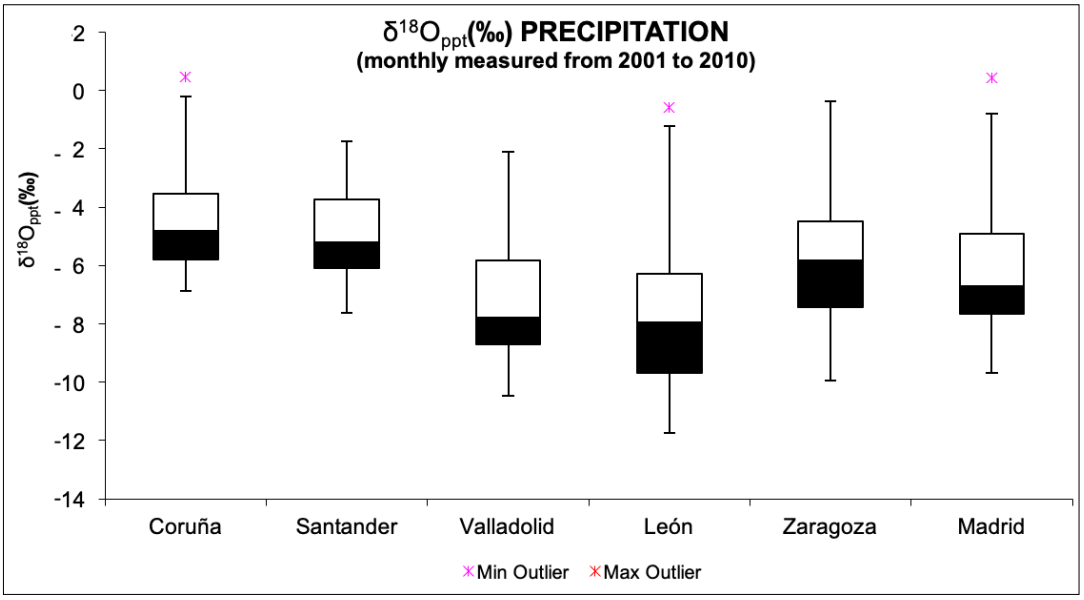


Figure 2.8: $\delta^{18}O$ variation of (Northern) Iberian precipitation in a ten-year time frame, monthly measured from 2001 to 2010 (data plotted were downloaded from http://www.cedex.es/: "*Datos tomados de la Red de Vigilancia de Isótopos en Precipitación (REVIP), gestionada por el Centro de Estudios y Experimentación de Obras Públicas (CEDEX) en colaboración con la Agencia Estatal de Meteorología (AEMET)*").

The general biomass of the species also counts according to larger animals derive proportionally more of their oxygen from drinking water and will therefore track surface water composition more closely than smaller animals (BRYANT & FROELICH 1995; KOHN 1996). In this sense would horse species track more efficiently the isotopic composition of surface waters than red deer or ibex.

It could be hypothesized based on the previous assumptions that horse's $\delta^{18}O$ isotopic signals represent the highest incorporation and genuine signal of surface waters. Spanish ibex, with a slightly smaller body mass as red deer, and potentially grazing/browsing changes and potential living in higher altitudes will likely reflect the most varied signal of $\delta^{18}O$. Red deer may represent intermediate-enriched $\delta^{18}O$ values of plant water influenced by browsing activity.

2.7 Relevance of El Mirón Cave site

2.7.1 The archaeological context

The project presented here can be understand as a continuation of previous archeozoological studies carried out at El Mirón. With only about one sixth of the vestibule having been excavated, this cave nonetheless has revealed a long cultural sequence of different cave uses from the Late Middle Paleolithic until recently. Importantly, cutting edge, multi-disciplinary research has been carried out. While during the Early Bronze Age and Chalcolithic caves in Iberia were often used as funerary places or ceramic deposits ('caches'), El Mirón was one of the few major residential (and animal stabling) sites of these periods to have been excavated in the region (STRAUS & GONZÁLEZ-MORALES 2012b). During the Neolithic period, the cave served as a living space for the first farmers of the Cantabrian area, as indicated by the earliest pottery, domesticated animals and (AMS- dated) grains of domestic wheat found on the Cantabrian region (PEÑA-CHOCARRO ET AL. 2005a, 2005b; STRAUS & GONZÁLEZ-MORALES 2012c). During the Azilian and Upper/Final Magdalenian the cave was only sporadically inhabited, while in the Middle and especially Lower and Initial Magdalenian, the cave revealed repeated and very dense/rich occupations. It is the first major Magdalenian site to be excavated on the flank of the Cantabrian Cordillera, surrounded as it is by c.1000m peaks. During the Upper and Middle Magdalenian, El Mirón was used as a residential camp by groups of hunter-gatherers who, during their movements along the Asón Valley, occupied the upper valley during the warm summer months (MARÍN-ARROYO 2010). The diet during this period was highly specialized on the exploitation of red deer and ibex, given the cave's close position to both species favored habitats: the broad, fairly flat Ruesga (middle Asón) valley c. 100-150m below the site and the steep, rocky slopes and cliffs immediately around the cave.

The Lower Magdalenian occupation layers at El Mirón are, however, special: characterized by thick horizons without obvious sterile layers between the occupations, which contain literally more archaeological remains than sediment. These layers are described as a dense, dark 'chocolate' brown occupation horizon packed with faunal remains, stone knapping debris and tools, bone artifacts, fire cracked rocks, charcoal and ochre powder and chunks (STRAUS 2013b). The dense nature of these deposits equals a "palimpsest deposit" (STRAUS 2013b: p. 238), so common for this cultural period (for example in El Castillo, Altamira, Santimamiñe and El Juyo). This seems to have been a time of high population density with many sites and frequent use of favored caves, some used for both residence and for (presumably ritual-related) decoration. It is, therefore, of great interest to complete the history of El Mirón site before, during and especially immediately after the Last Glacial Maximum. In addition, the discovery during the 2010 excavations of a human burial in a Lower Magdalenian level, completely covered/impregnated with red ocher, gives this deposit an exclusive place in the Cantabrian region and allows us to understand the ways of both life and death of these human groups (STRAUS et al. 2015a). Magdalenians, however had not been, the first hominins to occupy the cave, as El Mirón also gave shelter to early Cro-Magnons in Solutrean and Gravettian times. Although this cave never seemed to have been a den, sporadic alternating use by carnivores and Neanderthals is indicated for the Late Middle Paleolithic occupations (MARÍN-ARROYO ET AL. 2018a).

Following remarkable archaeological discoveries have been made at El Mirón Cave, most relevant to the present study: (A) parietal cave art, (B) Lower Magdalenian human burial, (C) engraved scapula, (D) Mediterranean shells, (E) lithic raw materials, (F) spear thrower, (G) fire cracked rocks and (H) bearded vulture activities.

A. Parietal art: Given that the research history in the Cantabrian region was driven first by the exploration of the Paleolithic cave art after the 1879 discovery of Altamira, the cave art in El Mirón cave will be reviewed here first as one part of the archaeological record and the cave's investigations. The figures in El Mirón amount just a few graphical manifestations of prehistoric cave art activity, compared with the outstanding

graphic works found in the cave art sites located nearby in the same mountain and where El Mirón is located, namely in Cullalavera, Covalanas (GONZÁLEZ-SAINZ & SAN MIGUEL LLAMOSAS 2001) and La Haza (GARCÍA DIEZ & EGUIZABAL TORRE 2007), as well as the minor site of La Luz (MONTES BARQUÍN ET AL. 2002).

The first graphical activities were discovered at the beginning of the project directed by Straus and González-Morales in 1996. Until then no cave art was known in El Mirón despite the early investigations by L. Sierra and Alcalde del Rio (ALCALDE DEL RÍO 1906b; GARCÍA DÍEZ ET AL. 2012), which had registered much prehistoric cave art within the Cantabrian region.

El Mirón contains several non-representational engraved lines and zoomorph depictions. A horse image and a cross-linked sign (Figure 2.9) were engraved in the northern cave wall right at the transition from the vestibule rear to the ramp leading to the inner of the cave (GARCÍA DÍEZ ET AL. 2012). In the same area, but on the southern cave wall, was discovered a possible bison through systematic cleaning and inspection of the limestone rock. A natural rock formation enhanced with engraved lines may outline the bison figure (GONZÁLEZ-MORALES & STRAUS 2000). Both of these engravings probably date to the Lower-Middle Magdalenian periods according to their height above the living surface and based on the horse image style typically seen in this region during that time period.

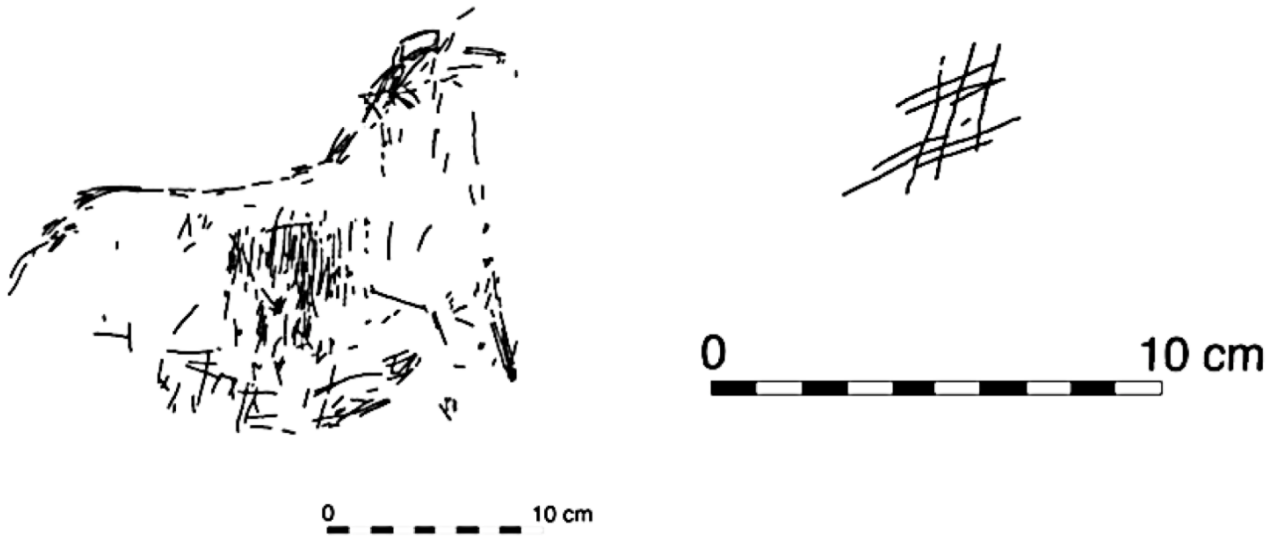


Figure 2.9: a horse engraving in group 1 (left) and a cross-linked sign in group 2 (right). Figures from García Díez et al., 2012: Figure 4 and 5.

Of special interest when considering the El Mirón cave art work, is the so called 'engraved block' (Figure 2.10). This large stone of about ~2x1x1m is actually a piece of the cave ceiling that had fallen atop an early Lower Magdalenian level and was then engraved on its sheered-off, formerly inner surface that faces west to the cave mouth, hence with sunlight shining on it at least in summer afternoons. These engravings were clearly made during Lower Magdalenian occupations (GONZÁLEZ-MORALES & STRAUS 2015). The surface under the block was dated to the early Lower Magdalenian with 16,130±250 uncal BP (GX-23396, conventional assay on bone collagen) and 16,520±40 uncal BP (UG-10628, AMS on bone collagen). According to these

dates fell the block possibly very shortly after about 16.5ka uncal BP (about 19.65ka calendar years ago) (GONZÁLEZ-MORALES & STRAUS 2015). Late Lower- and Middle Magdalenian sediments on the other hand already covered the engravings that reach the lower end of the west face of the block. The engraving on the block are constituted of various straight, parallel and crossed lines could represent human hands and, more clearly, based on a deeply and repeatedly engraved V-shaped motif, a pubic triangle, thus conceivably marking the 'Red Lady' burial (STRAUS et al. 2015a). Red ochre staining on the east side of the block was found during the excavations of the human burial and extended slightly over the top of the burial-containing level. The pigment is from the same outcrop source on a mountain at the present mouth of the Asón as the ochre in the grave, according to mineralogical analyses by Seva et al. (2019). The cave wall immediately behind the engraved block and at the level of the burial also bear four groups of engraved lines, which consist of some clearer deeper lines accompanied by finer striations.

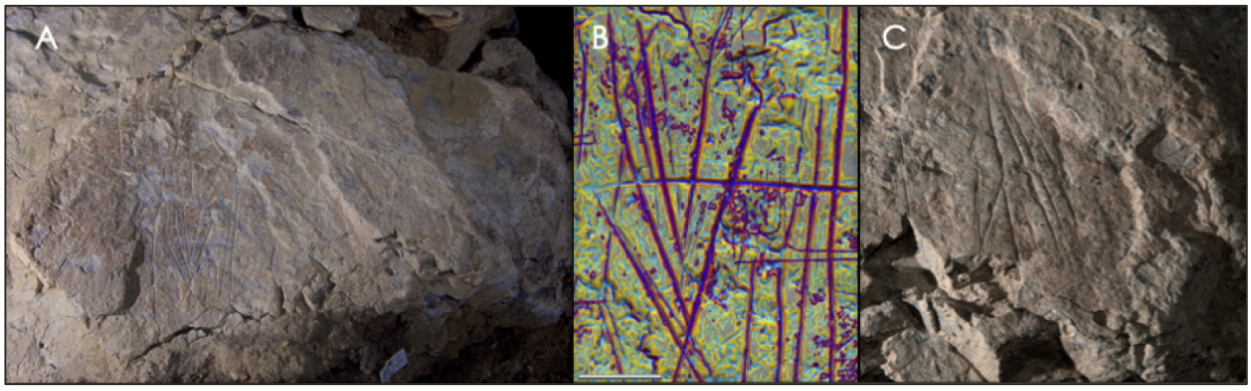


Figure 2.10: Details of the engraved block in the burial area: (A) location of the V-grouped lines on the west-face of the block, (B) laser scan image showing varied depths of the V-shaped engraving (by Vera Moitinho) and (C) details of the lines possible representing a hand. Pictures from González-Morales and Straus, 2015, A=Figure 8, B=Figure 9, C=Figure 10.

The graphic finds are not comparable in abundance to the density of occupational remains found within this site. This implies for El Mirón cave a general use as living space through different time periods, rather than a site that was used only for special, exceptional, 'sanctuary'-type activities. In contrast, the latter function may have applied to Covalanas, a cave situated circa 100m above El Mirón, that presents a complex assemblage of images of Paleolithic deer hinds and other ungulates painted realistically using a red dot technique associated with the Solutrean or late Gravettian period, but did not contain sediments with archaeological remains (GARATE-MAIDAGAN 2010). Given the proximity of the two caves (and La Haza), it cannot be excluded that they were used contemporaneously, one with a profane and the others with a sacred character. The Lower Magdalenian occupation levels of El Mirón, however, revealed an engraving of a hind on a stag shoulder bone (and fragments of other similar works of portable art), engraved stones, many personal adornments (perforated shells and teeth) and decorated osseous weapon tips, which are described in more detail in more relevant position later in this work (GONZÁLEZ-MORALES & STRAUS 2009).

B. Human burial during the Lower Magdalenian: Between 2001 and 2013, additional Lower Magdalenian layers were excavated in the smaller 'Burial area'. Initially these human remains were thought to be a secondary burial based on its incomplete character (STRAUS, GONZÁLEZ-MORALES, & CARRETERO 2011). However, a series of detailed cultural and natural science studies (STRAUS et al. 2015a) of the burial context revealed that this interment was in fact likely a disturbed primary human burial (STRAUS et al. 2015a) covered by

sediments with red ochre together with sparkling hematite crystals (SEVA ROMÁN ET AL. 2015) and stone slabs. Further anthropological (CARRETERO ET AL. 2015), human dental calculus (POWER ET AL. 2015), dental microwear and stable isotope (GARCÍA-GONZÁLEZ ET AL. 2015), taphonomic (MARÍN-ARROYO 2015), spatial distribution (GEILING & MARÍN-ARROYO 2015), sediment and plant remains (IRIARTE-CHIAPUSSO ET AL. 2015), lithic and osseous artifacts (FONTES ET AL. 2015), archeozoological (MARÍN-ARROYO & GEILING 2015) and ornaments (GUTIÉRREZ-ZUGASTI & CUENCA-SOLANA 2015) studies have been realized to further investigate the context of this first human burial yet to be found in the Late Glacial (Magdalenian) of the Iberian Peninsula. Human remains lack most long bones, but the tibia and mainly are represented through the mandible, vertebrae, pelvic girdle, hand and feet bones (Figure 2.11). These results give important insights into Lower Magdalenian lifeways of the El Mirón cave inhabitants.

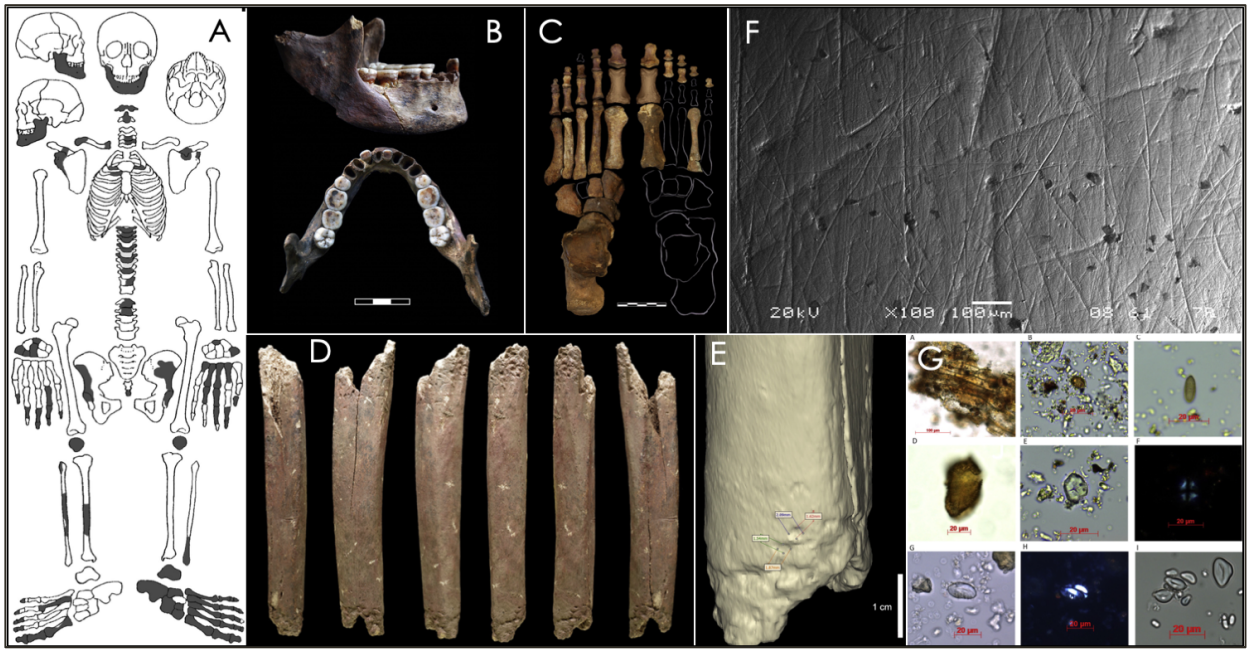


Figure 2.11: Summary of the Red Lady discovery found in the burial area of El Mirón: (A) portion of the skeletal remains found, (B) mandible, (C) feet bones with the left side more complete than the right side, (D) red ochre stained tibia with broken ends, (E) ends of the tibia contain carnivore bite marks, (F) dental use wear analysis and (G) micro-remains in dental calculus. Figures from Carretero et al. 2015: B=Figure3, C=Figure 6; from Marín-Arroyo: D=Figure 3, E=Figure 4; from García-González et al. 2015: F=Figure 1; from Power et al.2015: G=Figure 3.

The burial area is located behind (east of) the large engraved block (Figure 2.12), which might have served as a grave marker marked with red ochre (GONZÁLEZ-MORALES & STRAUS 2015). Clumped pollen found in the burial sediments might be related to the burial as they seemed to be deposited. Engravings on this block dating to the Lower Magdalenian period.

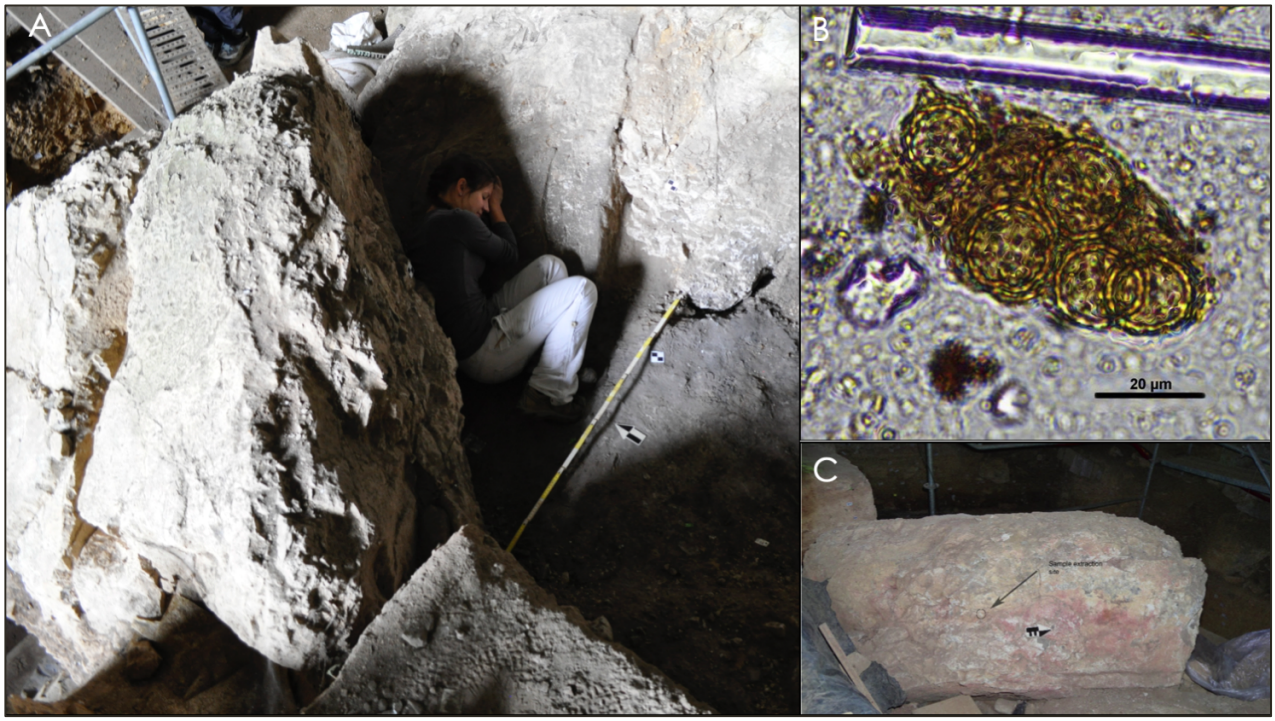


Figure 2.12: Burial context: (A) likely position of the 'Red Lady' when she was buried reconstructed by JMG (Photograph by M.R. González-Morales) and (B) clumped pollen grains in Level 504 (Iriarte-Chiapusso et al., 2015, Figure 5) and (C) red ochre cover of the back of the engraved block (Seva-Román et al., 2019, Figure 4).

C. Engraved scapulae: An extraordinary find from El Mirón cave is a large red deer stag scapula engraved with a head of a red deer hind and bovine (Omóplato n°1) from the middle of the Lower Magdalenian Level 17 (spits 52-54 of subsquare H2b). Now, the specimen is part of the permanent exhibition about portable art object from the Cantabrian Paleolithic in the MUPAC (Museo de Prehistoria y Arqueología de Cantabria) in Santander. Rapid burial might have contributed to its excellent condition (GONZÁLEZ-MORALES & STRAUS 2009).

There are several other pieces of engravings on scapulae from the Lower Magdalenian occupations, all but one located within the sunlit Cabin excavation area. What follows are some details on the engraved objects summarized after González-Morales (2006).

- Omóplato n°1: a hind engraved by complete red deer head and dorsal line filled with striated lines and precisely marked eye contour and a possible bovine with a very marked withers, part of the nose with a well-marked nostril (Square H2-1981, B, spit 54, Level 17), dimensions: 300x71x88mm. (Figure 2.13-A,B)
- Omóplato n°2: fine engraved lines, slightly curved (Square H2-2173, B, spit 55, Level 17), dimensions: 182x55x32mm.
- Omóplato n°3: small engraving of a head, neck and begin of the back, with lines of possible ears or horns (Square H3-3476, A, spit 74, Level 17), dimensions: 96x39x14mm.
- Omóplato n°4: clearly engraved with possible parts of a large animal (Square T8-2240 & T8-2387, B, spit 36,37, Level 116), dimensions: 53x35mm.

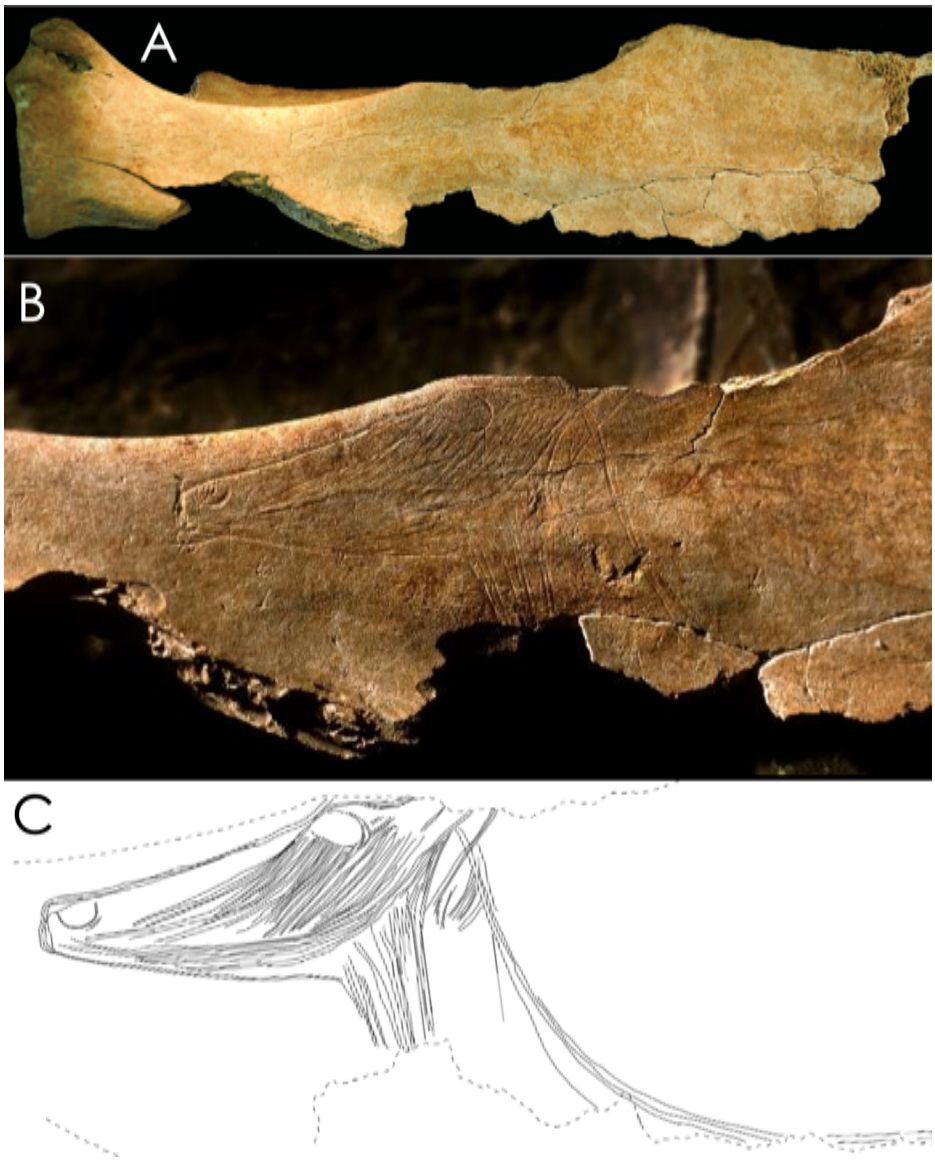


Figure 2.13: Large red deer stag scapula (Omóplato n°1) engraved with a head of a red deer hind and bovine and engraving of head-neck with possible ears from Lower Magdalenian Level 17 at El Mirón cave (photographs and drawing by M.R. González-Morales, (GONZÁLEZ-MORALES & STRAUS 2009) Figure 2, 3, and 4).

D. Mediterranean shells: Mediterranean shells (*Homalopoma sanguineum)* were identified among the ornaments in El Mirón cave (ÁLVAREZ-FERNANDEZ 2006), specifically within the Lower Magdalenian Level 17, outer vestibule. These ornaments suggest the existence of not-insignificant Mediterranean-Cantabrian exchange networks, with similar objects were found in other Cantabrian sites (*Cyclope pellucida* in Tito Bustillo Cave in eastern Asturias; *Zonaria pyrum* in La Garma A in central Cantabria, etc.) (UTRILLA ET AL. 2012; GUTIÉRREZ-ZUGASTI & CUENCA-SOLANA 2015). There is also a Cyclope shell in Level 503 above the burial (G-Zl and C-S 2015).

E. Lithic raw materials: Intensive lithic raw material exploitation is demonstrated in Lower Magdalenian economies in the Cantabrian region as groups maintained their mobile toolkits and were bonded to their landscape (Figure 2.14). Lithics have been studied under the aspect of transport of raw material types. Long distance social context might be exemplified by probably exchanged of exotic raw materials as evidence in El Mirón (FONTES ET AL. 2016).

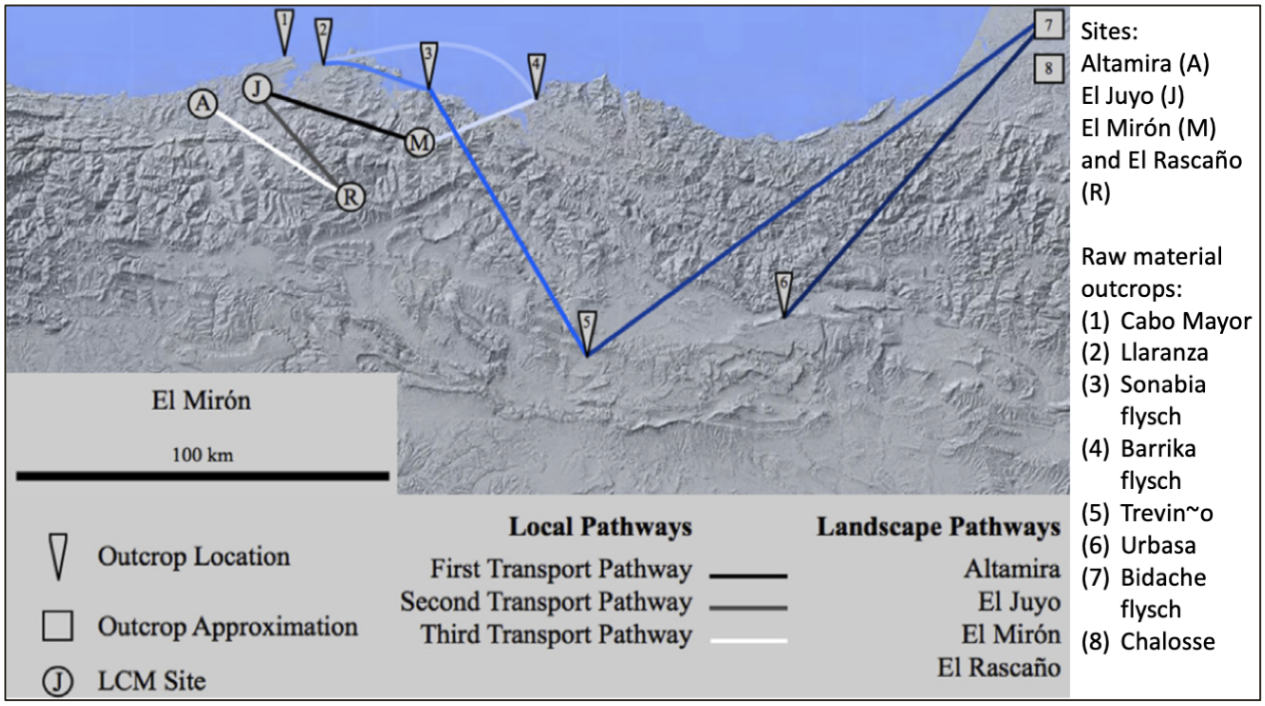


Figure 2.14: Example of mobile lithic toolkit and lithic raw material use in El Mirón cave. The blue line indicates toolkit movements. (Map from Fontes et al. 2016, Figure 5)

F. Spear thrower: The spear thrower or 'atlatl' (Figure 2.15) that was found in El Mirón Level 17 is a special find on its own, but of remarkable interest as so far it is the only piece of that kind found in the cave. The surface of the antler piece is completely worked. It has a very similar design to spear throwers found in the similarly dated Magdalenian level of Roc-de-Marcamps (Gironde, near Bordeaux, southwestern France) and also in undated Magdalenian deposit of Le Placard (Charente, southwestern France). Only one similar object found in the Cantabrian region might be also a spear thrower, which was origin from the early Magdalenian (beta) horizon at El Castillo cave (GONZÁLEZ-MORALES & STRAUS 2009). An atl-atl of possible Solutrean age has recently been described from Las Caldas (CORCHÓN-RODRÍGUEZ 2017).

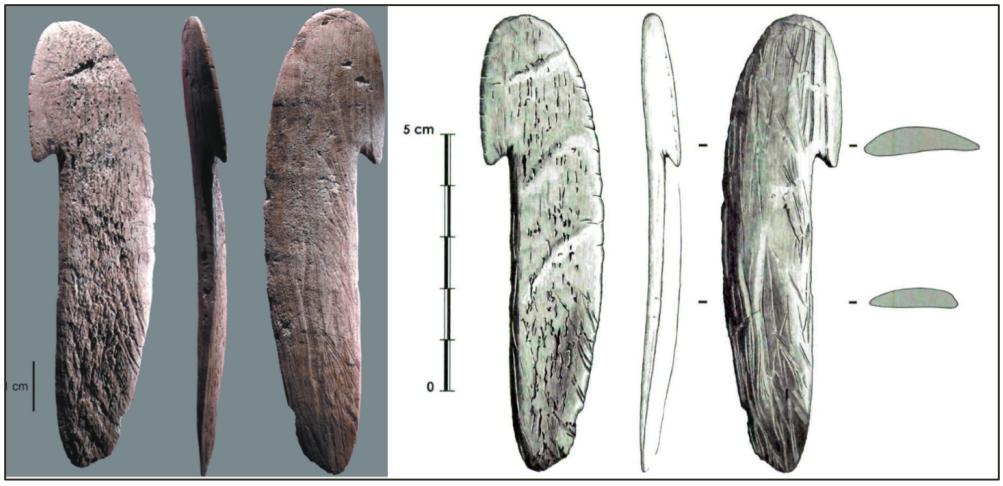


Figure 2.15: Spear thrower or 'atl-atl' from El Mirón Cave, Level 17. Photograph by M.R. González-Morales and drawing by L. Teira (GONZÁLEZ-MORALES & STRAUS 2009) Figure 6.

G. Fire cracked rocks: Stone boiling as a principal cooking method of hunter-gatherer societies is evidenced within El Mirón cave Lower Magdalenian horizons (Level 17) by the conjunction of finds of shallow hearths, fire-cracked rocks, lithic artifacts, heavily broken-up bones (probably for bone grease extraction by boiling) and use-life analysis of fire-cracked rocks (NAKAZAWA 2007; NAKAZAWA ET AL. 2009).

H. Bearded vulture activity: Bone cracking activity, digestion and regurgitate of macromammal remains by bearded vulture (Figure 2.16) was attested for the Middle and Upper Magdalenian levels in earlier studies (MARÍN-ARROYO 2010). The detailed patterns of bone modification made by these animals have been used to distinguish them from human made collections for identifying accumulation agents (DAVIS 2002; ROBERT & VIGNE 2002; DAVIS ET AL. 2007; COSTAMAGNO ET AL. 2008; MARÍN-ARROYO ET AL. 2009; VALENSI ET AL. 2011; MARÍN-ARROYO & MARGALIDA 2012; AGUDO PÉREZ 2015). Vulture eggshells have been identified at the site by Demarchi et al. (2019).



Figure 2.16: Bearded vulture feeds on ungulate long bones (Photographs adapted from FREY AND LLOPIS, 2015).

2.7.2 The environmental context

So far, El Mirón have been a key site in many ways, also in environmental reconstruction for the region. Interdisciplinary studies provide compound insights into environmental condition during the formation of occupation levels in El Mirón cave. On-site environmental reconstructions are based among others records on inter-stratigraphic macro-mammal, micro-mammal, pollen, stable isotope analyses, sediment, etc. (CUENCA-BESCÓS ET AL. 2008, 2009; FARRAND 2012; GONZÁLEZ-MORALES & STRAUS 2013; STEVENS ET AL. 2014).

El Mirón is located within the surroundings of the south-western part of the Cantabrian Cordillera, in the foothill range of the Sierra del Hornijo (STRAUS & GONZÁLEZ-MORALES 2012c). In the nearby highest range of the Cordillera (maximum local altitude of 1715m on Castro Valnera), 25km from the modern shoreline and without significant orographic barriers to access either adjacent valleys or the Northern Castillian *meseta* (Cordilleran passes in the eastern sectors range from about 400 to 900m.a.s.l.), the climate of the Ruesga Valley had great Atlantic (oceanic) influence. The development of Late Glacial montane glacier fronts, which depended on altitudinal thermal environment, snowfall and cloudiness were located at 400-600m to the north and 800-900m to the south of the site (SERRANO ET AL. 2013: p. 79). Altitude of the glacier fronts increase with the distance to the sea. The southern massifs within the Cantabrian mountains, however, are influences by winds from the southwest. This implies a southerly circulation of the atmospheric streams with wetter air masses reaching the southern Cantabrian Mountains (FLORINETH & SCHLÜCHTER 2000). It is generally assumed, that the Cantabrian region, therefore, enjoyed a milder climate than other parts of Pleistocene Europe during

cold spells (despite the absence of the Gulf Stream from the Bay of Biscay during the LGM and Late Glacial, while still of course experiencing significant and rapid environmental shifts caused by global climate processes.

The macro-mammal species representation varies in archaeological sites with which the general dominance of environments around a cave can be obtained. While red deer and ibex are the dominant species represented throughout the El Mirón stratigraphy, only a few other species records might be useful as environmental indicators. Within the Early Upper Paleolithic occupations, a mammoth tooth fragment was identified as an indicator of cold climate conditions (MARÍN-ARROYO ET AL. 2018a). Similarly, I identified a reindeer tooth ornament in the Lower Magdalenian levels, although, it is very likely that this item was brought or traded from a distant place, as no other reindeer bone has been identified so far. During Mesolithic occupations, different forest indicator species are present within the El Mirón levels which persist of roe deer and wild boar, with ibex absent in this level. With the begin of the Neolithic occupations at El Mirón, wild animal species disappear in favor of domestic species, which are not useful for environmental determinations around an archaeological site (ALTUNA & MARIEZKURRENA 2012).

Nevertheless, it has to be kept in mind that species composition not can be taken as direct links towards the environmental conditions. In environments, where severe climatic conditions might restrict natural resources (fodder, space through advancing ice sheets, water often in form of ice, less rainfall during glacier conditions, etc.), researchers have to be aware of that animals possible adapt according to their niche plasticity or disappear. Actually, recent research might have shown this animal behavior by the separation of red deer and horse isotopic values starting to drift apart after the end of the Mousterian, which seem to be introduced (for this two species) by environment change. In the Cantabrian region, these two species seem have occupied very similar ecological niches (similar isotopic signals) during the Mousterian, which change towards horses dwelling more in an open landscape (grasslands) compared with red deer later on (JONES ET AL. 2018). Some of the Late Pleistocene climatic pulses might have triggered the demise of several macro-mammal species in the Cantabrian region, possible in combination with other factors; such as the disappearance of panther at 16kyr BP, cuon at 15kyr BP, snow hare at 12kyr BP, reindeer and bison at 10kyr BP, cave bear at 8.7kyr BP, and cave lion at 8kyr BP (CUENCA-BESCÓS ET AL. 2008, 2009).

Also, many macro-mammal species are considered to be less useful climate indicators as many of them are highly versatile, of all also humans; they might show slow adaptions rates or avoid climatic extremes through mobility. Their indicator usefulness is further complicated, when main accumulating agents of (archaeological or paleontological) remains are humans, which might travel or trade objects over wide distances or select only a few species due to dietary preferences. Game species brought to a site might be only a human selection of what existed within the surrounding environment, and therefore, they might not be representative for the contemporary environmental conditions.

According to the above-mentioned reasons, other records, such are micro-mammals seem to be a better record of environmental conditions as they are either brought into the cave by predators, which normally hunt in the surrounding environment or they enter the cave by herself. At El Mirón cave, micro-mammal evidence provide information on seven events (Figure 2.17) indicating major environment changes during a period from the Middle Paleolithic to the Holocene (from 41ka BP to modern times), the first three apply to the period of study for the present discussion (CUENCA-BESCÓS ET AL. 2008, 2009) and are summarized in what follows.

Event 1 (Middle Paleolithic):

- Here the highest peak of mountain species appears (some of them disappearing from the sequence later on), they are namely:
    - Pyrenean water mole (*Galemys pyrenaicus),*
    - Pleistocene vole (*Pliomys lenki*),
    - Lusitanian pine vole (*Terricola lusitanicus*),
    - Red-toothed shrew species (*Sorex gr. coronatus-araneus*),
    - Water shrew (*Neomys fodiens*)
- An increase of mountain species appears slightly before an increase of humid meadow habits.

Event 2 (period between 30–40 and 27 kyr BP):

- New taxa appear in the sequence and species diversity increase. The peak in humid meadows might indicate cold conditions; a single rodent species is present:
- Northern water voles (*Arvicola terrestris*);
- Diversity of small mammal taxa is reduced, which indicates unstable conditions between H4 and H3 (temperatures rose and dropped several times), during the DO interstadial Is8-Is5 (applying to the period before the Upper Paleolithic).
- The Early Upper Paleolithic (possible Gravettian) occupations contain another peak in mountain species and dry grassland species, both indicating generally more dry conditions during this period.
- In the Solutrean levels water species were most dominant throughout the whole sequence, they indicate abundant surface waters, running or stagnant (=due to glacier melt?). Also, is reflected within the micromammal record a slight decrease in mountain species, forest species disappear entirely and a slight increase in open-country dwellers were detected, which more or less coincided with the LGM and represent glacial periods. Although water seem to be present within the surrounding environment, either it might not have been enough or severe temperatures did not support forest vegetation.
- Post-LGM conditions, at the onset of the Magdalenian (17kyr BP), seemed to be characterized by a major increase of montane species (living above the timberline), possible due to a retreat of ice shields in higher elevations and their recolonization. The subsequent deglaciation results in an increase in humid (evergreen meadow, stadial conditions) and temperate species, correlated with the cold Heinrich H1 period. A few forest species reappear, but humid meadow species were dominant throughout the Lower Magdalenian.

Event 3: (ca 15kyr BP):

- From 15kyr BP onwards, the beginning of the expansion of the forest is indicated. Forest related species get more abundant, they diversify onwards and new taxa appear in the sequence. The Pleistocene vole (*Pliomys lenki*) (CUENCA-BESCÓS ET AL. 2008, 2009) became extinct and other species disappeared temporarily, his could be the begin of the climatic recovery in the Iberian Peninsula, ironically beginning during the Younger Dryas; it marks the end of a cold and dry episode.

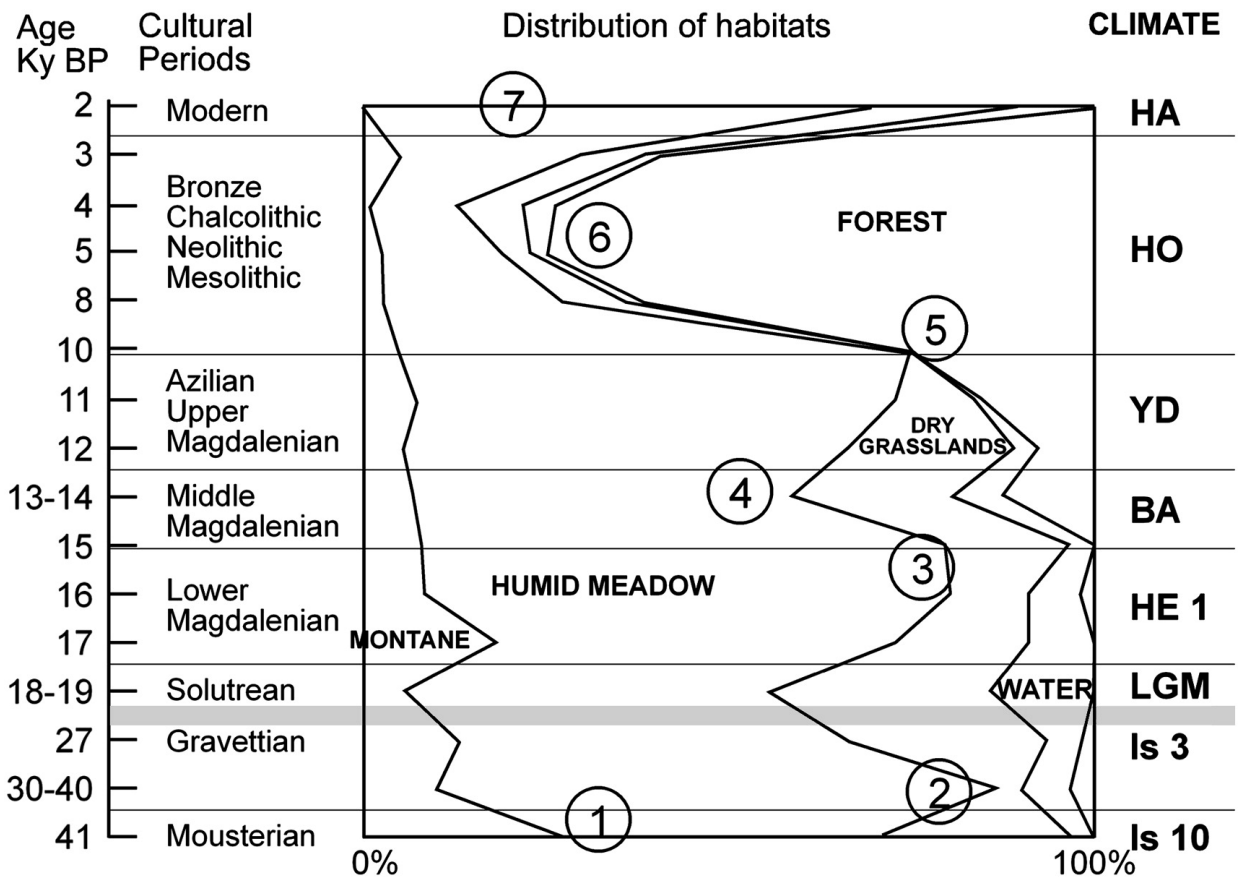


Figure 2.17: Micromammal composition reveals seven major climatic changes among the stratigraphy of El Mirón Cave (CUENCA-BESCÓS ET AL. 2009: p.953, Fig.4).

The study of micro-mammal species in the Lower Magdalenian Level 504 contained a combination of cold-climatic species (snow vole and root vole) and one that live on the edge of watercourses (water shrew and mole) indicate old and locally humid conditions for El Mirón site during that time (IRIARTE-CHIAPUSSO ET AL. 2015). All micro-mammal species live in humid environments, there are no woodland dwellers and surprisingly no field mouse (*Apodemus*) as it is commonly found throughout the El Mirón stratigraphy. Levels 504, 505 and 506 contain mole (*Talpa europeaus*) remains with weathering cracks that suggest that the sediment had been dried out over time (and possible before deeper burial). Importantly, seem the small mammal initiated mixture of sediment limited overall, this is coherent that there is no evidence of rabbit activity within that levels.

Pollen analyses are published for the Gravettian period at El Mirón. Gravettian occupation dates during an advanced stage of GI5 interstadial, where according to pollen analysis Level 128 began to form in an open landscape, with some pines and birches, the latter disappearing at the top of the level, which is identified as a worsening of the climate and the beginning of the immediately subsequent cold period (GONZÁLEZ-MORALES & STRAUS 2013). The vegetation points to a cold and dry climate.

The Solutrean pollen sequence represent adverse climatic conditions with an open landscape (STRAUS ET AL. 2011).

- Early Solutrean (Level 127 and lower part 126, ~23ka cal BP) attested the coldest conditions of the sequence, with arboreal pollen consisting only of pine, in herbaceous taxa, Compositae liguliflora dominates, lowest percentages reached by Poaceae and Ericaceae, and fern.

- Later Solutrean: slight amelioration of climatic conditions with a considerable increase in humidity, relative aridity and cold temperatures in the upper part of Level 126, continued during the formation of levels 125, 122, 121;
    - arboreal: birch rejoins pine, plus herbaceous-shrubs
    - roughly uniform presence of Ericaceae, Poaceae and Compositae liguliflora, with the combined heathers and grasses outnumbering the composites
    - development of ferns, along with such taxa as Juncaceae, Cyperaceae or Ranunculaceae

Lower Magdalenian Level 17 (the western (H-G/2) section) (IRIARTE-CHIAPUSSO ET AL. 2015). In three records of Level 17 pollen samples (Figure 2.18), were observed arid, stadial environmental conditions, especially the two lower ones containing small amounts of juniper, pine and birch. The second lower sample (Nr.2) has a remarkable stadial character. The most recent sample (Nr.3) show hints of a slight climatic amelioration.

- The dominant herbaceous-shrub contain:
    - Compositae liguliflora (35% and 47%)
    - Poaceae (27% and 22%),
    - C. tubuliflora, Ericaceae, Fabaceae and Cyperaceae all have percentages under 10%.
    - Cistus, Centaurea, Lamiaceae, Plantago, Brassicaceae, Ranunculaceae and Umbelliferae appear only sporadically in trace quantities

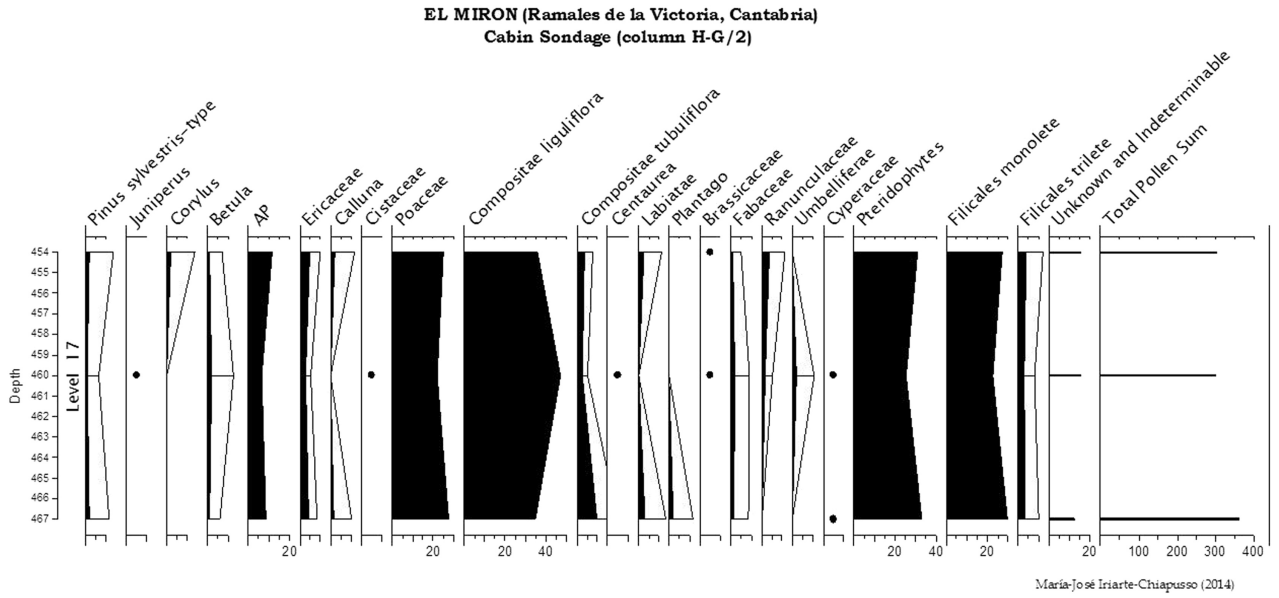


Figure 2.18: Pollen sequence from Level 17, El Mirón Cave. Figure from (IRIARTE-CHIAPUSSO ET AL. 2015).

The pollen spectrum from the Lower Magdalenian burial Level 504 revealed the taxonomic composition of an environment that was cold and not humid: (open landscape with a reduced woodland component) (IRIARTE-CHIAPUSSO ET AL. 2015)

- Arboreal pollen (9.6% almost entirely of pine (*Pinus sylvestris tp.*)
- fern spores (2.7%)
- herbaceous-shrub, dominated by *Chenopodiaceae* (49.5%)
- very small percentages of grasses (*Poaceae* = 11%),
- composites (*Compositae liguliflora* = 7.5% and *Compositae tubuliflora*)

- heathers (*Ericaceae*=4%),
- trace quantities (<2%) of *Labiatae, Plantago, Rosaceae, Artemisia, Asperula tp., Umbelliferae* and *Cyperaceae*.

Recent stable isotope investigation included the oldest levels in El Mirón cave, which comprise the late Middle to Early Upper Paleolithic transition (MARÍN-ARROYO ET AL. 2018a). These analyses were performed carbon-nitrogen combinations of ibex bone collagen, which provide initial insights into past environments. The general environment was characterized by open landscape and cooler conditions during the Early Upper Paleolithic. Collagen $\delta^{13}C$ values of ibex at El Mirón and red deer at El Castillo and Covalejos are within the ranges expected for animals consuming C3 plants within an open landscape (JONES ET AL. 2019). Higher nitrogen $\delta^{15}N$ values within the older Middle Paleolithic Level 130 (warmer and drier environments) compared with Early Upper Paleolithic values in Level 128 and 129 could be indicative of worsening in climatic conditions (slightly cooler and wetter).

A study carried out on carbon and nitrogen on ibex and red deer bone collagen from El Mirón cave will be examined further according to the distribution of the stable isotope results (compare Figure 2.19).

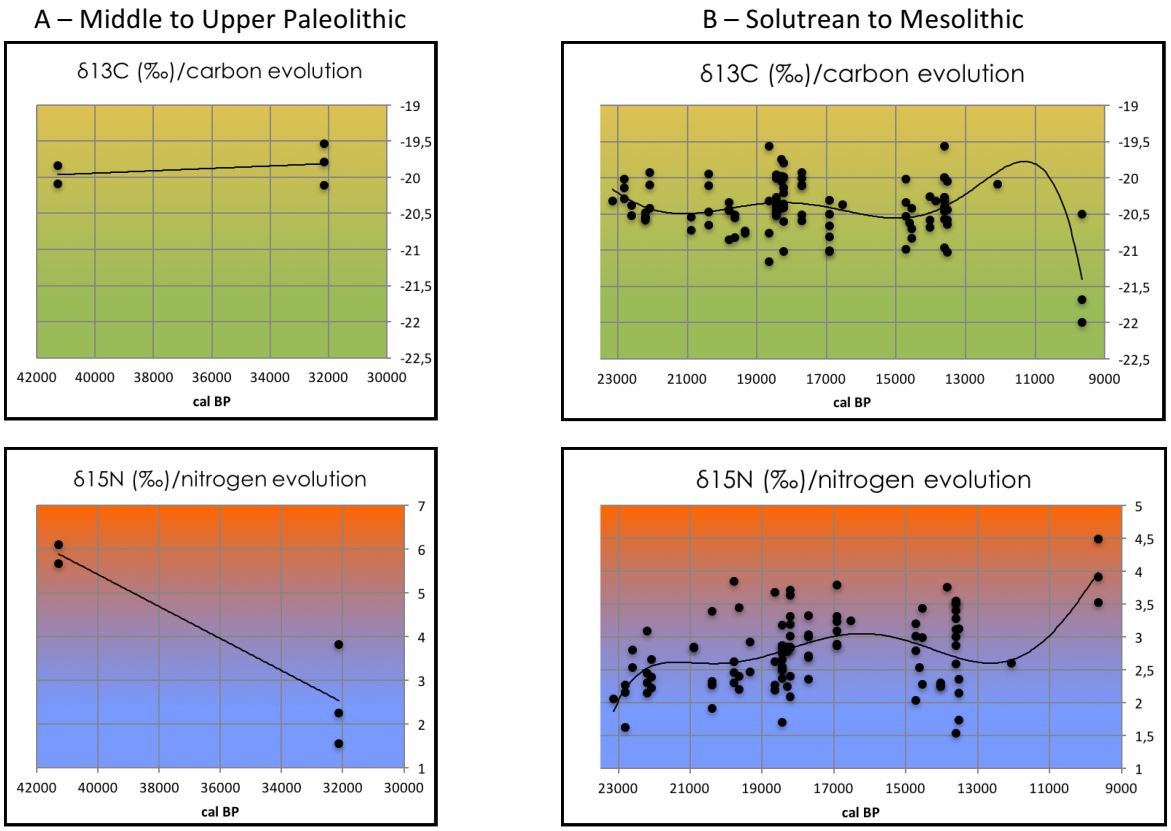


Figure 2.19: El Mirón bone collagen carbon and nitrogen evolutionary trend plotted by cal BP dates. Data used are (A) ibex bone from the Late Middle Paleolithic to Early Upper Paleolithic transition levels (Marín-Arroyo et al. 2018a) and (B) red deer bone from the Solutrean to Mesolithic levels (Stevens et al. 2014).

For the present dissertation, particularly relevant are: the stable isotope analysis based on samples taken from red deer bones from El Mirón cave that revealed varied climatic conditions for the Solutrean to Mesolithic time period for the Cantabrian region. Four distinguishable isotopic footprints were recorded according to sable isotope analysis in animals remains from different time zones/ slots along the El Mirón prehistoric stratigraphy (STEVENS ET AL. 2014).

1) Early Upper Paleolithic, Solutrean and Initial Magdalenian (27-20ka cal BP): open cool environment, but was not the coldest period during the Pleniglacial and may have been relatively humid (MORENO ET AL. 2012).
2) Late Initial Magdalenian and Early Lower Magdalenian (20-18.5ka cal BP): cold and humid period, with an open environment, Initial Magdalenian coincides with the onset of the last deglaciation event.
3) Late Lower Magdalenian and Early Middle Magdalenian (18.5-16.3ka cal BP): open environment, decreasing water availability, it is likely that in the Iberian Peninsula this interval and not the global LGM was the coldest and most arid period (MORENO ET AL. 2012).
4) Late Middle Magdalenian, Upper Magdalenian, Final Magdalenian/Azilian and Azilian (16.3–11ka cal BP): increasing water availability, start of forest expansion.

2.8 Conclusions on the state of the art

El Mirón is one of the best-studied Paleolithic sequences in the Cantabrian region, where the application of multidisciplinary studies, comprising analyses of stable isotopes, micro-mammals, pollen, sediments, phytoliths, among others (STRAUS & GONZÁLEZ-MORALES 2012c) have provide significant information of the inhabitant of the site during more than 40,000 years.

Specifically, the radiometrically controlled chronological sequence of El Mirón cave and richness of archaeological materials allow us to go a step further, passing over the reconstruction of broader climatic trends towards the description of micro-environments. As proposed here, these are the ones that affected the local landscapes, the animals lived in, and the humans who hunted them.

In conclusion, is it necessary to update the currently accepted economic understanding of the Cantabrian Upper Paleolithic. According to the rich archaeological record, we have a fair understanding of the cultural sequence in the region and observed different economic strategies.

El Mirón cave has provided faunal remains from a period of several climate oscillation and stratigraphic reliability. In detail, faunal analysis allows to unfold a broad spectrum of activities that created those animal deposits. Stable isotope analysis on human accumulated faunal remains provides a direct link between the landscape, the game species, and hunting practices. Serial isotope intra-tooth sampling allows further to reconstruct specific environmental conditions whose impact on hunting decisions is relevant and where present analysis intends to provide new knowledge. Thus, this study will provide a unique line of evidence for understanding local environmental conditions, prey species, and Upper Paleolithic hunter-gatherer behavior. It will discuss whether and how micro-environments (with their seasonal fluctuations) affected human-behavior (related to subsistence and settlement practices).

Within the given context, the faunal study of the development of economies at El Mirón allows to evaluate certain aspects of the economic human behavior also seen in its rich regional context and compare changes to the climate chronology.



Bone preservation in Level 17, El Mirón

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3 MATERIALS AND METHODS

El Mirón Cave, located in the Cantabrian Region, is the source of the archaeological materials studied in this dissertation. They are macro-faunal remains dating from the Late Middle Paleolithic to the Lower Magdalenian, with a primary focus on the last period. The following describes the regional context of El Mirón Cave, followed by the site characteristics, research history, stratigraphic sequences, radiocarbon chronology, and remarkable finds relevant for this dissertation. The archeo-faunal record is supplemented by a review of faunal data from contemporaneous Cantabrian sites to provide a diachronic, regional, and inter-site paleoeconomic context.

3.1 El Mirón Cave

3.1.1 Regional context

In Northern Iberia, the Cantabrian Cordillera runs parallel to the northern Atlantic coast of the Iberian Peninsula, forming a mountain range that separates the coastal North from the Castilian plateau in the South. The coastal zone is called the 'Cantabrian Region', 'Vasco-Cantabria', or 'the Cantabrian Coastal Strip' (in Spanish, Cornisa Cantabrica) including, from West to East, the modern provinces of Asturias, Cantabria and the northern (coastal) provinces of the Basque Region, namely Vizcaya-Bizkaia and Guipúzcoa-Gipuzkoa, plus the small Cordilleran part of Navarra.

Great topographic and environmental diversity characterizes Northern Iberia. The Cantabrian Region (comprising the northern Spanish coast and the southern Aquitaine) (Figure 3.1) is marked by a highly karstic coastal zone, with significant topographic variation (within a 350km long and 25-50km wide area), covering the distance between the River Nalón to the east and the Pyrenees to the west, and between the Atlantic Ocean in the North and the Cantabrian Cordillera to the South (STRAUS 1992).

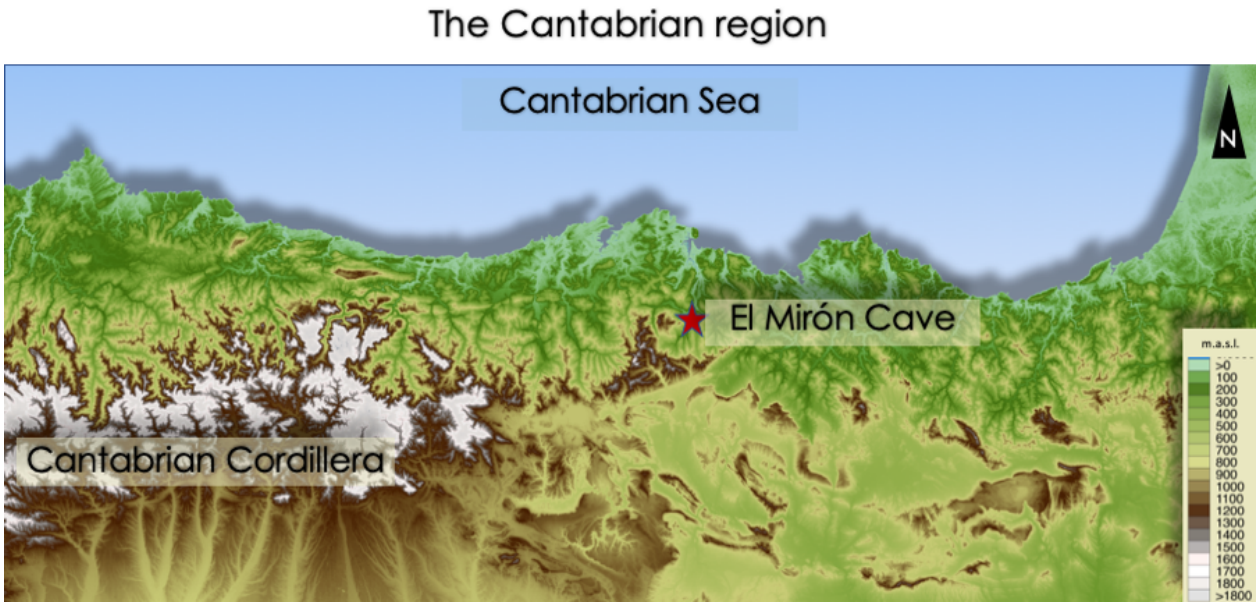


Figure 3.1: El Mirón Cave located in the Cantabrian Region, Spain.

Northern Iberia is part of 'España verde' (=green Spain), a narrow belt nowadays characterized by lush pastures and montane (and formerly also lowland) mixed deciduous/oak forests, with distinct vegetation zones at different altitudes and slope orientations. The heterogeneous topography, high relief (altitudinal variability) allow diverse ecosystems to exist within short distances to each other, in turn favoring biodiversity. The palynological and deep-sea evidence support the idea of Iberia (and specifically the Cantabrian coastal strip) has been a European climatic refugium that supported life among several trophic levels, at least during the Last Glacial Maxima, with further evidence from animals and even *Homo sapiens* seen in genetic analyses.

The Cantabrian Region can be subdivided into subareas or terrains: these are from the North to the South: The coast, the plain, the Cantabrian Cordillera/Picos de Europa and, behind them, the highland plateau known as the Meseta del Norte of Old Castile (Castilian Plateau); together this varied landscape allow a high biotic diversity within close ranges (BUTZER 1986; STRAUS ET AL. 2002). A narrow strip along the sea characterizes the coastal zone, the present shore being mostly steep cliffs with small coves and a few large estuaries of major rivers such as the Asón. The coastal plain includes relatively limited semi-flat areas located along valley bottoms or adjacent to the coast towards the inland, including low altitude hills.

Coastal areas in particular maintained a high phyto-diversity, which in turn provided stable food sources for various prey species and helped to keep animal populations relatively stable (GONZÁLEZ-SAMPÉRIZ ET AL. 2010). While littoral and sub-littoral areas were generally more humid than areas inland and at higher altitudes, grasslands, heaths and shrubs characterized coast and coastal plain Pleistocene vegetation in general (RAMIL-REGO ET AL. 1998).

Higher orographic and altitudinal variability characterize the montane area. The Meseta of adjacent northern Old Castile consists elevated, often flat plateau cut by deep canyons of the Ebro and its tributaries to the south of the Cantabrian Cordillera. It was often not or only lightly occupied during MIS2 because of cold and aridity, while the Cantabrian coastal strip was a relatively favorable region for human settlement (CACHO 1999; CORCHÓN-RODRÍGUEZ 2000, 2002).

The regional relief is extremely steep, as the distance between the mountain peaks and the sea is very short, and is traversed by complex river systems form North-South oriented valleys and connected from the mountainous interior to the coast (STRAUS 1979); they are supposed to be used as corridors for animal and human migrations. During glacial sea-level regression, a now submerged portion of the continental shelf of about 5-12km wide was exposed and significant parts of the Cantabrian Cordillera and the Picos de Europa were glaciated (CLARK & MIX 2002; LAMBECK ET AL. 2002).

Within the easternmost part of the province of Cantabria, almost on the border with Vizcaya and not far from the meseta of Burgos province, the Lower Cretaceous limestone (Urgonian) karstic landscape harbors a great quantity of caves. It is there where the upper Rio Asón drainage is located, some 20km upstream from the modern Atlantic shoreline. The main river (the Asón) rises from a spectacular waterfall, first run northward then eastwards along the northern flank of the Sierra de Hornijo, whose highest summit Pico San Vicente (913m) lies directly West of El Mirón Cave (Figure 3.2). Monte Pando (493m), bordered by the Rio Calera that merges into the Rio Gandara, which in turn merges into the Rio Asón at the town of Ramales de la Victoria, is the location of many caves. Several high mountains are located to the east of the city such as Peña del Moro (818m), El Mazo (823m), Reluso (783m); to the South La Mortera (722m) and to the west Pico de la Tobazona (1039m), Hoyufresnu (1056m), El Piquete (917m), etc.

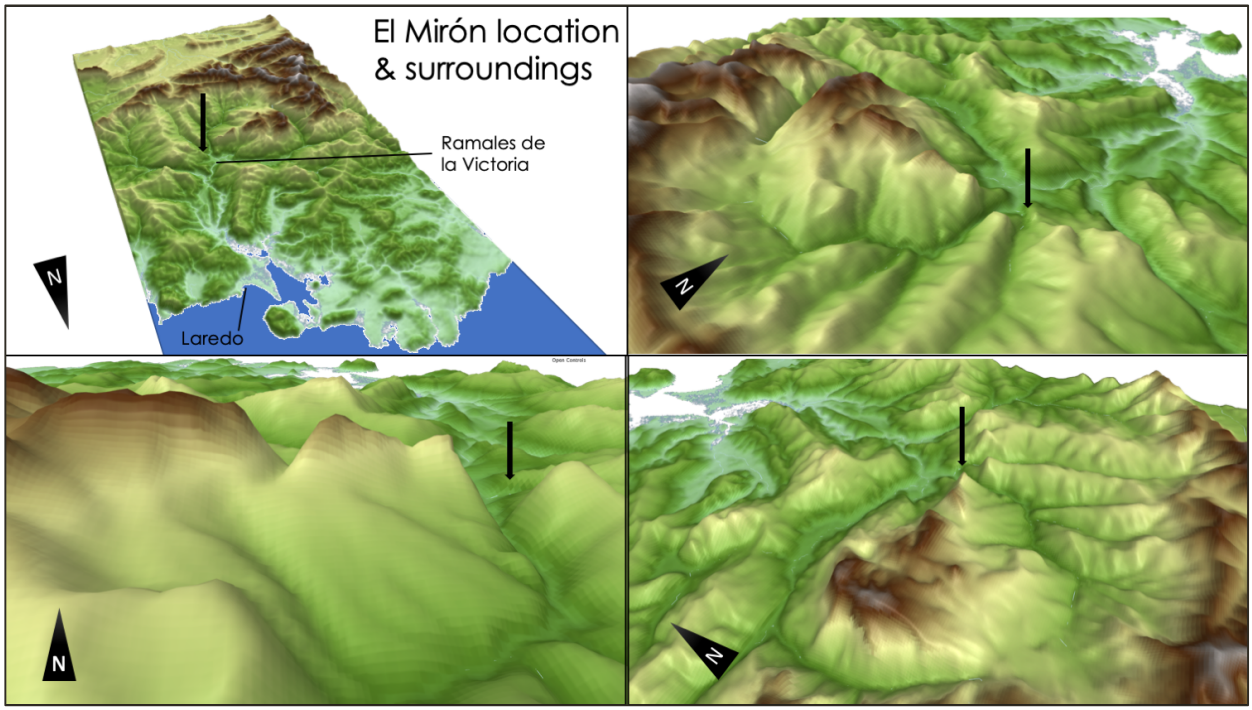


Figure 3.2: 3D-Digital elevation model (DEM) from the surroundings of El Mirón Cave (black arrow).

At the base of Monte Pando in Ramales de la Victoria is situated Cullalvera cave, which is today a still active karstic system, with periodic running water. Further upstream along the Rio Calera is located La Haza cave, with cave art and a small Solutrean site. The remaining caves in Monte Pando are Covalanas, El Mirón, La Luz, El Horno and Cuevamur, which are located at varying elevations above the river valleys. All but the last two of these caves contain Upper Paleolithic rock art of diverse importance. El Mirón is strategically located above the confluence of the Asón with the Calera and Gandar and not far from the confluence with the Carranza, providing easy routes of communication towards the north (the coast), the west (the relatively broad central coastal plain of Cantabria now the location of the Bay of Santander) and the east (the modern Basque Country and hence southwestern France). The following description will concentrate on El Mirón cave and its structural morphology in order to clarify the provenance of the materials presented in this study.

El Mirón cave mouth faces West towards the steep, greater than 1000m-high Hornijo mountains dominating the upper Rio Asón (Ruesga) valley on the northern edge of the Cantabrian Cordillera, some 20km upstream from the modern Atlantic shoreline (Figure 3.3a). It is located on a cliff-face at 260m.a.s.l. and 150m above the valley floor. Its coordinates are 43 1404800 N, 3 270500 W. The impressive, 20m-high entrance, opening into a 13m-high vestibule, 16-8m wide and 30m deep, looks across the Calera-Gandara gorge to c. 1000m-high Pico San Vicente and the Valle de Ruesga (middle course of the Asón, just west of Ramales de la Victoria) (Figure 3.3b). The bedrock in which the cave is formed is a hard limestone.

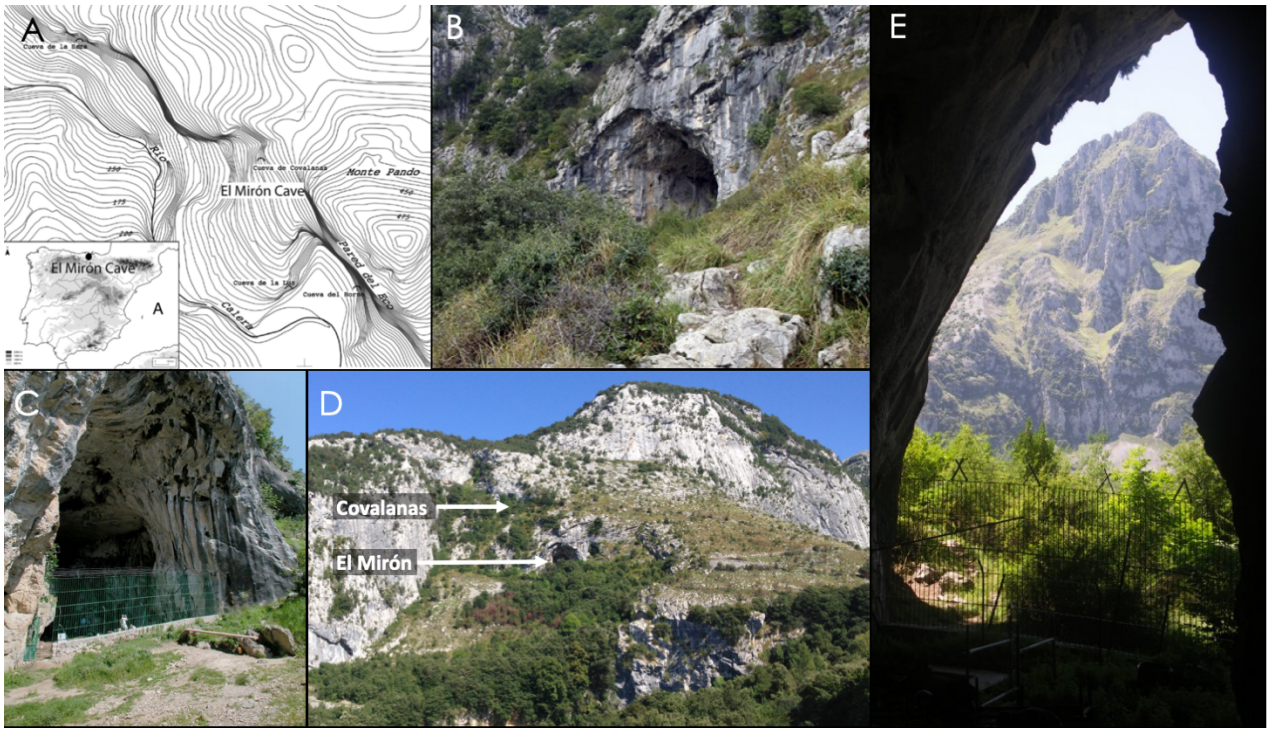


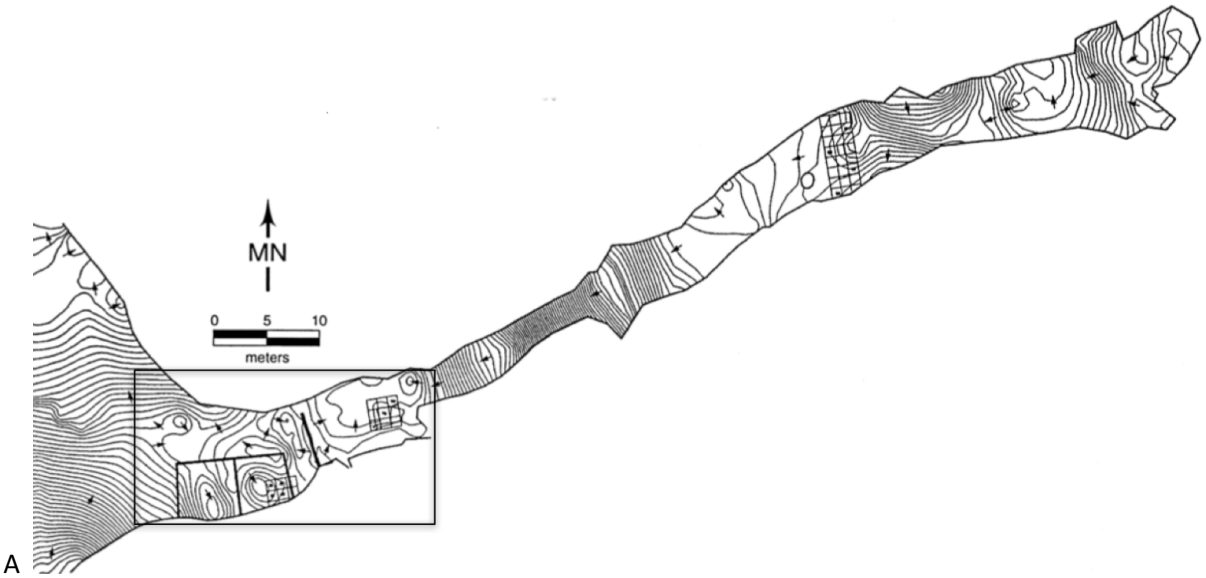
Figure 3.3: Topographic location (A) of the El Mirón Cave with the entrance (B,C) facing to the West, as part of the Monte Pando mountain formation located next to Covalanas Cave (D). View from inside of the Cave (E). Figure A from (GARCÍA DÍEZ ET AL. 2012) and photographs B,C,E by M.R.González-Morales & L.G.Straus; D by J.M.Geiling.

3.1.2 Research history and stratigraphy

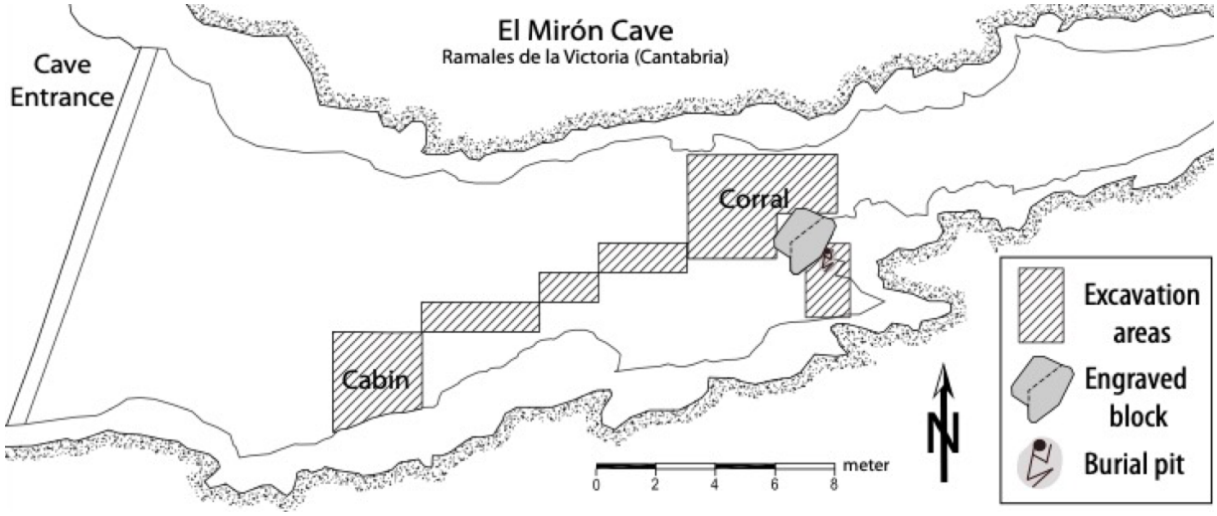
Until recently shepherds used the shelter of El Mirón cave (and such was the case when L.G. Straus first visited it in 1973) and maintained a corral for their goats in the rear of the vestibule. The scientific discovery of the site was by L. Sierra and H. Alcalde del Rio in 1903, after which, however, the cave remained virtually ignored by archeologists. No one observed the rock engravings in El Mirón, despite the presence of spectacular cave art paintings in the adjacent sites of Covalanas and La Haza. Indeed, it was thought for a long time (beginning with Hugo Obermaier) that El Mirón cave did not contain intact archeological deposits, despite the presence of finds on the surface.

At El Mirón Cave, the excavations under the direction of L.G. Straus and M.R. González-Morales commenced in 1996 (STRAUS & GONZÁLEZ-MORALES 2012b). Together with those of much smaller Rascaño cave, in the adjacent Rio Miera valley re-excavated in 1974, El Mirón was one of the first Paleolithic montane sites in the region to be excavated using modern digging methods as explained in detail here.

Depending on where one places the front end of the vestibule of El Mirón Cave, it measures at least 250m^2 and the excavations covered at most about 35m^2, to highly varying depths; see Figure 3.4.



A



B

Figure 3.4: El Mirón Cave: (A) Overall plan of the cave (topography by E. Torres; map modified after L.G. Straus & R. Stauber); and (B) location of main excavation areas within its vestibule, and highlighted is the spatial location of the engraved block and the burial pit containing the Lower Magdalenian human remains. (Cave plan by GIM GEOMATICS, M.R. González-Morales and modified by J.M. Geiling).

During the work in El Mirón cave, modern standard methods of Paleolithic excavations were applied (STRAUS & GONZÁLEZ-MORALES 2012b). These methods include: three-dimensional individual recording of lithics larger than 1cm, osseous artifacts, 'manuports' (notably fire-cracked rocks) and bones longer than 5cm plus smaller, but field-identifiable specimens (e.g., teeth, phalanges, sesamoids) with a total station theodolite (EDM). Most relevant field codes that define the type of data recorded are the following:

- B= bone, individually registered ('piece-plotted')
- T= tooth, individually registered
- L= lithics or stone tools
- H=charcoal remains
- M=manuports (mainly unworked cobbles and fire-cracked rocks)
- O=ochre remains
- GB= 'general bags' contained smaller finds that were non-piece-plotted

The excavations were conducted in subsquares measuring 50x50cm by spits of usually 1-3cm thick, especially in Level 17. The sediments were then sorted or water screened to collect the smaller fraction (finds often smaller than 3cm, mostly 'non-identifiable' bones, tooth fragments, also lithic debris, micro-mammals, shells, etc.) in the 'general bags'. When in the following is referred to 'general bags' it is meant the macro-faunal remains generally smaller than 3cm, often taxonomically and anatomically non-identifiable. Spits are arbitrary subdivisions of natural levels created during excavation. Measurements were recorded for top and bottom heights of each spit center and sub-square corner.

The cave stratigraphy extends from the late Middle Paleolithic to the Early Bronze Age (with hints of Medieval and more recent occupations). In the caves vestibule rear, where excavation began in the summer of 1996, the top stratum was composed of goat excrement, mixed surface fill and reworked sediments (likely the activity of looting) [L.G. Straus personal communication 2018; (STRAUS & GONZÁLEZ-MORALES 2012b)]. Despite these anthropogenic alterations in the cave, the stratigraphy in the back of the vestibule follows the angle of the slope coming down from the ramp gallery that connects in turn with the inner cave and which contains re-deposited colluvial-alluvial sediments (FARRAND 2012). Levels in the front of the cave are generally more horizontally, as described below. Levels were studied from the different excavation areas of the cave (Figure 1.5).

Two main excavation areas (each about $9m^2$) exist, one located in the sunlit cabin in the vestibule front, and the other in the corral, which is located in the darker vestibule rear. Both main excavation areas are connected by a 9m long x 1-0.5m wide mid-vestibule trench (Figure 3.4). Additional excavations were done in the space behind a large engraved block (~2x1x1m) in an area in the archaeologically rich, vestibule rear not affected by previous looter activities. It is the Magdalenian human burial area (STRAUS, GONZÁLEZ-MORALES, & CARRETERO 2011: p. 1154) in the South-East corner of the vestibule (Figure 3.4), an area of around $3.75m^2$ bounded by the cave wall to the east and south and the block to the northwest, which was excavated in the final years of the project, after preliminary testing in 2001. A $3m^2$ sondage was also dug below the base of a large looter hole in the North-East corner of the vestibule rear to sample the Solutrean, Gravettian and Mousterian levels. A narrow ramp gallery that leads east- and upward inside the cave from the northeast corner of the vestibule rear, connecting it to the dark inner cave, which contains another test trench that yielded evidence of Magdalenian presence.

Cultural Period	Cabin	ka uncal BP	Trench	ka uncal BP	Corral	ka uncal BP	Burial area	ka uncal BP
Mixed	1		300		100			
Early Bronze Age	2							
	3							
	4		302					
Chalcolithic	5							
	6							
	7							
Neolithic	8		303					
	9							
Early Neolithic	10		303.1					
Early Mesolithic	10.1		304					
Azilian			305	10.3				
	11	11.8						
Final Magd./Azilian	11.1	(11.2)	306	11.7	102.1	12.0		
	11.1	11.7						
	11.2				102.2			
			307		103			
	12	12.8	308	12.4	104	14.1		
Upper Magdalenian					105	13.5		
					105	14.7		
					106	12.5		
	13	(14.9)			107			
	14	14.6			108	13.7		
Middle Magdalenian					108	13.7		
					108	14.7		
					108	14.9		
	15	15.0			110	14.8	503.1	15.1
	15	15.2			110	14.8		
	16	15.2			110	15.7		
					110	(16.1)		
	17	15.4			110	(16.5)		
	17	15.5			111	15.6		
	17	15.5			111	(16.4)	504	15.5
Lower Magdalenian	17	15.6			112	15.4	504	15.7
	17	15.7			114	(16.5)	505	15.7
					114	(16.8)		
					115	(13.8)		
					115	(16.8)		
					116	15.2		
			312	15.9	116	15.5		
					116	17.4		
	18	16.1			117	17.1		
					117	17.2		
	19	(16.6)			118	(15.5)	Niche	16.6
	20				119	17.0		
Initial Magdalenian					119	17.2		
	21	16.1			119.1			
					119.2	(16.3)		
					119.2	17.6		
					119.3			
			313	17.4	120			
					121	18.4		
					122	18.0		
					123			
Solutrean					124			
					125	19.0		
					126	19.0		
					127	19.2		
					127	20.4		
Early Upper Paleolithic					128			
					129			
Late Middle Paleolithic					130			

Figure 3.5: Archeological levels at El Mirón Cave. Grey shaded levels are included in this study.

Outer vestibule excavation area (Cabin)

The archaeological layers in the outer vestibule were deposited nearly horizontally according to the north and west profiles, while the layers as seen in the east profile, on the other hand, slope slightly against the cave wall. Especially the Magdalenian levels have yielded extraordinarily well preserved archaeological finds. The sediments seem undisturbed by natural or human agencies, as was observed during the excavations (Figure 3.6). By now, the stratigraphic sequence in the Cabin area includes sediments beginning in the Initial Magdalenian to the early Bronze Age, although on its base the bedrock was not reached and contain older deposits of possible previous occupations.

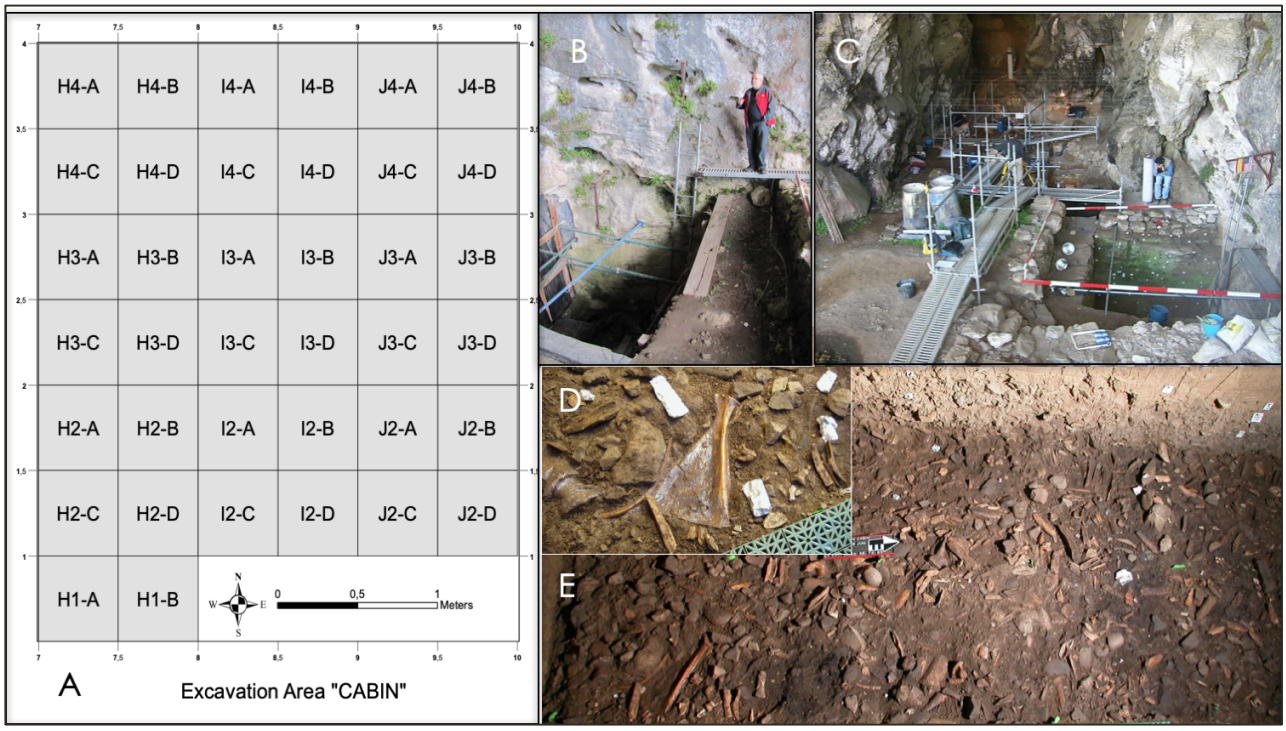


Figure 3.6: Cabin excavation areas: Excavation grid of square meters with four sectors per m^2 (A), southern cave wall of the area with M.R. González-Morales (B), general view of the excavation area (C) and archaeological density of Lower Magdalenian Level 17 (D,E). (Photographs by M.R.González-Morales & L.G.Straus)

The lowest Levels 21 to 18, attributed to the Initial Magdalenian, were only excavated within one square (J2) as a depth sondage. While Level 15 and 16 can be referred to as late Lower Magdalenian, Level 17 represents the mayor Lower Magdalenian occupation. Level 17 was described as thick, dark 'chocolate' brown, highly organic sediment with a sandy silt-loam matrix with abundant limestone rock fragment inclusions (*éboulis*), rich in lithic artifacts and large, well-preserved bones. Levels 16, 15, and 14 have similar clayey silts with small angular rock fragments inclusions; the boundaries between Levels 17 and 16 are very diffuse to nonexistent according to excavators (STRAUS ET AL. 2001; STRAUS & GONZÁLEZ-MORALES 2012b). Levels 14 and 13 belong to the Middle and Level 12 to the Upper Magdalenian (compare Figure 3.7 and Figure 3.8). The uppermost layers have been attributed to the Holocene time period.

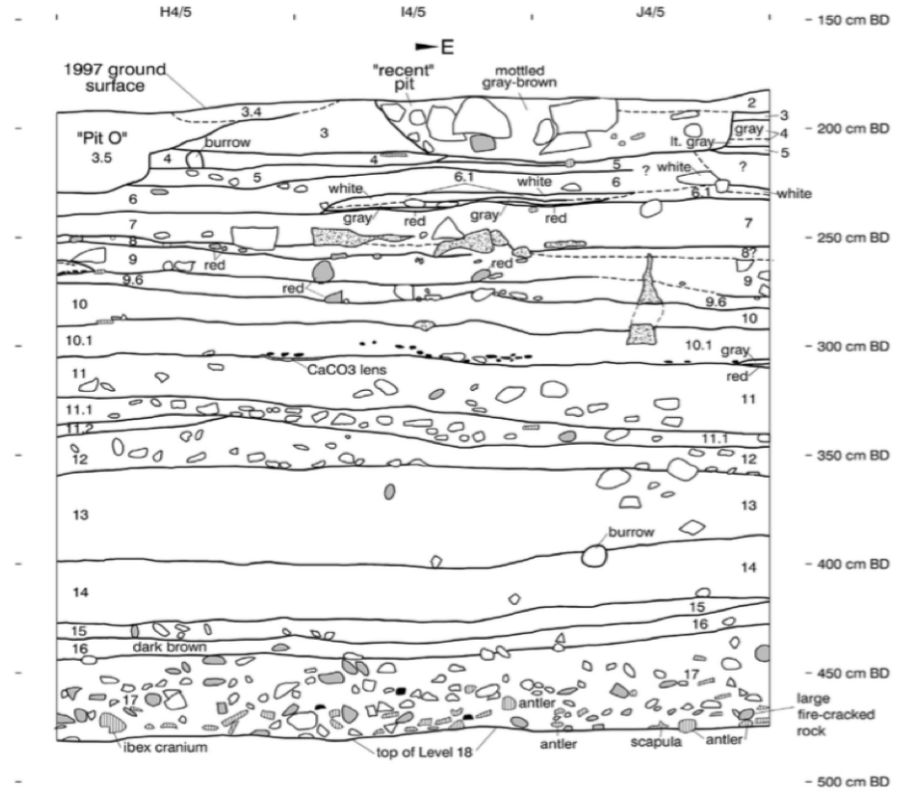
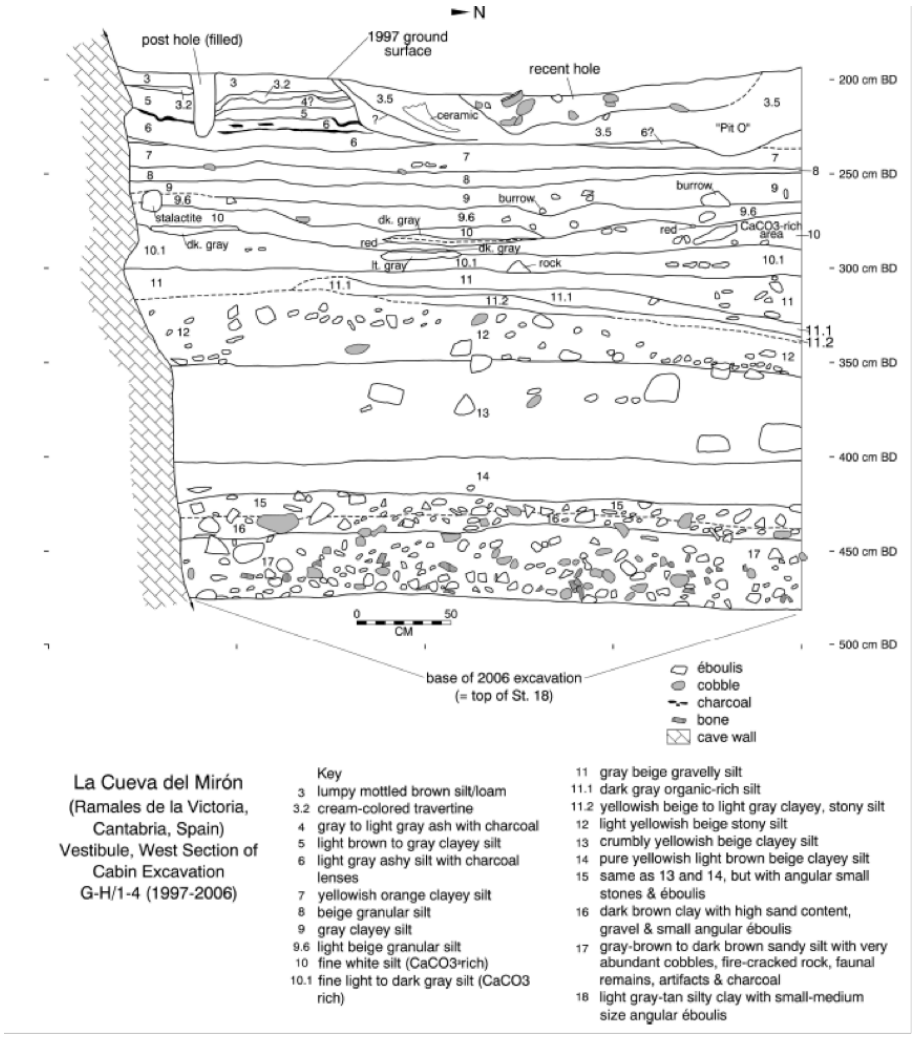


Figure 3.7: North stratigraphic section of the Mirón 'Cabin' excavation area in the vestibule front (G-H/1-4). Figures by L.G. Straus and R. Stauber.



La Cueva del Mirón
(Ramales de la Victoria, Cantabria, Spain)
Vestibule, West Section of Cabin Excavation
G-H/1-4 (1997-2006)

Key

3 lumpy mottled brown silt/loam
3.2 cream-colored travertine
4 gray to light gray ash with charcoal
5 light brown to gray clayey silt
6 light gray ashy silt with charcoal lenses
7 yellowish orange clayey silt
8 beige granular silt
9 gray clayey silt
9.6 light beige granular silt
10 fine white silt (CaCO3-rich)
10.1 fine light to dark gray silt (CaCO3 rich)
11 gray beige gravelly silt
11.1 dark gray organic-rich silt
11.2 yellowish beige to light gray clayey, stony silt
12 light yellowish beige stony silt
13 crumbly yellowish beige clayey silt
14 pure yellowish light brown beige clayey silt
15 same as 13 and 14, but with angular small stones & éboulis
16 dark brown clay with high sand content, gravel & small angular éboulis
17 gray-brown to dark brown sandy silt with very abundant cobbles, fire-cracked rock, faunal remains, artifacts & charcoal
18 light gray-tan silty clay with small-medium size angular éboulis

Figure 3.8: West stratigraphic section of the Mirón 'Cabin' excavation area in the vestibule front (G-H/1-4). Figures by L.G. Straus and R. Stauber.

Rear vestibule excavation area (Corral)

The archaeological levels in the vestibule rear, or Corral, area (Figure 3.9) contain cultural remains from the Middle Paleolithic all the way up to the Azilian. The archaeological layers follow the geometry of the underlying erosional surface of the colluvial- alluvial slope coming from the inner part of the cave. The rear vestibule levels, therefore, angle down towards the cave mouth, which is located c. 25m. west of the Corral excavation (STRAUS ET AL. 2014: p. 49).



Figure 3.9: Corral excavation areas: (left) view to the West, (right) view to the northern cave wall. Photograph from Garcia-Diez et al. 2012 Figure 10.

The deepest and oldest Level 130 has been radiocarbon dated and attributed to the Late Middle Paleolithic. Level 128 is of Early Upper Paleolithic age, but lacks diagnostic artifacts (129 is lacking in artifacts, but did yield some faunal remains). Levels 127-121 are attributed to the Solutrean based on the presence of characteristic projectile points and radiocarbon dates; the sediments of these layers clearly follow the erosional slope of the colluvial-alluvial ramp leading down from the inner cave toward the West (Figure 3.10). Level 120 was also attributed to the Solutrean, but is finally understood by the excavators as back dirt filling at the base of the looters' hole (STRAUS ET AL. 2013). The Initial Magdalenian Levels 119.3-117 are banked up against the Solutrean ones, but with ever-decreasing slope angles. The Lower Magdalenian Levels 116-110 underlying the possibly Middle Magdalenian Levels 108-107, the Upper Magdalenian Levels 106-103, the Final Magdalenian/Azilian Levels 102.1-102.2 and the Azilian Level 102. Level 101, which is virtually sterile, may correspond to ephemeral visits to the cave in Mesolithic times, since there are only a few banal artifacts (flakes).

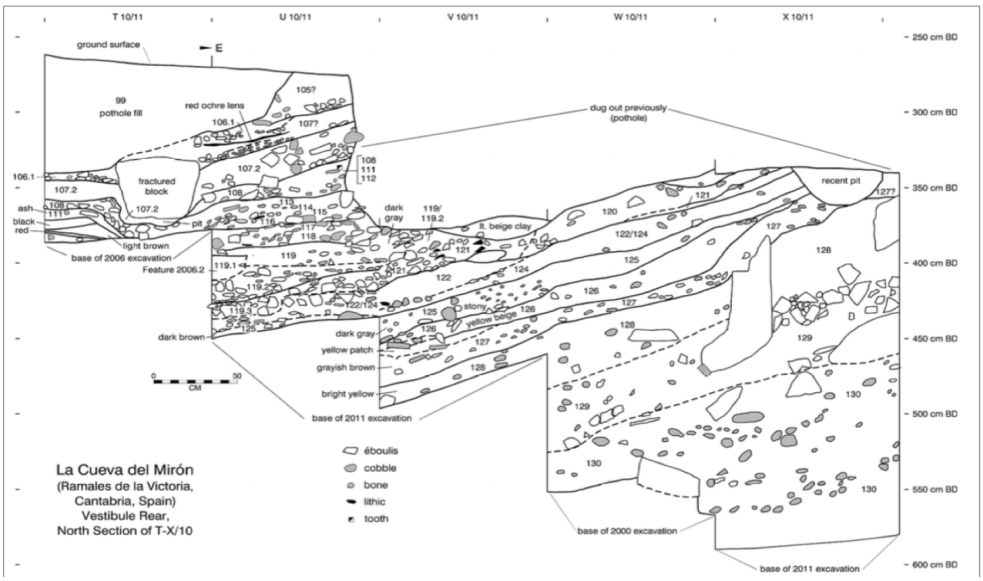


Figure 3.10: North stratigraphic section of the Mirón 'Corral' excavation area in the vestibule rear (T-X/10-11). Figures by L.G.Straus and R.Stauber.

Mid vestibule trench

The mid vestibule trench (Figure 3.11) excavated in square rows K-S with a deep sondage in P6, contained the following Levels: 313 Initial Magdalenian or Solutrean without diagnostic artifacts, 312 Lower Magdalenian, 309-311 Middle Magdalenian, 307-308 Upper Magdalenian, 305-306 Azilian, 304 Mesolithic and 302-303.3 Neolithic. None of the materials under study, however, come from this excavation area.

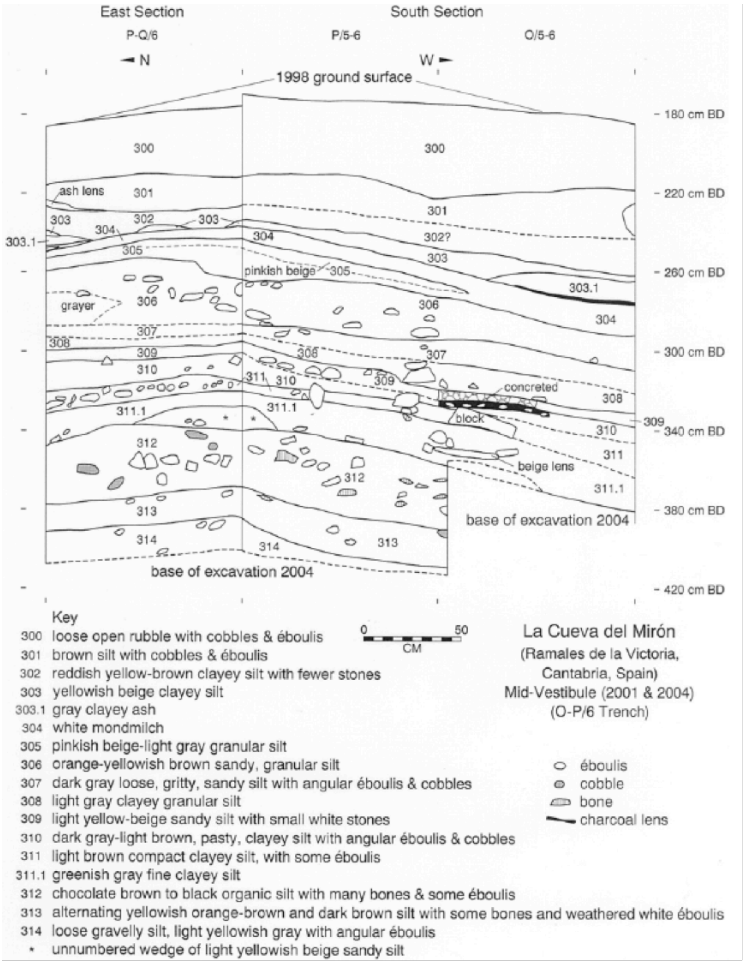


Figure 3.11: North-West stratigraphic section of the Mirón 'Mid-Vestibule Trench' excavation area in the vestibule (O-P/6)(L.G.Straus and R.Stauber).

Burial Area

The stratigraphy of the burial area has also been extensively summarized (GEILING & MARÍN-ARROYO 2015: p. 48; STRAUS ET AL. 2015b) and important characteristics are: the different stratigraphic layers follow a 'bathtub'-like distribution (Figure 3.12). Level 503 is undisturbed and covers entirely the burial area, the sediment of Level 504 contains large amounts of red ochre with sparkling specular hematite crystals. The small burial pit, which was filled with this material, had been cut partially into Level 505 in square X7 and in the northern end of the burial the pit reached down to the shallow, uprising cave wall (a bedrock ledge). The grave was in a c.1 m-wide space between the cave wall and a large (2x1x1 m) block that was decorated with engravings on its west face and the same red ochre as filled the grave on the east face. The c.100 human bones were inside these physical borders.

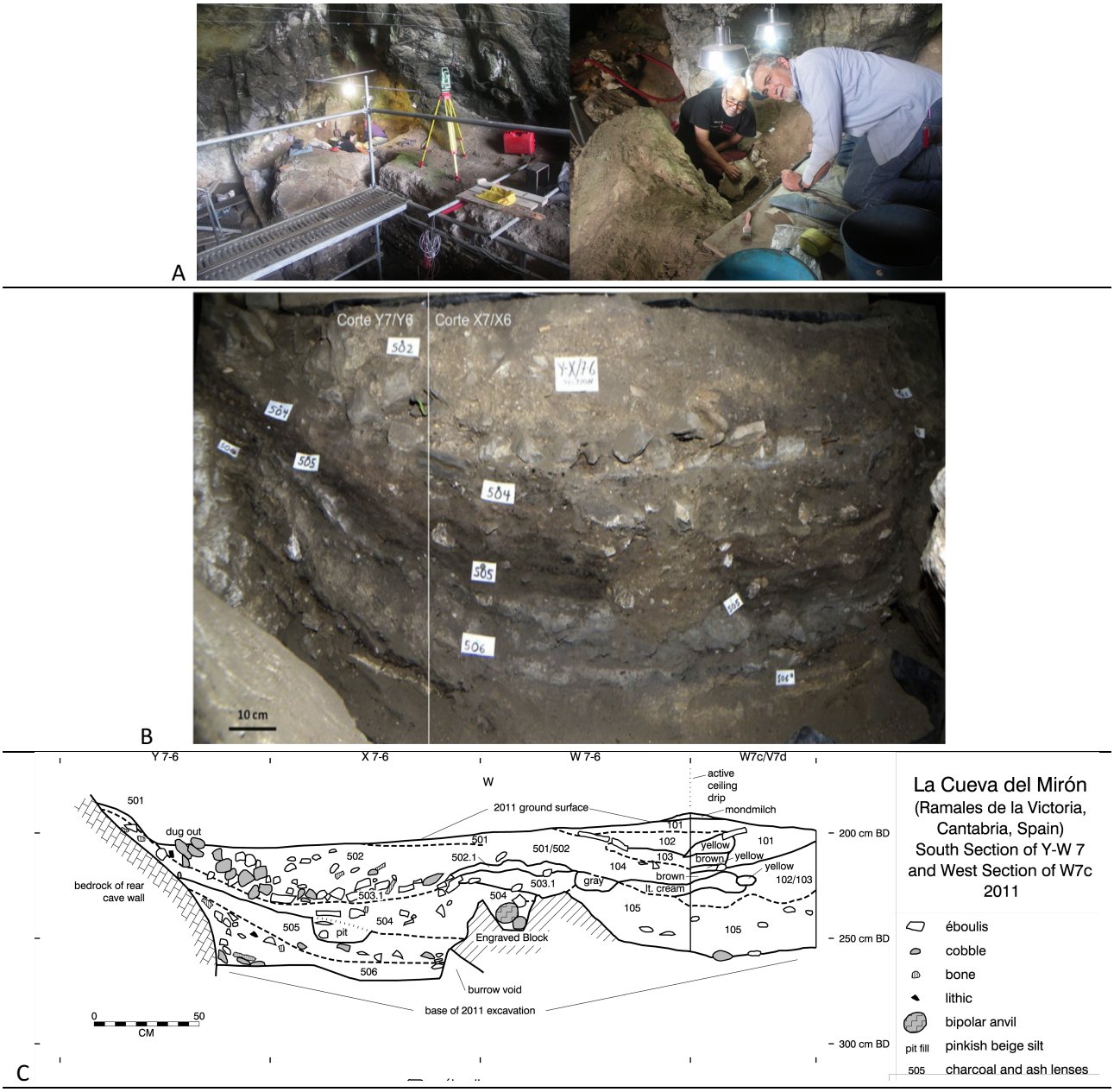


Figure 3.12: (A) Burial area excavations. (B) The stratigraphic section between X-Y/7 and X-Y/6 in the burial area. Fotos by L.G. Straus & M.R. González-Morales. (C) Drawing of the South-West stratigraphic section of the El Mirón 'Burial' excavation area in the vestibule rear (X-Y/7-6) with the South end of the burial pit. Figure by L.G. Straus and R. Stauber.

3.1.3 Chronology and sedimentology

The sedimentological characteristics of the studied levels are summarized in the following Table 3.1 (HUBBARD 2000; STRAUS ET AL. 2001; FARRAND 2012; STRAUS & GONZÁLEZ-MORALES 2012b).

Table 3.1: Description of the levels of interest for this study (STRAUS ET AL. 2001; FARRAND 2012; STRAUS & GONZÁLEZ-MORALES 2012).

Level	Sediment and color description in the field	Additional comments
15	yellowish beige sandy, silty clay, clayed, darker brown, loose, grainy silt (5-10 cm thick)	abundant small angular stones and *éboulis,* culturally rich (many lithic debitage, but very little bone)
16	Grey dark brown clay with high sand content (15-20 cm thick)	Gravel and small angular *éboulis,* water-worn cobbles, lithics are abundant, faunal remains are in poor condition
17	Gray-brown, lighter brown to dark-brown, (less) sandy clayed, gritty silt (30-40 cm thick)	With very abundant cobbles, enormous wealth of occupation debris, densely packed medium- size rocks, well preserved fauna, several hearths in charcoal-stained sediments
18	Light gray-tan silty clay (20 cm thick)	Small- medium angular *éboulis*
19	Yellowish-light brown clayed silt (10 cm thick)	With more large clasts
20	Yellowish-light brown clayed silt (10 cm thick)	Clayier and much larger clasts
21	Yellowish-light brown clayed silt (10 cm thick)	With smaller éboulis and large block at base of excavation
504	Dark, reddish, gray-brown loose, powdery silt, with sparkling hematite crystals and red ochre (~10 cm thick)	Small stone slabs, lithic and faunal remains, human burial
120	Yellowish-beige, orange-yellow-brown, clayed silt (~10cm thick)	With rock fragments and pebbles, appearance of organic and cultural sterility, angular éboulis, water-worn cobbles; lithics and numerous faunal remains under the surficial veneer of compact clayed silt matrix
121	dark (in places, blackish) brown, stony silt lens (3-7 cm thick)	relatively high organic content
122	Yellowish-beige, homogenous, compact, colluvial sandy clayed silts (~5 cm thick)	With tones, gravel, cobbles, only a few bones and lithic artifacts
123	Very thin greyish brown lense of silt, which does not exist in the northern half of V10, (3-7 cm thick)	With stones and abundant flecks of charcoal, fire-cracked rocks, possible hearth (Feature 2010.2)
124	compact, yellowish beige stony, sandy-clayey silt, (5 cm thick)	scattered bones, lithics, charcoal flecks, water worn cobbles, possible fire-cracked rocks
125	relatively dark brown clayey silt (10-12 cm thick)	bones and lithic artifacts, rounded, medium-size cobbles
126	light, yellowish beige, compact, clayey, sandy silt (20-25 cm thick)	Many cobbles, *éboulis*, abundant charcoal flecks, numerous bones, mollusk shells, lithic, osseous artifacts, coprolite containing small bone fragments
127	Dark gray-brown stony silt, loose 'organic-cultural' lens (10 cm)	Large flakes, abundant faunal remains, hearth feature (2010.3)
128	Bright yellow, smooth, compact clayey silt (25-45 cm thick)	A few angular limestone fragments do appear in the lower part of the W10 pit, accompanied by a modest increase in the $CaCO_3$ content of the fine fraction, artifacts are scarce and scattered
129	Brighter, pasty, 'pure' clayed silt (40 cm thick)	Almost completely sterile, boundary defined as under the blocks of Level 128, also many large blocks
130	Reddish-yellow, sandy silt (less clay content), (more than 100 cm thick)	Virtually no angular *éboulis*, many pebbles and large , water-worn cobbles, includes some meter-sized limestone blocks; very few artifacts and charcoal fragments

For El Mirón, it has been previously shown, however, that vegetation cover and environmental conditions varied according to fluctuating global climate. Within the following figure (Figure 3.13) are summarized last glacial environmental parameters of pollen and plant macro fossil record for the Cantabrian Region; the long stratigraphy of El Mirón levels is contextualized therein, (HOYOS-GÓMEZ 1995; FARRAND 2012; STRAUS & GONZÁLEZ-MORALES 2012b), although environmental evidence needs to be further detailed and more palynological results are currently awaiting publication. Thus, the environmental context, of El Mirón occupations are incomplete and still not fully understood. The past environment of El Mirón will be further discussed within the respective results chapter.

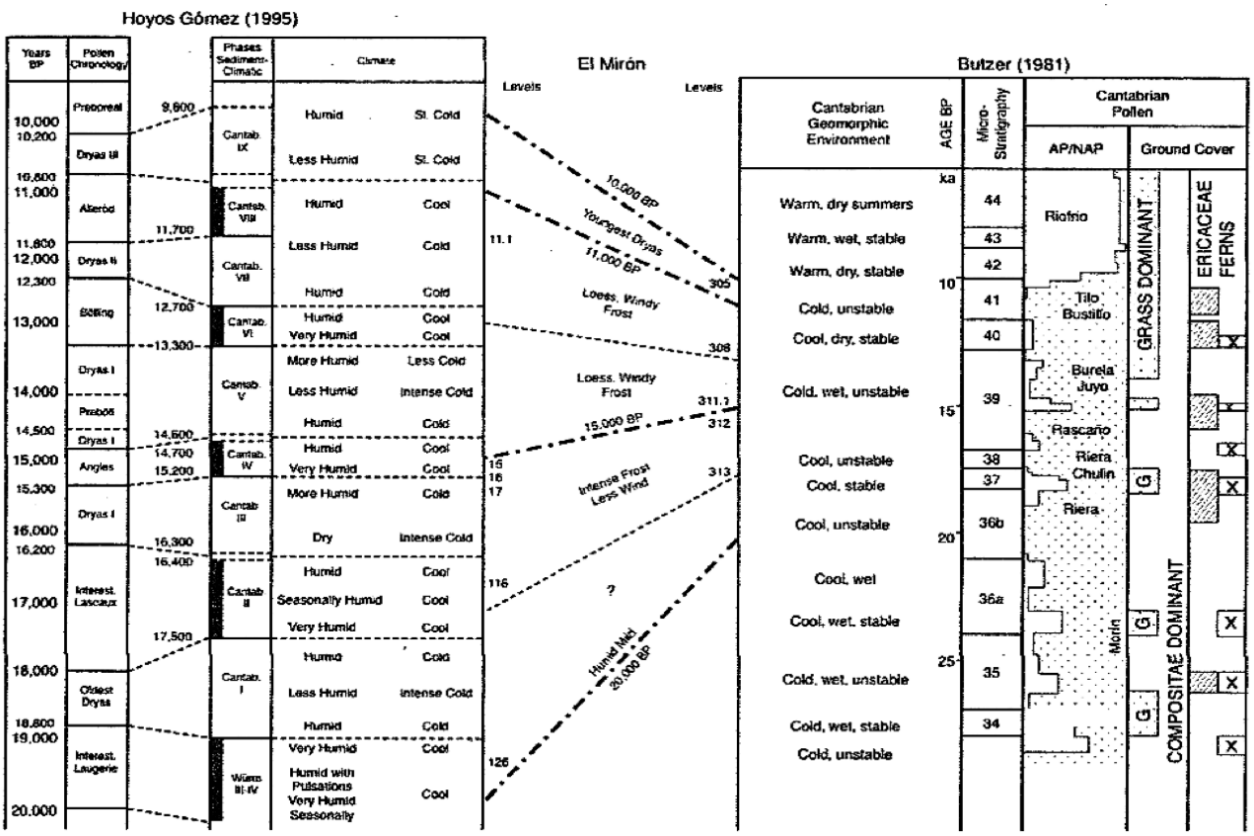


Figure 3.13: Chronology and climatic association of El Mirón levels. Figure adapted from Farrand (2012), based on data pollen chronology and sediment phases from Hoyos (1995).

Extensive use of the ^{14}C dating at El Mirón cave (see Appendix A) helped establish a long chronological sequence, compare also (STRAUS & GONZÁLEZ-MORALES 2003), especially for Upper Paleolithic cultures in the Cantabrian Region. The long C14-chronology of well dated archaeological horizons make El Mirón cave favorable to study varied question of chronological relevance. According to the radiocarbon ages retrieved from El Mirón Cave following occupation model can be obtained, compare Figure 3.13.

The stratigraphically lowest charcoal date from El Mirón cave is an accelerator mass spectrometry (AMS) date on charcoal located in the vestibule rear ('Corral') (STRAUS & GONZÁLEZ-MORALES 2003). Two new bone collagen AMS ultrafiltration dates confirm a Middle Paleolithic age of these occupations, although reaching older ages (STRAUS & GONZÁLEZ-MORALES 2016; MARÍN-ARROYO ET AL. 2018a); dated to 49ka cal BP to 44.6ka cal BP. The new ultrafiltration AMS dates would suggest that the later charcoal date of the Middle Paleolithic occupation might be too young seen in the regional context (MARÍN-ARROYO ET AL. 2018b). When

considering the quite old date of around 49ka cal BP, the El Mirón Late Middle Paleolithic Level 130 belongs to one of the older C14 ages for the Late Middle Paleolithic occupations within the Cantabrian Region. The Early Upper Paleolithic (presumably Gravettian) level is also dated with AMS on charcoal (STRAUS & GONZÁLEZ-MORALES 2003) and represents the only early Upper Paleolithic occupation detected until now within the cave. A sequence of different Solutrean levels has been excavated, some of which were measured with ultrafiltration AMS (STRAUS & GONZÁLEZ-MORALES 2003, 2007a; HIGHAM ET AL. 2006; STRAUS ET AL. 2015c).

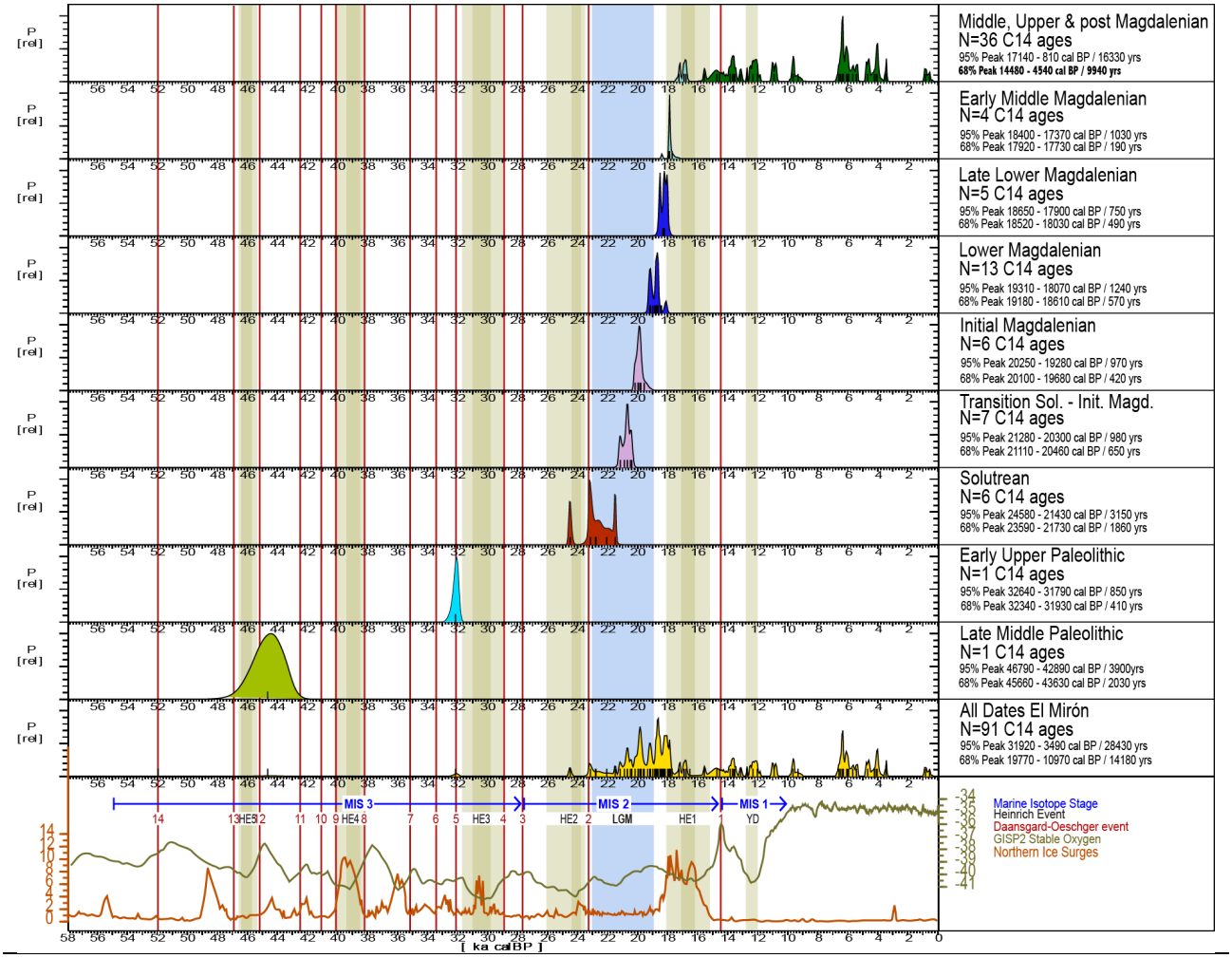


Figure 3.14: Multiple plot for El Mirón radiocarbon- age model Upper: Cumulative multigroup-calibrated probability distributions for radiocarbon- ages from the Cantabrian culture periods. Lower: Age calibration uses the GISP2(Hulu) curve with the program CalPal2016 in green (WANG ET AL. 2001; WENINGER & JÖRIS 2008). Selected climate record: Marine Isotope stages in blue (SÁNCHEZ-GOÑI & HARRISON 2010), Dansgaard-Oeschger high stands corresponding to warmer phases in red, and Northern Ice Surges at the Iberian Atlantic Margin as proxy for cold surface water in orange. Darker shaded areas show particularly cold phases of Heinrich stadials (H1- H5). Blue shading marks the range of the Last Glacial Maximum.

The well radiocarbon dates sequence at El Mirón cave made it possible to further differentiate its occupation phases. One cluster of dates resamples a transitional phase between the Solutrean and the Magdalenian, not (yet) found in the Vestibule Front, but in the Trench and Vestibule Rear, dating from 21.1 to 20.5ka cal BP. The Initial Magdalenian sequence in the Cabin area is dated on samples from a sondage of ~60cm^2 in square J2 located close to the southern cave wall. The stratigraphic sequence in this part of the cave appears to be flat and undisturbed, and fit to dated levels form the Vestibule Rear. However, possible prehistoric downward

percolation of some materials could have occurred along the cave wall and the fact that the dates were done on different materials might be the reason for a younger age of the stratigraphic lowest date in this excavation unit (STRAUS & GONZÁLEZ-MORALES 2010). C14 dates from this occupation, nevertheless, fit well with some Initial Magdalenian dates obtained from the Corral area, dating to 20.1 and 19.7ka cal BP.

Level 17, the massive, ~30cm thick deposit that is the central focus of this dissertation, is the most impressive occupation level within El Mirón cave; it differs from the others in terms of its extraordinary organic richness and high density of artifacts, presumably reflecting long and/or repeated occupation of this area resulting in a palimpsest-like assemblage. This level was dated using different radiocarbon techniques (AMS, conventional dating and conventional-extended count) on different materials (charcoal and bone collagen) over a dozen years (1998-2010). Taking into account the circumstances in which these radiocarbon dates were done, all do lie within a tight range of around 570 years (STRAUS & GONZÁLEZ-MORALES 2003, 2007a; STRAUS ET AL. 2015c), between 19.2 and 18.6ka cal BP.

Levels 15 and 16, in the outer vestibule, mark the end of the (or late) Lower Magdalenian occupation in El Mirón Cave from 18.5 to 18.0ka cal BP. The late Lower Magdalenian sequence in the Cabin area in the outer vestibule is tightly closed with dates from 17.9 to 17.7ka cal BP from the overlying early Middle Magdalenian levels 14 (STRAUS & GONZÁLEZ-MORALES 2003).

Age ranges of calibrated radiocarbon dates of cultural periods at El Mirón relevant for this study can be summarized as follows (Table 3.2). Some radiocarbon ages from multiple dated levels overlap with other occupation phases inside the cave and by doing so, potentially represent intrusions from other Magdalenian levels mainly in the Vestibule Rear. For example, the (wall) structure made from blocks or the large engraved block that was fallen during the Magdalenian times, also may have mixed some sediment and distorted horizontal sediment accumulations in this area of the cave. The occupational history for the Magdalenian, however, was oriented on the Cabin and Trench levels in the Vestibule Front as they were described by the excavators as nearly horizontally accumulated with a clear, thus, most reliable stratigraphy.

Table 3.2: Age ranges of calibrated radiocarbon dates of cultural periods at El Mirón relevant for this study. *=some materials potentially mixed with other levels.

Modelled likelihood: (N= number of dates)	Vestibule Front & Mid	Vestibule Rear	68% ka cal BP	Duration (yrs.)	95% cal BP	Duration (yrs.)
Late Middle Paleolithic, N=2		130	54.4 - 44.3	10110	58.4 - 43.2	15200
Early Upper Paleolithic, N=1		128	32.3 – 31.9	410	32.6 – 31.8	850
Solutrean, N=6		121,125, 126,127	23.6- 21.8	1860	24.6 – 20.3	3150
Transition Solutrean-Magdalenian, N=7	313	116, 117, 119, 119.2	21.1 – 20.5	650	21.3 – 20.3	980
Initial Magdalenian, N=6	19	114, 115, Ramp, (110, 119.2)*	20.1 – 19.7	420	20.3 – 19.3	970
Lower Magdalenian, N=13	17, 18, 312, (21)*	112, 504, 505, (118)*	19.2– 18.6	570	19.3 – 18.1	1240
late Lower Magdalenian, N=5	15, 16	503.1, (116)*	18.5 – 18.0	490	18.7 – 17.9	750
early Middle Magdalenian, N=4	14	110, (108)*	17.9 – 17.7	190	18.4 – 17.4	1030
Middle Magdalenian, N=4		108, (104, 105)*	17.2 – 16.8	460	17.4 – 16.7	750
Upper and post Magdalenian, N=32	12	1-12,100-106	13.7 – 4.4	9350	15.3 – 0.8	14540

Multidisciplinary archaeological relevant studies have been carried out at El Mirón cave making it one of the best studied, well recognized and most important sites in the Cantabrian Region. Many publications and dissertations are available on many aspects of the discoveries in the site and more are underway. (Table 3.3).

Table 3.3: List of multidisciplinary research and publications from El Mirón Cave.

Objective	References
General overview	(González-Morales & Straus 2005, 2013; Straus & González-Morales 2009, 2012b)
Chronology	(Straus & González-Morales 2003, 2003, 2007, 2010, 2016, 2016, 2016, 2018; Straus et al. 2015c; Marín-Arroyo et al. 2018a)
Sediments	(Hubbard 2000; Straus et al. 2001; Farrand 2012)
Features & site structure	(Straus & González-Morales 2007b, 2018a; Nakazawa et al. 2009; Geiling & Marín-Arroyo 2015)
Special finds & art	(González-Morales & Straus 2000, 2009, 2015; García Díez et al. 2012)
Lithic & Osseous industry	(Rissetto 2005; Straus et al. 2008, 2015, 2016, 2018; Fontes et al. 2015, 2015, 2018; Fontes 2016; Straus & González Morales 2019, 2020)
Lithic micro-wear analysis	(Straus et al. 2016)
Human remains	(Marín-Arroyo 2015; Carretero et al. 2015; García-González et al. 2015; Power et al. 2015)
Macromammal	(Altuna et al. 2004; Marín-Arroyo 2008, 2009a, 2009b, 2010; Altuna & Mariezkurrena 2012; Pérez-Ripoll & López-Gila 2012; Marín-Arroyo & Geiling 2015; Marín-Arroyo et al. 2018a; Demarchi et al. 2019)
Vulture activity	(Marín-Arroyo et al. 2009; Marín-Arroyo & Margalida 2012)
Eggshells	(Demarchi et al. 2019)
Micromammal	(Cuenca-Bescós et al. 2008, 2009, 2012; Cuenca-Bescós & García Pimienta 2012)
Mollusks	(Gutiérrez-Zugasti & Cuenca-Solana 2015)
Plants	(Peña-Chocarro et al. 2005a,2005b; Straus & González-Morales 2012a)
Phytoliths	(Zurro 2010)
Ochre	(Seva-Román et al. 2015, 2019)
Stable isotope	(Hermoso-Buxán Unpub.; Stevens et al. 2014; García-González et al. 2015; Marín-Arroyo et al. 2018a)
Genetics	(Consuegra et al. 2002; Meiri et al. 2013; Fu et al. 2016; Olalde et al. 2019; Baca et al. 2020)
Spatial analysis	(Nakazawa 2007; Geiling et al. 2016, 2018)
Micromorphology	(Courty & Vallverdu 2001)
Sediment magnetic susceptibility (MS)	(Ellwood et al. 2001)

In summary, the cultural sequence identified in El Mirón cave pertains to the Late Middle Paleolithic, Gravettian, Solutrean, Initial, Lower, Middle, Upper, and Final Magdalenian, Azilian, (Mesolithic), Neolithic, Chalcolithic, Bronze Age, Medieval Age and modern times, thus, making this site one of great importance for understanding human evolution in the Cantabrian Region and beyond. In fortune of modern excavation techniques, a rich set of information accompanies each excavated level, providing excellent contextualization of observed human behavior by means of faunal remains.

3.2 Faunal materials of study

For this study, the macromammal remains from the Middle Paleolithic, the Gravettian, the Solutrean, small samples from the Initial Magdalenian (square J2) and a major (c. 50%) sample from Lower Magdalenian Level 17 (plus 15 and 16) in the Cabin from El Mirón were selected for analysis. The main foci of this dissertation are the Solutrean and Lower Magdalenian levels in the Corral and Cabin areas respectively, while the Late Middle Paleolithic and Early Upper Paleolithic (Gravettian) levels were also included to establish the

evolution of subsistence strategies on-site. The results of the already-published Middle and Late Magdalenian layers from El Mirón cave (MARÍN-ARROYO 2010) were used for further assemblage comparisons by continuing the sequence after the Lower Magdalenian. All of these datasets covering the range from the Late Middle Paleolithic until the Magdalenian, ending with the beginning of the Holocene, are integrated here and used to understand how developed human economic behaviors at El Mirón cave during its human occupations. All samples studied are detailed in Appendix B.

The Late Middle Paleolithic Level 130 was excavated in squares W10, in ten spits (18-27), and X10, in twelve spits (25-36). Levels 129 and 128 appear to represent a clear Upper Paleolithic occupation of the cave, radiocarbon dates fall within the range of the Gravettian period. The Solutrean faunal remains under study comprise the following units: Level 127 (square X10- spit 13), 126, 125 (square U10- spit 60), 124 (U10- spit 58, 59), 122 (square U10- spit 54, 56, 57) and 121 (square V9- spit 4,5). The Initial Magdalenian faunal remains contain only a few finds from the very small *sondage* in the outer vestibule excavation area that was dug in square J2, constituting the Levels 18, 19, 20 and 21. Level 504 contained the human burial of the 'Red Lady' in the SE rear corner of the vestibule and, although, the context suggests some modification of the burial's depositional context, its Lower Magdalenian attribution and dating are reliable (STRAUS et al. 2015b). The Lower Magdalenian NISP from Level 17 is extraordinary rich, despite the fact that the assemblage represents only a small part of the total likely occupied area of the vestibule. The excavated area in the Cabin amounts to only 9.5m^2 out of a total area of approximately 8-16m wide by 30m long (Figure 3.15).

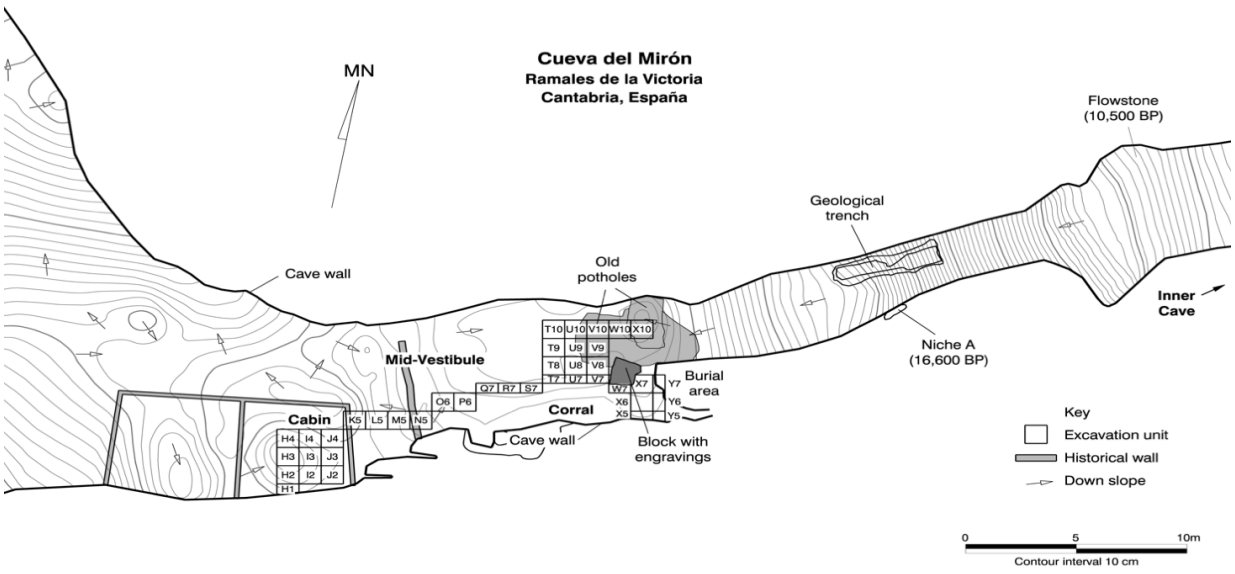


Figure 3.15: Excavation areas and location of squares where studied materials origin from. Topography by E.Torres and map modified after L.G.Straus & R.Stauber.

The Lower Magdalenian faunal assemblages from Levels 15, 16 and 17 studied here all come from the 'Cabin' area. For this analysis, it was important that the horizontal layering of the finds including the faunal material allows us to create vertical units to subdivide the massive (c. 30 cm-thick) Lower Magdalenian Level 17 palimpsest deposit (Figure 3.16). This was possible given the meticulous single-item piece-plotting and depth records for the top and bottom of every subsquare for each spit excavated. The stratigraphic section constituted by Levels 15-17 from 15.25-15.85m above datum in the excavation area was divided for analytical purposes here into thirteen arbitrary layers, each approximately 5cm-thick and sometimes composed of

more than one excavation 'spit' each, depending on each square and its excavation history. All materials from Levels 15 and 16 were included, corresponding to the samples 1 to 5 for this analysis. Because of the overwhelming richness of Level 17, only the even-numbered samples (6, 8, 10 and 12) were analyzed; hence a ca. 50% sample.

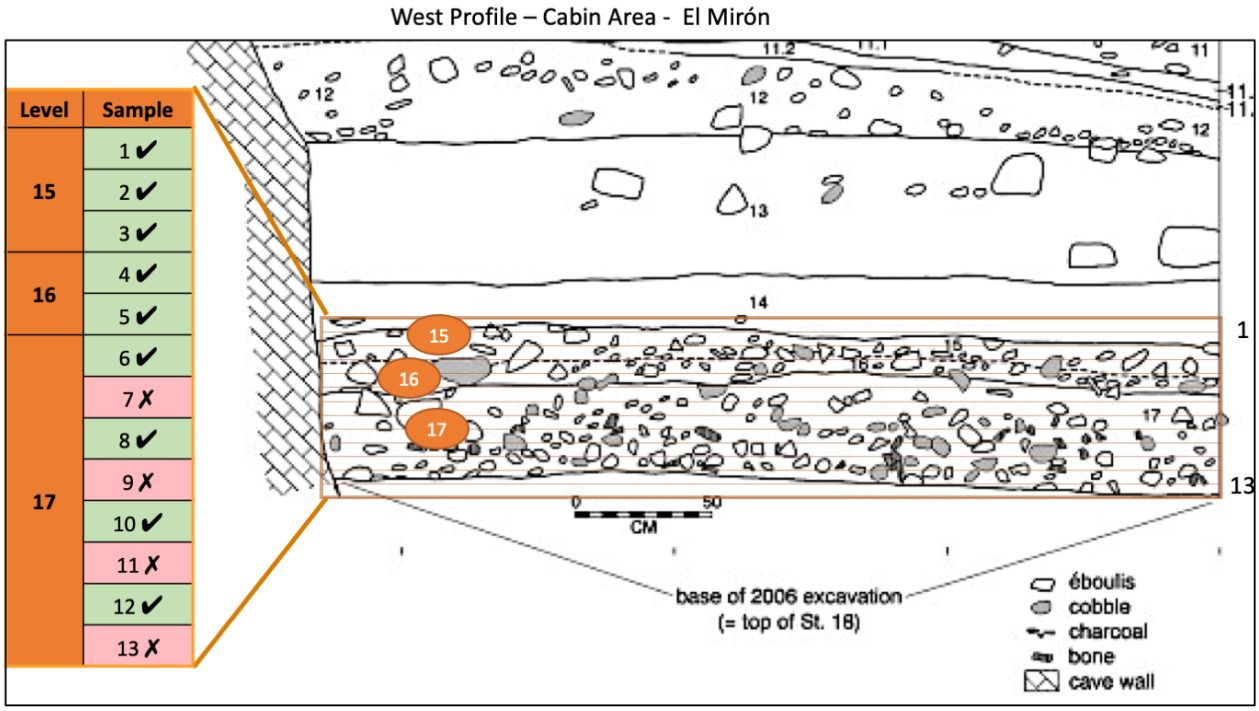


Figure 3.16: Schematic sequence of sublayer samples for Lower Magdalenian Levels 15, 16 and 17 in the Cabin area.

A total of 241,285 bone specimen was studied for this faunal analysis. All faunal remains are described in detail in Appendix C by level and species. They came from 18 different levels and from 20 different excavation squares (Table 1.4).

Table 3.4: El Mirón faunal materials included in this dissertation.

Period	Level	Number of squares (m^2)	Number of artificial spits
Late Middle Paleolithic	130	2	10
Early Upper Paleolithic (Gravettian)	129	2	5
	128	3	15
Solutrean	127	2	2
	126	1	3
	125	2	2
	124	2	4
	123	1	1
	122	2	5
	121	2	5
Initial Magdalenian	21	1	1
	20	1	1
	19	1	1
	18	1	3
Lower Magdalenian	17	10	71
	16	10	30
	15	10	27
	504	7	17
Total Faunal Analysis	18 Levels	20 squares	203 spits

Materials for the case study in spatial distribution analysis uses macrofaunal data and taphonomic categories from Levels 15, 16 and 17, which together form a very rich Lower Magdalenian horizon (15.7-15ka uncal BP) excavated in an area of 9.5m^2, in the so-called 'Cabin' area, located in the outer part of the cave vestibule (Figure 3.15). The studied levels are well preserved and no disturbances among the sediments were observed either during excavation or in sedimentological analysis (FARRAND 2012). The nature of the archaeological deposits and its preservation state make El Mirón cave suitable for the analytical approach proposed here.

During excavations in El Mirón cave, in the 80cm-thick Lower Magdalenian deposit in the 9-10m^2 Cabin area of El Mirón cave (STRAUS & GONZÁLEZ-MORALES 2007b), lithics over 1cm, bones over 5cm, teeth and osseous artefacts were individually recorded and piece-plotted. The anatomically and taxonomically unidentifiable bone micro-fragments, were recovered after water-screening or sieving sediments of each excavated spit and quarter-meter sub-square units and gathered in 'general bags'. The present spatial studies include individually plotted macro-mammal finds and remains from the 'general bags'. The latter were included to increase the usable taxonomic, anatomic and taphonomic information and find categories were teeth or bone fragments smaller than 5cm, burnt bones, bone flakes, young spongy bones or digested bones.

Spit-depths: Based on these data, subsamples, corresponding to different heights above the site's 0-datum plan were created for later study the archaeological density in levels of interest.

The excavation that concentrated on the space behind a large engraved block (2x1x1m) – an area in the archaeologically rich, vestibule rear not affected by previous looter activities (STRAUS, GONZÁLEZ-MORALES, & CARRETERO 2011: pp. 1154, Fig.3) is located in the southeastern corner of El Mirón cave, at the rear of the vestibule (Figure 3.15); and is referred to as burial area. This area of around 3.75m^2 is bounded by the cave wall to the east and south and the engraved block to the northwest and was excavated in the final years of the project, after having first been identified in 2001 as apparently containing Magdalenian deposits. The

first human remains were actually recovered in partial squares X7 and Y7 in 2001. The excavation of these two squares was eventually completed in 2010 (when discovery of the red ochre-stained human jaw and tibia made clear the existence of a burial, not simply isolated small bones) and 2011 (STRAUS ET AL. 2015b, Fig.3). The author joined the excavations in 2013 when the burial area was extended to the south (squares X5/6 and Y5/6), revealing a few more human remains from Level 504, characterized, as in the earlier years, by sediments with sparkling hematite crystals and red ochre. This case study examines the spatial distribution of human and animal bones, lithic and osseous artifacts, and chunks of red ochre from Level 504 found within the burial area (GEILING & MARÍN-ARROYO 2015).

For seasonal environmental reconstructions, stable isotope studies were carried out on teeth of faunal materials from El Mirón cave, molars from horse, red deer and Spanish ibex were chosen for sampling. In autumn 2016, the initial sampling of molar teeth was performed thanks to the collaboration and teaching with Dr. K. Britton in the Isotope Laboratory at the University of Aberdeen, where running projects focus on "Palaeobiogeography and Palaeoecology of late Pleistocene Herbivores of Northern Europe". The continued sampling and materials for further preceding as necessary laboratory space as well as mass spectrometry analysis were kindly made possible in the biogeochemical laboratories of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, in summer 2017.

An intra-tooth sequential sampling strategy was applied on horse, red deer and ibex teeth from archaeological Levels 15, 16 and 17 dating to the Lower Magdalenian (17.15-16.4 cal BP) of approximated ~750year-long formation duration located in the cabin area of El Mirón cave. However, chrono-stratigraphic groups were build for specimen from the Lower Magdalenian levels defined by archaeological criteria resulting in a stratigraphically lower (ISO-low_1-8 ~ lower part of Level 17), middle (ISO-mid_1-3 ~ middle part of Level 17) and upper (ISO-up_1-3 ~ Levels 16 and 15) unit. The details of results are collected in Appendix G. Following teeth were selected for stable isotope analysis (Table 3.5):

Table 3.5: Teeth sampled for stable isotope analysis (C, O and Sr).

Species	Element	Level	Square	Nr	Spit	Code	Isotope Analysis
Capra pyrenaica	lower M3 right	16	I2	396	28	**ISO-CP-up_1**	O (P)
		16	H3	872	59	**ISO-CP-up_2**	
		15	H4	1061	51	**ISO-CP-up_3**	
		17	H4	1792	60	**ISO-CP-mid_1**	O/C(C), O(P), Sr
		17	J2	957	23	**ISO-CP-mid_2**	O (P)
		17	H3	1648	67	**ISO-CP-mid_3**	
Equus ferus	upper P left	17	I3	5535	66	**ISO-EQ-low_1**	
Equus ferus	upper M2L	17	J3	4681	47	**ISO-EQ-low_2**	
Cervus elaphus	lower M3 right	17	I4	5083	72	**ISO-CE-low_3**	
	lower M2					**ISO-CE-low_4**	
Cervus elaphus	lower M3 right	17	H3	3510	74	**ISO-CE-low_5**	
Capra pyrenaica	lower M3 left	17	H3	5278	80	**ISO-CP-low_6**	
	lower M2 left					**ISO-CP-low_7**	
	lower M3 right	17	I4	3427	66	**ISO-CP-low_8**	O/C(C), O(P), Sr

Dental calculus samples were additionally collected from the tooth surface of 23 teeth for comparison with the stable isotope analysis of samples throughout the Lower Magdalenian levels. Following teeth were selected for dental calculus analysis (Table 3.6):

Table 3.6: Teeth sampled for phytolith analysis in dental calculus.

Species	Element	Level	Square	Number	Spit	Code	Isotope- sample
Capra pyrenaica	Lower M3, right	15	J4	1404	60	**PHY-01**	YES
		16	H3	872	59	**PHY-02**	YES
		17	H3	1648	67	**PHY-03**	YES
		17	H2	1500	50	**PHY-04**	YES
		17	I4	3893	68	**PHY-05**	YES
		17	H3	5278	80	**PHY-06**	YES
Equus ferus	Molar	17	H4	1253	54	**PHY-07**	
***Bos/Bison* sp.**	Premolar	17	H2	1362	49	**PHY-08**	
Cervus elaphus	Molar	17	I4	5702	73	**PHY-09**	
Capra pyrenaica	Lower M3, right	17	J2	262	17	**PHY-10**	
		17	I4	1532	54	**PHY-11**	
		17	J4	1538	61	**PHY-12**	
		17	H3	1291	64	**PHY-13**	
		17	H3	1745	68	**PHY-14**	
		17	I3	1668	51	**PHY-15**	
	Lower M3, left	17	H3	1997	69	**PHY-16**	
	Lower M3, right	17	J4	3898	68	**PHY-17**	
Equus ferus	Molar	17	H3	1542	66	**PHY-18**	
Capra pyrenaica	Lower M3, right	17	H4	1061	51	**PHY-19**	YES
		17	I3	1031	47	**PHY-20**	YES
		17	J2	957	23	**PHY-21**	YES
		17	H4	1792	60	**PHY-22**	YES
		17	I4	2032	59	**PHY-23**	YES

The diachronic evolution of subsistence strategies from El Mirón cave was compared among sites within the Cantabrian Region to better understand settlement dynamics and wider factors that influence subsistence behavior. Archaeological data considered from Cantabrian sites are presented in Table (Table 3.7) and site locations are shown on a map (Figure 3.17). Appendix H.1 provides more detail on the location of these sites. Several published archaeological and faunal datasets from the region were reviewed for cultural, radiocarbon and archeozoological data to summarize available Paleoeconomic data. They were summarized during this study which include a database of archaeological sites, a radiocarbon database (based for El Mirón on the successive publications by Straus and González-Morales in *Radiocarbon*) and an archeozoological database as source for further data interpretation (see complete Appendix H).

We can sum up that El Mirón materials with its modern excavations, good preservation and comprehensive, already accomplished multidisciplinary analysis enable to use this archaeological material to draw in detail, complex human behavior patterns. These archaeological materials also have a great potential to further develop methods to scrutinize information about specific activities from several ten thousand years ago with which Archaeologist can better understand past human behavior. Faunal materials are here the focus of analysis, because of their interlinking character between human dietary needs, environmental conditions and carrier of human actions in terms game choice, animal processing, raw material, and many more.

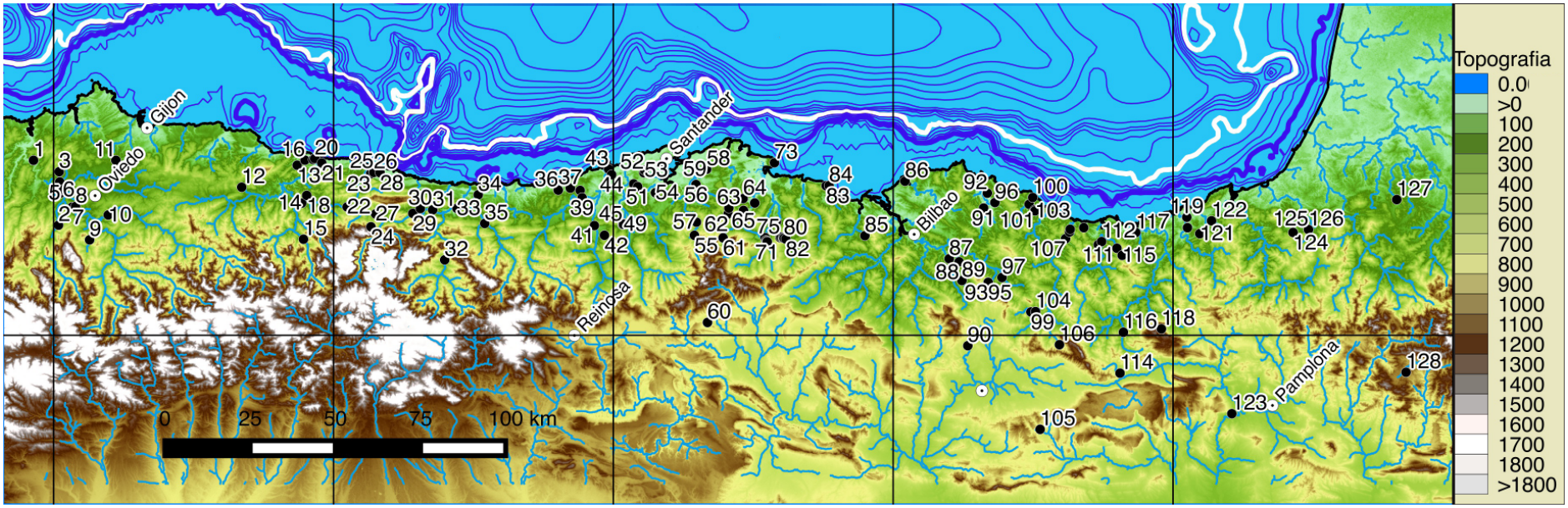


Figure 3.17: Map of the Cantabrian Region with sites from the Late Middle Paleolithic to the Mesolithic used for chronological, spatial distribution and/or economic comparison. Some sites contain archaeological remains and cave art. Site names see Table 3.7.

Table 3.7: Relevant Paleolithic sites in the Cantabrian Region.

ID	Site	ID	Site	ID	Site
1	Peña de Candamo	44	Cudon	87	Lezetxiki
2	El Conde	45	Las Monedas	88	Arlanpe
3	La Paloma	46	La Pasiega	89	Axlor
4	Oscura de Ania	47	El Castillo	91	Atxeta
5	Sofoxo	48	Las Chimeneas	92	Antoliñako
6	Las Mestas	49	La Flecha	93	Askondo
7	La Lluera I & II	50	Covalejos	94	Atxuri
8	Las Caldas	51	El Pendo	95	Sailleunta (San Lorenzo)
9	Entrefoces	52	El Ruso	96	Santimamiñe
10	La Viña	53	El Juyo	97	Bolinkoba
11	El Olivo	54	Morín	98	Abittaga
12	El Sidron	55	El Salitre	99	Labeko Koba
13	Cova Rosa	56	Fuente del Frances	100	Lumentxa
14	La Guelga	57	Rascaño	101	Atxurra
15	Cullubil	58	La Garma	102	Armiña
16	El Cierro	59	Truchiro	103	Laminak II
17	Pedroses	60	Palomera	104	Etxaluze
18	El Buxu	61	Cubera	105	Atxoste
19	La Lloseta	62	Cofresnedo	106	Antonkoba
20	Tito Bustillo	63	Los Emboscados	107	Etxeberri
21	San Antonio	64	El Otero	108	Ermittia
22	Sopeña	65	Cobrantes	109	Praile Aitz
23	Tres Clabres	66	La Chora	110	Urtiaga
24	Covaciella	67	Cullalvera	111	Ekain
25	Cueto de la Mina	68	La Haza	112	Danbolin
26	La Riera	69	El Mirón	113	Amalda
27	Los Canes	70	Covalanas	114	Coscobilo
28	Balmori	71	La Luz	115	Erralla
29	Trauno	72	El Horno	116	Usategi
30	Coimbre	73	Perro	117	Altxerri
31	Llonín	74	El Valle	118	Abauntz
32	Esquilleu	75	Sotarriza-Covanegra	119	Ametzagaina
33	La Loja	76	Morro del Horidillo	120	Astigarraga
34	Fuente del Salín	77	Arco (A,B,C)	121	Aitzbitarte III/IV
35	Chufín	78	La Pondrá	122	Torre
36	Las Aguas	79	Venta Laperra	123	Legintxiki
37	Cualventi	80	El Polvorín	124	Lezia (Grottes du Sare)
38	Altamira	81	El Rincón	125	Berroberria
39	La Estación	82	La Cadena	126	Alkerdi
40	La Llora (St. Clotilde)	83	El Cuco	127	Isturitz
41	Sovilla	84	Urdiales	128	Zatoya
42	Hornos de la Peña	85	Arenaza		
43	La Pila	86	Kurtzia		

3.3 The faunal methodological approach

This faunal analysis uses a multidisciplinary approach to study the Paleolithic economic dynamics (=Paleo-ecodynamics) in El Mirón cave and the Cantabrian Region. The aim is to establish reliable interconnections among multiple research areas. Climate and landscape are factors considered as essential as well as human social interaction and demographic factors (Figure 3.18). Archeozoological methods comprise zoological, ecological and taphonomic analytical techniques in order to study human-animal interactions. They are useful measures to reconstruct site formation by aiming to record, evaluate, understand and reconstruct human behavior related to animals, which allow to consider which agents accumulated which remains and to what degree they were modified. The taphonomic history of a faunal assemblage is essential to isolate human made modifications for behavioral analysis and site function in correspondence to other accumulation agents involved in creating it. These processes have been modeled in various ways (Binford 1981; Brain 1981; Lyman 1994; Schiffer 1996; Fernández-López & Fernández-Jalvo 2002; Reitz & Wing 2008), mainly to differentiate biotic from abiotic factors that modified faunal assemblages. Site formation processes can be subdivided into biostratinomy and fossil diagenesis. Biostratinomic analyses (pre-burial) mostly include the study of anthropogenic and carnivore accumulation and alteration processes. Diagenetic analyses encompass color variation, weathering degree, or carbonate encrusting on faunal remains that occur after the initial burial (post-burial). Spatial distribution analyses that localize taphonomic modification processes help investigating the pattern of activity areas within a site and thus infer site use. Such biotically active modification processes on faunal remains are different to abiotic ones that happen post-depositionally. The latter can also contribute to site relevant environmental reconstructions, named here micro-environemt, which provide information about the contextual settings of human actions. Particulry, supplement stable isotope and phytolith analysis on ungulate teeth the reconstruction of paleo-environments constext at times of human occupations. This dissertation faunal approach employe a combination of methods to reconstruct the *chaîne opératoire* of human actions spanning the great range of activities, from food acquisition, over animal carcass processing, to discard behavior.

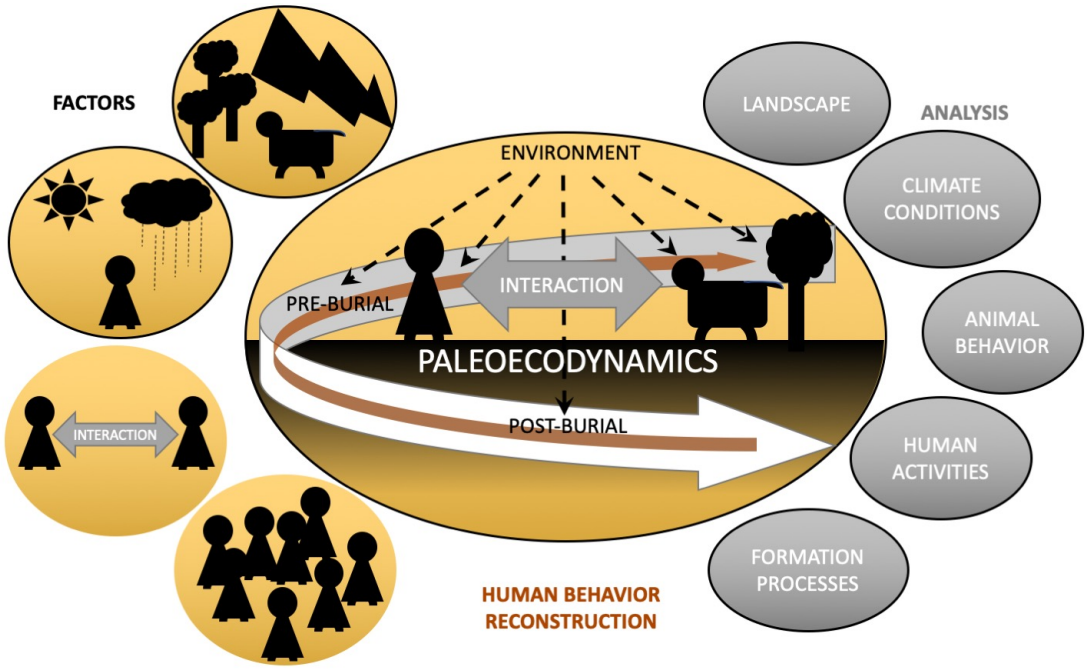


Figure 3.18: Multidisciplinary methods studying Paleo-ecodynamics using macrofaunal material.

The proposed multidisciplinary methodology combines varied strategies contributing to different aspects of human ecodynamics. Each strategy contains a set of methods in correspondence to the objectives of this analysis, they are taphonomy, spatial and environmental analysis. Those strategies are aiming to determine, the taphonomic history by means of first, quantification, state of preservation and fracture patterns of the faunal material; second, anthropogenic modification marks; third, skeletal profile analysis and site function; fourth, mortality profiles, animal biomass and seasonality; fifth, adaptation in economic behavior; sixth, the role played by other accumulation agents during formation of the faunal deposit; and finally, post-depositional modifications. Spatial analysis encompasses pre-analytical steps of field methods and laboratory methods, before spatial distribution analysis of zoological and taphonomic categories are performed with computational methods. Environmental and animal ethological reconstructions are attended by stable isotope analysis and a study of phytolith analysis from dental calculus of the same ungulate teeth. The last set of methods study the inter-site chrono-cultural-climatic evolution for the Cantabrian Region.

3.4 Taphonomy and reconstructing human activities

In order to determine economic strategies employed by Stone Age inhabitants of the cave, exploitation strategies were evaluated. To identify the main accumulation agent within an archaeological deposit and to understand the accumulation history, methods identifying biological modifications are applied next. All modifications affecting faunal remains prior to final burial are summarized under the term 'biostratinomy', which usually includes the study of animal and anthropogenic alterations (FERNANDEZ JALVO ET AL. 2002). The type of alterations (anthropic, carnivore, rodents, birds of prey, etc.) allow one to distinguish whether or not primary access to carcasses was primarily to humans (BRAIN 1981; CRUZ-URIBE 1991; KUHN ET AL. 2008; MARÍN-ARROYO 2010; LLOVERAS ET AL. 2011). Common general biostratinomic alterations identified in Paleolithic faunal assemblages are fractures of bones. Human animal processing activities usually produce cut marks, impact marks, burning traces on bones and artificially modification of osseous remains is recurrent. Typical carnivore alterations are tooth marks and digestion. Post-depositional alteration includes the weathering process, the changes in coloration and mineral (iron, manganese and calcite) component through coating processes, and localized dissolution by root- etching activity. How each of them is studied, is explained in what follows.

In search of anthropogenic, biological and natural alterations each faunal remain was observed with the naked eye, as well as under binoculars (Leica S8 APO, magnification 10x-80x) with various lightnings (BLUMENSCHINE 1995; DOMÍNGUEZ-RODRIGO ET AL. 2009).

3.4.1 Faunal quantification and fracture patterns

Quantification methods of faunal materials in Archeozoology and Taphonomy allow to characterize the taphonomic preservation of the faunal assemblage by means of several quantification parameters; key measures are:

Number of Specimens (NR) of faunal remains is a quantification per level. All bones or teeth available from each level are included in analysis, from general bags or which were in-field presorted into 'identifiable' and 'non-identifiable' specimens by excavators. This procedure allows imrpoving, first, the identification rate for the studied sample and, second, to exclude biases from the presorting of faunal remains. NR thus represents the total amount of faunal remains, in contrast to NISP, which comprises anatomically/taxonomically identified faunal remains.

The comparison of number of bones and teeth per level can identify preservation conditions. The distinct natural structure of bones (containing around ~60% of inorganic material [$Ca_{10}(PO_4)_6(OH)_2$], i.e., calcium hydroxyapatite) and teeth (the hardest components in a mammal body based on their high crystalline structure of hydroxyapatite in dentin 70-75% and enamel 96-7%) (TÜTKEN 2003) is likely the reason for

different rates of preservation. Varying quantity implies either remarkable dissimilarities in the accumulation history of these elements or selective destructive alterations (especially diagenetic in origin) among levels.

In order to evaluate the preservation of the faunal assemblage, weight (in grams) for all faunal specimens were recorded. Weight was obtained with standard balances that display values to one decimal place. Weight is a more realistic way to present the amount of bone in each size class (OUTRAM 2001), as fragmentation size can vary due to the animal size, the animal exploitation pattern, the intra-site preservation or the excavation techniques. Weight as a measure is used in relative terms referring to the specific level or sample of study to avoid taphonomic biases through geochemical changes in weight as a result of possible, normally prolonged fossilization processes. While it is possible that differing mineralization and adhering soil (normally cleaned before) can increase the individual weight of remains, the degree of uncertainty is considered generally low for this quantification method and probably can rarely compensate for the cumulative loss of remains due to recovery processes (BARRETT 1993).

Size classes were recorded by maximal dimensions in full centimeters. The overpass of the full centimeter surpasses the specimen to the next size class, for example a bone of 6,2 cm length falls into the size class of 7cm. The separation was achieved by placing the fragments on plastic sheets with circles representing the full centimeter of each size class (OUTRAM 2004: p. 176).

The quantity of complete bones was compared per species and levels as an indicator of preservation degree, targeting species explored for within-bone nutrients and general indicator of processing activities.

Based on previous prehistoric faunal studies (ALTUNA 1972; YRAVEDRA 2005; CORCHÓN-RODRÍGUEZ & ÁLVAREZ-FERNÁNDEZ 2008; MARÍN-ARROYO 2010; GÓMEZ-OLIVENCIA ET AL. 2018), the following species have been identified as had some kind of animal-human relationship in the Cantabrian Region Table 3.8:

Table 3.8: Paleolithic animal species in the Cantabrian Region identified in archaeozoological studies.

	Species		
Herbivores	mammoth (*Mammuthus primigenius)* rhinoceros (*Coelodonta antiquitatis)*, horse (*Equus ferus)*,	bison (*Bison priscus)*, aurochs (*Bos primigenius)*, Spanish ibex or ibex (*Capra pyrenaica)*, chamois (*Rupicapra Rupicapra)*,	giant deer (*Megaloceros sp.)*, red deer (*Cervus elaphus)*, reindeer (*Rangifer tarandus)*, roe deer (*Capreolus capreolus)*
Omnivores	brown bear (*Ursus arctos),* cave bear *(Ursus spelaeus)*	wild boar *(Sus scrofa)*	
Carnivores	leopard (*Panthera pardus)*, Iberian lynx (*Lynx pardinus)*, cave lion (*Pant. leo spelaea)*, lynx (*Lynx lynx)*, wild cat (*Felis silvestris)*,	cave hyena (*Crocuta spelaea),* wolf (*Canis lupus)*, Arctic fox (*Alopex lagopus)*, red fox (*Vulpes vulpes)*,	Eurasian otter (*Lutra lutra)*, badger (*Meles meles)*, wolverine (*Gulo gulo)*, common weasel (*Mustela nivalis)*, common polecat (*Mustela putorius)*, short tailed weasel (*Mustela ermine)*, European pine marten (*Martes martes)*, stone marten (*Martes foina)*
Lagomorpha	European hare (*Lepus europeaus),* Arctic hare *Lepus timidus,*	European rabbit (*Oryctolagus cuniculus)*	
Aves	bearded vulture (*Gypaetus barbatus)*,	common kestrel (*Falco tinnunculus),* golden eagle (*Aquila chrysaetos),*	starling (*Sturnus sp.),* red-billed chough (*Pyrrhocorax pyrrhocorax)* common raven (*Corvus corax)*
Marine mammals	grey seal (*Halichoerus grypus),* harbor seal (*Phoca vitulina)*		long-finned pilot whale (*Globicephala melas),* sperm whale (*Physeter macrocephalus catodon)*
Fish	Atlantic salmon (*Salmo salar)*, brown trout (*Salmo trutta)*	marine fish (*Raia spp.)*	

Macro-mammals are commonly represented in European faunal assemblages and, thus, their morphological identification criteria are described in the literature very well, e.g. (PALES & LAMBERT 1971; SCHMID 1972; WOLSAN 1982; PRUMMEL & FRISCH 1986; PRUMMEL 1987a, 1987b, 1988; HILLSON 1990; DAVIS 1995; O'CONNOR 2000; BRÄUER 2006). Red deer morphological criteria are well defined. But for Spanish ibex identification criteria often refer only to a goat of large size, but with a great span of sexual size dimorphism (ALTUNA 1978). The species *Capra pyrenaica* (Spanish ibex—in distinction to *Capra ibex,* the Alpine ibex) is endemic to the Iberian Peninsula, but several subspecies are extinct or in danger of it (ACEVEDO & CASSINELLO 2009). On a few occasions species- specific diagnostic criteria are described and illustrations are published (PÉREZ-RIPOLL 1988; SARRIÓN MONTAÑANA 1988; GALINDO-PELLICENA ET AL. 2017), but it is less well-represented in the common identification literature. To overcome these shortcomings, a collection of identification criteria and a catalog for Spanish ibex skeletal morphology by photos (see Appendix C) was compiled which will be helpful for future works (also including landmarks as explained later).

The taxonomic and anatomic identification at the species or genus level was made with the use of the modern bioarcheological reference collection hosted at the Instituto Internacional de Investigaciones Prehistóricas de Cantabrica - IIPC-University of Cantabria in Santander. In cases where it was necessary, other comparative faunal collections were consulted, including the ones belonging to Prof. Jesus Altuna at that time located in the Centro de Patrimonio Arqueológicoo de Gipuzkoa in San Sebastian, the Museo Nacional de Ciencias Naturales and the Laboratorio de Arqueobiología in the Centro de Ciencias Humanas y Sociales (CSIC), the latter two in Madrid. The studied faunal materials compromise three types of faunal remains: 1) those which could be identified anatomically and taxonomically; 2) those which were only identified anatomically and sorted into animal size-classes from megafauna size to small mammal size (Table 3.9), and 3) those which were too fragmentary for a definitive identification into either one or the other previous categories. The latter ones are simply categorized as unidentified.

Table 3.9: Animal body-sized classes. Approximate height at withers and weight is given, when available for females and for males.

Indeterminate in size classes	Animal	~Height at withers	~Weight
medium Carnivore	wolf-size	60-90cm	f:23-55kg; m:30-80kg
small Carnivore	fox- size	35-50cm	2.2-14kg
Large Ungulate	red deer, male Bos/Bison (bovine), young horse, young	90-120cm	80-160kg
Medium Ungulate	red deer, female or young ibex (male) reindeer	90-110cm 70-90cm 85-150cm	50-100kg 60-80kg f:80-120kg; m:>150kg
Small Ungulate	ibex, female or young roe deer chamois	75cm 75cm	35-46kg f:23.2kg; m:25.5kg f:25-45kg; m:30-60kg
XL: extra large sized animal	aurochs (adult) bison (adult) horse		>150kg
ML: medium-large sized animal	ibex/reindeer/red deer size		~50-150kg
SM: small-medium sized animal	ibex/chamois size		~25-100kg
S: small sized animal	chamois, fox, lynx		~10-30kg
XS: extra small sized animal	marten, hare, wild cat,		<~10kg

After a specimen was identified anatomically and taxonomically or by body size class, this information was recorded in a faunal analysis database (Figure 3.19), which was elaborated especially for this study. Advanced archeozoological quantification methods comprise several calculation steps that need to be done sequentially. This faunal database was created to record, quantify and analyze the faunal specimens that later could provide answers to the different hypotheses proposed in the introduction. To facilitate data-entry, drop- down menus were created for each field (Figure 3.19).



Figure 3.19: Faunal database (MS Access) with field data from excavation and newly created archeozoological information used for recording.

Fields (Table 3.10), data -entry and output were designed in the database with the aim to optimize the interpretation of results. The database covers a broad spectrum of archaeological, zoological and taphonomic data fields to record information for every single archaeological item.

Table 3.10: Fields of the faunal database.

Category		Fields
Field data		Object ID, square (ES: “cuadro”), subsquare, Level (ES: “nivel”), spit (ES: “tramo”), CL=classification, number
Individual characteristics		Suffix, size, weight, long bone circumference, general bag category, notes
Identification	Diagnostics	species, skeletal elements, bone part, side, landmark
	Individual	Tooth eruption, tooth wear, epiphyses fusion, sex, pathology, estimated age
Taphonomy	Fracture	Type, angle, outline, edge, breakage
	Impact	Position, point, notches
	Cut marks	Structure, position, direction, mark profile, specials, cut mark pattern after Binford (1981), implied activity
	Anthropogenic	Bone artifact, artifact type, burnt? Burning location, burning degree, (trampling)
	Other agents	Carnivore, activity, digestion, rodents
	Diagenetic	Weathering, color, natural alterations, Mn coating, calcite forming, fungi, roots
total		58 fields

During analyses, data summaries are processed automatically within PivotChart Views (MS Access 2007) for preliminary trend breakdowns and queries of specific data requests. Cross tables are created within the database to address questions of interest, which were enabled with a function to export easily excel sheets for further analysis and visualization. These queries summarize, for example: NISP and weight records by species and level, the number of carnivore or cut marks, the number of bones for each color type, impact positions vs. type, number of fracture types, the number of items that represent different burning degrees, etc. Altogether the database facilitates, optimize and speeds up the working step in between the bone identification and the summary of results for future publication. Another important reason to create the present database was simply to manage the enormous amount of raw data as well as the newly produced data throughout detailed analyses on the very large El Mirón faunal collections material where 'normal work sheets' were not convenient.

Indices are derived quantification methods, considering multiple factors. Here were used:

- Faunal Density Index (FDI). Amounts of excavated sediments per spit were standardized to obtain uniform information about each level's faunal density, considering thickness and extension in square units of excavated levels. This was applied to control whether changing quantities were real density variations or the result of differing excavation unit thicknesses. This density index allows one to better control quantities in terms of number per 1cm depth of square meter units as a measurement for comparison among the studied units. The faunal density index was calculated taking into account the total NR, square meter and thickness of the excavated area for each level:

$$\text{Faunal Density Index}_{\text{level}} = \frac{\text{total}_{\text{NR}}}{\text{m}^2{}_{\text{excavated}}} \times \text{thickness(cm)}_{\text{excavated}}$$

- The Fragment Size Index (FSI) was calculated to describe the general distribution of the fragment size, which is especially useful when the faunal assemblage includes indeterminate mammal specimens, in this case, usually collected in the general bags (REITZ & WING 2008: P. 200; GEILING ET AL. 2018). FSI was used, thus, to quantify the degree of fragmentation for the studied material. Thus, FSI (Weight/NISP) per levels and squares is compared to observe, if fragment sizes do differ among species, spatial location or levels. The distribution of varied fragment sizes might be influenced by cave topography or other structural elements in the cave. The FSI was calculated for each level and main prey species with the following equation:

$$\text{Fragment Size Index} = \frac{\text{total}_{\text{weight}}}{\text{total}_{\text{NISP}}}$$

- The common index used to quantify the identified faunal remains is the Number of Identified Specimens (NISP), which reflect the quantity of taxonomically (or in size classes) and anatomically bone or teeth fragments. The total NISP of sites and levels depends on various factors, thus for inter-site or inter-level studies species related %NISP is used for comparisons (GRAYSON 1984; MARSHALL & PILGRAM 1993; WOLVERTON 2002; LYMAN 2008; REITZ & WING 2008; CANNON 2013). Advantageously NISP is automatically counted during the identification process when introduced in the database. Limitations to the values of NISP in an assemblage depend basically on the anatomical landmarks available on a specimen, the zoological training of the scientist and the reference collection available. Some deficiencies of the NISP include the inter-taxonomical variation of frequencies in bones and teeth, the change of bone frequencies within animals due to age fusion stages and bone recovery depending on animal size (for example bovid vs. bird) (GRAYSON 1979; LYMAN 1994), which were considered during analysis.

– The Minimum Number of Individuals (MNI) is the final step within the quantitative zooarchaeological analysis, which is taking into account all the below described considerations of age, size, season, etc. The estimation of MNI was introduced into Zooarcheology by White (1953), who attempted to infer human behavior through dietary reconstructions; this method has been amply used in paleontology. The measurement is expected to reflect the meat quantity provided by each taxon as opposed to a measure of taxonomic abundances. MNI measures the most commonly occurring skeletal element of left-right side counts from paired bones of a taxa in an assemblage. It is referred to the 'modified MNI' when individuals of clearly different size, ontogenetic age and sex characteristics within each taxon are included, which normally increase the counts of individuals (KLEIN & CRUZ-URIBE 1984; LYMAN 2008). There are different opinions on the relationship of MNI calculation and fragmentation degree of a faunal assemblage (see summary MAREAN ET AL. 2001). MNI is based on MNE and is less affected by the degree of fragmentation; therefore, it is better measure of taxonomic abundances than NISP. Highly fragmented assemblages, on the contrary could blur MNE values towards an overestimation of MNI. Rare taxa are always over-estimated, especially in small samples. Subsampling is often referred as holding the possible error to overestimate MNI by counting individuals more than once. This could be avoided by using the same skeletal element and landmarks in each subsample for MNI calculations. The final maximum MNI count, then, is based on the highest number of one skeletal element and part represented by the same landmark from one side and the advanced MNI estimation includes, when possible, variation in side, age, sex, and size in specimens (WHITE 1953; REITZ & WING 2008).

In summary, NISP, MNE and MNI are different, important measurements in past economic analysis and all three were employed in detail, as explained in the next paragraphs.

Fracture pattern analysis seek to determine the degree and origin of detruction of the faunal remains, mostly of the bones. Among Paleolithic bone assemblages, bone- cracking activities are omnipresent; bone cavity opening is possible to do in different ways (Figure 3.20). Mostly, those activities produce impact flakes and notches implying marrow extraction (STINER 2002a; GALÁN ET AL. 2009; DE JUANA & DOMINGUEZ-RODRIGO 2011; BLASCO ET AL. 2014) and low fragmentation rates of cancellous bones can be the result of intentional fracturing for grease rendering (LUPO & SCHMITT 1997; BRINK 1997; OUTRAM 1998, 2001; CHURCH & LYMAN 2003; MUNRO & BAR-OZ 2005; KARR ET AL. 2010).

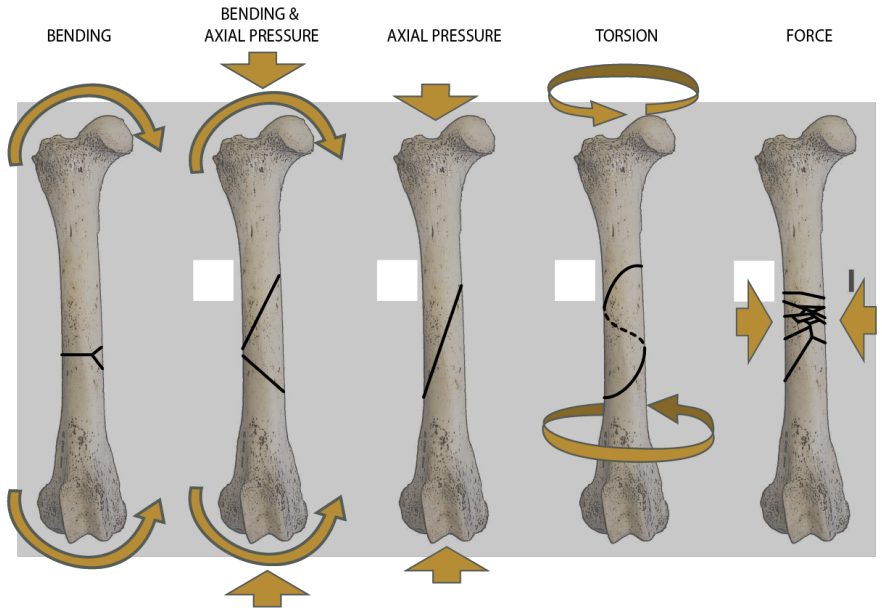


Figure 3.20: Possibilities of bone fracturing.

Codes used in the database for the description of long bone parts are shown in Figure 3.21.

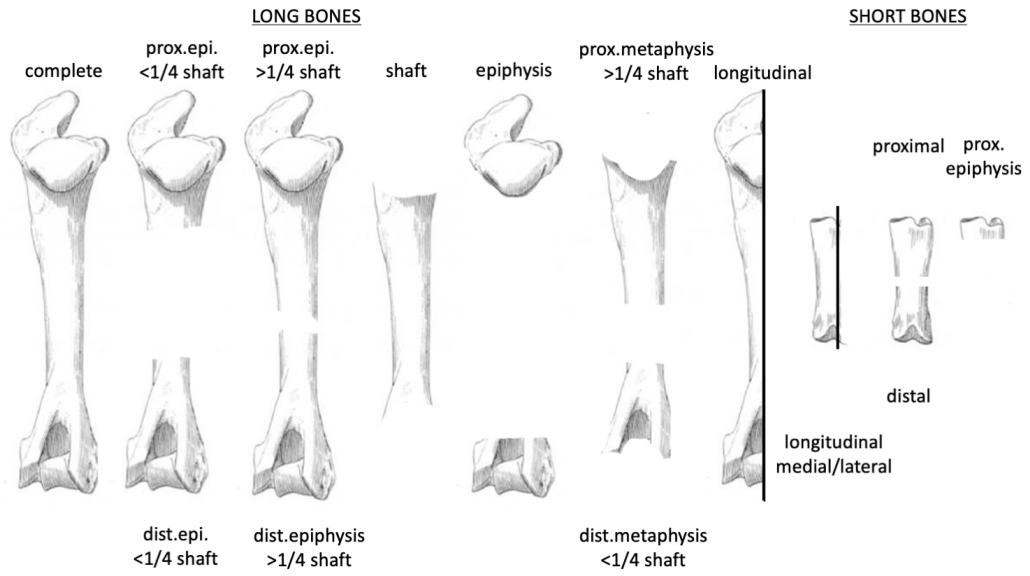


Figure 3.21: Resulting variation in fragment size and form after bone fracturing. Illustrations of bones modified from SCHMID 1972.

Type and angle of fracturing (fresh-green vs. old-dry) was determined to establish the origin of fracturing from overburden sediment pressures or biological agents. Fracture type analyses were not performed on teeth or obviously on complete bones. For that reason, only bone 'fragments' are included in NISP and %NISP values presented in the fracture pattern tables in the result section.

The criteria stated in the next table (Table 3.11) describe the fracture pattern considered during the study which were introduced into the database:

Table 3.11: Breakage pattern description.

Criteria	Observation
Fracture angle:	'oblique (acute-angled)' 'right' 'oblique and right (variable angles)'
Fracture outline:	'transverse' 'curved-V-shaped' 'intermediate'
Fracture edge:	'smooth' 'jagged'
Fracture type:	'flaking' 'irregular' 'longitudinal' 'saw-toothed' 'smoothed perpendicular' 'spiral' 'stepped' 'V-shaped'
Breakage profile:	'green (fresh) fracture' 'dry fracture' 'recent fracture' 'undetermined' 'green and dry fracture' 'old fracture with two phases'

The breakage pattern is measured considering angle, outline, edge, type and breakage profile (Figure 3.22), according to established fracture pattern descriptions (HAYNES 1983a; VILLA & MAHIEU 1991).

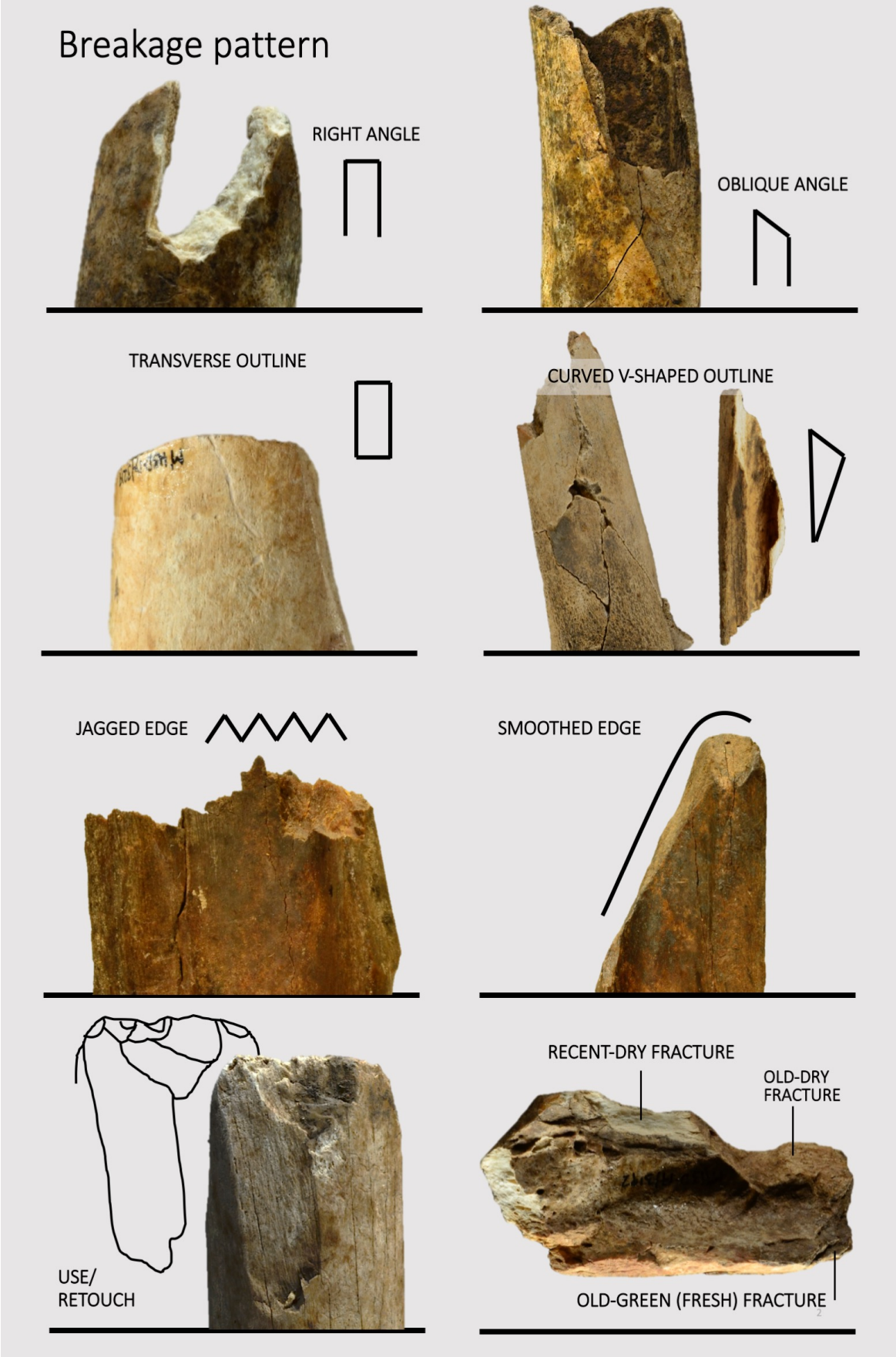


Figure 3.22: Variation in breakage pattern on bones.

3.4.2 Anthropogenic modifications

The following methods were used to analyze the nature of anthropogenic modifications on faunal materials at El Mirón. Criteria for differentiating human made modifications were defined according to the observations made on El Mirón faunal material. The determination of the type of anthropogenic modifications is made using various descriptive criteria that can be summarized in the following four groups: cut marks, impact marks, objects artificially modified into osseous industry and burning traces; each one can be recognized as direct anthropogenic modifications. Green fractures in general, which result from bone cracking activities, could be classified as indirect anthropogenic modifications when at first it was out ruled that carnivores were not the main accumulation agents. Thermo-alterations are commonly also human-made. It is important to note that different kind of marks can appear on the same specimen.

Cut marks (CM) on bones can result from highly specific types of human activity, which can vary among actions that involve skinning, defleshing, joint disarticulation, tendon or periosteal removal and artificial modifications of the element (BINFORD 1981: pp. 96–142; POTTS & SHIPMAN 1981; SHIPMAN & ROSE 1983; PÉREZ-RIPOLL 1992; ANDREWS & FERNÁNDEZ-JALVO 2012; EGELAND ET AL. 2014; FERNANDEZ-JALVO & ANDREWS 2016; SOULIER & COSTAMAGNO 2017). Typically, they are characterized by V-shaped groove profiles, internal striations, feathering and shoulder-effect (POTTS & SHIPMAN 1981; BLUMENSCHINE ET AL. 1996; LYMAN 2005; DOMÍNGUEZ-RODRIGO ET AL. 2009) (see examples in Figure 3.23).



Figure 3.23: Varied patterns of cut marks on bones represent different activities.

For the present work, a detailed description of the observed cut marks was applied, according to their structure, location, orientation and morphology. Cut marks were categorized as follows:

- Structure: 'simple-short (<1cm)', 'simple-long (>1cm)', 'simple-x-long (>2cm)', 'parallel-short (<1cm)', 'parallel-long (>1cm)', 'parallel-x-long (>2cm)', 'irregular-short (<1cm)', 'irregular-long (>1cm)', or 'irregular-x-long (>2cm)'
- Position:
  - any bone: 'close to *Facies articularis'*, 'on breakage surface', 'medial', 'interior', 'close to muscle insertion'
  - for mandible: 'close to *Facies articularis'*, 'on diastema'
  - for vertebrae: 'proximal to *Proc. spinosus'*, 'on the corpus', 'medial-posterior-distal'
  - for ribs: 'inside', 'outside'
  - for long bones: 'close to muscle insertion', 'on the shaft', 'between condyles'
- Profile: 'weak-spiky', 'weak-edgeless', 'strong-spiky', or 'strong-edgeless'
- Orientations: 'parallel to the shaft-longitudinal'=LO, 'right angle to the shaft'=RI, 'oblique'=OB, 'parallel to articulating-face'=FA, 'various', 'parallel to body axis', 'slightly oblique to the surface', 'semi-circle', or 'crossed'. See Figure 3.24.

The frequency of cut marks was obtained by counting and summing up presence of cut marks, in detail for red deer and Spanish ibex, which are by far the most common species in the faunal assemblage.

As well for human behavior inferences, the orientation of the cut marks was investigated. Cut mark orientations are considered to encode information on butchering techniques (STEWART 2010) as well as on social behavior (MILO 1994: p. 13). Previous studies indicate that the cut mark patterns vary according to the preservation state of the carcass (BINFORD 1984: p. 110), position of the muscles and ligaments especially on the long bones (LYMAN 1987), the degree of food-sharing (STINER ET AL. 2009), whether many or single butchers were involved (EGELAND ET AL. 2014).

Common cut mark orientations and directions are 'parallel and close to the *Facies articularis*' (FA), 'right angle to the shaft' (RI), 'longitudinal' (LO) and 'oblique' (OB) (Figure 3.24). They are often caused during skinning, dismembering and filleting activities and here they are used to infer specific butchering activities (NILSSEN 2000). More occasionally occurring cut mark orientations include 'semi-circular', 'crossed' and 'various marks'; the first two are often seen in intentional decorations (engravings) or functional modifications of bone or antler objects. FA cut marks are associated with disarticulating and dismembering practices during the butchering process. Given that the ligaments, tendons and stronger muscles are closely attached to the joints for stabilization, cuts need to be made more forcefully to separate these supporting structures (LYMAN 1987). RI cut marks may originate from disarticulating or skinning activities. Filleting activities can produce LO cut marks (NOE-NYGAARD 1989), as sometimes skinning activities do (as on metapodials). OB cut marks commonly appear during filleting or skinning activities (SOULIER & COSTAMAGNO 2017).

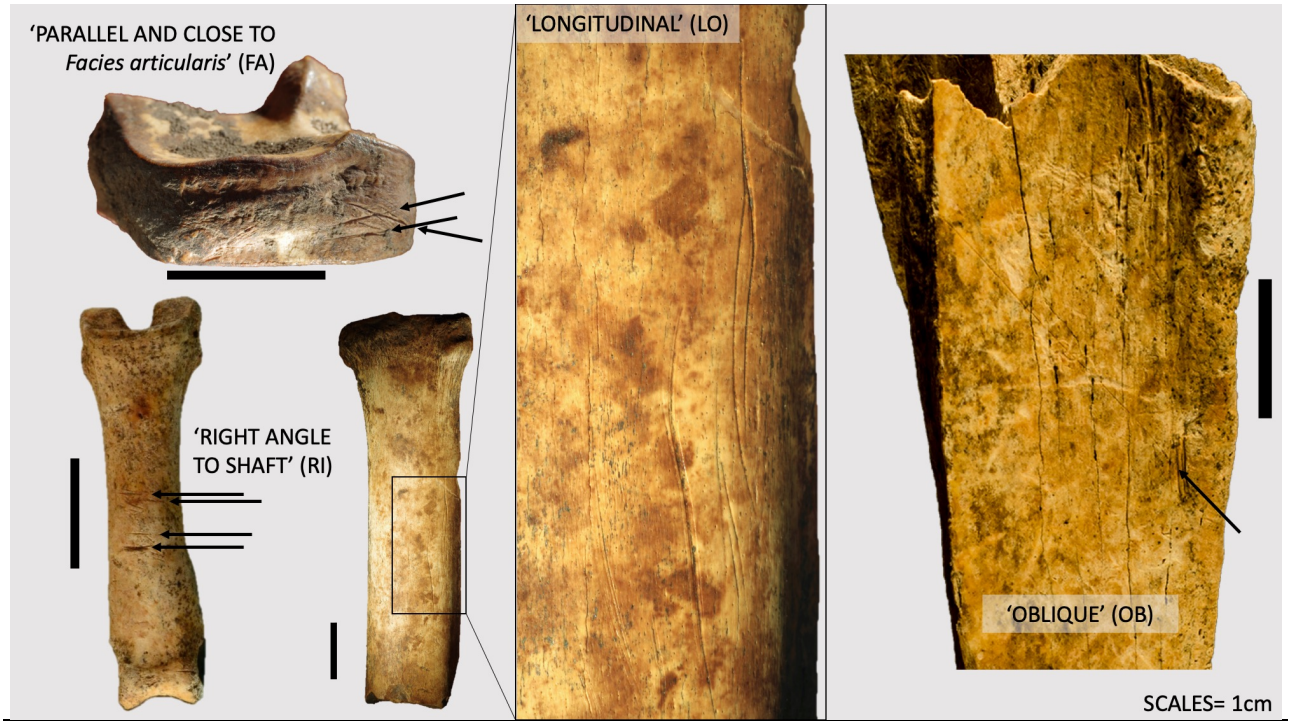


Figure 3.24: Orientations of cut marks related to butchering activities.

Additionally, cut marks patterns similar to published data were registered as such. Cut marks were, therefore, when possible categorized according to the inventory of described skinning and butchering marks after Binford (1981, Table 4.04).

The final database field related to cut marks is a more interpretational entry made to determine the implied activity of either 'evisceration', 'disarticulation', 'dismembering', 'marrow extraction', 'bone grease extraction', 'periosteum removal', 'skinning', 'hide removal', 'defleshing', 'filleting', 'meat extraction', or 'sinew or tendon removal'.

Table 3.12: Human behavioral implications associated with simple ranked distribution of cut marks along animal body parts.

	skinning (after NILSSEN 2000; CAMPANA & CRABTREE 2019)	filleting: small bovid (after NILSSEN 2000)		filleting & disarticulation: small bovid (after NILSSEN 2000)		raw material (hypothetical)
HEAD	10	0	0	0	0	0
AXIAL	0	10	0	20	0	0
UP FRONT	20	40	16,3	20	16	10
UP HIND	0	10	1,65	10	4	0
LOW FRONT	0	30	7,95	30	38,5	20
LOW HIND	20	20	3,5	40	49	20
META	40	0	0	0	0	30
FEET	30	0	0	0	0	0

A dataset of ranked cut mark distribution was created for interpreting patterns observed in the archaeological materials. Ethnographical (BINFORD 1981), experimental (NILSSEN 2000; CAMPANA & CRABTREE 2019), as well as a theoretical pattern were the bases here (see Table 3.12). The hypothetical rank

distribution of cut marks on bones used as raw material reflect that metapodial are best suitable for such exploitation, followed by radius/ulna (lower front), tibia (lower hind) and scapula (upper front).

A corresponded analysis of these activities reflecting skinning, filleting, filleting and disarticulation, and bone used as raw material marks were first performed to set up the data for the method Figure 3.25. This exploration show that these different human behaviors can be distinguished based on three axes: Axis 1 (explain 75.4% of variation) distinct 'skinning' and 'raw material' result in cut marks distinct from those from filleting and disarticulation, Axis 2 (explaining 17.3% of variation) separates 'raw material' working from the other activities and Axis 3 (explaining 7.3% of variation) differentiates between 'filleting' and 'filleting & disarticulation' activities. Such cut mark frequency by body part is used for interpreting cut marks pattern in the archaeological materials.

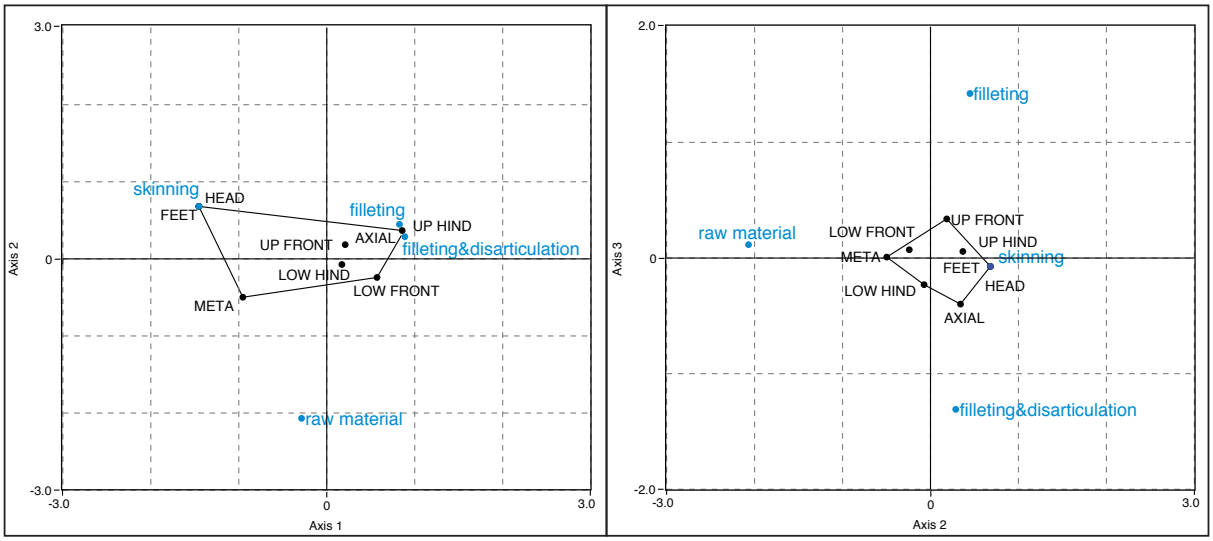


Figure 3.25: Correspondence analysis of cut marks patterns from 'skinning', 'filleting & disarticulation', only 'filleting' and bones used as 'raw material'.

Osseous industry, among the faunal remains, was recorded in the database and distinguished by the following criteria when possible:

- Osseous artifact: describe the general category such are bone or antler blank, tool, production failure or tooth pendant. Common groups are: bone flake, used bone, worked antler, point fragment, etc.
- Artifact type: describe the more specific function of the artifact as hammer, retoucher, wedge, point, *sagaie*, needle, spatula, used bone, art object, ornament, etc.

Ornamental objects were listed by skeletal element and described in detail. Similarities and differences to comparable objects in the region and beyond are discussed. With this step of analysis, a tendency in the exploitation of faunal resources towards raw material preferences for tools is used to explore depth of planning and status of use or production that let one infer site function.

Other activities that leave complex cut marks patterns behind are involved when antler was used as raw material and, as such, human activity interpretations are possible. Antler piece analyses were subdivided into the distribution of antler artifact types and their density among the studied levels, taking into account that it is a find category of exclusively raw material character compared with bone. Human modifications marks were used to distinguish antler tool production steps (see also Figure 3.26). A detailed description of these

elements found in the studied material were used to decipher human actions, however, they do not represent the whole osseous industry from El Mirón.

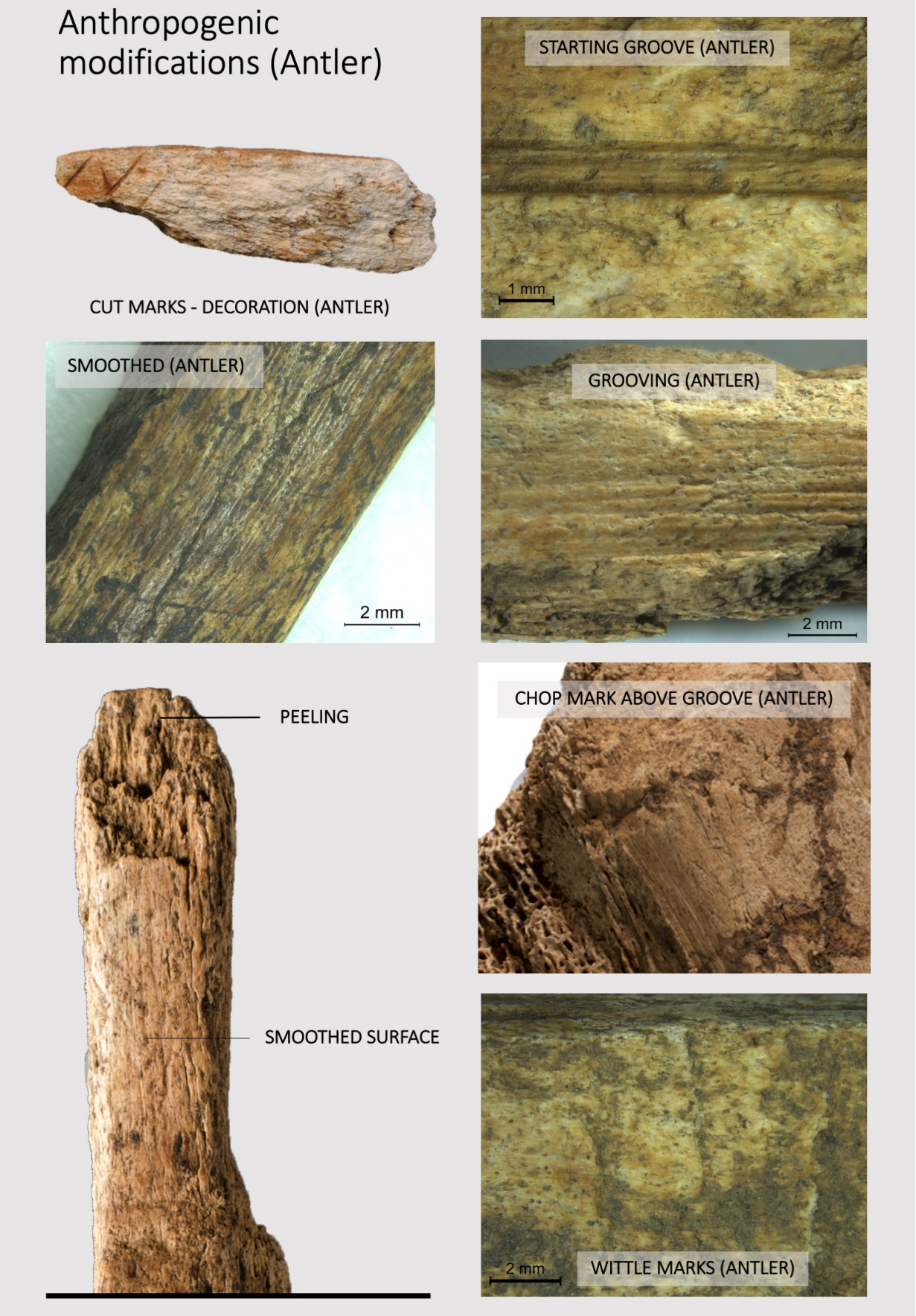


Figure 3.26: Antlers with human modification marks.

Percussion marks (produced usually during bone cavity opening activity) are a direct evidence of bone cracking activities as described elsewhere (BINFORD 1981; PÉREZ-RIPOLL 1992; CAPALDO & BLUMENSCHINE 1994; BLUMENSCHINE 1995; PICKERING & EGELAND 2006; GALÁN ET AL. 2009). Typical impact marks are characterized through conchoidal breakage and "when a hammer stone was used punctures are irregular and imprint the shape of the stone with which the bone was struck to break it and extract the marrow" (FERNANDEZ-JALVO & ANDREWS 2016: Fig. A331). Impact marks or percussion notches are semicircular- to arcuate- shaped scars on bone fractures with negatives, often on medullary surfaces (CAPALDO & BLUMENSCHINE 1994; PICKERING & EGELAND 2006).

Those anthopogenic marks were recorded in the category of impact marks using the following characteristics:

- Impact position: 'proximal-anterior'; 'proximal-posterior'; 'distal-anterior'; 'distal-posterior'; 'mid-anterior'; 'mid-posterior'; 'proximal-lateral'; 'proximal-medial'; 'distal-lateral'; 'distal-medial'; 'mid-lateral'; 'mid-distal'; 'mid-medial'; 'from inside'; 'edge retouch'; 'striking platform'; 'negatives'
- Impact point: 'direct-hammer'; 'indirect-anvil'; 'hammer+anvil'
- Impact notches: the amount of impact blows visible is recorded in numbers according to the negatives observed.

Bone flakes are counted as such only when they had a clear identifiable striking platform/butt with adjunct bulb (INIZAN ET AL. 1999).

Characteristics of typical impact marks on bones produced during within-bone nutrient exploitation and other impact marks are illustrated next (Figure 3.27).

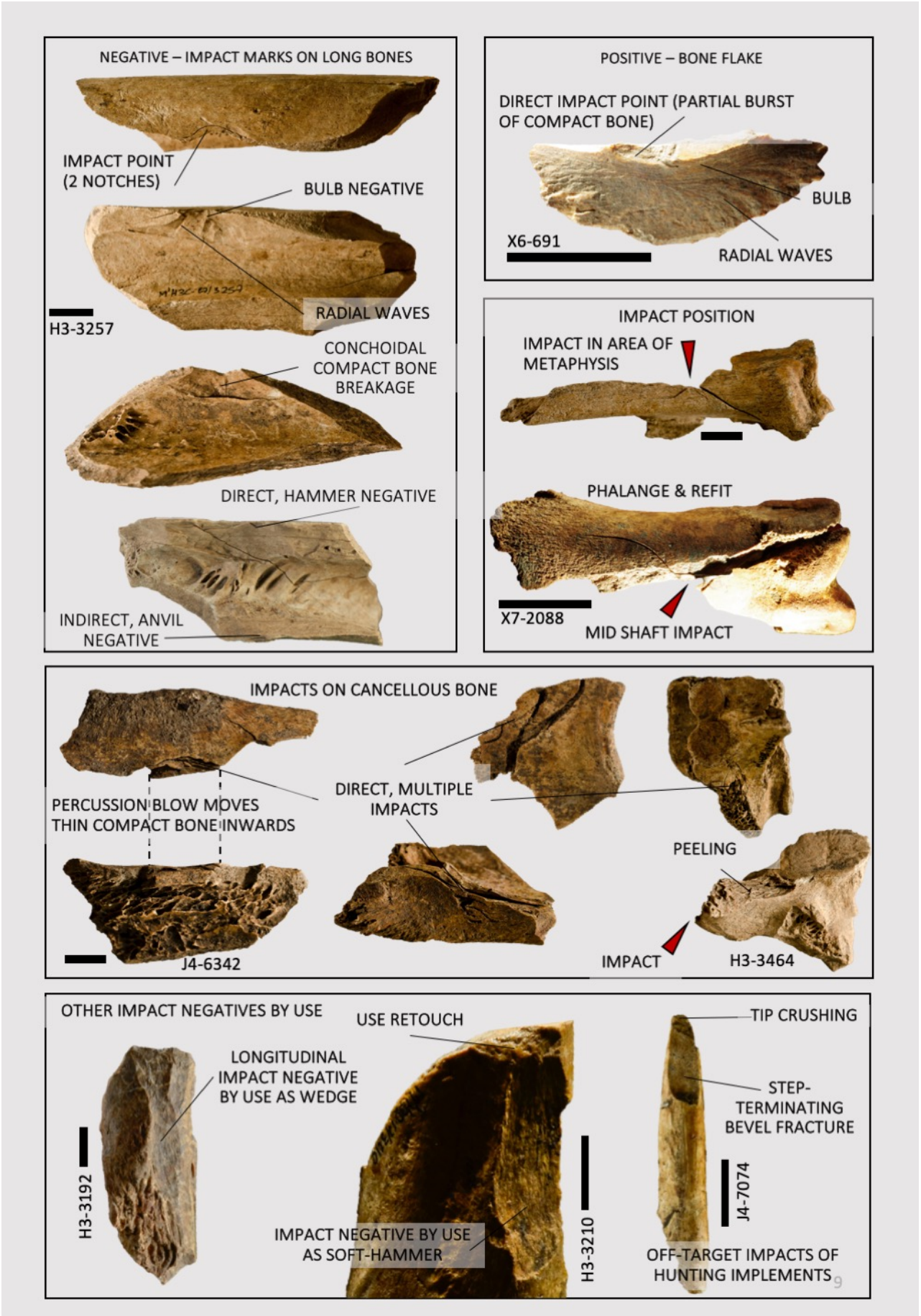


Figure 3.27: Percussion bone impacts and flakes.

Direct-hammer impact points and bone flakes represents directly the action of a human activity. Impacts were counted by levels and species in reference to working tasks carried out for that processing activity. The implied activities observed, such are bone marrow extraction or grease rendering techniques, can be compared to similar activities in other Paleolithic sites (STINER 2002a) or ethnographic comparison (BINFORD 1981: pp. 148–177). The mass of bone marrow fat is located in the cavities of appendicular long bones and the mandible, while bone grease can be found in the spongy, cancellous part of the axial skeleton and the appendicular epiphyses (OUTRAM 2001). Bones are the most reliable source of animal fat as it persists within bone tissue even when the animal has died of starvation (BALLARD 1995). Thus, the deliberate fragmentation of bones in Paleolithic sites might indicate the extraction of nourishing bone fats (bone marrow and grease) (DAVIS 1995: p. 150; BRINK 1997; CHURCH & LYMAN 2003; JANZEN ET AL. 2014), which in consequence might be linked to certain levels of subsistence stress (BINFORD 1978; BUCKLAND ET AL. 1996; OUTRAM 1998, 1999, 2002).

While being aware of equifinality, attrition and human modifications on bones resulting from bone grease-rendering activities required to observe varied parameters to justify the latter interpretation (MUNRO & BAR-OZ 2005). For distinguishing whether bone grease rendering was applied to the faunal assemblage under study, following parameters can be considered: frequency of bone cracking activities, fragment sizes and bivariate statistical tests.

To identify density of bone cracking activities, an index was calculated that represent the number of notches per impacted bone, here referred to as BONE CRACKING EFFICIENCY INDEX = BCE Index. The total number of impact notches is the sum from the number of direct impacts per bone item (fragment). The total number of impacted bones is the sum of all bones that carry impact marks. The BCE, thus, represent how efficiently was explored within-bone nutrients. An BCE index of 1 indicate that one impact was enough to break one bone entirely, while a higher index suggests that more impacts were needed for the same activity.

$$\text{BCE Index} = \frac{\text{total number of impact notches}}{\text{total number of impacted bones}}$$

Additionally, the amount of bone flakes within the studied levels was recorded. Given that each bone flake is the result of one action, here, percussion on bone, those are a stand-alone category considering direct anthropogenic activities. A Density Index was calculated by dividing the number of bone flakes with the multiplication of the excavated square meter and the thickness of the excavated level.

$$\text{Bone Flake Density Index} = \frac{\text{Number}_{\text{bone flakes}}}{\text{m}^2{}_{\text{excavated}} \times \text{Thickness (cm)}_{\text{layer excavated}}}$$

The FSI (fragment size index) of long bone shafts and the spongy bones preserved were compared among levels. The degree of bone fragmentation might imply how bone grease and marrow were exploited, which is stored within the spongy, cancellous part of the axial skeleton and the appendicular epiphyses and long bone-shafts (OUTRAM 2001), respectively. This means, for example, unexpected high portions of small fragments could indicate intentional fracturing as explained later.

From this part of the study onwards, analytical methods will switch from analyzing direct anthropogenic modifications on bones to the evaluation of indirect modifications.

Thermo-alterations on faunal remains are considered to represent (at least) indirect human activities and evidence among the faunal remains were categorized according to location and burning degree. Different

burning stages can be referred to increasing burning temperatures (STINER ET AL. 1995). Within the faunal database thermos-alterations were described accordingly:

- Location: 'proximal-epiphyseal, partial', 'distal-epiphyseal, partial', 'complete', 'proximal-epiphyseal-shaft, partial', 'distal-epiphyseal-shaft, partial', 'longitudinal', 'red-dotted', 'partial', 'only outside'
- Burning degree: 'reddish (roasted)', 'brown to grey', 'black-partial (superficial)', 'black-and white-partial', 'black complete-carbonized', 'blue (inside sometimes black)', 'white-calcined- chalky- soft'

In consequence of thermo-alterations, typical burning sequences on bones include reddish to brown to grey to black to white in coloration, which in this order also reflect the burning degree. Within black-carbonized bones the collagen is burned and in white-calcined the continued heating has oxidized the carbon (BRAIN 1981: p. 55; STINER ET AL. 1995; CAIN 2005: p. 875). Burning stages for this study are recorded in color stages, which are comparable to the observations made by Shipman (1984: p. 312), summarized in the table below (Table 3.13). Here, beginning by a partial reddish coloration of the bone, where the breakage follows a stepped fracture due to collagen destruction presumably through local heating influence. Given these criteria, the implied activity could be either roasting or combustion as fuel (COSTAMAGNO ET AL. 2005; MORIN 2010; FERNANDEZ-JALVO & ANDREWS 2016: p. 164), while cooking activities are still difficult to determine macroscopically (ALHAIQUE 1997; KOON ET AL. 2010; SOLARI ET AL. 2013). Recent studies also have shown that the bone reaction process to heat-treatment is not only temperature-based, but is also time- dependent and differing assignments as to which each coloration represents do exist (GREINER ET AL. 2019). Superficial heat treatment of bones, such are roasting action, results in reddish bone colorations. During roasting or baking activities "the bone is insulated (by the meat) from the direct heat source such that temperatures experienced by the bone are much reduced" (ROBERTS ET AL. 2002: p. 486), and they are exposed for relatively short times and comparable low temperatures (~200°C). Prolonged heat treatment favors collagen loss making possible that affected bones react differently during diagenesis, an effect that remains difficult to distinguish over archaeological timescales (ROBERTS ET AL. 2002; COLLINS ET AL. 2002).

Table 3.13: Color modifications produced during burning (after Shipman 1984).

Burning stages	Temperature	Dominant color
Stage I	20 -<285°C	neutral white, pale yellow, yellow
Stage II	285 -<525°C	reddish brown, very dark grey-brown, neutral dark grey, reddish- yellow
Stage III	525 -<645°C	neutral black, with medium blue and some reddish-yellow appearing
Stage IV	645 -<940°C	neutral white predominates, with some light blue-grey and light grey
Stage V	940 +°C	neutral white predominates, with some medium grey and reddish-yellow

The black coloration stage needed to be distinguished from manganese coating processes previously observed among the El Mirón faunal remains (MARÍN-ARROYO 2010). Typical surface modifications of incineration, like splitting, warping, fracturing, exfoliations, were used to differentiate these two groups of dark- colored bones (SHIPMAN ET AL. 1984).

The amount of burnt remains by body parts is compared among the levels, based on the density index of burnt remains.

$$\text{Density Index} = \frac{\text{Number}_{\text{burnt remains}}}{\text{m}^2{}_{\text{excavated}} \times \text{Thickness (cm)}_{\text{layer excavated}}}$$

Trampling marks were considered during analyses. Trampling marks are inorganic processes, describing when the primary agent (human or animal) moves stones or bones against bone by trampling (OLSEN & SHIPMAN 1988). Characteristics of trampling marks are still under discussion, but some features of already short-time, low-intensity trampled bones include: shallow open groove section shape with a wide base, irregular and flat cross section, variability in groove size, multiple marks with identical directions, randomly placed (located without respect to muscle insertions), sinuous mark trajectory, and abundant discontinuous-curvy micro-striations (BEHRENSMEYER ET AL. 1986; DOMÍNGUEZ-RODRIGO ET AL. 2009; ANDREWS & FERNÁNDEZ-JALVO 2012; FERNANDEZ-JALVO & ANDREWS 2016: p. 53). The effect of long-term trampling provides very fine, shallow striations intersecting on various angles, cut marks lose their internal micro-striations and shoulders. Intensive trampling also favors bone pitting and irregular, retouched like flaking along the bone edges upon a polish of edges can be developed (OLSEN & SHIPMAN 1988). The frequency of 'trampled bones' might imply the high intensity of human activities among specific affected areas of the site.



Figure 3.28: Trampling marks (Level 15, H4C-53/1162).

Finally, the different taphonomic and archaeozoological analyses are combined to reconstruct the *chaîne opératoire* of osseous remains with which will be provided a model of human behavior based on actions involved in food acquisition.

The *chaîne opératoire* concept (BAR-YOSEF ET AL. 2009) is used in this context to record the consequent steps of human actions along the continuum from animal acquisition to waste abandonment as readable from faunal remains. Provisioning of shed antler as raw materials resulted presumably from collection during the pursuit of game and other activities on the landscape Different categories of animal processing are reviewed, antler and bone industry production and the use of organic remains as tools as they can represent the leftovers of an occasionally long *chaîne opératoire* of animal carcass exploitation, which will be elucidated with the obtained information and therefore used to reconstruct the activities involved in these processes.

Prey animals were exploited presumably primarily for food acquisition, but their secondary products leave us derivate cultural and behavioral manifestations. Manufacturing tasks can be deduced by details on the osseous remains. The consideration of the patterns of abandonment of objects ties in with this. All of these faunal items represent a class of ultimate end-products along the potentially long *chaîne opératoire* of animal carcass exploitation and then should be considered if the whole process is to be reconstructed. In this sense, I consider which body parts from which animals were brought to the site and how intensively were skeletal parts exploited in terms of nutrition and raw material.

3.4.3 Skeletal profiles and Site function

Identification and recording of skeletal elements are given in Minimum Number of Elements (MNE) counts. MNE calculation involves various assumptions and is taking into account the skeletal element, side, anatomical landmarks and ontological development (according to fusion stage, milk tooth presence, etc.). Results of MNE calculations in each species and level are explained in detail in Appendix C. Landmarks or anatomical 'diagnostic zones' (WATSON 1979) used to estimate the number of skeletal elements represented are listed below (Table 3.14). Expected numbers of each skeletal element within the animal body are also shown in this table.

Table 3.14. List of body parts and corresponding skeletal units defined for this study.

Body Part	Bone code	Skeletal element	Number
HORN	ANT/ HORN	Regarding *Pecora*: antler or horn	0 or 2
HEAD	CRA	*Neurocranium* with occipital, temporal, sphenoidal bone that lodges the brain	2
	VISCRA/MAX	*Viscerocranium* or facial bones (orbits, oral cavity and nasal one), maxillary bone	2
	UP T	Upper teeth, part of the maxillary unit	2*
	MAN	Mandible	2
	LOW T	Lower teeth, part of the mandibular unit	2*
	HYO	Hyoid bone	2
AXIAL	CERV	Cervical vertebrae	7
	THOR	Thoracic vertebrae (number: EQ=18, Bos=13, CEEL=13, Ovis =13, Lepus=14, Homo=12)	13-18
	COST	*Costa*, rib	26
	LUMB	Lumbar vertebrae (number: EQ=6, Bos=6, CEEL=6, Ovis=7, Lepus=5, Homo=5)	5-7
	SACR	Sacrum bone (number: EQ=5, Bos=5, CEEL=4, Ovis=4, Lepus=1, Homo=4)	4-5
	CAUD	Caudal vertebrae (number: EQ=13-20, Bos=19, CEEL=11, Ovis=7, Lepus=13-15, Homo=4)	4-20
	VERTE	Indeterminate vertebrae	/
UPPER FRONT	SCA	Scapula, shoulder	2
	HU	Humerus,	2
LOWER FRONT	RA	Radius	2
	UL	Ulna	2
	ULRA	Ulna and Radius	2
	CARP	Carpal unit includes carpale 2&3, carpale 4, carpale pisiforme, carpale ulnare, carpale intermedium and carpale radiale	12
UPPER HIND	PEL	Pelvis bone with Illium, Ischium and Pubic	2
	FE	Femur	2
	PAT	Patella	2
LOWER HIND	TI	Tibia	2
	TAL	Talus	2
	CAL	Calcaneus	2
	TAR	Tarsal unit: *Os tarsale primum*/ first tarsal bone/ small cuneiforme,	6

		Os tarsale secundum et tertium/ second and third tarsal bone/ big cuneiforme, *Os centroquartale*/ central tarsal bone/ scapho-cuboide	
METAPODIAL	MC	Metacarpal bone (Ungulates= 2, Lepus/ Homo= 5)	2 or 5
	MT	Metatarsal bone (Ungulates= 2, Lepus/ Homo= 5)	2 or 5
	META	Metapodial bone	/
FEET	PHI	Proximal Phalange A= anterior, P= posterior (Ungulates= 8, Lepus/ Homo= 20)	8 or 20
	PHII	Intermediate Phalange A= anterior, P= posterior (Ungulates= 8, Lepus/ Homo= 20)	8 or 20
	PHIII	Distal Phalange A= anterior, P= posterior (Ungulates= 8, Lepus/ Homo= 20)	8 or 20
	ATRO	Atrophic phalange	24
	SESAM	Sesamoid bone (2x proximal and 1x distal)	3 per feet
Long bone indeterminate	HU-FE	Humerus or Femur bone	/
	LoBo	Long Bone fragment	/

The maximum MNE - mxMNE, according to Lyman (1994), represents the number of anatomical elements identified, based on overlapping NISP on specific anatomical locations, referred to as landmarks. An overlap of landmarks in the same skeletal element infers that each specimen represents a single bone. Side attribution adds an additional variable, where the same landmark can belong to the right or left body part. Fusion stage variations, which infer different ages, also represent different animals. Also, tooth eruption patterns need to be taken into account when using teeth for MNE calculations, because milk teeth (dP4) are not contemporarlly present with M3s. While MNE quantification takes into account skeletal characteristics of each taxon, it is considered to give a better overview of the skeletal representation than NISP, which can be biased by fragmentation degree.

Refits and rearticulation among bone elements have an additional benefit. The rearticulation and refitting of faunal remains can give information on the depositional history of the assemblage (ENLOE 1995). Identified refits and re-articulation items were inter-linked in the faunal database. These are spatially interesting in the reconstruction and correlation of activities among faunal remains, e.g. broken bones, bone flakes and bones with negatives of impacts (CAHEN 1987; ENLOE 2010; BLASCO ET AL. 2016; GEILING ET AL. 2016). Human activities, such as deliberate item movement/carrying, walking, trampling, cleaning, digging, destruction, etc., can disperse faunal remains within these living areas (MORIN ET AL. 2005; JÖRIS ET AL. 2011; MODOLO & ROSELL 2016). These all enable us to develop interpretations of site function, while archeozoological skeletal profile analysis also contributes a major part for several reasons.

For the present analysis, the faunal database was programmed with queries that automatically sum up NISP ordered by previously defined anatomical landmarks for each species (KLEIN & CRUZ-URIBE 1984). Those cross-tab queries have rows of landmarks sorted for each skeletal element and columns of side and age estimations. The way, correctness and replicability of calculation procedure is important as MNE measurements are used for calculations of MNI and further economic and taphonomic interpretations (MAREAN & KIM 1998; MAREAN ET AL. 2001; STINER 2002b, 2004; WOLVERTON 2002; PICKERING ET AL. 2003; CLEGHORN & MAREAN 2004). For this reason, in the present study, an easy replicable and efficient way for mxMNE estimation was realized; the explicit procedure calculating mxMNE includes following steps:

- During the identification process, specimen characteristics (i.e., element, part, landmark, age, sex, …) were registered in the faunal database.
- Each identified specimen was sorted and stored into separate labeled bags by species and skeletal elements.
- After finishing one faunal assemblage (level), a database query was run, designed to obtain the three highest NISP that contain the same landmark registered for each element and species. This query includes also information about individual age and sex (demographic class i.e., infantile, juvenile, or adult).
- Those elements from identical demographic classes with the same landmarks were checked for refits benefitting from previous sorting of anatomical parts. Finally, MNE were summed up from estimations by each demographic group to obtain mxMNE.

When possible, the following landmarks were distinguished by anatomical part (Table 3.15); Latin names refer to definitions of anatomy in domesticated animals (NICKEL ET AL. 1992). Appendix I shows the anatomical location of these landmarks on ibex and red deer skeletal elements.

Table 3.15: Anatomical landmarks used to identify and distinguish faunal specimens.

All
complete bone
Facies articularis
Facies articularis distalis
Foramen nutritium
Foramen nutritium interior
Lamina epiphysis
Cranium
Sutura
Tuber faciale
Alveolar exterior
Alveolar interior
Foramen infraorbitale
Foramen palatinum majus
Condylus occipitales
Bulla tympatica
Pars mastoidea
Pars petrosa
Proc. zygomaticus
Mandible
Diastema
Foramen mandibulae
Foramen mentale
Incisura mandibulae
Teeth
Corona

Scapula
Angulus caudalis
Angulus craniales
Cavitas glenoidalis
Collum scapulae
Fossa subscapularis
Spina scapulae
Pelvis
Acetabulum
Facies auricularis
Fossa medialis femoris
Linea glutaea
Spina ischiadica
Tabula ossis ischii
Humerus
Tuberculum supraglenoidale
Caput humeri
Collum humeri
Condylus humeri
Crista epicondyli lateral
Crista humeri
Crista tuberculi minoris
Epicondylus lateralis
Epicondylus medialis
Fac. Musculi infraspinati
Facies musculi infraspinati

Distal cusp
Mesial cusp
Root

Vertbrae
Tuber spinae

Carpals
C.intermedium
C.pisiforme
C.quartum
C.radiale
C.secundum et tertium
C.ulnare

Calcaneus
Proc. coracoideus
Tuber calcanei

Talus
Trochlea tali

Metapodial
Both Trochleas
Canal distalis
Canal proximalis
III/ medial- half fragment
IV/ lateral- half fragment
Sulcus longitudinalis dorsalis

Phalange
Planum cutaneum
Tuberositas phalangis distalis

long bone
Caput
Spongiosa interior
Trabeculae
Facies articularis lateralis
Facies articularis medialis

Fossa olecrani
Fossa radialis
Sulcus intertubercularis
Tuberculum majus
Tuberculum minus
Tuberositas deltoidea
Tuberositas teres major

Ulna/Radius
Facies interosseum RA/UL
Spatium interosseum antibrachii
Sulcus radio ulnare interosseum
Sulcus tendinum medial
Tuberositas radii

Femur
Condylus laterlis
Condylus medialis
Facies poplitea (disto-kaudal)
Fossa supracondylaris
Fossa suprapatellaris
Fossa trochanterica
Fovea capitis
Linea/Facies aspera
Trochanter major
Trochanter minor
Trochanter tertius
Trochlea ossis femoris

Tibia
Cochlea tibiae
Eminentia intercondylaris
Linea muscularis medial post.
Malleolus lateral
Malleolus medial
Margo cranialis
Sulcus extensorius
Tuberculum intercondylare
Tuberositas tibiae

The formation of the faunal assemblage can be used to infer human behavior via the selective transport of prey animal body parts (WHITE 1953; BRAIN 1981; MORIN & READY 2013). The degree of anatomical disorder is considered in direct relationship to which degree an animal had been used or consumed as a result of human activities (BINFORD 1978, 1981). On a kill-site, large prey animals are butchered in the field, separated into several parts and only a selection is carried to the consumer location (referred to as 'Schlepp effect': dominance of limb bones and low frequencies of axial elements indicate camp sites (BUNN 1986; BUNN ET AL.

1988; MAREAN ET AL. 1992). Information about the selective transport of prey body parts (WHITE 1953; BRAIN 1981; O'CONNELL ET AL. 1988; MAREAN ET AL. 1992; MORIN & READY 2013), the ways an animal had been used or consumed (BINFORD 1978, 1981), can be used to study human behavior.

According to the different food-preparation techniques (usage of meat, marrow, grease, etc.) and the act of eating itself, the skeletal elements are distributed further, thus the greatest disorganization of the anatomical parts occurs at the consumption site. From animal processing activities derive interpretations of site function (SCHOVILLE & OTÁROLA-CASTILLO 2014; MARÍN-ARROYO & OCIO 2017) and degree of energy efficiency in resource management among hunter-gatherer groups (SPETH & DAVIS 1976; METCALFE & JONES 1988; MADRIGAL & HOLT 2002; MAREAN & CLEGHORN 2003; LUPO 2006). Together with cut marks patterns, these activities reflect prey animal processing strategies.

Utility models derived from skeletal abundancies are used for the interpretation of site function (SCHOVILLE & OTÁROLA-CASTILLO 2014). Several factors need to be taken into account. An important component in evaluating subsistence strategies is not only considering yield/benefit of these activities, but also its costs (METCALFE & JONES 1988; LUPO 2006). The high or low cost of defleshing different skeletal parts affected also transport decision, while the presence of low survival/high cost processing elements is generally observed as being lower in archaeological materials (MADRIGAL & HOLT 2002; MAREAN & CLEGHORN 2003). Different aspects need to be included or excluded when considering past human decision- making based on skeletal profiles. Limiting factors are, for example, the size of the prey animal (O'CONNELL ET AL. 1988), density- mediated destruction of bones (LYMAN 1985; GRAYSON 1989) or the distance of transport ('Schlepp effect'). Other factors that influence transport decision making might be the seasonal variation of nutritional values (SPETH & DAVIS 1976), such are seasonal abundancy of species or bone fat content before and after the winter. The species size differences might be ruled out when only comparing skeletal profiles among the same species. The distance of transport obviously depends on the population density of the prey species and topography; although, it can be inferred by a topographical factor (CLARK 1952; CLARKE 1977; BAILEY & DAVIDSON 1983).

The Minimum Anatomical Units (MAU) is an index calculated to illustrate the amount of different body parts represented from each prey animal. MAU is calculated by dividing MNE values for each element by their total number in a complete skeleton. MAU values are standardized by the use of percentages for (inter-level) comparisons (BINFORD 1984; REITZ & WING 2008); normed MAU values were produced by dividing total MAUs by the highest MAU and multiplied by 100 for each assemblage and taxon of interest (BINFORD 1978; LYMAN 1994), where a 100% representation of all body parts would infer the presence of complete animal bodies (%MAU).

To simplify a visual comparison based on %MAU, a method is presented where the body part values are compared due to their portions within the body, while is assumed that in complete animals each body part should be presented equally. The visualization is based on that assumption. The body is subdivided into eight regions: horn, head, axial, upper front limb, lower front limb, upper hind limb, lower hind limb, metapodial and feet; here, each contributing 12,5% to the Body Part Representation Index (BPRI). A higher %BPRI infer, therewith, a dominance and a lower value an underrepresentation of this body part in comparison to the other ones. Equal %BPRI values infer complete bodies and were set up as the standard assumption for this kind of analysis.

When variations in body parts profiles are identified using %MAU and %BPRI, carefully need to be considered further human behavior interpretations. While the %MAU measure can illustrate either selective carcasses transport to the occupation site or partial destruction through taphonomic alterations, its only interpretation has been taken with caution due to the problem of equifinality (LYMAN 1994; ROGERS 2000b; WOLVERTON 2002). More exactly, to infer human behavior decision- making through skeletal profiles in El Mirón Paleolithic levels, accumulation and destruction by carnivores or other accumulation agents need to be

excluded as well as selective destruction considered (either density mediated or intentionally for grease-rendering, for example). For humans, it is assumed that the differential transport of carcasses is related to travelling time from the kill site to the base camp in order to optimize energy return rates (CANNON 2003; MARÍN-ARROYO 2009c). Density- mediated destruction of bone remains depends on the bone part, as especially long bone shafts have a higher bone density than epiphysis, for example (LYMAN 1994).

Varied indices exist for testing those skeletal representation patterns, which are summarized here in a schematic view (Figure 3.29): (1) Smaller and denser bones are better represented than more fragile ones with thin cortical structures when density mediated destruction plays a role; (2) the meatier the bone, the higher its percentage within in a camp site after selective transport according to MGUI; (3) bone parts with most spongiest tissue are underrepresented due to destruction when grease rendering have taken place; (4) bones with the largest bone cavities are better represented when marrow was the focus of extraction.

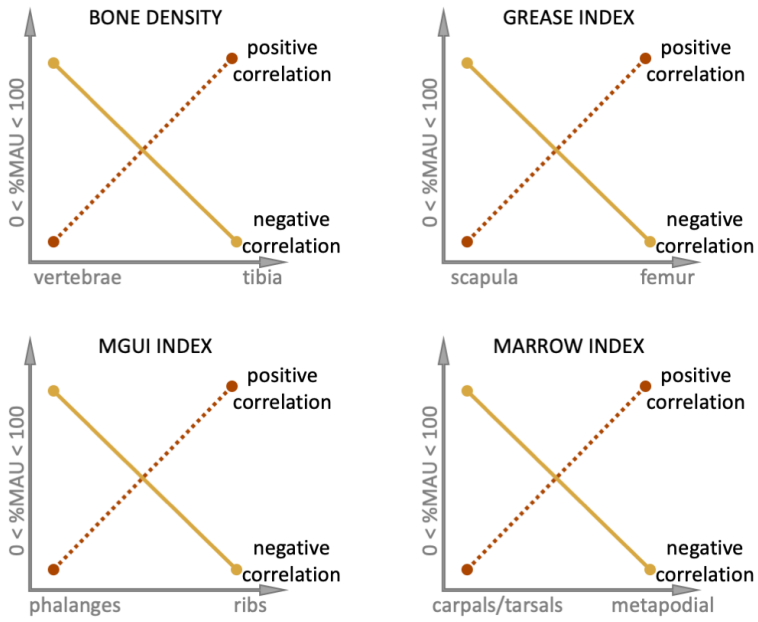


Figure 3.29: A priori assumptions of correlations between %MAU and bone density, MGUI, grease and marrow indices.

What can influence body part representation in Paleolithic contexts can be complex and exploration is typically done by using multivariate indices of food utility or bone survival in bivariate correlations to %MAU. In this context, the interpretational framework of bivariate statistical analysis can help to interpret site function, which also can infer subsistence decision made by prehistoric hunter-gatherers. Bivariate plots allow identifying the body part use strategy after the Modified General Utility Index (MGUI) adopted by those hunters (%MAU versus %MGUI) (BINFORD 1978; WOLVERTON 2002) and the effects of attrition (%MAU versus %bone density), where test results of correlation are interpreted based on their outcome as insignificant, positive or negative significant (GRAYSON 1989; LYMAN 1992).

During such analysis, attention has to be given to taphonomic processes that can mimic the human factor within the bivariate plots. Given those constrains, maximum bone density tests (LYMAN 1985, 1992; GRAYSON 1989) in rank order correlations were undertaken to establish the degree of attrition that the animal skeletons underwent. Economic decisions made effecting differential transport of body parts can also establish varied skeletal patterns. Red deer skeletal profile representations are compared to reindeer (a similar albeit smaller cervid) (LAM ET AL. 1999) and ibex skeletal elements to sheep bone densities (LYMAN 1984) to investigate these aspects further.

Statistical correlation analyses testing %MAU ($value_{\%MAU}$), MGUI and bone density ($value_{index}$) correlation were performed to get a better sense of the origin of accumulation of the studied faunal deposit. The strength, direction and significance of the test results for those correlations were identified. The values were tested against an index for the complete bones rather than bone portions, where the different values from the same element were averaged when proximal and distal values were different. This was done according to the hypothesis that human butchers would have transported proximal ends, shafts and distal ends as not separate pieces or in different abundancies (O'CONNELL ET AL. 1990). For example, the MGUI of reindeer for proximal humerus is 43,47 and for distal humerus is 36,52, the average of 40 was used for the present correlation analysis; this was done in the same way for meat and bone density indices (also for marrow and grease index). Statistics were realized with Pearson and Spearman rank correlation (Table 3.16) and the following equations were applied according to the number of ranked positions represented ($_{Variable}$n).

Table 3.16: Equations for linear and monotonic correlation analysis.

Pearson(r)	=PEARSON($range_{\%MAU}$; $range_{index}$)
Pearson p	=TDIST(ABS($_{Pearson}r$*(($_{Variable}$n-2)/(1- $_{Pearson}r$ ^2))^0,5); $_{Variable}$n -2;2)
Spearman (rho)	= CORREL(RANK.AVG($value_{\%MAU}$;$range_{\%MAU}$;1); RANK.AVG($value_{index}$;$range_{index}$;1))
Spearman p	=TDIST(ABS($_{Spearman}rho$*(($_{Variable}$n -2)/(1- $_{Spearman}rho$ ^2))^0,5); $_{Variable}$n -2;2)

According to the following p-values, the test results were interpreted (LYMAN 1992); a p- value of 0,01<p<0,05 is significant and p value < 0,01 is highly significant.

Marrow extraction in Paleolithic sites is indicated by broken up shafts to access the medullae of major limb bones and mandible, a technique which is also known as 'cold' marrow extraction (STINER 2002a; MANNE ET AL. 2006). Since these easily accessible fats were rarely left unexploited during the Paleolithic, cracked long bone cavities are a feature of Prehistoric faunal assemblages and also human behavior (ALTUNA 1986; LUPO 1998; OUTRAM 1998; STINER 2002a; BAR-OZ & MUNRO 2007; KARR ET AL. 2010). With the appearance of Upper Paleolithic heat-in liquid rendering technique and bone grease exploitation (BINFORD 1978; LUPO & SCHMITT 1997), carcass-processing activities became increasingly complex. In moments where, key resources became or were generally limited, this kind of labor-intensive resource- use presumably became an advantage and was a trade-off for these hunter-gatherer groups which were using it. The spongy or cancellous bone tissue of vertebra and the softer bone limb ends are the skeletal elements where bone grease is abundantly locked in. Those elements are preferentially exploited for grease- rendering and in consequence they are found highly fragmented (OUTRAM 1998).

Although still under debate, for recognizing within-bone nutrient rendering techniques, a focus relies on the skeletal and fragment abundance analysis where two exploitation ways are considered. First, the correlations between the fragmentation ratio NISP/MNE of each element in the assemblage (LYMAN 1994) and, second, the Marrow and Grease Indices (BINFORD 1978; LYMAN 1994) were calculated. In attempting to avoid a bias due to taxonomical identification rates within the study of marrow and grease exploitation patterns, a correlation with only anatomical identified elements, based on ranked NISP data was added. Spearman's coefficient of correlation was used to test the quantitative validity and significance (via p-value) of these correlations.

The following values (Table 3.17) are retrieved from the literature and used here for comparison. Values were obtained from bone density (LAM ET AL. 1999), meat utility calculations or MGUI, content of marrow and grease for each skeletal element and modified utility indexes of skeletal elements (BINFORD 1978).

Table 3.17: Values Meat, MGUI, bone density, marrow and grease (LAM ET AL. 1999, BINFORD 1978).

	Meat		MGUI			Bone Density			Marrow		Grease	
Skeletal element	**Reindeer**	**Sheep**	**Reindeer**	**Sheep**	**Ø Reindeer/Sheep**	**Reindeer**	**Sheep**	**Ø Reindeer/Sheep**	**Reindeer**	**Sheep**	**Reindeer**	**Sheep**
Horn				1.0					1.0	1.0		
Cranium	9.1	12.9	8.7	12.9	10.8				1.0	1.0		
Mandible	31.1	43.4	30.3	43.6	36.9	1.1		1.1	5.7	10.4	12.5	11.8
Cervical vert.	29.3	44.8	28.3	44.9	36.6	0.5	0.2	0.2	1.0	1.0	16.2	13.1
Thoracic vert.	47.2	46.5	45.5	46.5	46.0	0.5		0.5	1.0	1.0	12.3	9.8
Rib	51.6	100	49.8	100	74.9				1.0	1.0	7.5	9.3
Sternum	66.5	90.5	64.1	90.5	77.3				1.0	1.0	26.0	11.1
Lumbar vert.	33.2	38.9	32.1	38.9	35.5	0.5	0.2	0.3	1.0	1.0	14.8	14.7
Scapula	44.7	44.9	43.5	45.1	44.3	1.0	0.3	0.7	6.4	6.2	7.7	3.9
Humerus	28.9	28.2	40.0	35.0	37.5	1.1	0.4	0.8	29.0	34.7	51.7	33.0
Ulna-Radius	14.7	14.0	24.4	22.2	23.3	1.1	0.6	0.8	54.9	52.2	35.1	25.7
Carpal unit	5.2	4.7	15.5	13.4	14.5	0.7	0.7	0.7	1.0	1.0	36.5	23.0
Pelvis	49.3	81.3	47.9	81.5	64.7	1.0	0.3	0.7	7.9	9.6	29.3	34.7
Femur	100	78.2	100	80.6	90.3	1.2	0.3	0.7	41.5	47.3	63.5	61.8
Patella						0.6	0.4	0.5				
Tibia	25.5	20.8	55.9	44.8	50.4	1.1	0.5	0.8	68.3		47.7	
Tarsals						0.8	0.6	0.7		78.9		41.6
Talus	11.2	6.4	31.7	23.1	27.4	0.7	0.6	0.6	1.0	1.0	32.5	24.4
Calcaneus	11.2	6.4	31.7	23.1	27.4	0.9	0.6	0.7	21.2	23.1	47.0	34.4
Metacarpus	11.2	4.7	11.3	9.3		1.1	0.6		64.4	62.9	29.6	13.2
Metatarsus	11.2	6.4	26.9	13.9		1.1	0.6		90.9	71.9	30.5	33.6
Metapodial					15.4			0.8				
Phalanx prox.	1.7	3.4	13.7	8.2		0.9	0.5	0.7	30.0	33.8	33.3	15.7
Phalanx med.	1.7	3.4	13.7	8.2		0.7	0.3	0.5	22.2	25.1	24.8	13.3
Phalanx dist.	1.7	3.4	13.7	8.2		0.5	0.3	0.4	1.0	1.0	13.6	9.8
Phalanx indet.					11.0			0.5				

Towards an interpretation of skeletal exploitation, micro-bone fraction and bone sizes seem to play a role. New criteria have been recently published with which to identify grease- rendering activities in archaeological faunal assemblages based on morphological criteria, crushing marks, tear marks and micro-inclusions (MORIN & SOULIER 2017). The authors of this experimental analysis processed one assemblage only for marrow extraction (referred to as the marrow-cracking experiment – MCE) and another for grease rendering (referred to as the bone grease-rendering experiment - BGRE) (MORIN ET AL. 2017). The authors also considered the size distribution of specimens as one differentiating criterion between these two faunal assemblages. I used this datasets for comparative reasons and applied first a Spearman rank correlation test

between Ref-BDRE and Ref-MCE and retrieved distributions that did not significantly correlate with each other (n=6, Spearman(rho)=0.6571, p=0.1562). Furthermore, the El Mirón faunal data were selected for comparison with those datasets. During El Mirón faunal analysis, information was gathered on all types of bones, many of them not identified anatomically at a skeletal element level, but rather on a bone type level, such are spongy bone parts or long bone shaft fragments. Most of those items are smaller than 2cm, they were referred to as micro-bone fragments. All of the identified bones were counted, weight and classified according to size classes from which the number of bones in each size category can be sorted. Then, I plotted the tally for each category by cultural levels for diachronic analysis, whereby followed the new identification protocol with reference data of marrow- (Ref- MCE) and grease- processing (Ref- BGRE) according to %NR.

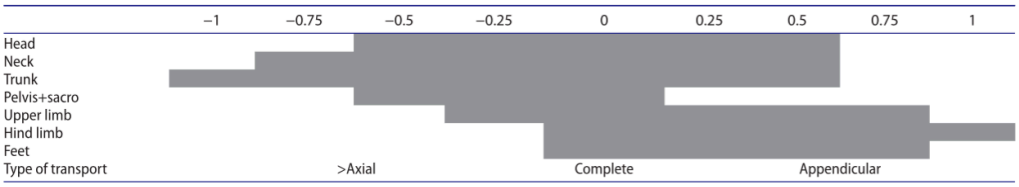
According to skeletal profile analysis, a phenomenon reported from a diverse number of Paleolithic sites is that correlations with the meat index and MGUI often show a negative relationship or reverse utility curve (BINFORD 1981, 1984, 1985; STINER 1991, 1994). When using this method, the majority of sites imply a high percentage of attritional effect, which means the loss of a great part of the spongy tissue that can be associated with scavenger- or density- mediated destruction due to trampling, sediment compaction, weathering, chemical disintegration, or intentional bone breakage. Reverse utility curves might be the product of density-mediated destruction of bones and introduces the problem of equifinality (LYMAN 1994; ROGERS 2000b). A newly developed method of Bayesian model inference proposes a solution for such problem of equifinality by analyzing the two factors simultaneously. Such a promising method considering the context of attritionally modified faunal assemblages should be tested in detail.

The last method applied for disentangling the faunal skeletal profile in El Mirón cave is the new probabilistic method of Bayesian Modeling (BM method) (MARÍN-ARROYO & OCIO 2017). The application of a generative model tackles the two major components that are commonly argued to have caused faunal assemblages accumulation, which are transport decisions by accumulating agents (BINFORD 1978; BUNN 1986; LUPO 2001, 2006; FAITH & GORDON 2007; SCHOVILLE & OTÁROLA-CASTILLO 2014) and posterior attrition (KLEIN 1989; LYMAN 1994; LAM ET AL. 1999; LAM & PEARSON 2004).

The model addresses an alpha (α) and a beta (β) parameter that are active during the formation of the assemblage. The former, transport preference (α), can take any value between -1 (mostly axial contribution) and +1 (mostly appendicular contribution) based on butchering efficiency in skeletal elements (MARÍN-ARROYO 2009c). The latter, degree of attrition (β), relates the survivorship in bone elements to their maximum bone density (LAM ET AL. 1999; ROGERS 2000a). Only levels with NISP more than 50 specimens are included. Figure 3.30 shows an example of the test results and their interpretational framework.

(A) Interpreting the Bayesian model results:

α parameter



β parameter

β	0	1	2	3	4
Survival (%)	100	50	26	15	8

(B) An example: *Capra pyrenaica*, Level 128
Median: α=0.11; β=5.29

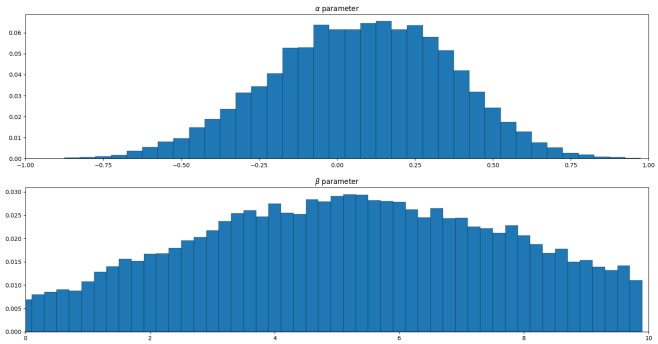


Figure 3.30: (A) Interpreting the Bayesian model of skeletal profiles: alpha parameter= skeletal transport, beta parameter = attrition for main prey species. (B) example of the test results from the Bayesian analysis.

This new method aims specifically to overcome the problem of equifinality in skeletal profile interpretations (ROGERS 2000b; LYMAN 2004; MUNRO & BAR-OZ 2004).

3.4.4 Mortality profile, animal biomass and hunting seasonality

Measure of intensity of site use to approximate duration and human group size are mortality profile anaylsis, animal biomass calculation and estimation of hunting seasonality, which are described following.

Mortality profile analysis determine the portion of young or old individuals brought to the site. When possible, individual animal age was determined based on dental eruption, wear stage and stage of long bone epiphyseal fusion. Red deer age of death was estimated on teeth (BROWN & CHAPMAN 1991a, 1991b; AZORIT 2011) and bones (MARIEZKURRENA & ALTUNA 1983a) referring to modern analogies for the birth season in May and June (CARRANZA 2011). For ibex I used birth times between April and June (ALADOS & ESCÓS 2012); age-determination followed commonly used tooth eruption and replacement schemes (VIGAL & MACHORDOM 1985; PÉREZ-RIPOLL 1988) and bone fusion stages (NODDLE 1974; SILVER 1980; SERRANO ET AL. 2006). Chamois dental eruption pattern follows (PEREZ-BARBERIA & MUTUBERRIA 1996), with a birth time in April and May. Some anatomical and taxonomic identifications of fetal bones were compared to modern newborn individuals of

reindeer and sheep based on the existing literature (PRUMMEL 1987b) and fetal bones of red deer and sheep in the osteological collection at the Laboratorio de Bioarqueológia, UC.

Age determination is usually more accurate on tooth eruption times than on epiphyseal fusions. For example, in Spanish ibex it has been shown that fusing stages vary based on individuals' fitness, which are influenced by mechanical, endocrine (hormones) and nutritional factors (MARIEZKURRENA & ALTUNA 1983a; NAP & HAZEWINKEL 1994; SERRANO ET AL. 2004).

Animal age classes were defined as shown in the following table (Table 3.18):

Table 3.18: Definition of animal age classes.

Stage	Description
fetal	unborn
neonate	newborn
infantile	animal in its first year, about 1 month to 1 year old
juvenile	animal in its second year, about 1 year to 2 years old
sub/preadult	grown-up individual that not participate in the reproduction of its species
adult	animal that participate in the reproduction of its species
mature	old individual with ageing symptoms
senile	very old individual with advanced ageing symptoms
young	generalized, not further determined than neonate to subadult
old	generalized, not further determined than mature to senile

Tooth eruption pattern can be challenging to determine, when mostly only loose, individual teeth are present, which can only contribute by their individual tooth developmental stage. The older the animal was, the more developed the root. Eruption patterns differ among species, for example in red deer eruption is estimated for mandibular M1 at 5-10 months, for M2 at 10-18 months and for M3 at 18-27 months (BROWN & CHAPMAN 1991b). In comparison, tooth eruption in Spanish ibex is estimated for lower M1 at 0-8 months, lower M2 to 9-18months, and for M3 at 26-36 months (VIGAL & MACHORDOM 1985).

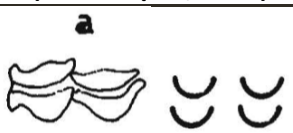
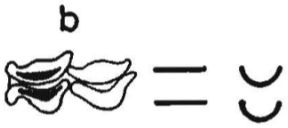
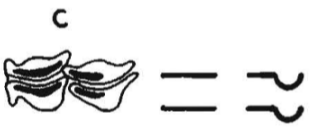
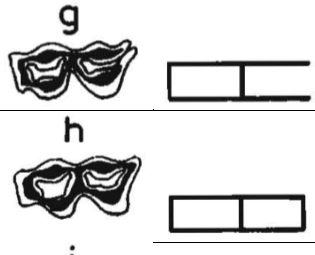
Tooth eruption stages were recorded in the database as follows:

- 'germen'; 'without root'; 'root'; 'massive root'

Crown height measure (after KLEIN ET AL. 1981) is a useful criterion with which to observe ageing patterns in ungulates and varied wear stage patterns are reported in archeozoology, among them the most relevant here are for red deer (BROWN & CHAPMAN 1991a, 1991b; AZORIT 2011) and ibex (VIGAL & MACHORDOM 1985; PÉREZ-RIPOLL 1988). Accordingly, teeth were sorted by their wear stage; the number of teeth contributed are given and the variation of crown height is summarized in figures in the results chapter. Earlier wear stages (beginning of abrasion at a young physical age) usually refer to shorter time spans than the later ones, which is a well-known caveat of crown height observations. Younger animals represented by milk teeth normally have good time- resolution due to their determinate end of use and relatively short period of use (about the first 24months of life). During analysis were defined different groups of crown heights with varied tooth wear or abrasion stages.

Wear or abrasion stages (AS) in teeth (see Table 3.19) were subdivided into twelve stages, AS1 to AS12 for molars and milk molars.

Table 3.19: List of abrasion stages of teeth from *Capra pyrenaica*.

Abrasion Stage (AS)	Description	(Pérez-Ripoll, 1988)
AS1	'unworn' tooth	
AS2	'first cusp wear start'	
AS3	'more wear at the 1st cusp and 2nd wear start'	
AS4	'dentin of the first prism is visible'	
AS5	'dentin is in both prism visible and start to connect '	
AS6	'dentin starts to join together'	
AS7	'dentin area melted together, all cusps are connected'	
AS8	'dentin divides the holes in the first prism'	
AS9	'dentine exposure almost complete'	
AS10	'the hole in the first prism is weekly visible'	
AS11	'only a hole in the second prism'	
AS12	'only dentin, no holes visible'	

Epiphyseal fusion stages were recorded, when available, in the database as:

- 'porous bone' = bone within the (cartilage) ossification process
- 'unfused' = constitute of separated parts, where the future fusion area of the lamina epiphysis is visible;
- 'fusing' = is meant when the suture line is still visible;
- 'fused' = suture line is not visible anymore;

For a priori assumptions, some mortality profiles were adapted from published analysis to distinguish accumulation context of faunal assemblages (KLEIN 1982; STINER 1990; STEELE 2002). The frequency of infantile (0-1 year), juvenile, (1-2 years) and adult (+2years) individuals were used for further analysis. How they distribute is shown in the following table (Table 3.21).

Table 3.20: Mortality profiles of ungulates showing pattern of varied accumulation origin.

Age (in years)	Infantile (0-1)		Juvenile (1-2)		Adult (2+)	TOTAL
Living	500	30%	250	15%	55%	1694
Attrition	250	50%	25	5%	45%	500
Human kills	72	30%	47	20%	50%	226
Wolf kills	45	45%	3	5%	50%	96

For further analysis of mortality profiles, ternary plots were employed. Their classical scheme was adapted (as it would not be informative) to the El Mirón dominance of young individuals. In the three corners were plotted the amount of infantile, juvenile and adult individuals from published data (Figure 3.31).

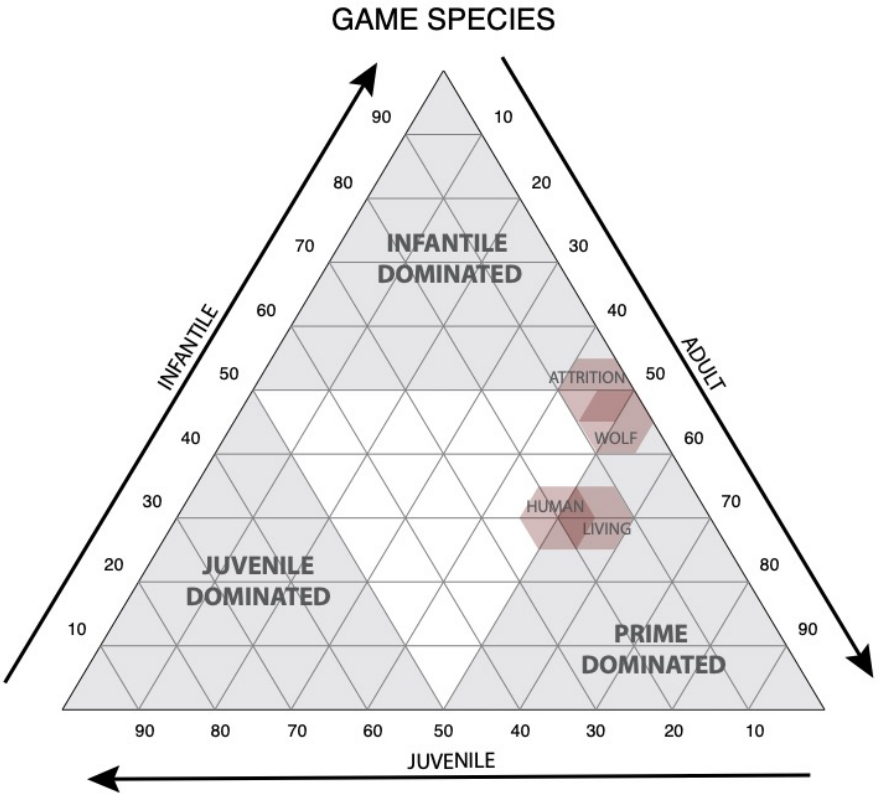


Figure 3.31: Ternary plots used for illustrating main game species mortality profiles.

Osteometric measurements were taken with a digital vernier caliper on anatomical identified bones. All osteometric data are presented in millimeter (mm). Standard measurements were taken according to published manuals (VON DEN DRIESCH 1976; FERNANDEZ 2001), references can be found in the table below (Table 3.21) and other were added when necessary were it seems reasonable; for example teeth length and breadth were measured at column/ERJ due to preservation and less variability due to age differences. Osteometric measurements were used to differentiate size variation, and to infer when possible, the sex of individuals. What follows focuses on presenting the measurements that were used for comparison, these are: proximal scapula, distal humerus, carpals, distal tibia, distal metapodial and sesamoids for extracting information of size variation and sexual dimorphism.

Table 3.21: Osteometric measurements.

Meas.	Description
Teeth	
L	Greatest length of enamel, measured rectangular to distal end from distal to medial; =l (KLEIN ET AL. 1981)
B	Greatest breadth on the occlusal surface, measured rectangular to lingual in lower teeth and to buccal in upper teeth; =b (KLEIN ET AL. 1981)
LC	Length of the column/neck, measured on enamel- root junction (ERJ); = RW (D'ERRICO & VANHAEREN 2002)
BC	Breadth of the column, measured on ERJ; = RT (D'ERRICO & VANHAEREN 2002))
HC	Crown height, measured from occlusal lowest point between the two cusps of the enamel to the ERJ (in lower molars measured on lingual surface and in upper molars measured on buccal surface); =h (KLEIN ET AL. 1981)
Scapula	
Bprox	Greatest breadth on proximal epiphyses; = BG (VON DEN DRIESCH 1976)
Tprox	Greatest depth on proximal epiphyses; = GLP (VON DEN DRIESCH 1976)
Humerus	
HT	Height of the trochlea incision; =SHT (VON DEN DRIESCH 1976; FERNANDEZ 2001)
BFD	Breadth of articulating surface, distal; = BT (VON DEN DRIESCH 1976)
Carpal bones	
C23: *Os carpi secundum et tertium* or *Os trapezoideocapitatum*	
T dist	Depth of the complete bone measured from anterior to posterior
C4: *Os carpi quartum* or *Os hamatum*	
Tprox	Greatest depth of the bone measured from anterior to posterior
C.rad: *Os carpi radiale* or *Os scaphoideum*	
Tprox	Greatest depth of the bone measured from anterior to posterior
C.uln: *Os carpi ulnare* or *Os triquetrum* or *Os pyramidale*	
T dist	Greatest depth of the distal bone measured from anterior to posterior
Tibia	
Bdist	Greatest breadth on distal epiphyses; = Bd (VON DEN DRIESCH 1976)
Tdist	Greatest depth on distal epiphyses
Metapodial	
SDCm	Smallest diameter of medial condyle, lateral part (FERNANDEZ 2001)
TM	Greatest depth of the sagittal crest of the distal medial condyle; = Dd (VON DEN DRIESCH 1976)
Distal sesamoid	
B	Greatest breadth, measured from medial to lateral
T	Greatest depth, measured from anterior to posterior

Sex determination can be made based on direct and indirect sexual dimorphism criteria. Direct morphological differences are the growth of antlers or the growth of massive horns in male *Capra sp*. individuals; whereas female red and roe deer do not develop antlers and female Capra have normally smaller and thinner horns

than adult males. Indirect evidences for sexual dimorphisms are size variations between sex, which manifestation can vary between species, environments (including diet and temperature) and chronological periods—e.g., glacial vs. interglacial (SCHMID 1972; UERPMANN 1978; PÉREZ-RIPOLL 1988; BROWN & CHAPMAN 1991a). A distinctive offset in bone dimensions between female to male has been observed in previous studies on red deer and goat bones. A study of red deer post- cranial elements compared the dimensions of red deer (MARIEZKURRENA & ALTUNA 1983a, 1983b) in the Basque country. For Spanish ibex (ALTUNA 1978), based on the established method to distinguish male from female bones by their dimensions, when possible dimensions of identified bone elements were taken and recorded for exploring sex differentiation via osteometric measurements. Graphs were made according to osteological measurements.

Animal biomass calculations are Archaeologists attempt to estimate the amount of soft tissue represented by faunal assemblages to analyze human diet and behavior. An early use of biomass referred to the value of the "approximate annual average live weight of all age classes" (GUTHRIE 1968) was a multiply of estimated MNI and body weight. For this, genetically closely related modern taxa were used to estimate Paleolithic animal weights. The estimations of the amount of meat was introduced later (WHITE 1953; FREEMAN 1973), and refers to the actual *edible meat parts* of the animal. The use of recent biomass or meat weight as a reference should take in to account animals inter-individual seasonal weight variation, ontogenetic variety and gender differences in body sizes when calculating an annual average from living populations. Researchers need to be aware that those biomasses calculated from archaeological assemblages depend on MNI calculations; slight value variations of those can substantially change the results. However, biomass values give an idea in which manner resources were processed at a site. The biomass definition has to be differently understood compared to biology, where the biomass calculation is represented for a certain area at a certain point of time (LYMAN 2008). A paleo-ecological assemblage represents, in comparison, an accumulation or deposit over a time period, thus being a 'time-averaged' collection. This temporal resolution has to be factored when answering a specific research question. The biomass supplied by each main game species was calculated using the average values of available meat given by Freeman (1973: p. 22), which were modified according to species age by Marín-Arroyo and González-Morales (2009: p. 54). This procedure adopts a simplifying hypothesis where all the usable meat from a carcass is assumed to have been consumed by the human group. This assumption is possible to make for comparative purposes. With this estimate, the approximate energetic contribution, thus, the importance of each game animal to the overall diet can be established (MARÍN-ARROYO & GEILING 2015). The amount of animal resources available at El Mirón were calculated in four steps:

The available biomass according to average values of available meat given by Freeman (1973: p. 22) was calculated for each level, according to the following the steps:

- (1) MNI (biomass of infantile=33.3%, juvenile=66.7%, adult=100%; modified by Marín-Arroyo and González-Morales (2009: p. 54)) of red deer, ibex and chamois are multiplied by corresponding kilogram averaged estimates, acknowledging sex ratios:
    - Red deer: infantile = 33.3kg; juvenile = 66.7kg; adult = ∅100kg (weight average females:50-100kg, males 80-160kg) (CARRANZA 2011)
    - Spanish ibex: infantile = 16.7kg; juvenile = 33.4kg; adult = ∅50kg (weight average females:35-46kg, males 60-80kg) (ALADOS & ESCÓS 2012)
    - chamois: infantile = 7.5kg; juvenile = 15kg; adult = ∅22.5kg (weight average females:24kg, males 30kg) (PÉREZ-BARBERÍA ET AL. 2004)

For calculating their resource value, i.e. their caloric yield, following assumptions and calculations are realized:

- (2) From each kilogram by species is calculated the usable content in percentage of meat and fat content and the total energetic value is obtained by sum up the amount of energetic yield (kcal) adapted for each species (BINFORD 1978; BYERS & UGAN 2005; MARÍN-ARROYO 2010):
  - Red deer: 39.3% meat & fat content of total body mass (1110kcal/kg)
  - Spanish ibex: 37.9% meat & fat content of total body mass (1140kcal/kg)
  - Chamois: 37.7% meat & fat content of total body mass (1140kcal/kg)
- The total energetic yield= red deer (kcal)+ ibex (kcal) + chamois (kcal)
- Energetic yield is divided by caloric value required every day by a person of hunter-gatherer lifestyle (value is derived from ethnographic comparisons, (KELLY 1995))
- The percentage amount of animal-based diet can vary according to the subsistence strategy applied and was calculated for 20%, 50%, 80% and 100% meat based diets.
- The number of people possible to fead from the energy obtained through hunting can then be calculated and compared among the studied periods of time.

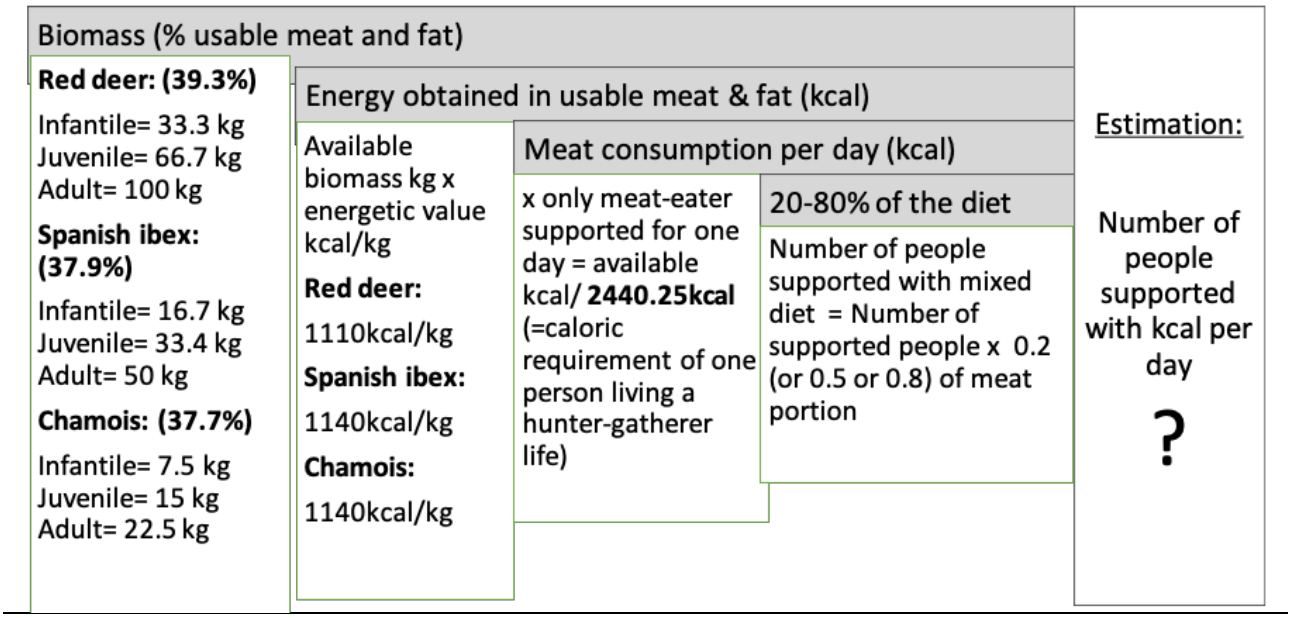


Figure 3.32: Summary of calculation steps to estimate how many people can be supported by the available biomass (after FREEMAN 1973: P. 22; MARÍN-ARROYO & GONZÁLEZ-MORALES 2009: p. 54).

Hunting seasonality determines the time and duration of occupations in archaeological deposits. Only a small number of bones and teeth are commonly suitable to estimate ages, based on their well-established and short season of fusing time, eruption or displacement. Table 3.22 provides a summary of seasonal determinations that can be considered. Each group of teeth and bones indicate animals at either their first (green shading of fields), second (yellow shading) or third (pink shading) year of life. Seasonal signals (growing/ossification processes in bones) also vary seasonally; meaning that in cases where age indicators overlap, the more often a specific season would be identified in an archaeological sample and an overrepresentation of this signal can be expected. To handle this issue, a maximum MNE was used to literally carry out a wiggle- matching to obtain a maximum MNI that most likely infer the seasonof death signal. Season estimation is stated as a derivate from modern subdivisions of the year into twelve months with spring (M=March, A=April, Ma=May), summer (Jn=June, Jl=July, Au=August), autumn (S=September, O=October, N=November) and winter (D=December, J=January, F=February) months. June is for red deer and ibex considered as the first month of life as birth times are considered to occur between May and June (CARRANZA 2011) for the former and between April and June (ALADOS & ESCÓS 2012) for the latter species.

Table 3.22: Tooth eruption and fusion stages for calculating seasonality for ibex and red deer. June was considered to be the first month of life. 0=Fusion time.

Species	Year	Element	Part	Age	M	A	Ma	Jn	Jl	Au	S	O	N	D	J	F
Spanish ibex	1st	radius	proximal	4-9 m						0	0	0	0	0	0	
	1st	lower teeth	dP4	4-9 m							0	0	0	0	0	0
	1st	lower teeth	M1	6-9 m									0	0	0	0
	1st	lower teeth	M1	6-12 m	0	0	0						0	0	0	0
	1st	upper teeth	dP4	6-12 m	0	0	0						0	0	0	0
	1st	upper teeth	dP3	6-12 m	0	0	0						0	0	0	0
	1st	scapula	processus	9-13m	0	0	0								0	0
	1st	phalanx 2	proximal	9-13m	0	0	0								0	0
	1st	humerus	distal	11-13m	0	0	0									
	1st	phalanx 1	proximal	11-15m	0	0	0	0	0							
	2nd	lower teeth	dP4	16-18 m							0	0	0			
	2nd	upper teeth	M1	18 m									0			
	2nd	lower teeth	dP4	18-20 m									0	0	0	
	2nd	upper teeth	dP3	18-24 m	0	0	0						0	0	0	0
	2nd	upper teeth	dP4	18-24 m	0	0	0						0	0	0	0
	2nd	tibia	distal	19-24m	0	0							0	0	0	0
	2nd	metacarpal	distal	23-26m	0	0	0	0								
	2nd	metatarsal	distal	23-26m	0	0	0	0								
	3rd	upper teeth	dP4	24-27 m			0	0	0	0						
	3rd	lower teeth	M2	24-30 m			0	0	0	0	0	0	0			
	3rd	upper teeth	M1	24-30 m			0	0	0	0	0	0	0			
	3rd	upper teeth	M2	24-30 m			0	0	0	0	0	0	0			
	3rd	upper teeth	dP4	27-30 m						0	0	0	0			
	3rd	lower teeth	M3	27-30 m						0	0	0	0			
	3rd	upper teeth	M3	30 m									0			
	3rd	upper teeth	M3	32 m											0	
	3rd	lower teeth	M3	30-36 m	0	0	0						0	0	0	0
	3rd	upper teeth	M2	30-36m	0	0	0						0	0	0	0
	3rd	upper teeth	M3	36 m			0									
Red deer	1st	phalanx 3	proximal	neonate-1m			0	0								
	1st	radius	proximal	5-8m								0	0	0	0	
	1st	lower teeth	M1	5-10 m	0							0	0	0	0	0
	1st	lower teeth	dP2	10-13 m	0	0	0	0								
	1st	lower teeth	dP3	10-13 m	0	0	0	0								
	2nd	phalanx 2	proximal	11-17m		0	0	0	0	0	0	0				
	2nd	humerus	distal	12-20m			0	0	0	0	0	0	0	0	0	
	2nd	lower teeth	dP2	15-18 m						0	0	0	0			
	2nd	lower teeth	dP3	15-18 m						0	0	0	0			
	2nd	lower teeth	dP4	15-18 m						0	0	0	0			
	2nd	phalanx 1	proximal	17-20m								0	0	0	0	
	2nd	lower teeth	M1	18 m									0			
	2nd	scapula	processus	20m											0	
	2nd	pelvis	acetabulum	20m											0	
	2nd	tibia	distal	20-23m	0	0									0	0
	3rd	lower teeth	M1	27 m						0						
	3rd	lower teeth	M2	27 m						0						
	3rd	lower teeth	M3	27 m						0						

Determination of seasonal occupations at El Mirón followed two steps: first the season of death was estimated for the chief prey species, red deer and Spanish ibex. Both have been found to be the main humanly targeted species at Cantabrian Late Upper Paleolithic sites. They were chosen to ensure to represent the time of the human occupations, rather than the activities of other possible background fauna such as carnivores. Later, the results are expressed graphically. To do so, each seasonal record was taken as one evidence of the seasonal occupation and their frequency distribution was plotted, thus, a higher contribution origin from a better representation of the seasonal signal. Every seasonal illustration contains two graphs (Figure 3.33). Graph A) shows the year-round seasonal cycle with the number of individuals that were identified for each month in the year. Graph B) shows the density of MNI of each species per season and total maxMNE values are the sum of elements that contributed to this seasonal estimation.

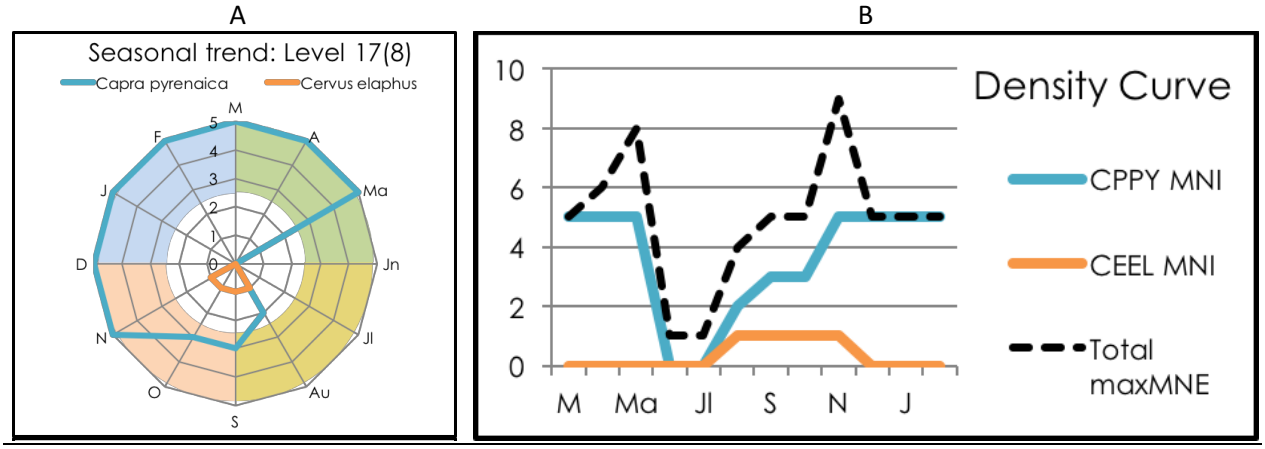


Figure 3.33: One example for seasonal trend and density curve of main prey species. (A) seasonal trend; (B) density curve of annual signals.

Multiple MNE with the death signal in the same months strengthen the interpretation towards the existence of a main (preferred) season of occupation for that corresponding study unit (levels). It should be clearly stated here that such kind of results are always estimations and never surely determine the exact 'month' of hunting. In general, a rather narrower spread of seasonal signals indicates shorter occupations and a large variety of signals imply longer durations of occupations (or multiple occupations leading to the formation on an individual, archeologically defined level).

Seasonality at age of death of animals can be used as important indicators of site occupations. In order to ascertain human territoriality and mobility through time, seasonal site- use information (MENÉNDEZ FERNÁNDEZ ET AL. 2005) was also collected from the published data from the Cantabrian Region to determine regional settlement systems.

3.4.5 Adaptation in human economic behavior

Advanced bioarcheology studies are used to estimate the relationship between diet, demography and climate change by investigating how climate variability and the increase in human populations affected the economic strategies adopted; thus, quantification indices are employed (estimate of NISP, MNI, NME and MAU). Its calculation will allow an objective evaluation of economic strategies. Special attention is given to MNE quantities (Minimum Number of Elements) (MAREAN ET AL. 2001; WOLVERTON 2002; CLEGHORN & MAREAN 2004).

For further paleoeconomic analysis, archaeological levels from the Cantabrian Region were chosen by their comprehensible correlation between radiocarbon dates, assured cultural attributions and presence of ample, useable faunal data (compare Appendix Table H4.1). A lack of sufficient subsistence evidence and chronologically related datasets for the Late Middle to Early Upper Paleolithic transition (modernly excavated, reliably dated and archeozoologically studied with consideration of taphonomy) leads me to concentrate paleoeconomic analysis on the Gravettian, Solutrean and Magdalenian cultures. For reasons of some ongoing discussion on the internal subdivisions of cultural phases (such are Lower, Middle, Upper, etc.) and uncertainties in their chronological overlapping (STRAUS 1986), Magdalenian phases were subdivided into Initial, Lower, Middle, Upper and Final.

Age boundaries of cultural periods of the faunal data used for paleoeconomic reconstructions:

- Gravettian (31.6-19.2 ka BP; 35.5-23.1 ka cal BP),
- Solutrean (21-16.4 ka BP; 25.1-19.7 ka cal BP), and
- Magdalenian (17.4-10.3 ka BP; 20.9-12 ka cal BP).

Palaeoeconomic data were also collected in a database for the Cantabrian Region. For the subsequent evaluation of palaeoeconomical behavior during the Upper Paleolithic period, it was necessary to create a set of data on hunting behavior of the different sites and periods in the region of interest to standardize the available information. This included the archaeozoological data published for northern Spain (Asturias, Cantabria, Basque Country) that fulfilled some basic, standard zooarchaeological criteria. In addition, the database includes the location of the sites (coordinates, distance from the modern coast, altitude above sea level), topographical location, NISP and MNI of the identified taxa (herbivores, carnivores, birds, fish), lithic production data, hunting weapons, sedimentary and climatic when available, etc., as well as other important information from Gravettian, Solutrean and Magdalenian sites. Datasets, which were suitable for this inter-site paleoeconomic study, were collected from publications, entered and curated in this especially developed regional database aiming to be used for unraveling key aspects of prehistoric paleoeconomic behavior. Datasets where subsequently extracted in order to answer various questions of economic development (settlement, hunting biodiversity, seasonality, etc.) within the region under study here.

The aim to reconstruct dynamics behind paleoeconomic behavior change was approached with criteria of hunting biodiversity, hunting pressure and site function, as well as a chrono-cultural-climatic assessment to observe how human groups coped with environmental determinations. These data were finally merged to evaluate the climatic context of the generated settlement and economic model. This part of the study analyzes signs of economic stress.

Resource ranking evaluates the hunted preys according to their high/low resource value in terms of cost/yield ratios of energy expended vs. energy obtained (MACARTHUR & PIANKA 1966). The degree of subsistence intensification is visible as relative portions of low- versus high- ranked animal ratios in prey species or different age (MUNRO 2009). Two kinds of prey ranking can be made to observe hunting pressure: one is the percentage of young animals among the hunted individuals and the other is the ratio of low- ranked hunted species.

These stress indices were compared based on chronologically sequenced zooarchaeological data found in archaeological sites in Cantabrian Region using various indices to track dietary changes carried out by the human populations. The degree of hunting specialization, the age of the consumed individuals, the abundance of prey species that are difficult (or even dangerous, e.g., boar) to hunt, the intensity of prey exploitation, the type of carcass transport, the extent of logistic mobility and the sort of butchering process are estimated and compared as it follows.

Body part representations by level for red deer and ibex were tracked and expressed by the Minimal Anatomical Unit Percentage (%MAU). It has been calculated based on skeletal profile representations, where 100% values would indicate complete animal bodies.

The Inverse of Simpson's Index (I.SimpInd) measures the biodiversity of an archaeological sample while taking into account the frequency of animal species represented (SIMPSON 1949; MARÍN-ARROYO 2013). In cases with unequal representation of species, the I.SimpInd shows the number of dominant species within the sample.

NISP are more frequently published than MNI data. The problems that frequently occur with MNI data as explained earlier, led me to choose NISP values for exploring the biodiversity of different archaeological sites in the Cantabrian Region. The origin of the data, how they were summarized to make them comparable among different sites and their consequent I.SimpInd value are presented in Appendix Table h4.1.

The estimated age of individuals that were hunted and accumulated at the site will be compared with different economic models to estimate the type of economic strategy practiced. The age is considered significant, as young individuals have relatively less energetic return rates (they are assumed to have less biomass and fat content) in comparison with the adults of the same species (STINER 1994). For example, the identification of prime age dominated assemblages is taking into account the amount of young, subadult and adult animals often illustrated by triangular plots, while generally adults are as more productive estimated compared to juveniles (STINER 1994). The young-adult- ratio can also be used as an indicator for dietary stress, while its decrease would demonstrate over-hunting processes (GEILING & MARÍN-ARROYO 2013; MARÍN-ARROYO 2013). The adult to juvenile ratio reflects the degree of intensity in prey animal exploitation (MUNRO 2009).

The species variable groups high and low return species depending on their higher biomass or/and their lower energetic cost or risk to hunt them. Low capture cost can account for preferences against other species with similar body sizes. Accordingly, high caloric values in large animals outweigh capture cost, which is not the case in smaller animals. Fast- moving, steep-climbing or dangerous animals are associated with high capture cost (MARÍN-ARROYO 2009c, 2013) and are considered as low-return species. High return preys are species like bovines, horse and red deer or reindeer while low- return preys are roe deer and wild boar (MARÍN-ARROYO 2009d).

3.4.6 Non-human bone modification marks

There are other agents than humans also collecting bones and what role they have played in the formation of a site needs to be deciphered first to known if either carnivore or human activity was the main accumulation component. Animal activities can also disturb the original/primary bone accumulation context, either natural or human caused. Such non-humanly accumulated specimens also can have typical features of carnivore-ravaging, including birds of prey nesting in caves, for example. For analysis, common non-human bone modifications of tooth marks spanning forms of pitting, scoring, gnawing, chewing and digestion (BINFORD 1981; BRAIN 1981; LYMAN 1994; BLUMENSCHINE 1995; MARÍN-ARROYO & MARGALIDA 2011; MORIN 2012; FERNANDEZ-JALVO & ANDREWS 2016; SALA & ARSUAGA 2018) were distinguished and recorded. However, it was considered that humans can also sometimes produce tooth marks on bones (LUPO & O'CONNELL 2002; ROMERO ET AL. 2015).

Different types of carnivore modification on bone surfaces caused by dental action of carnivores were established according to the criteria proposed by different authors (BINFORD 1981; HAYNES 1983b; DOMÍNGUEZ-RODRIGO 1994; LYMAN 1994; FOSSE 2012; ANDRÉS ET AL. 2012; FOURVEL 2012; SALA & ARSUAGA 2018; SAUQUÉ ET AL. 2018): Types of carnivore activity such as 'punctures', 'scoring', 'pitting', 'furrows' include actions where

carnivore teeth hold and bite into the bone matrix. Punctures, circular or arcuate in shape, occur when the impact of the tooth perforates the cortical bone, mainly located on epiphyses or spongy skeletal elements (vertebrae, pelvic bone, etc.). Single, superficial tooth marks without perforations, where the cortical bone appears compressed are pits and they are located primarily on the compact bone areas of the long bone diaphysis. In the same areas can be often found scoring marks in form of long line trace as the results of friction of teeth against a bone surface. Furrowing is the result of carnivore gnawing and chewing bone portions rich in spongiosa (i.e., long bone epiphyses) and might be associated with scooping out cancellous tissue. If parts have been eaten from a compact bone, the edge left is often crenulated.

Another category of carnivore modification is digestion alteration known from wolves, hyenas and other carnivores (ANDREWS & FERNÁNDEZ-JALVO 2012; FOSSE 2012; LLOVERAS ET AL. 2012). Digestion corrosion traces were registered as present or absent. Identification criteria including also bird of prey digestion modifications are described elsewhere, e.g., for bearded vulture (MARÍN-ARROYO ET AL. 2009; MARÍN-ARROYO & MARGALIDA 2011; SANCHIS ET AL. 2014).

Criteria for differentiating non-human marks were defined according to the observations made on El Mirón faunal material. Examples of tooth and digestion marks on bones and teeth showing identification criteria are illustrated below (Figure 3.34).

For evaluating carnivore activity further at El Mirón cave, carnivore alterations have been categorized into 'carnivore interaction types', which are ordered towards successive steps or degree of density in carnivore actions. Three types were defined:

- Type A includes carnivore modifications of punctures, certain pitting and scoring, which might occur as first sign of prey killing, separation of elements or as the carnivore transport pieces of a carcass within its mouth.
- Type B involve furrowing, intensive pitting and scoring as the result of gnawing and chewing, which reflect further separation and eating of parts of the skeletal element.
- Type C presents the commonly ultimate kind of activity, which is the digestion of the bone fragments and deposit either through regurgitation or scat.

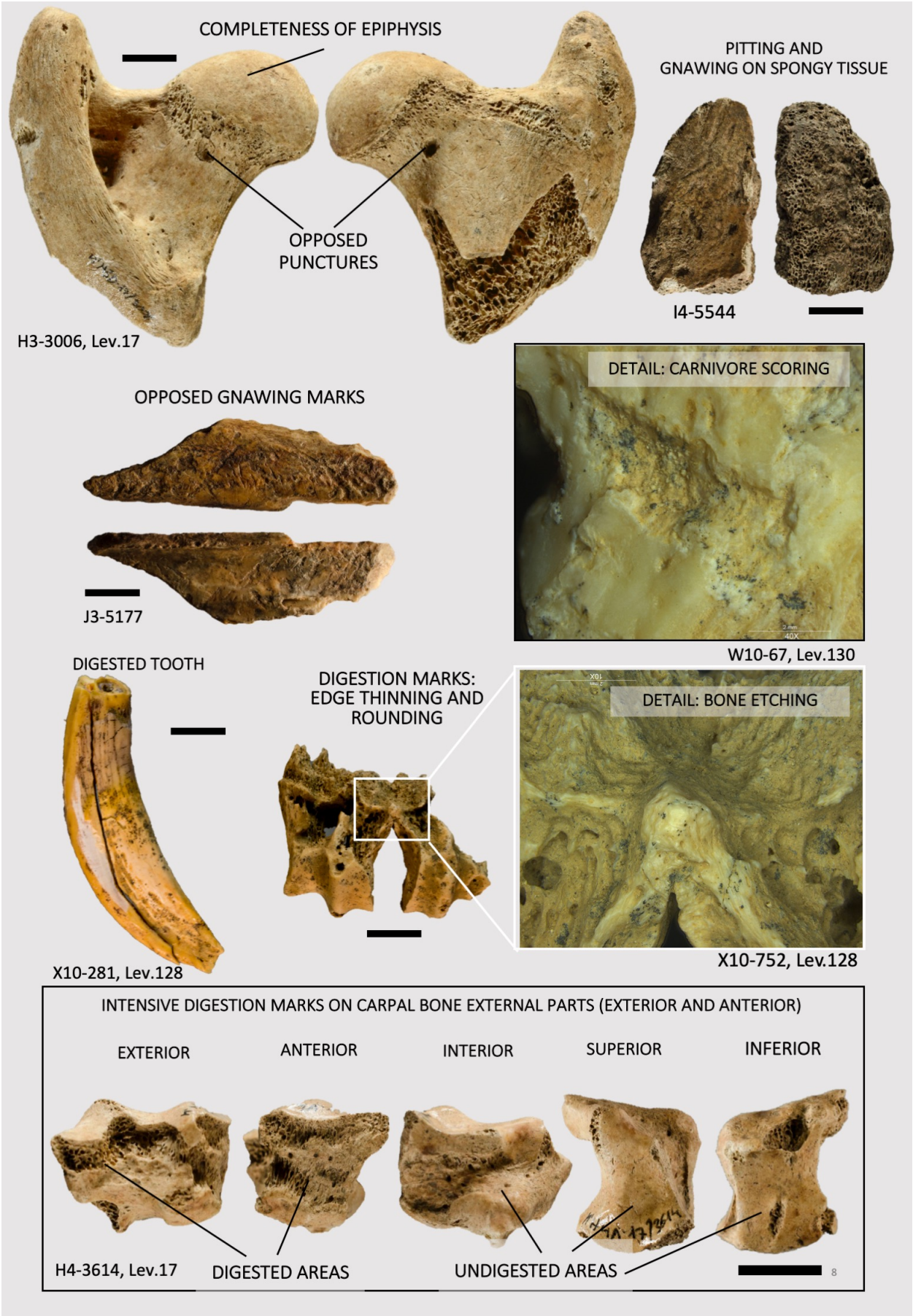


Figure 3.34: Distinguished carnivore modifications: punctures, pitting, scoring, furrowing, and digestion.

3.4.7 Diagenetic alterations

The taphonomic pattern of accumulation context, sedimentation rate, soil minerals, temperatures, humidity, etc. modify an assemblage in their summary. These conditions suggest that each stratigraphic layer has its own characteristic, diagenetic 'fingerprint', which in consequence reflects the (chemical) environment during the time of deposition (KARKANAS ET AL. 2000: p. 917). However, intensity of post-burial alterations is higher on superficial-close deposits and decreases with deeper burial. Changes of specific environmental parameters, therefore, might be reflected in chemical diagenetic alterations of bone material to achieve chemical equilibrium.

Traces of diagenetic (physical-chemical) alterations that affected faunal material can be grouped in four analytical categories: the weathering stage of the bones, the coloration of the bones, mineral (iron, manganese and calcite) coating processes of the bones, and localized dissolution by root- etching activity.

Weathering stages were recorded according to the variations observed within the faunal assemblages of El Mirón Cave. The definitions of the weathering stages are only suggestively oriented on the published data (BEHRENSMEYER 1978; LYMAN 1994; O'CONNOR 2000) as these observations were made in environments (open, dry African savanna) that differ greatly from the cave environment (sunlit outer and darker inner vestibule) where the studied fauna was deposited. The following six weathering stages (W0-W5) were defined for this project:

Table 3.23: Weathering stage descriptions.

Type	Description	Factor
W0	No cracks, good preservation of the surface	0
W1	Thin cracks; bone surface show cracking parallel to collagen fibers (longitudinal), articular bone surface with mosaic cracking	1
W2	Deeper cracks, no exfoliation	2
W3	Rough homogenously altered compact bone resulting in fibrous texture, beginning exfoliation, crack edges are rounded	3
W4	Crack edges rounded, extensive exfoliation and deep multiple, splinters of bone loose on surface	4
W5	The bone is disintegrating into splinters, falling apart *in situ*, the original shape may no longer be apparent, bone material very fragile	5

The Weathering Stage Index (WSI) was calculated using the subsequent formula:

$$\mathrm{WSI} = \sum \%\mathrm{NISP}_{\mathrm{Type\ x}} \times \mathrm{Factor}_{\mathrm{Type\ x}}$$

This index comprises each factors NISP percentages multiplied by its factor. Each weathering stage has its own factor according to the table above.

Coloration variation of bones is commonly observed among archeo-faunal assemblages (FERNÁNDEZ-JALVO & ANDREWS 2016; RANDOLPH-QUINNEY ET AL. 2016). Depositions within sediments leave faunal remains exposed to diagenetic color modifications. While it might be assumed that longer exposure provokes more intense coloration, it has been demonstrated that organic content (human waste, animal husbandry, guano deposits, etc.), soil microbe activities, mineral content and water presence as transmitting media are crucial factors

(LÓPEZ-GONZÁLEZ ET AL. 2006; BIRD ET AL. 2007; KARKANAS & GOLDBERG 2010; MARÍN-ARROYO ET AL. 2013; BERGADÀ ET AL. 2013). Relevant are also the exposure to inorganic meteorization (temperature and humidity variation, mineral movement, etc.) and organic degeneration (microorganism activity) processes.

The present study of diagenetic processes in El Mirón cave aims to understand the diversity of taphonomic factors that modified the bone assemblage after their deposition. The present studies contain bones with different color variations coming partially from an undisturbed and well-dated stratigraphic sequence in the outer vestibule. The variability of color within the studied bones that belong to one in time and space well-defined cultural entity, although the layer itself being a palimpsest, strained the question about triggers of those varied taphonomic appearances.

Previously, described staining process in El Mirón levels from the Corral area were categorized by color code types with the following criteria (MARÍN-ARROYO ET AL. 2008, 2013):

- Type 0: Bones with typical light coloration.
- Type 1: Bones with a light surface and small, dark brown, circular, internal stains.
- Type 2: Bones with a uniformly light brown tone and glossy appearance.
- Type 3: Bones with a uniformly dark brown tone and matt appearance.
- Type 4: Completely blackened bones with occasional irregular bluish stains superimposed on the black pigmentation.

During examinations of the faunal assemblage, especially from the outer vestibule in El Mirón cave, a variety of surface bone colors were documented. Some of these bones show characteristics that fit into previously defined color code types in the same cave, from the further inside located inner vestibule excavation area (Corral) (MARÍN-ARROYO 2010). But they also show similarities to other coloration variations as described by López-González et al. (2006: p. 709). However, a greater part of bones shows colorations that seem far more complex to enter into either of these coloration types.

Here is suggested that 'bone color' observations by the naked eye have their limitations, but they can differentiate the geochemical bone modifications associated with specific colorations in combination with other taphonomic factors, if they are priory defined geochemically.

The following color codes have been created to describe the coloration variation of outer vestibule Levels 15, 16 and 17 and then they were used among the faunal remains of the other studied levels. Examples of these bone color modifications can be found among the microscopic photographs (Figure 3.35).

Geochemical analysis of bone samples representing common color types of the present study were kindly determined by specialist in this field of analysis. I sincerely thank to Prof. Romualdo Seva Román, M. Dolores Landete Ruiz and Cristina Biete Bañon who analyzed bone samples in the Archeometry laboratory at the University of Alicante, Spain. Bone samples of the different color types from Level 17 have been analyzed with established methods (MARÍN-ARROYO ET AL. 2008, 2013; SEVA-ROMÁN ET AL. 2015, 2019). The following strategy was applied:

- Analysis of sediments in the level 17 in different depth;
- Binocular loupe was used to explore the bone surface;
- scanning electric microscope (SEM-EDX) to obtain the geochemical composition of the bone surface;
- Raman spectroscopy for characterizing specific zones of the bones were different coloration was seen;
- Infrared Spectroscopy with Fourier transform (FT-IR) for characterizing the chemical structure of the sample and
- energy-dispersive X-ray photoelectron spectroscopy (XPS) for investigate the state of oxidation on the bone surface, to obtain images and the elemental composition of pigment samples of bones.

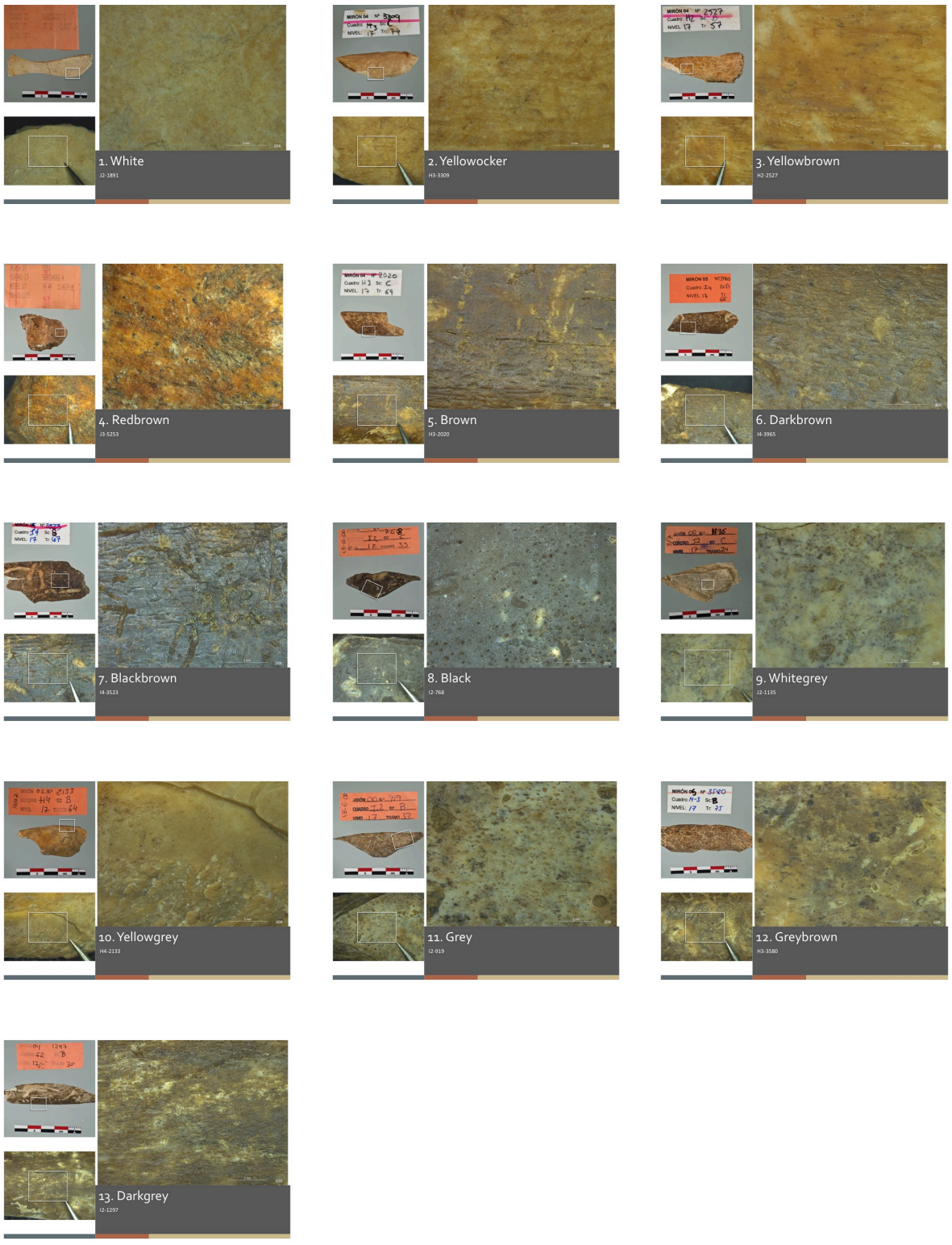


Figure 3.35: Grades of several bone color variation categorized.

The taphonomic factors considered here concentrate on diagenetic modifications that are mostly active when the bone lies on the surface or is just buried under little sediment; i.e. those are commonly considered to occur post-burial. Other examples of these modifications are root activity or calcite concretions

(BEHRENSMEYER 1978; FISHER 1995). It is suggested to use cluster analysis to further investigate the relationship of these different phenomena that are often being found associated in archaeological assemblages.

The circumstance that in the recent study of the outer vestibule levels 15, 16 and 17, alternating bone colorations have been identified giving rise to the questions, if changes between water-rich and water-poor conditions affected the bone diagenesis and if they are recordable. With the help of statistical analysis, taphonomic clusters were designed, where supplementary vertical and horizontal spatial distributions studies can be realized. Later, it is tested if these clusters coincide with changes in environmental condition. It is also considered environmental conditions necessary to create such geochemical bone modifications according to the following prior knowledge.

Major elements of bones are calcium (CA) and phosphorus (P), the natural bone components, but aluminum (Al) and manganese (Mn) are typical elemental components of metallic coatings (LÓPEZ-GONZÁLEZ ET AL. 2006). Mineral manganese is abundant in certain rocks, calcareous rocks, where its soluble components of the manganese are mobilized during the disintegrating of the limestone, but precipitation depends on the pH; they are authigenic minerals. Authigenic minerals (formed inside of caves and not transported into them) reflect the tendency of sedimentary materials to achieve chemical equilibrium when new environmental conditions are imposed, thus, they are indicative of the conditions that prevailed at the time of formation (KARKANAS ET AL. 2000). Conditions stay more stable further inside of caves in comparison with cave entrances, where environmental conditions affected sediments more directly. Especially, manganese coating processes by oxidizing bacteria seem to be related to presence of organic matter and environmental fluctuations (TEBO ET AL. 2004, 2005).

Most of these taphonomic alterations are widely recognized and they have been documented in several sites, but what they imply seem to be hardy understood. Geochemical analysis will help to obtain a detailed understanding of processes that have modified faunal assemblages in the past. The additional motivation behind this study is to make the understanding of the variety in bone color modifications to an accessible-to-anyone method with which to track diagenetic processes via naked eye observations (when especially trained to do these) or with basic (low-level foci) microscopy. Recording bone coloration is easily doable during common faunal studies as the color of individual remains can be documented in the database during specimen recording.

The calculation of a Coloring Index by level and by species was performed following the formula from previous studies (MARÍN-ARROYO ET AL. 2008, 2013; MARÍN-ARROYO 2010). Additional factors were given to the new color types, which were observed in the present study, but not described in the previously defined, published ones. New colors observed within this study are mainly grey shades (Table 3.24).

Calculation of the Coloring Index:

$$\mathrm{CI} = \sum \%\mathrm{Weight}_{\mathrm{Type\ x}} \times \mathrm{Factor}_{\mathrm{Type\ x}}$$

The Index comprises each factor's weight percentages multiplied by its factor. Each coloration has its own factor according to the table below, which include previous published color types (MARÍN-ARROYO ET AL. 2008; MARÍN-ARROYO 2010) and their extension through the present study.

Table 3.24: Coloration types and factor.

Color	Type	Factor	Color Cluster Code (CCC)
1. White-beige	TP0	0	1
2. Yellow-ochre	TP1	1	2
3. Yellow-brown	TP2	2	2
4. Red-brown	TP2/3	2,5	2
5. Brown	TP3	3	2
6. Dark brown	TP3/4	3,5	3
7. Black-brown	TP3/4	3,5	3
8. Black	TP4	4	3
9. White-grey	GreyTP1/2	0,5	4
10. Yellow-grey	GreyTP1	1	4
11. Grey	GreyTP1	2	4
12. Grey-brown	GreyTP2	2,5	4
13. Dark grey	GreyTP3	3	4

The various colors observed was given an additional Cluster-Color-Code (CCC). The CCC refers to the group of discoloration, which is either in white (1), brown (2), black (3) or grey (4) shades. The frequency of each color code was then observed and compared among the different studied levels to detect possible trends in color variation by location and/or time. These clusters also can be used to study spatial variation in the presence of these discoloration.

Bone surface modifications such are mineral manganese (penetrating the bone, dendritic crystal growth, speckles and coating) and superficial deposits, carbonate concretions (calcite), fungi as well as root activity (negative root shadows can occur when roots cover the bones building a barrier/wall towards manganese coating processes) were recorded using the following quantitative system (Figure 3.36). The percentage of covering the bone surface was determined and recorded recalling the outside, the inside or the complete surface of the bone. It was noted that the bone surface was either covered up to 25%, 50%, 75% or 100%. If none of the categories were observed, this field was left empty within the database.

Carbonate concretions develop on faunal remains when carbonate enriched water evaporates in surface close sediments in which animal remains are deposited. For example, secondary calcite tends to form at locations where water drips from the cave ceiling onto the sediments (KARKANAS ET AL. 2000). Rain water can get slightly acidic through the interaction of the CO2 in the atmosphere and the soils. The water then can get enriched in carbonates when it is percolating through the lime stone matrix of karstic caves as it is the case in Cretaceous rocks (Urgonian limestone) that are the bedrock of El Mirón cave.

Root and fungi activity detection was made using the subsequent criteria and necessary conditions are described when possible. Root marks are linear, sometimes wavy, marks and the interior of the marks is swallow-U-shaped, sometimes darker in color through the activity of humic acids (produced by the vascular plants and symbiotic associated bacteria/ fungi that lower pH values at the surroundings of the growing root tips) (FERNANDEZ-JALVO & ANDREWS 2016: p. 109). Intensive root activity can cover larger parts of the bone surface; marks are commonly divided into branches, textures seem to be corroded and root mark bottoms may have internal cracks from acids as a response of the bone to chemical damage by the root. The depth of the marks might vary among plant types. Roots dissolute the surfaces of swallow buried remains in possible depleted soils, but sub-aerial plants such as moss also produce root marks on bones in search for minerals.

(A) Quantitative Recording system

0	1	2	3	4	5	6	7	8	9	10	11	12
0	25	50	75	100	25	50	75	100	25	50	75	100
no	outside				inside				complete			

(B) Examples: of post-dispositional bone surface modifications

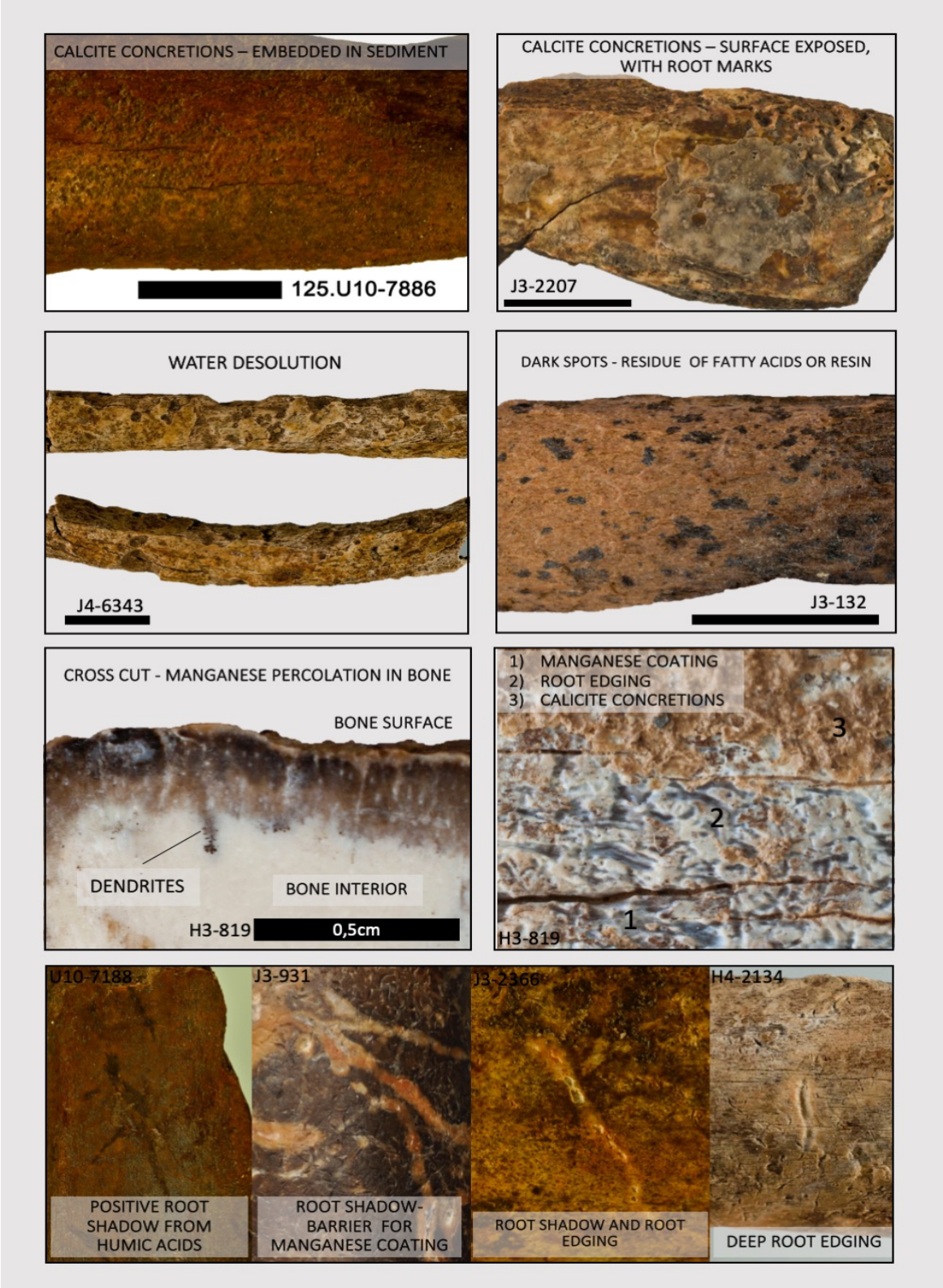


Figure 3.36: Recording scale (A) and diagenetic surface alterations on bones (B).

Additionally, different kind of natural alterations can preserve information about the diagenetically history of the archaeological deposit. The reason for that is that certain types of alterations occur under specific conditions, examples are listed here:

- Well-preserved – Bones with an exceptional well-preserved surface that expose any kind of 'non-destructive' taphonomic alterations, especially biostratinomic ones such are cut marks from stone tools are of interest. Normally are any kind of anthropogenic modifications being 100 percent visible on these items.
- Fragile bones, especially fetal bones indicate good preservation conditions of the material. Fetal animals refer to fragile and spongious bones that belong either to fetal or newborn individuals. Their higher presence, measured with the density index in reference to $0.01m^3$(1m*1m*0.01m), is indicative of the good preservation conditions, otherwise these bones are generally destroyed.
- Water activity – Rounded edges and especially bone surfaces are in 'solution' and/ or diverse sizes of pits mark the areas of dripping action.
- Rounded – The type of fracture is not determinably due to the presence of rounded edges among the bone surfaces. This kind of rounding might origin from water activity (chemical) or sediment movements (mechanical).
- Exfoliation – The extended form of bone structure disintegration leaves bones with destroyed collagen fibers breaking along the crystalline structure of the mineral parts of the bone (in long bones normally along the longitudinal axis) presumably through some kind of tensions against the bone surface (for example sediment movement or trampling).
- Brittle bones – mostly the exterior cast is well preserved-sometimes shiny, but specifically the inside structure of the bone is porous, chalky, crumbly and parts may fall off when touching. It seems at a certain point the interior structure of the bone degenerates in that collagen fibers are destroyed.

Those diagenetic alterations described and observed among the faunal remains of El Mirón as listed above are clear taphonomic signals with information about site formation and the local environment. Such identification of differences in water presence and temperature change, for example, aid to determine environmental changes specifically in the caves direct surroundings.

3.5 Spatial analysis

This dissertation work includes a multi-approach for studying the spatial distribution of faunal remains in archaeological deposits. Details for each method applied are specified separately for each approach.

The preparatory work for using three-dimensional records from finds by photogrammetry analysis is described as the initial work done for spatial analysis.

Three case studies will demonstrate the advantage of intra-site spatial analysis when human behavior studies are being addressed:

- A new protocol was developed for the spatial distribution of bone micro-fragments, and how they can be used to decipher archaeological palimpsest. This procedure follows a new protocol incorporating a small fraction of faunal remains by classifying bone fragments, mostly smaller than 3cm of general bags, to identify areas of activity within site and compare their spatial distribution over time.

- A new protocol for reconstructing activity zones of humans in the cave site. Surface reconstructions through the distribution of findings with GIS (Geographic Information System) programs to represent

zones of Paleolithic human activities; for example, working, walking, depositional waste areas, and possible cooking zones. In addition to that, changes in cave use can be observed through time.

- A new strategy was developed to analyze the Paleolithic burial of El Mirón. Spatial analysis was performed of the faunal and animal remains, in particular the special materials belonging to funerary rituals, such as the red ochre cover in animal and human bones, as well as the burial area selected for this purpose. Also, it includes the spatial distribution of stones slaps, red ochre pieces, human bones, lithic remains, ochre/hematite chunks. This kind of spatial analysis revealed exceptional details about human activities on the only primary human burial of Magdalenian are in Iberia.

3.5.1 Field methods

During excavation at El Mirón cave, standard, modern methods of Paleolithic excavation were applied. These methods include three-dimensional individual recording of lithic artifacts larger than 1cm, bones longer than 5cm, and some smaller, but field-identifiable specimens (e.g., teeth, phalanges) a total station theodolite. The excavations were conducted in subsquares (50x50cm) by spits (app. 1-3 cm thick in rich levels such as 17; thicker in poor levels such as 128 or 130), the sediments were then water-screened through fine mesh to collect the smaller finds or 'non-identifiable' bones in so-called 'General Bags' (GB). Spits are arbitrary subdivisions of natural levels. Nine depth measurements were taken for top and bottom heights of each spit's meter square center, edge center, and corner, and their average difference represents spit-depths. Based on these data, sub-samples, corresponding to different heights above the site's 0-datum plane were created for later study the archaeological density in levels of interest.

Precisely, for further analysis, the macrofaunal assemblages from Levels 15, 16, and 17 in the outer vestibule area were examined and compared in horizontal faunal study units. As shown by the stratigraphic sections and the ~0º dip angle of elongated objects such as long bones and cobbles, these levels are virtually horizontal. Those study units were made by subdividing the Lower Magdalenian sequence of Level 15, 16, and 17. It was created with thirteen sub-samples throughout the levels, made possible by meticulous individual find piece-plotting and depth measurements of the top and bottom of every sub-square corner for each spit during excavation. The deposit from 15.25-15.85m above datum was split in thirteen arbitrary layers each around 5cm-thick, and sometimes each layer composed of more than one excavation 'spit'. The present analysis includes all the materials from Levels 15 and 16, called Samples 1 to 5. However, because of the overwhelming richness of Level 17, only its even-numbered samples (Sample 17-6, 17-8, 17-10 and 17-12) were analyzed (i.e., a c. 50% of Level 17 is presented here). Those subdivisions were used for the spatial distribution analysis of human activities.

3.5.2 Laboratory methods

These 'general bags' micro-fragments were separated into taphonomic categories by using sorting maps specifically created by the author for this type of analysis. These laminated printout displays (templates) have spaces for each previously defined category into which to sort the bones, helping significantly to speed up the sorting process (compare Figure 3.37). General bags usually contain some small identifiable bones (<5cm) such as carpals, tarsals, phalanges and sesamoids. Once separated, per subsquare, these items were individually recorded in the faunal database, together with worked bone and antler pieces.

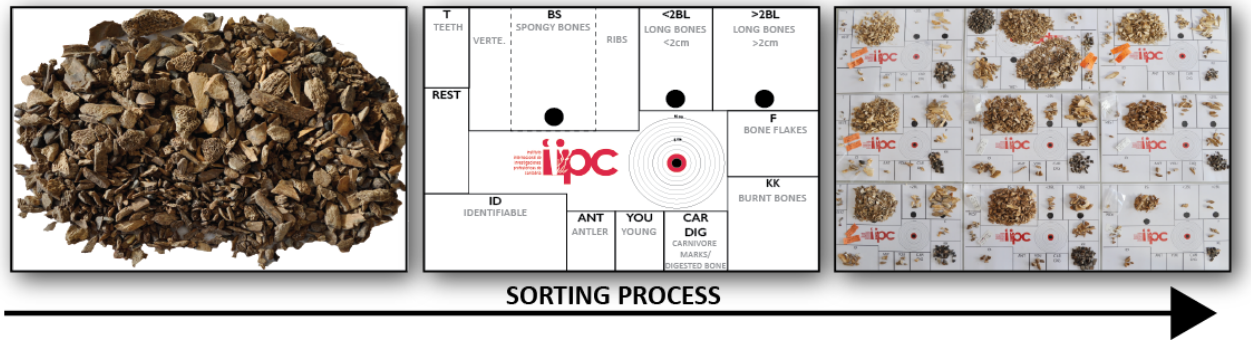


Figure 3.37: 'Sorting maps' facilitate and accelerate the working process of sorting bone refuse within taphonomic categories (T = teeth, BS = spongy bone, BL = long bone; F = bone flakes; KK = burnt bone; CAR/DIG = carnivore activity-digested; YOU = porous bone; ANT = antler; Rest = no bone items).

The taphonomic categories used in this study are designed to address different questions and to provide more details about the accumulation history of the archaeological deposit. Specific attention was given to include items with anthropogenic modifications such as cut marks for carcass processing but also to other biostratinomic and diagenetic alterations. Subsequently, taphonomic categories have been organized according to the research aim. In the seldom case where an item would fall into two or more categories, here in this study priority has been given to anthropogenic modification before a carnivore activity; before diagenetic alterations and before unaltered material categories. GBs also contained teeth enamel fragments or small bone fractions. Other categories follow specific types of anthropological modifications like burnt bones for hearth activities or bone flakes originating from percussion through intentional bone cavity opening related to actions for bone marrow and grease extraction (OUTRAM 1998; MANNE ET AL. 2006; COSTAMAGNO 2013). In this context, we used bone flakes (defined as intentionally green-fractured bone fragments with a clear striking platform, often a bulb, and sometimes visible bulb scars) as evidence of anthropogenic actions. Burned bones, which include color variations that range from slightly carbonized to half-calcined bones (STINER ET AL. 1995), are also indicators of human activity, despite where a differentiation between intentional and accidental origin were not possible. Gnawing and digestion marks (HAYNES 1983c; MARÍN-ARROYO & MARGALIDA 2011; DOMÍNGUEZ-RODRIGO ET AL. 2015) could be indicative of direct carnivore or bird of prey activities. The presence of porous (i.e., fetal, neonatal and young animals) bones reveals very good preservation conditions at the site. Other sorting categories were spongy and long bone shaft fragments (separated into less and more than 2cm), vertebrae, ribs, antlers and teeth. All the items of each category were sorted, counted and weighted. All results were entered into the working database for indices calculations.

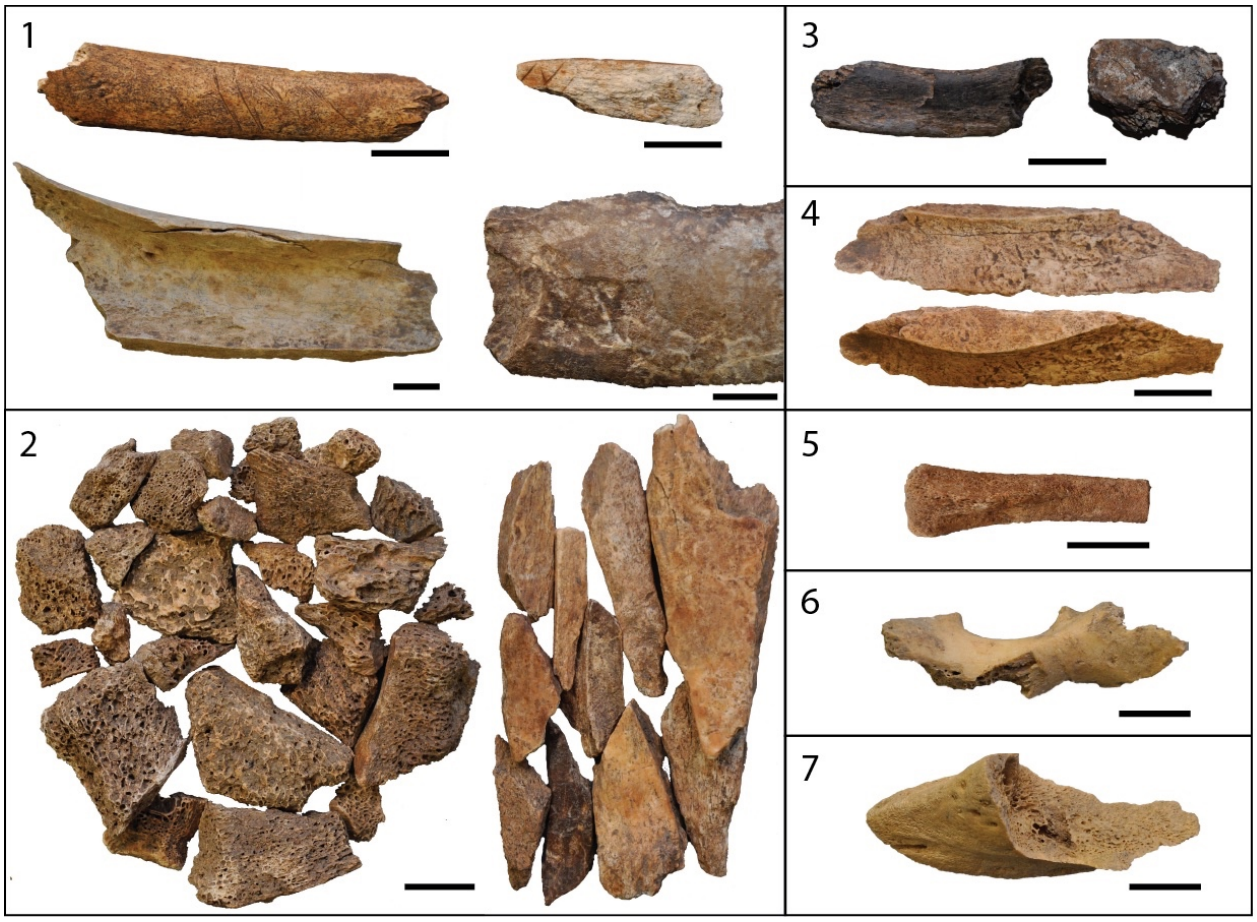


Figure 3.38: Common categories that can be differentiated within the findings of Paleolithic excavation units: 1) cut marks, decorations, impact negatives or worked/used bones; 2) small fragments of spongy and long bones; 3) burnt bones; 4) bone flakes; 5) fetal bones; 6) bones with carnivorous bite marks and 7) digestion, especially of bearded vultures. (Fauna materials from El Mirón Cave.).

3.5.3 Computational methods

Three-dimensional data were obtained by photogrammetry analysis for areas, where the theodolite was not used during excavations. At first, it was necessary to obtain the missing coordinates of Levels 15, 16 and 17 from El Mirón cave for which was established a new photogrammetry protocol including the following steps (Figure 3.39): geo-referencing of each photograph was required for every excavated section. Secondly, the individual findings were marked manually in the photographs. Third, a three-dimensional surface was created before the photographs were projected over them. Finally, an integrated ArcGIS software extraction tool was used to locate the coordinate of each piece. The individual coordinates were used to analyze the density of certain types of artifacts in different areas of the site.

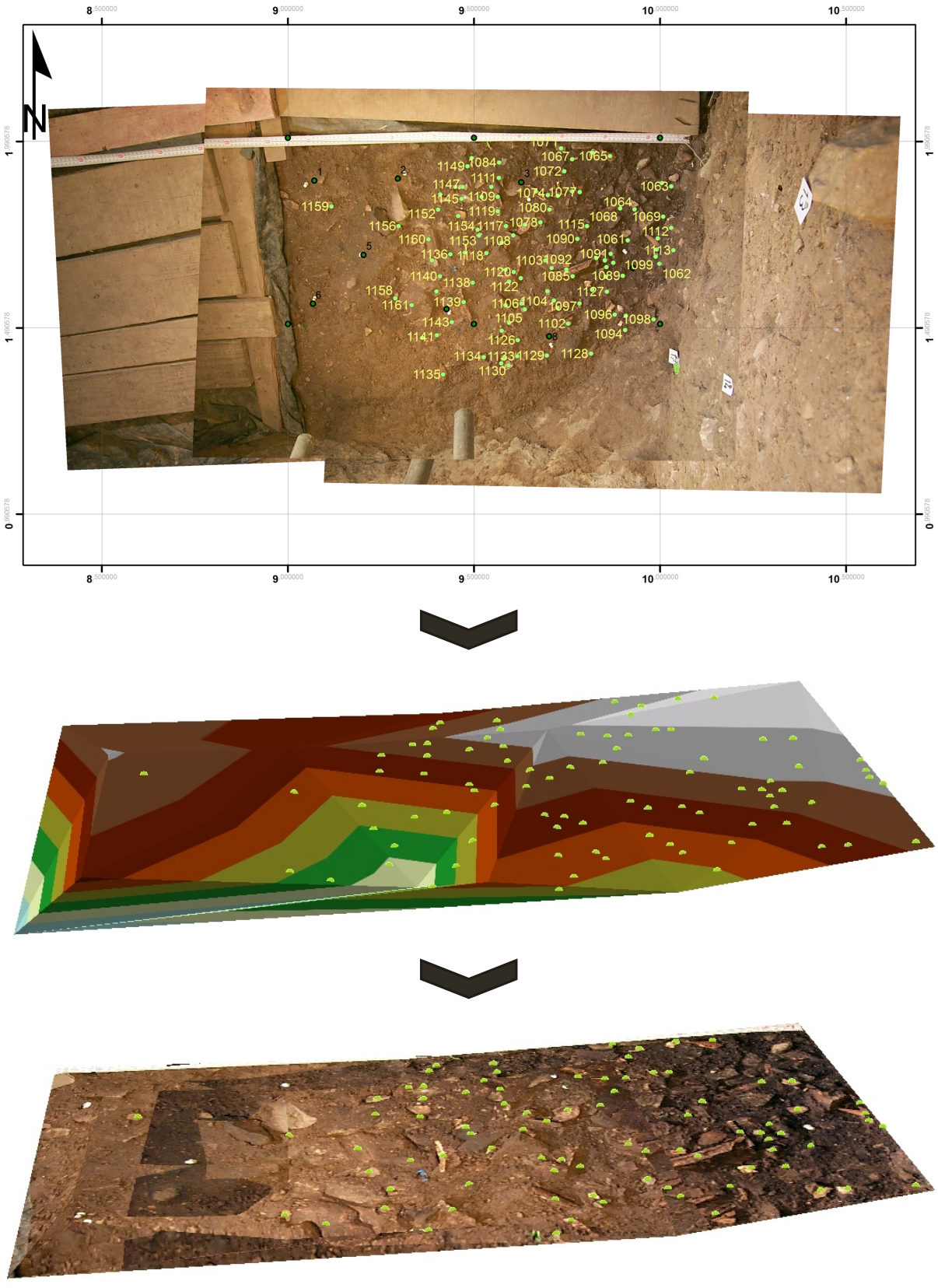


Figure 3.39: Photogrammetry. Georeferenced ortofotos and individual finds were marked. Creation of a TIN Surface representing the depth of the finds. Floating of the finds on the TIN surface (3D view in ArcScene).

Protocol for deciphering archaeological palimpsest by find density variations.

The next methods follow the assumption that variations in spatial density can be useful indicators for deciphering archaeological palimpsest. Humans structure and modify deposit in a way that density variation is created, different from horizontal and random ones of natural origin (HARRIS 1989).

Density and cluster analysis are methods used to simplify high concentrated data points (HODDER & ORTON 1976; BLANKHOLM 1991), but also to find patterns and allow comparisons between levels. The term density used here refers to 'relative density' by comparing quantities of objects per unit area or surface measured in square meters. Consequently, density is a relative term, while it refers to the overall data found within a given unit.

The taxonomically and anatomically identified GB items were assigned to sub-squares and do not have coordinates. In order to make them available for distribution analysis a program tool was used to plot identified GB finds; GB items received coordinates based on an excel-function (GILEAD 2002). The function *RANDBETWEEN (0;50)/100* was used to give random numbers according to the two-dimensional subsquare extensions between 0 and 0.50m in each direction, for X and Y coordinates respectively. Gathered identified GB data creates more reference points for distribution analysis and also increases the density of point clouds. The higher concentrated single data points inside a defined unit are, the less informative simple scatter plots become (ORON & GOREN-INBAR 2014).

Later, heat-maps were created to represent artefact densities. Heat-maps show areas of high and low point density visually distinguished by color coding. For individual data sets counts the procedure points features (representing artefacts) inside a specified area; this study used analytical radiuses of 0.2m around each point. The outcome of a kernel density analysis is a surface of raster cells, illustrating the sum of overlapping radiuses around each point. Here, was chosen a small cell size of 0.01m to create smooth density maps. The highest values within the plots correspond to 1 and the lowest values correspond to 0, represented by color codes, red to blue respectively (SILVERMAN 1986; BAXTER ET AL. 1997).

Areas with different densities can be summarized in clusters (WHALLON 1984; SILVERMAN 1986; BAXTER ET AL. 1997). To identify clusters during analysis were defined two threshold values: one 50 % boundary to delimitate low from high densities, plus an additional 95 % boundary to identify hot spots with high concentrations. These clusters are considered to be a sample from the gathered raw data and provide useful insights in distribution patterns (WHALLON 1984; BLANKHOLM 1991).

The small fraction categories are of particular interest in identifying Paleolithic activity zones, and heat-maps were created for each sublevel by subsquare. The color code used for the subsquares ranges also from blue to red, from low to high density respectively.

The aim of calculating density indices was to obtain uniform information about each taphonomic category per unit that enabled to investigate density variability throughout the whole archaeological deposit. In order to control whether changing quantities are real density variations or correspond to varying excavation unit thicknesses, a standardization procedure was applied. For that reason, three indices were created to calculate quantities in terms of number and weights per 1cm sub-square unit. A *Density Index (DI)* was calculated by dividing the numbers of items in each category from a spit, with its individual spit depth in cm (Z_{Spit}) for each sub-square, which in turn is the difference between its top (Z_{top}) and bottom (Z_{bottom}) depth measured in meters. For weight was done the same (in grams) for each category to get a *Weight Density Index (WDI)*. Finally, a *Fragment Size Index (FSI)* was obtained by dividing the weight of each category with its number for comparison with the other categories. The following equations were used:

(1) $$Z_{Spit} = (Z_{top} - Z_{bottom})x100$$

(2) $$\text{Density Index (DI)} = \frac{N_{Category}}{Z_{Spit}}$$

(3) $$\text{Weight Density Index (WDI)} = \frac{Weight_{Category}}{Z_{Spit}}$$

(4) $$\text{Fragment Size Index (FSI)} = \frac{Weight_{Category}}{N_{Category}}$$

For example, in a spit of 3cm of depth/ thickness, every count and weight of that spit was subdivided by a value of 3. By applying the different indices, the obtained count, weight or size-related value per 0.25 square meter excavated, corresponding to a cuboid of 50cm long x 50cm wide x 1cm thick, was taken as representative for that sub-square sub-sample unit.

Relevant for reconstructing human activity areas and spatial analysis, it is supposed that human space-use within a cave must be accommodated to its structural limitations and, that the overall nature of human occupations remained similar through time (according to Paleolithic hunter-gatherers). For spatial statistical analysis, a random distribution of archaeological finds was assumed, making the two subsequent hypotheses (H0) the analytical baseline: (1) The Lower Magdalenian horizon (specifically Level 17 in the outer vestibule area) in El Mirón represents a more or less uniform and constant vertical accumulation deposit; (2) The archaeological remains were distributed randomly within the thirteen study units addressed here.

The calculated density indices of taphonomic groups provided the basis for spatial analyses and each obtained value is associated to a polygon in a raster resembling the position of the study unit in the outer vestibule of El Mirón cave. GIS-based spatial distribution analyses were performed to identify variations in density vertically and horizontally, by referring to profile plots and distribution maps, respectively. The profile plots provided first insights into density variation throughout the archaeological sequence of the Lower Magdalenian context. The cluster method of the ESRI 'Voronoi Map' tool that grouped polygons into five class intervals was employed. The method searches for similarities among neighboring units allowing the identification of local outliers, colored grey, and it visualizes regions of high vs. low clusters using a color scale (ESRI 2007). In the next step, was created distributions maps based on polygons and used the ArcGIS statistic tool for 'spatial autocorrelation of Moran's I global index' that evaluate whether the pattern expressed among polygons with associated attributes is dispersed, random or clustered. This tool's output refers to the significance on how likely it is that the pattern observed was due to a random chance (ESRI 2009a). After a distribution was identified as no random chance, the ESRI cluster and outlier analysis tool 'Anselin Local Moran's I Index' was applied. These results would then evaluate the relationship among neighboring units, where high Z-values indicate that features of similar values building a cluster (of 'hot' or 'cold' spots) and contrary low Z-values indicating high dissimilarities in features between neighbors identifying outliers (ESRI 2009b).

The different, previously calculated index values are expressed in the figures in relation to symbol size, where larger symbols represent the higher values. Additionally, when the Moran's I Index was calculated it is illustrated as thick square outlines for cluster or double line outlines for outlier, both in either red or blue,

for high or low values respectively. Areas with overlap of high DI and WDI values in burnt bones might indicate concentrations of hearth-related activities with high counts and weights. The combination of high DI and low WDI represent areas of higher fragmentation rates that should correspond to lower FSI values. Areas of high FSI indicate large fragment sizes. The workflow of this protocol is illustrated below in Figure 3.40.

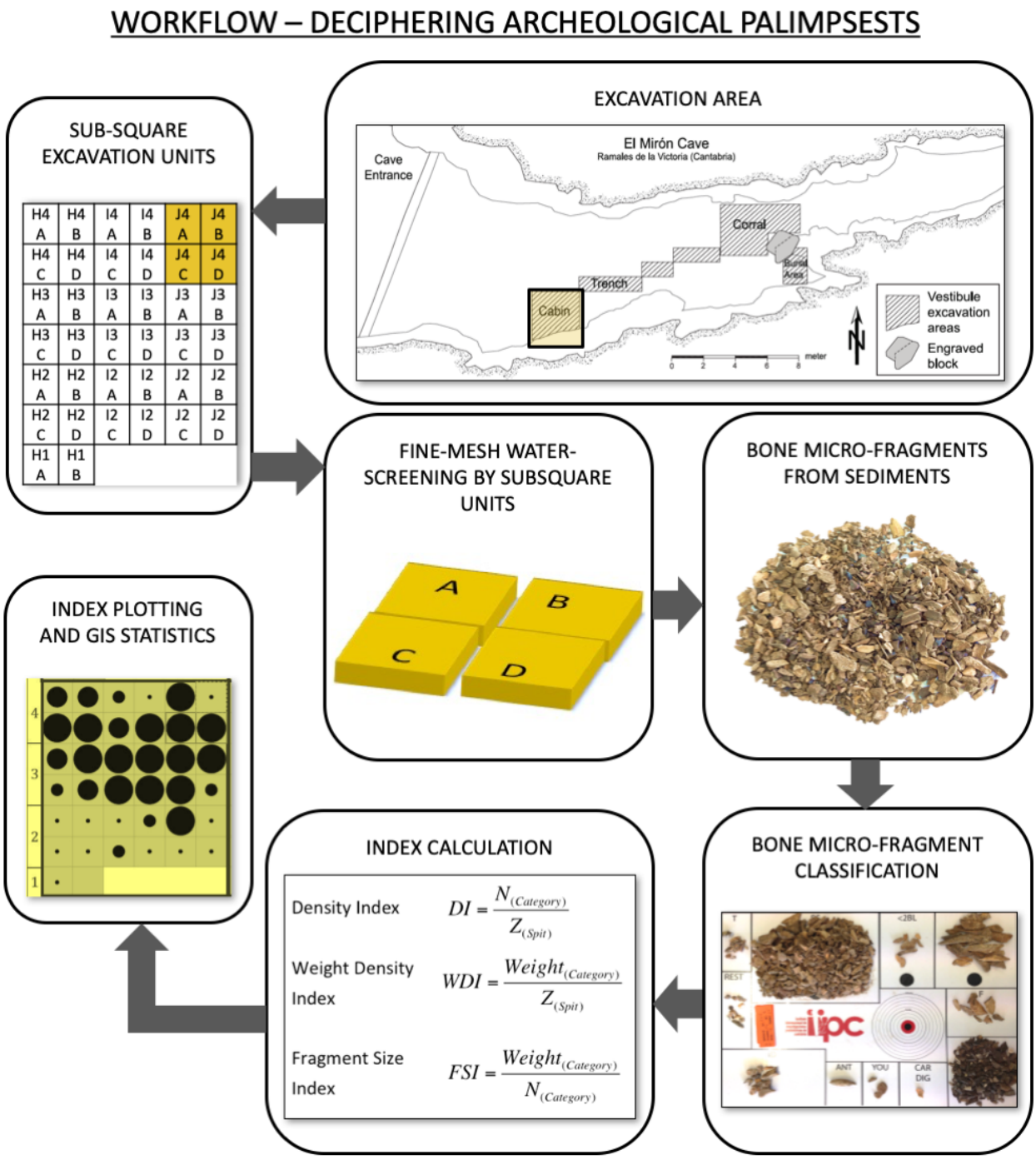


Figure 3.40: Workflow for deciphering archeological palimpsests.

Specifically, in the case study addressing the human burial from El Mirón, were examined the spatial distribution of human and animal bones, lithic and osseous artifacts, and chunks of red ochre from Level 504

found within the burial area by using their three- dimensional- coordinates as recorded by an EDM total station. For stratigraphic studies, Level 504 was compared to the over- (503) and under-lying (505, 506) levels. It was made two- and three-dimensional (2D & 3D) distribution plots, respectively by applying Quantum GIS and ARC GIS 10. The individual coordinates recorded during excavation were used to display the stratigraphic sequence in the X5/6/7 squares. Photographs taken during excavation were geo-referenced to reconstruct burial limits and features. By using the Triangulated Irregular Network (TIN) tool, was created a three-dimensional polygon surface to visualize the distribution of ochre. The reconstruction of the human body position was based on vector graphics overlying the distribution of human bones by means of their X and Y coordinates. Density plots were generated by artifact frequencies within a 0.25 m^2 mesh grid overlay.

All those spatial distribution analyses contribute significantly to our understanding of not only the spatial organization in human activities, but also of their intensity and sequence. When this is then supplemented by more contextual analysis, such are local environmental conditions and animals ecoethology, a deeper understanding of past human behavior is reached.

3.6 Environment and animal ethology

With the next analysis, it is aimed to reconstruct local hunter-gatherer environments, specifically around El Mirón cave, because these are the ones that actually affected their daily life activities. Type of main prey species also affects environmental-human relationships, where animal ethology is defined as "The scientific study of the behavior of animals in their normal environment, including all the processes, both internal and external, by which they respond to changes in their environment" (ALLABY 2009: p. 194). Refining our understanding of Upper Pleistocene animal ethology, the science of animal behavior and its evolution, also improve reconstructing human economic actions and decision making. To do so, two approaches have been achieved: 1) stable isotopic analyses on red deer, ibex and horse teeth exploring effects of annual climate seasonality and 2) analysis of phytolith embedded in the dental calculus of those same animal teeth considering composition of dietary intakes.

Tooth enamel, the hardest body tissue in all mammals, was selected to carry out stable isotope analyses on the hydroxylapatite or bioapatite fraction for this study on 'old' Paleolithic archaeological material. This body material is considered being the most resistant to diagenetic alterations (BRYANT ET AL. 1996). The lower organic content and a lower porosity due to larger apatite crystals making of it the least prone body material to undergo diagenetic alteration, relative to dentine and bone (KOHN & CERLING 2002); why it is preferred for Paleolithic studies. Tooth bioapatite $Ca_{10}(PO_4,CO_3)_6(OH,CO_3)_2$ has two ionic variations of oxygen which can be used for isotope analysis: the more abundant phosphate (PO_4=$\delta^{18}Op$ = $\delta^{18}O_{PO4}$ = oxygen in phosphate) and the structural carbonate (CO_3=$\delta^{18}Oc$ = $\delta^{18}O_{CO3}$ = oxygen in carbonate).

Tooth formation takes place as shown in a compiled eruption pattern for red deer and ibex species (Figure 3.41). This pattern is also of interest for stable isotope analysis as it is fundamental for the patterning of stable isotope signal distribution, where seasonal environmental signals will be inferred (chapter 4.3). Because during the mineralization process of tooth enamel, it records the isotopic composition of local environment conditions and dietary intake within its anorganic fraction (e.g. oxygen and carbon stable isotope composition). Hypsodont (e.g. large bovids, horse) and brachyodont (red deer) herbivore teeth, preferentially lower M3 (sometimes the associated M2) were chosen for intra-tooth sampling. These molars have the longest formation duration (VIGAL & MACHORDOM 1985; BROWN & CHAPMAN 1991b) (compare Figure 4), thus, their isotopic signal spans the longest time range.

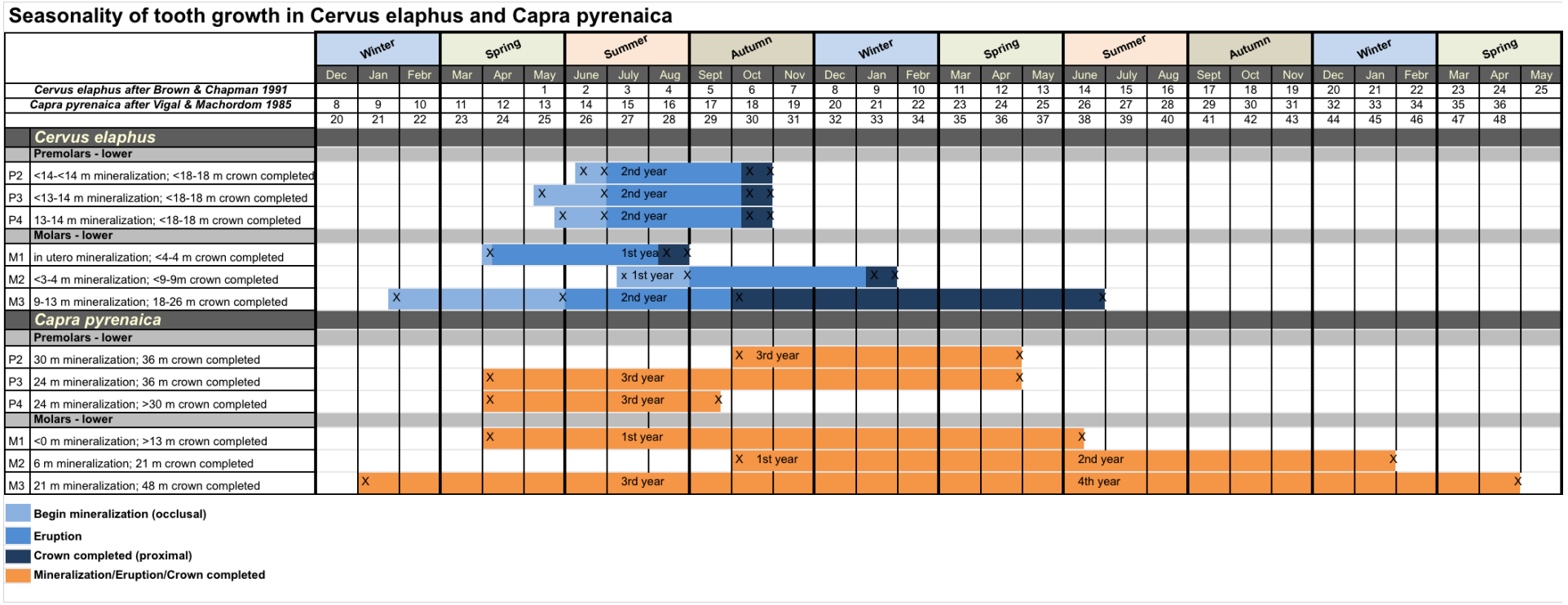


Figure 3.41: Dental mineralization duration of red deer and Spanish ibex teeth.

3.6.1 Stable isotope analysis

First, teeth with a well-preserved Enamel-Root-Junction (ERJ), with the highest and most complete lobe and limited visible taphonomic alterations were preselected for analysis. On the best-preserved buccal face of the lobe (either anterior or middle) were measured the height from the ERJ to the occlusal surface.

A fume extractor was prepared by using a large piece of tin foil as underlay, placing inside in easy to reach distance a hand- drill and some diamond drilling bits with flat, conical surfaces. The chosen and measured surface for sampling was gently cleaned with the drill bit until all sediments, cementum, encrustations, etc. were cleaned away. A ~6min ultrasonic bath in and quickly rinsing with ionized water was used to remove the smallest particles from the sampled teeth, which were then left for drying overnight.

Every individual enamel powder was collected with a hand-held burr with diamond tipped dental drill bits on a weighing paper. Grooves were drilled sequentially on the buccal face and perpendicularly to the tooth growth axis from the cervix to the apex of the crown. Each sample consist of a horizontal 1-2mm-thick band spanning the width of one, either anterior or middle/posterior, molar lobe (compare Figure 3.42). The first sample was taken on the closest possible point to the ERJ to obtain the very last signal of enamel formation and the last closest to the occlusal surface for the oldest one (FRICKE & O'NEIL 1996; FRICKE ET AL. 1998, Fig.2; BALASSE ET AL. 2003; TÜTKEN ET AL. 2008; JULIEN ET AL. 2012). The most possible amount was tried to take out of every sampling band, with up to ~12mg of enamel powder. A caliper was used to record the distance from the ERJ to the middle of the sampling band. After each sampling, drilling bits were cleaned with dipping into weal nitric acid (4%), dipping in ionized water and an ultrasonic bath in ionized water.

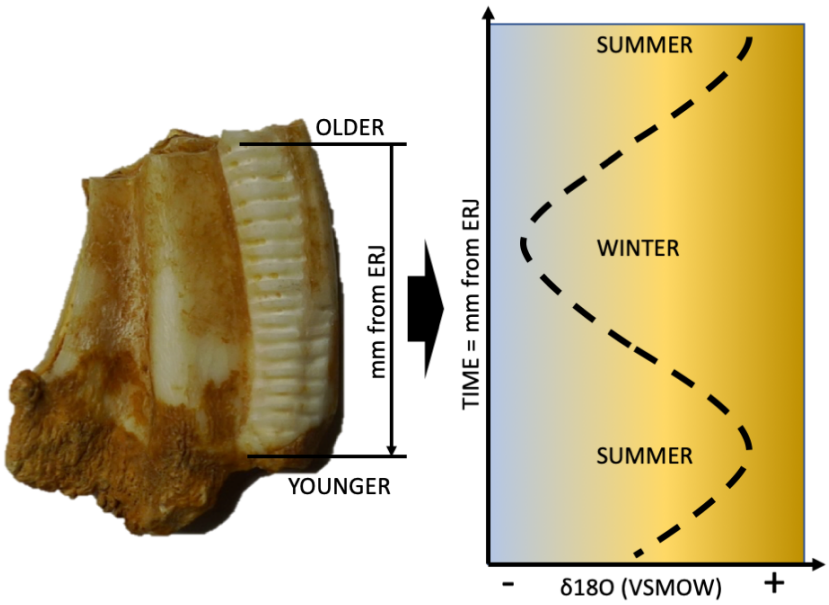


Figure 3.42: Intra-tooth sampling strategy and model of seasonal variation of isotopic composition tracked in tooth enamel powder samples.

On tooth enamel powder samples for carbonate analysis, researcher often apply a pretreatment protocol with the aim to clean the sample. The procedure includes to remove organic matter, before bioapatite analysis is performed (BOCHERENS ET AL. 1994; BALASSE 2002). With ongoing research in stable isotope analysis, the pretreatment procedure (H_2O_2) is questioned for introducing secondary carbonates into the samples, and some recommend no pre-treatment for tooth enamel at all (CHENERY ET AL. 2012). Different experiments on samples preparation for carbonate analysis have been performed to test these hypotheses. A pretreatment

process would ideally remove contamination (proposed to use acetic acid to remove secondary, non-lattice-bound carbonates) without affecting the isotopic composition or introducing additional carbonate material (example of pretreatment effects can be found in LEE-THORP & VAN DER MERWE 1991; KOCH ET AL. 1997), while pretreatment experiments have shown that the carbonate fraction of the bioapatite can be affected to varied degrees (CROWLEY & WHEATLEY 2014; SNOECK & PELLEGRINI 2015). First, some chemical treatments increase the $\%CO_3$ content of the sample, which clearly imply an introduction of external-surrounding carbonates, which could alter the original isotopic signal. For example, all oxygen isotopic values are increased after pretreatment with unbuffered acetic, with a low pH may prevent the absorption of treatment-induced carbonates during oxidation. Untreated fossil material is slightly depleted in $\delta^{18}O$ and enriched in $\delta^{13}C$ compared to fully pretreated fossil enamel (ROWLAND 2006). The difference between mean isotopic values of untreated and fully pretreated enamel is within the 95% confidence level and lower than uncertainties associated with other aspects in isotopic studies (ROWLAND 2006).

These pretreatment problems of tooth enamel mainly affect the carbonate group of the bioapatite, while the phosphate group is generally more resistent to diagenesis. At an intra-tooth level, the carbonate-phosphate oxygen isotopic fractionation factor ($\Delta CO_3\text{-}PO_4$) can be used to test for possible diagenetic alteration of the isotope values (IACUMIN ET AL. 1996; MARTIN ET AL. 2008; CHENERY ET AL. 2012). The relation of VSMOV and VPDB according to the conversion of can be used. Structural carbonate measurements on oxygen values stated in relation to VPDB (Vienna PeeDee Belemnite) were transferred to VSMOW standard values, accordingly $\delta^{18}O_{CO3}$(‰VSMOW). For transferring oxygen ‰VPDB values to ‰VSMOW the equation of Coplen 1983 was used (COPLEN ET AL. 1983: p. 237):

$$\delta^{18}O_P(‰\text{VSMOW}) = 1.03091 \times {}^{18}O(‰\text{VPDB})) + 30.91$$

The correlation of oxygen values in phosphate and carbonate have been calculated using following equation (IACUMIN ET AL. 1996):

$$\delta^{18}O_P = 0.98 \times \delta 18c - 8.5$$

The mean, relative constant fractionation factor between phosphate and structural carbonate is described in modern mammals by a difference of 9.1‰ (suggesting to regard samples with offsets of <7‰ and >11‰) (BRYANT ET AL. 1996; MARTIN ET AL. 2008; PELLEGRINI ET AL. 2011; CHENERY ET AL. 2012; DOMINGO ET AL. 2015) .

$$\Delta^{18}O_{CO3} - {}^{18}O_{PO4} = \delta^{18}O_{CO3}(‰\text{VSMOW}) - \delta^{18}O_{PO4}(‰\text{VSMOW}) = \delta^{18}Oc \quad - \delta^{18}Op \quad = (\sim 9.1\%)$$

In a similar manner, researchers thought that the pretreatment for analysis of the phosphate group need to be performed to remove competing sources of oxygen such as associated organic matter. The pretreatments techniques should equally effectively remove organic matters and not modify original $\delta^{18}O$ values. However, empirical tests of different methods, such are sodium hypochlorite (NaOCl) alone and in association with sodium hydroxide (NaOH), and hydrogen peroxide (H_2O_2), showed that pretreatment is completely unnecessary in highly mineralized tissues, such are teeth (GRIMES & PELLEGRINI 2013). It can be summarized that in general, the phosphate group is more stable against replacement, and alterations.

According to the above stated aspects of stable isotope analysis, the following sampling procedure was applied:

A dual stable isotope analysis on carbon and oxygen of enamel carbonate was made. No pretreatment is performed to avoid the inclusion of secondary carbonates. From the same samples oxygen analysis is

performed on the phosphate group, and the $\delta^{18}O$ value difference is used to identify diagenetic alterations of the samples. The predominant and hence a large reservoir of oxygen is the phosphate, its amount acts as a buffer therewith it resists better exchange with the sedimentary environment. However, tooth enamel samples from the Lower Magdalenian in the Cabin (Outer Vestibule) area of El Mirón Cave, are often referred to being well-preserved (GEILING ET AL. 2016; STRAUS ET AL. 2018). From the row of sequential sampled tooth enamel, the samples from the oxygen peaks and troughs of the obtained oxygen curve were combined to perform strontium analysis, to later determine whether $\delta^{18}O$ fluctuation coincide with migratory behavior.

Within bioapatite, both phosphate and carbonate oxygen, precipitate cogenetic in equilibrium with body water (BRYANT ET AL. 1996; CHENERY ET AL. 2012) with a fractionation factor between phosphate and carbonate of 1.0090 at 37°C by invariant mammalian body temperatures (IACUMIN ET AL. 1996). On that basis, bioapatite diagenetic alteration can be assessed calculating the difference between $\delta^{18}O_{CO3}$ (in carbonate) and $\delta^{18}O_{PO4}$ (in phosphate) values ($\Delta^{18}O_{CO3}–PO_4 = \delta^{18}O_{CO3} – \delta^{18}O_{PO4}$). The signal differences were compared among tooth enamel of two teeth from this study.

The carbon content (%), the carbon and oxygen isotope values of the enamel powder was measured by mass spectrometry via Iso-Analytical Ltd., Sandbach, Cheshire, UK. Isotopic composition was expressed using the δ notation as parts per thousand (‰) difference from the Vienna Pee Dee Belemnite (VPDB) standard for $\delta^{13}C$ values and $\delta^{18}O$ values are reported relative to Vienna Standard Mean Ocean Water (VSMOW).

The silver phosphate precipitation (for PO_4 analysis) from tooth enamel samples was done by the author and S.Pederzani and K.Britton in the laboratories of the Department of Human Evolution at the Max Planck Institute in Leipzig, Germany. For analysis 232 samples were treated. The wet chemical procedure used for the rapid silver phosphate precipitation from enamel samples followed a method developed by Dettman et al. and modified by Tütken et al. (DETTMAN ET AL. 2001; TÜTKEN ET AL. 2006) include the following steps as shown in the figure below (Figure 3.43). Between 3-10mg of tooth enamel was weighed in Eppendorf tubes and dissolved in 400-800µl of 2M HF and the supernatant was collected after 24h. One drop of Bromothymol blue and NH_4OH was added until the solution was neutralized. 400µl of silver nitrate solution (0.2M $AgNO_3$) was added to the supernatant. Samples were centrifuged for ~5min and rinsed 4 times with DI water, and then were left in an oven for 8h at 50°C for drying of yellow crystals of Ag_3PO_4. Ag_3PO_4 crystals were recovered and weighed into pressed silver capsules. The sample silver phosphate samples were measured in triplicate, together with quality control and normalization standards, which encompass ~964 silver capsules.

Mass spectrometry. Silver phosphate (Ag_3PO_4) samples were analyzed by S.Pederzani and the author at the stable isotope laboratory at the Max Planck Institute for Evolutionary Anthropology (MPI-EVA) in Leipzig, Germany. The silver phosphate precipitate was weighed into silver capsules in three aliquots. Analysis were conducted on a high-temperature conversion elemental analyzer (TC/EA) coupled to a Thermo Fisher Delta V Advantage via a Conflo IV interface. Samples were pyrolized in the TC/EA using a reactor temperature of 1450°C. Sample were two-point scale normalized using a commercially available Sigma Aldrich silver phosphate (AS337382; $\delta^{18}O = 14.0 \pm 0.3$ ‰) and a commercially available Sigma Aldrich benzoic acid (242381; $\delta^{18}O = 21.4 \pm 0.3$ ‰). Aliquots of in-house standard silver phosphates (after every eight samples) were repeatedly analyzed along with the samples for quality control purposes. Repeated measurements of in-house standards are precise to within 0.3‰. The standards used were an in-house bison enamel standard, WMB14E ($\delta^{18}O = 19.5$‰) and the ashed enamel, standard NIST SRM 1400 ($\delta^{18}O = 16.4$‰), which were precipitated alongside samples to ensure equal treatment. Triplicate $\delta^{18}O_{PO4}$ analyses were carried out in 100% of the samples. The average absolute difference for $\delta^{18}O_{PO4}$ of replicates was 0.15‰ and the standard deviation of this average difference was 0.08‰. Oxygen $\delta^{18}O_{PO4}$ results are reported relative to the VSMOW standard.

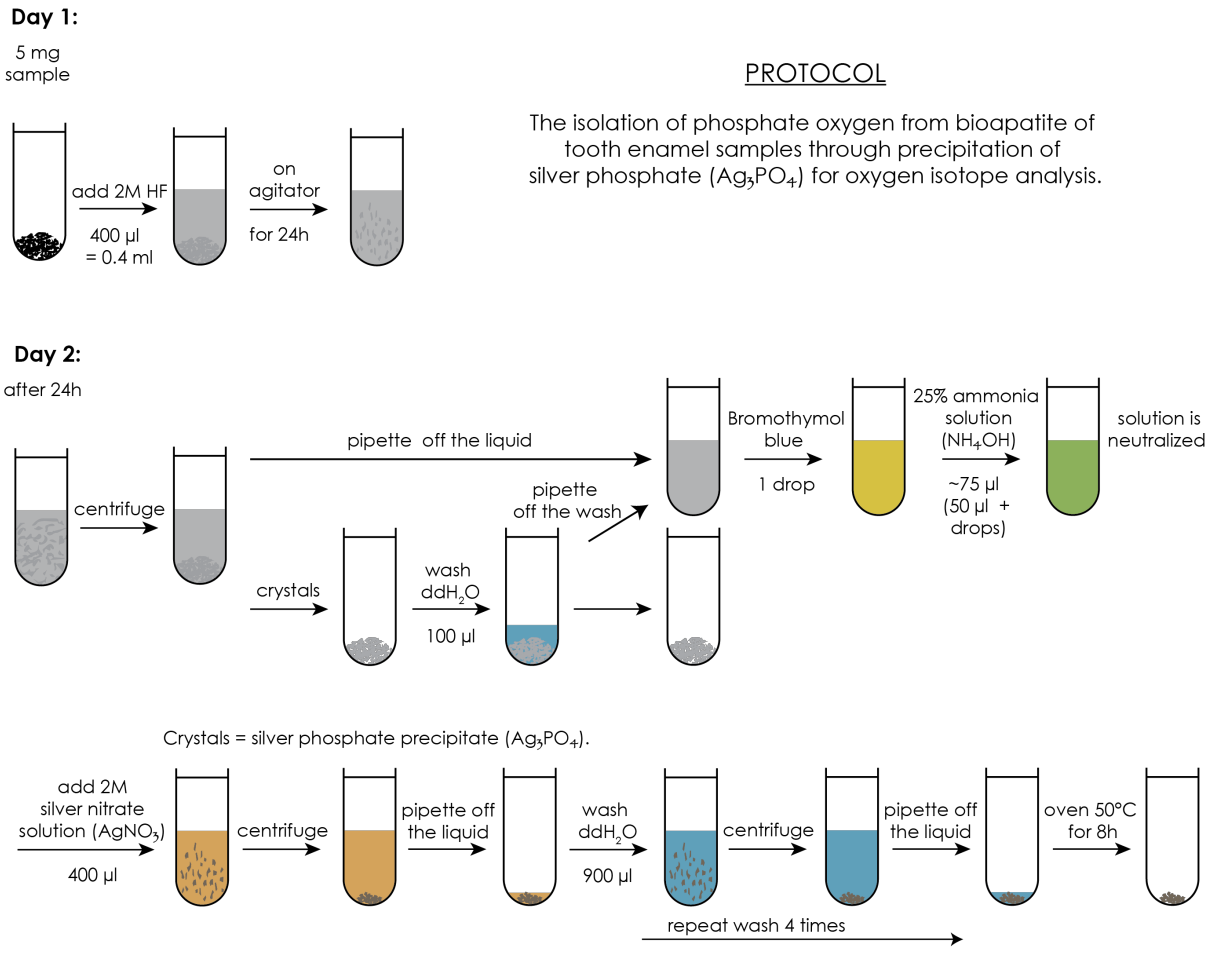


Figure 3.43: Workflow illustrating the protocol applied for silver phosphate precipitation of tooth enamel samples.

Empirical studies have shown that oxygen incorporation during mineralization of body tissues can be related to environmental waters, because $\delta^{18}O$ compositions of body water derive from ingested water in food and drink (LONGINELLI 1984; LUZ ET AL. 1984; BRYANT & FROELICH 1995; KOHN ET AL. 1996; KOHN 1996).

By applying different equations, the oxygen signal of imbibed environmental waters was reconstructed and compared:

- for horse $\delta^{18}O$ enamel (VSMOW)= ($\delta^{18}O_{PO4}$-22.6)/0.71 (DELGADO HUERTAS ET AL. 1995);
- for red deer $\delta^{18}O$ enamel (VSMOW)= ($\delta^{18}O_{PO4}$-25.53)/1.13 (ANGELA & LONGINELLI 1990; DOMINGO ET AL. 2012);
- for ibex $\delta^{18}O$ enamel(VSMOW)= ($\delta^{18}O_{PO4}$-24.39)/0.91) (DELGADO HUERTAS ET AL. 1995).

Expected possible seasonal models of $\delta^{18}O$ variation are shown in the following table (Table 3.25). Influential factors can be temperature, precipitation, altitude, diet, mobility, etc.

Table 3.25: Possibilities of seasonal $\delta^{18}O$ variation in animal tooth enamel samples.

$\delta^{18}O$ Variation	Obligate drinker					Non-obligate drinker					
Season	spring	summer	autumn	winter	spring	spring	summer	autumn	winter	spring	
Moderate rainfall with seasonal difference in temperature	normal, sinusoidal curve					normal, sinusoidal curve					colder←→warmer
Dry summer, winter season rainfall	normal, sinusoidal curve					enriched summer values					colder←→warmer
Groundwater or mixed water (lake) ingestion	seasonal damping					seasonal damping					colder←→warmer
Meltwater summer (periglacial zones)	reversed curve, depleted summer values					depleted summer values in plant water					colder←→warmer
Migration	damped seasonal curve					normal, sinusoidal curve					colder←→warmer
Dietary shifts	normal, sinusoidal curve					stretched sinusoidal curve					colder ←→ warmer

Strontium was extracted from enamel at the clean laboratory facilities of the MPI-EVA using the following method. Clean enamel samples (~10mg) were weighted in large size container and dissolved with 2ml nitric acid 65% solution (HNO3). All dissolved samples are put on a heating plate, 120°C, and were then evaporated to dryness. The resulting residue was re-dissolved in nitric acid before loading three times the sample into pre-conditioned micro-columns containing strontium-specific resin that hold the strontium and were rinsed with water. Strontium was eluted from the resin in adding acid and dried. Isotope analyses were conducted with a ThermoFinnigan Neptune Multi collector mass spectrometer by Dr. Klervia Jaouen. Results are quoted as Sr87/Sr86 ratio. The strontium isotope composition from the underground are absorbed by local plants which are consumed by herbivores. Differences in strontium isotope signature compared to the local

bioavailable $^{87}Sr/^{86}Sr$ signals determined by the surrounding underground can provide information regarding human and animal mobility (BENTLEY 2006).

3.6.2 *Phytolith analysis from herbivore dental calculus*

Complementary to the above stable isotope analysis, trial dental calculus analyses of horse, bos/biosn, red deer, and Spanish ibex teeth of El Mirón Lower Magdalenian levels were done. While floral organic dietary remains are often hardly preserved in paleontological contexts, phytolith silicate bodies preserve very well as representatives of dietary intakes. Those plant mineral particles, phytoliths, can be preserved in tooth representing food remains consumed and accumulated during the animals live. The aim is to determine whether dietary variability might be responsible for varying stable isotope values and if they vary through time. It is considered accordingly, what kind of plants were consumed from the animals that were consumed by humans by means of phytoliths content in main game dental calculus, which also can affect stable isotope signals in those animals. Such kind of analysis applied in combination with stable isotope analysis can improve both interpretations.

Samples of dental calculus were taken under clean conditions using tin foil, powder free gloves and dentist tools in the Bioarchaeological laboratory at the University of Cantabria. The dental calculus preserved on top of the teeth surface, sometimes falls of on its own or can be easily removed without destroying the tooth surface (Figure 3.44). All teeth were photographed before and after sampling. Following protocol was applied: Working space was prepared with tin foil and cleaned with methanol. A smaller piece (circa 10 cm x10 cm) of tin foil was used to collect the sample, also cleaned before with methanol. A dentist tool was cleaned with methanol and used to extract the samples of dental calculus from the teeth. A unique code was given to the samples, for example: PHY-01, PHY-02, or PHY-03. Tin foil, dentist tool and nitrile powder-free gloves were cleaned after each sample with methanol to avoid contamination from previous samples.



Figure 3.44: Dental calculus sampling from animal teeth (Bos/Bison H2-1362, Level 17, Spit 49)

The samples were sent to L.M. Hilbert at the University of Exeter where he performed the following protocol for phytolith extraction: The dental calculus sample were put in solution to dissolve all other parts than the silica bodies. Then, the extracted phytoliths were placed onto microscopic slides. Phytolith identifications were made using published material (BOYD ET AL. 1998; PIPERNO 2006) and by direct comparison with the phytoliths reference collection of the Archaeobotany and Palaeoecology Laboratory in the Department of Archaeology of the University of Exeter by Dr.L.M.Hilbert. Phytolith slides were fully scanned, counted and photographed under a Zeiss Axioscope 40 light microscope at 500X magnification. Raw data of phytoliths identified are recorded in an excel table. Relative frequencies of phytoliths identified per sample are compared and morphotypes are presented. Finally, the phylogenetic classification of the *Poaceae* family used in this study will follow the reports of Soreng et al. (2015) and Judziewicz et al. (2000).

All these analysis, however, should be interpreted in context of contemporary settlement records available through radiocarbon record in the Cantabrian Region, which will be considered.

3.7 A chrono-cultural-climatic assessment

For modeling age probabilities and human dispersal of human occupation in the Cantabrian Region following analytical steps include radiocarbon age modeling and maps of locations with evidence of human presence.

An age model for the Cantabrian Region from the late Middle Paleolithic to the final Magdalenian is established using a quantitative analysis of radiocarbon dates. The radiocarbon dates available are plotted for the Cantabrian Region, while certain dates were excluded for reasons of disagreements in chronological displacement (for example, dates incoherent with the archaeological context) or lack of diagnostic cultural attribution or layer admixture. When multiple radiocarbon dates are available for the same layer, the youngest date for the targeted faunal comparison was used to obtain a minimum age and to avoid the need to average dates, which can produce other uncertainties.

A multigroup age model was created with the program CalPal2016.2 (using CalPal2007 Hulu calibration curve, CALPAL March 2007 version, WENINGER & JÖRIS 2008) for late Middle to Upper Paleolithic occupations of El Mirón cave and the Vasco- Cantabrian Region. It is based on an accumulated probability curve of calibrated radiocarbon dates to which will be referred to within the following sections. For comparison were plotted the oxygen isotope variation curves ($^{18}O/^{16}O$) obtained from Greenland ice cores GISP2 (GROOTES ET AL. 1993; MEESE ET AL. 1994) and IBERIAN MARGIN C37_4 400 ka core data (MARTRAT ET AL. 2007).

Cantabrian Paleolithic sites were subdivided by cultural entities, namely Late Middle Paleolithic, Aurignacian, Gravettian, Solutrean, Initial-Lower Magdalenian, Middle Magdalenian, and Upper-Final Magdalenian. Sites with evidence of human occupation and sites with cave art were included to better understand human territoriality for the different cultural periods. Individual sites were plotted on a GIS map (Quantum GIS) and selectively plotted by cultural periods. For visual mapping of cultural dispersion, they were then used to draw contour lines of 20km diameter to let merge sites within a 10km range to each other, a reachable distance within a day.

3.8 Summary of materials and methods

Finally, Table 3.26 summarizes the multidisciplinary methods applied, including extended collaborations with a diversity of researchers and institutions. Such collaborations, as espoused since 1996 (and in their earlier projects) by the El Mirón Cave Prehistoric Project Co-Directors Professors Straus and González-Morales, constitute the most promising approach with which to study the paleoeconomic dynamics (Paleoecodynamics) in El Mirón cave and the whole Cantabrian Region and to establish reliable interconnections among multiple research areas and institutions, in Spain, the rest of Europe and the USA.

Table 3.26: Summary of the methodological approach applied in this multidisciplinary dissertation.

Material	Method	Who? Where?
Quantification of materials	NISP, MNE, MNI, MAU, etc.	JMG (UNICAN)
Zoological identification	anatomic atlas, reference collections	JMG consulted collections: Laboratorio de Bioarqueología (UC) in Santander, Centro de Patrimonio Arqueológico de Gipuzkoa in San Sebastian; MNCN (CSIC) and CCHS (CSIC), both in Madrid
Taphonomic identification	naked eye, magnifying class, binoculars Leica S8 APO, reference collections	JMG consulted collections: Laboratorio de Bioarqueología (UC) in Santander
Hunting strategy	statistical analysis (MS Excel, R, PAST)	JMG (University of Cantabria)
Mineral identification of bone coloration	SEM-EDX and X-ray analysis	R. Seva (University of Alicante)
Intra-site spatial distribution analysis	GIS visualization and spatial statistics (ArcGIS, Quantum GIS)	JMG (UNICAN)
Stable isotope analysis	sampling	JMG (MPI-EVA, University of Aberdeen)
	pretreatment	JMG, S. Pederzani (MPI-EVA)
	mass spectrometry	O→S. Pederzani O→JMG Sr→K. Jaouen C,O→IsoAnalytical Ltd.
Phytolith analysis	sampling	JMG (UNICAN)
	identification	L.M. Hilbert (University of Exeter)
Published C14 dates	CALPAL program and age model	JMG (UNICAN)
Regional mapping	GIS analysis and visualization (Quantum GIS, ArcGIS)	JMG (UNICAN)
Combined data	Synthesizing a *Chaîne opératoire* of human actions, subsistence strategies & economic changes	JMG (UNICAN)

CHAPTER 4: PALEO-ECONOMY AT EL MIRÓN CAVE



El Mirón site location

CHAPTER 4:

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4 PALEO-ECONOMY AT EL MIRÓN CAVE

4.1 Taphonomic agents and modification processes

In this chapter, the results of the inter-level taphonomic analysis from the macro-mammal faunal remains of Levels 121 to 130 (vestibule rear, corral area), Level 504 (burial area), and Levels 15 to 21 (vestibule front, Cabin area) will be presented. The different types of anthropogenic, carnivore and natural taphonomic modifications on individual bones will be compared among the levels to disentangle the accumulation history.

This chapter is organized as follows: first, the general analytical results on the preservation state of the material are provided; secondly, the biostratinomy of faunal remains is described and, thirdly, the post-depositional components (diagenesis) that modified the faunal assemblage are presented. Once the origin of the deposit and its accumulative agents are known as compiled in this chapter, archeozoological interpretations could be made, in particular those relevant to human economic behavior (Chapter 4.2). After the role of human groups has been identified in each archaeological and cultural level, the taphonomic results are used to reconstruct the *chaîne opératoire* of human actions from food acquisition to its further exploration as raw material source.

4.1.1 Preservation and quantification of faunal materials

The quality of the faunal assemblage is reflected in the abundance and preservation of the material. Here, the total faunal quantity, bones versus the teeth frequency, identification rate, fragmentation size index, and fracture pattern are compared among the levels.

First, the quantity of faunal materials, as shown in Figure 4.1, varies among the levels. Levels 20, 21 and 120 (Level 120 is actually mixed material at the very base of the looter pit) contain less than 100 items, and these have been excluded for the statistical analysis, while the Middle Paleolithic Level 130, Early Upper Paleolithic Levels 128/129, Solutrean Levels 121-127, Initial and Lower Magdalenian Levels 15-19 and 504 contained a significant Number (NR). In contrast, remains in Lower Magdalenian levels (specifically Level 17) of the vestibule front are abundant compared to the Solutrean and older levels located within the rear vestibule of the cave. The overwhelmingly richness of faunal assemblages of Lower Cantabrian Magdalenian context is a known phenomenon (STRAUS 1992; STRAUS ET AL. 2015d).

For better comparison of numbers of faunal remains were investigated quantification methods that relates densities to each other as excavated levels were of very different thicknesses. For example, the NR from Level 17 is extraordinarily rich, yet the material studied represents only about 50% of the excavated Lower Magdalenian (LM) faunal material. It has to be also kept in mind that the excavated part of the Cabin area represents 9.5m^2 in a cave vestibule of at least 250m^2 (approximately 8-16m wide by 30m length) in surface dimensions. In total, the faunal material studied here comes from an area of 13.25m^2, still only representing a small part of the cave vestibule surface area. Almost all archeological assemblages represent a sample of the original information, which is a decline in integrity by natural or unnatural alterations or filters according to its taphonomic history and sample selection (BINFORD 1981; LYMAN 1994; SCHIFFER 1996; ORTON 2000). I'd like to highlight this fact as it emphasizes that knowledge about the taphonomic history of a sample will enable interpretation of such and "the recovery of unobservable hominid behaviour" (CLARKE 1973: p. 17).

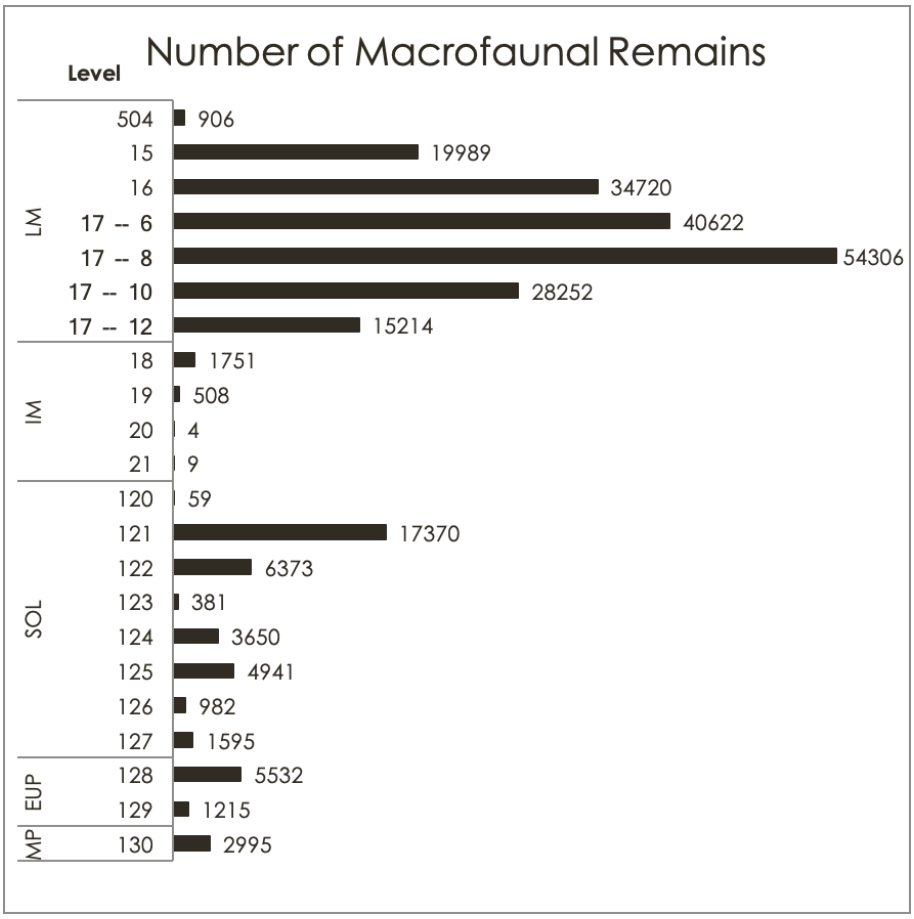


Figure 4.1: Number of macrofaunal remains organized by levels and cultural periods.

Second, the presence of bones versus teeth within the faunal assemblage is evaluated. The percentage of teeth within every sample varies between 0% and 78% (shown as percentage of the number of specimen=%NR, Figure 4.2). Extremities therein are represented likely by outliers coming from small assemblage numbers (Levels 20, 21 and 120). The other levels, however, have a tooth representation between 0.5% and 12% with an average of 3.4% and a standard deviation of 2.96. This low standard deviation shows that the relationship of these two categories is relatively stable between most of the levels. Given the stable relation of these two categories (bones and teeth) through the levels, major perturbation or destruction processes or loss of materials can be excluded that would have biased further intra-level comparisons. This is not the case here.



Figure 4.2: Percentages of bones and teeth per levels by NR.

Third, a Faunal Density Index (FDI) was calculated. The Faunal Density Index indicates the quantities of remains in terms of NR per 1cm depth by square meter (m^2) based on the excavated squares, level and thickness of each square meter (Table 4.1). This index is used as a good indicator of quantity among the studied units.

Table 4.1: Excavated area indicating the levels, excavated m^2 and thickness of each levels that correspond to the studied faunal material.

Cultural attribution	Level	Studied (m^2)	Level thickness (cm)	Faunal Density Index (FDI)
Lower Magdalenian (LM)	504	3.75	~10	24.2
	15	9.5	5-10	210.4
	16	9.5	15-20	182.7
	17--6	9.5	~5	855.2
	17--8	9.5	~5	1143.3
	17--10	9.5	~5	594.8
	17--12	9.5	~5	380.4
Initial Magdalenian (IM)	18	0.25	20	350.2
	19	0.25	10	203.2
	20	0.25	10	1.6
	21	0.25	10	3.6
Solutrean (SOL)	120	1	~10	5.9
	121	2	3-7	1240.7
	122	2	~5	637.3
	123	1	3-7	54.4
	124	2	5	365.0
	125	2	10-12	205.9
	126	1	20-25	39.3
	127	2	10	79.8
Early Upper Paleolithic	128	3	25-45	41.0
(EUP)	129	2	40	15.2
Late Middle Paleolithic (MP)	130	2	>100	15.0

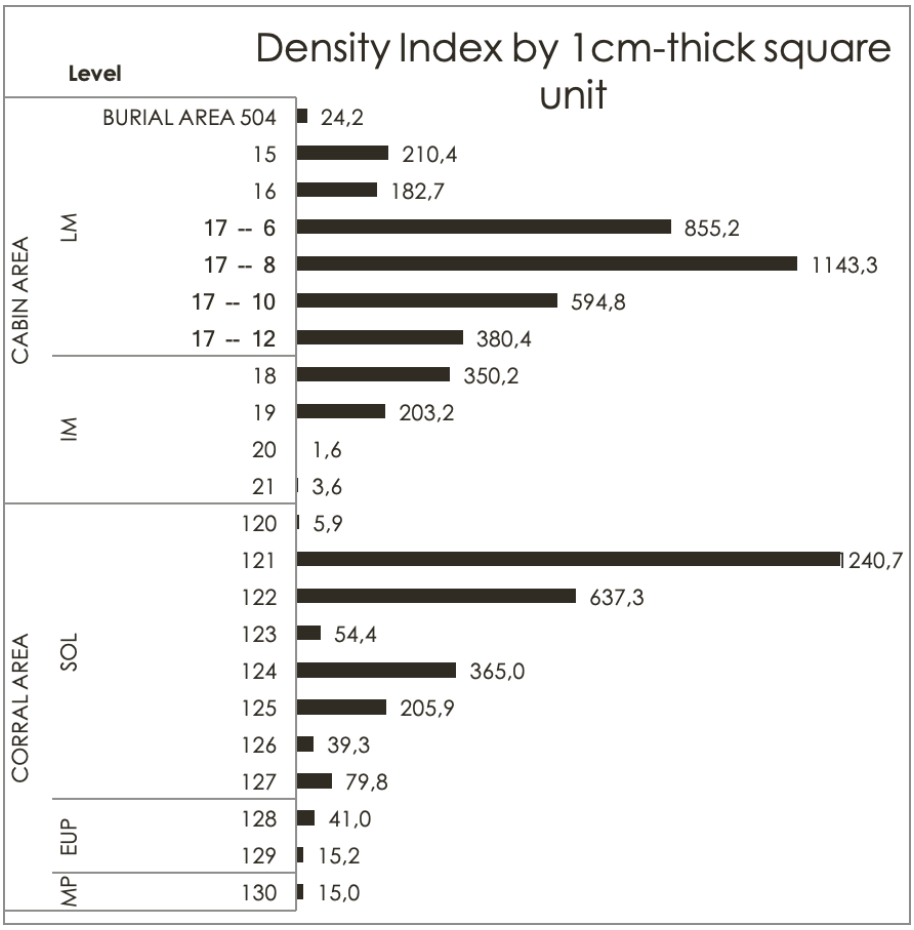
The results indicate that the Lower Magdalenian (LM) is the cultural period with the largest amount of faunal remains and highest density (Figure 4.2), while the lowest density is seen during the Late Middle Paleolithic (MP). Levels 20, 21 and 120 reflecting the small sample size.

By considering the excavated square meters, the following levels and cultural periods show very low densities: Middle and Early Upper Paleolithic and some of the Solutrean levels (123 and 126). They all might represent some repeated but limited human visits.

The other 50% of the Solutrean levels, late Initial and Lower Magdalenian levels show a high density within the stratigraphic units, which is only lower in Levels 15 to 16 and Level 504. The Lower Magdalenian Level 504 shows a lower density in comparison with the front vestibule, maybe due to its spatial location in the rear corner of the cave vestibule with reduced sun exposure and in a narrow space between the cave wall and a very large block. Maybe this area was used more indirectly during occupations producing lesser find density than the more exterior areas of the vestibule, before the burial was dug and this area obtained a new purpose. The difference in find density of contemporary levels infer that the Lower Magdalenian human occupations were distributed widespread throughout the cave vestibule, but more intensively in the front

vestibule area compared to the rear one. Later will be tested, if such intensity of archaeological remains and finds is the results of domestic activities and residential site use.

It is worth mentioning that Solutrean Level 121, located on the rear vestibule already, shows a density comparable to some of the Lower Magdalenian occupations found on the front, suggesting that a likely intensified use of the rear vestibule corral area started at the end of the Solutrean occupations. An alternative interpretation could be that some mixture of archaeological materials occurred during excavation as Solutrean levels were described as following the lay of the steep erosional slope (of ~15 degrees) of ancient alluvium to the inner cave and Magdalenian levels were banked horizontally against them, without hiatus (STRAUS ET AL. 2013).



$$\text{Faunal Density Index} = \frac{\text{total}_{\text{NR}}}{\text{m}^2{}_{\text{excavated per level}}} \times \text{thickness(cm)}_{\text{level excavated}}$$

Figure 4.3: Comparison of faunal density per level and cultural periods. Below: equation for calculation of the Faunal Density Index for one centimeter thickness of excavated square meter.

Fourth, through an identification rate can be evaluated the quality of results. As shown in Figure 4.4:, the faunal remains identified within the general bags contributed significantly to increase the numbers of anatomically and taxonomically specimens. Without considering these remains, usually categorized as the non-identifiable fraction and presorted during excavation, essential information for the understanding of the transported prey, socio-economic activities or spatial organization would have been lost coming from smaller items. This is the most important aspect of the study of this small fraction that, in addition, the success of these tasks often depends on the skills of the faunal identification specialist. The advantage of this task is

that usually elements such as teeth, horn and antler fragments are frequently found within the general bags, thus increasing the representation of the skull. The lower front and hind limbs also increase by including carpal and tarsal bones.

Thus, these results indicate that this not truly 'non-identifiable fraction' increased in average to 94.7% the identification of anatomical and taxonomical identified specimen in the Early Upper Paleolithic, 57% in the Solutrean and 52% in the Lower Magdalenian to the identification rate. This is especially interesting and important when looking at the distribution of the identification rate among the skeletal representation and derived interpretations in what will follow. These results highlight that obvious and necessary adaptations of excavation and faunal study techniques to density of finds in levels can impact the interpretative outcome, requiring adequate consideration. The former is already taken care of by modern excavation techniques, and the latter should therefore be focused on (future) zoo-archaeologists.

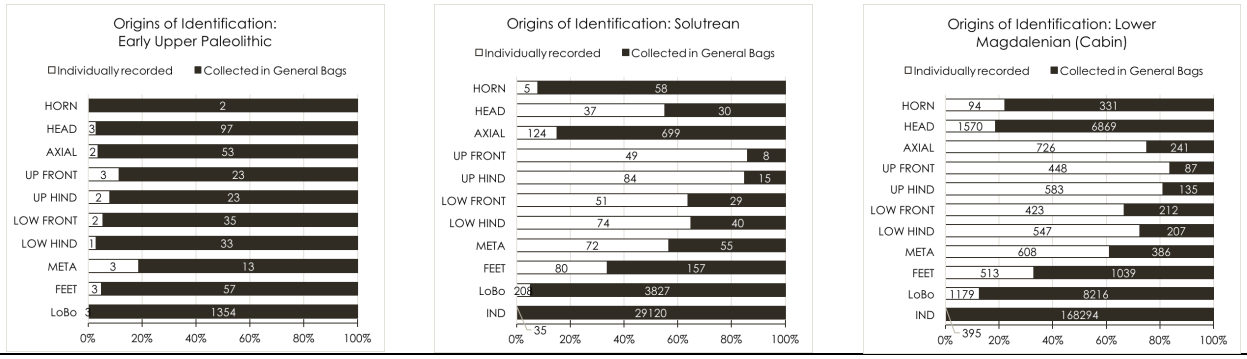


Figure 4.4:Total body part representation for Early Upper Paleolithic, Solutrean and Lower Magdalenian levels related to its precedence (either individual or generally recorded during excavtion).

Fifth, a Fragment Size Index (FSI) was calculated. The Fragment Size Index (FSI) is compared through the sequence for red deer, ibex, horse, bovine, chamois, the medium to large size mammal category as well as the combined of all fragments. The results indicated the higher values, the higher the degree of fragmentation.

The average FSI stays around 3 to 4 over time (Figure 4.5), although increase up to 7 to 8 in the samples 17-12 to 17-8. Level 16, however, shows a general decline and in Level 15 increases again. The change of the FSI among the levels might indicate that preservation conditions are less favorable in the older levels, in relation to overburden sediment pressure or other diagenetic alterations. However, this scenario is not very likely, because a gradual increase of fragment size was not observed. Instead a general change towards an accumulation of larger fragments in younger levels might be more plausible, which might not be explained taphonomically, but rather behaviorally. The fragmentation degree is often referred to as being associated with bone marrow and grease rendering techniques employed by human groups (OUTRAM 1998; MANNE ET AL. 2006; COSTAMAGNO 2013; FLADERER ET AL. 2014; KARR ET AL. 2015), which imply a more intensive use of bone nutrients and, thus, more exhaustive bone processing. The explanation of a transport of bones from larger animals (bison or horse) or more elaborated exploitation techniques that leave larger splinters behind or the collection pieces as raw material resources might be other explanations which should not be discarded.

Additionally, the different sample sizes might give rise to a more diverse bone assemblage. Each of these scenarios, however, do not explain the change in the average value after 17-6 (the uppermost part of Level 17) to the overlying Level 16, which are both Lower Magdalenian occupations. Either the value was oddly

high in Level 17, or the results imply that in Level 16, presumably another factor influenced the accumulation and preservation of this deposit, which will be explored further.

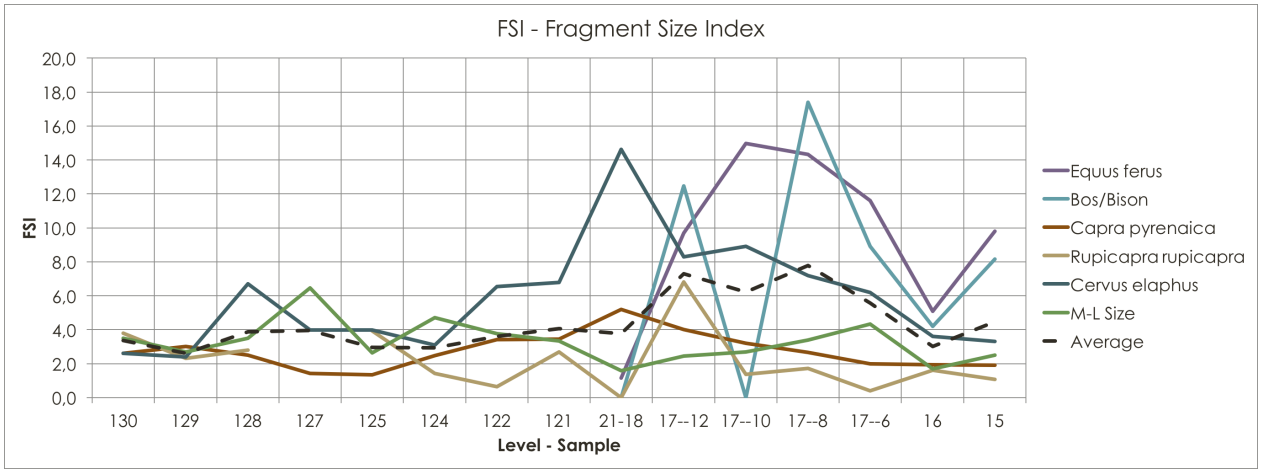


Figure 4.5: Fragment Size Index variation. 130: Late Middle Paleolithic, 129 to 128: Early Upper Paleolithic, 127 to 121: Solutrean, 21 to 18: Initial Magdalenian, 17 to 15: Lower Magdalenian.

Sixth, the fracture pattern of bones is analyzed. A relatively high amount of fresh (green) fractures was observed among the Middle Paleolithic, the Early Upper Paleolithic, most of the Solutrean (125 to 121), the Initial (21 to18) and Lower Magdalenian (17 and 504) levels. Initially, these results indicate that a high percentage of these bones are the results of biostratinomic agents that intentionally cracked the bones when either they were still in fresh conditions, or were lying on the surface before sedimentation. Together, human, carnivores and birds of prey, such as the bearded vulture, are the possible accumulation agents that can leave fresh fracture patterns when cracking bones (RUSSELL 1987; DAVIS ET AL. 2007; MARÍN-ARROYO & MARGALIDA 2011; BORAO ÁLVAREZ ET AL. 2016; COIL ET AL. 2017). The bone breakage morphologies, tooth/impacts marks, prey representation and skeletal profiles as such allow to determine more in detail the accumulation agent.

The fracture pattern observed during the study is summarized as the amount of fresh fractures per level/sample in Figure 4.6: . The lower percentages (~20% or less) of fresh fractures in Levels 127, 16 and 15 can have different explanations. Some of the faunal assemblages have different amount of completely preserved bones (Level 504), so that, complete bones do not count on the fracture pattern, but one long broken bone can provide several fractured items for the record. Some of these levels seem to represent main occupations or animal processing areas and others 'garbage' areas, hence, the cave area was differently used by humans or carnivores. Alternatively, advanced weathering stages can 'hide' the original fracture pattern, which is then no longer determinable (possible Level 16 and 15). Fresh fractures can also be overprinted by diagenetically younger arisen fractures, which occur later within the taphonomic history, such as sediment or recent fractures. Some bones may have lied in surface exposed to diagenetic alterations for longer than the others experienced a more rapid interment having more fresh fractures (early Level 17).

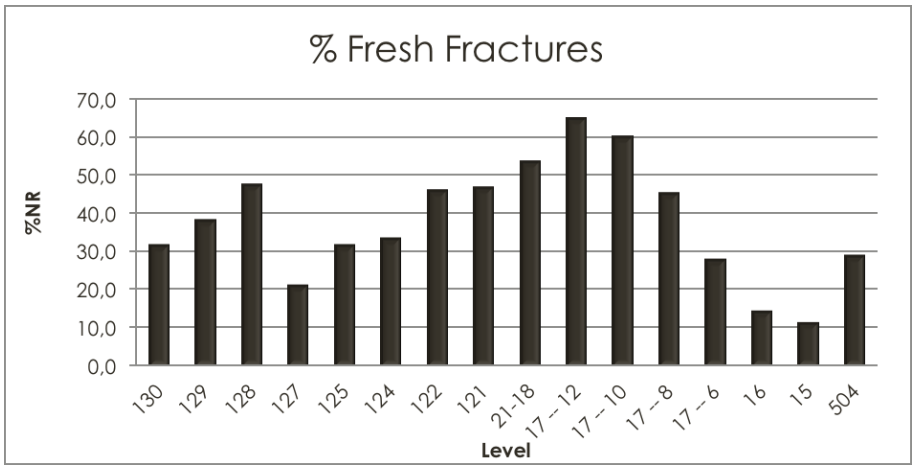


Figure 4.6: Percentage of fresh fractures among the studied faunal remains.

4.1.2 Carnivore activities

Within the following section the biostratinomic alterations, those that occurred before the burial, recorded within the faunal assemblage are presented as they have been essential to identify the accumulation agents and to reconstruct the accumulation history of the assemblage. Here is reconstructed the Carnivore activity at El Mirón Cave.

Carnivore marks appear in two main groups: tooth and digestion marks. They are distributed differently among the levels as Figure 4.7: shows:

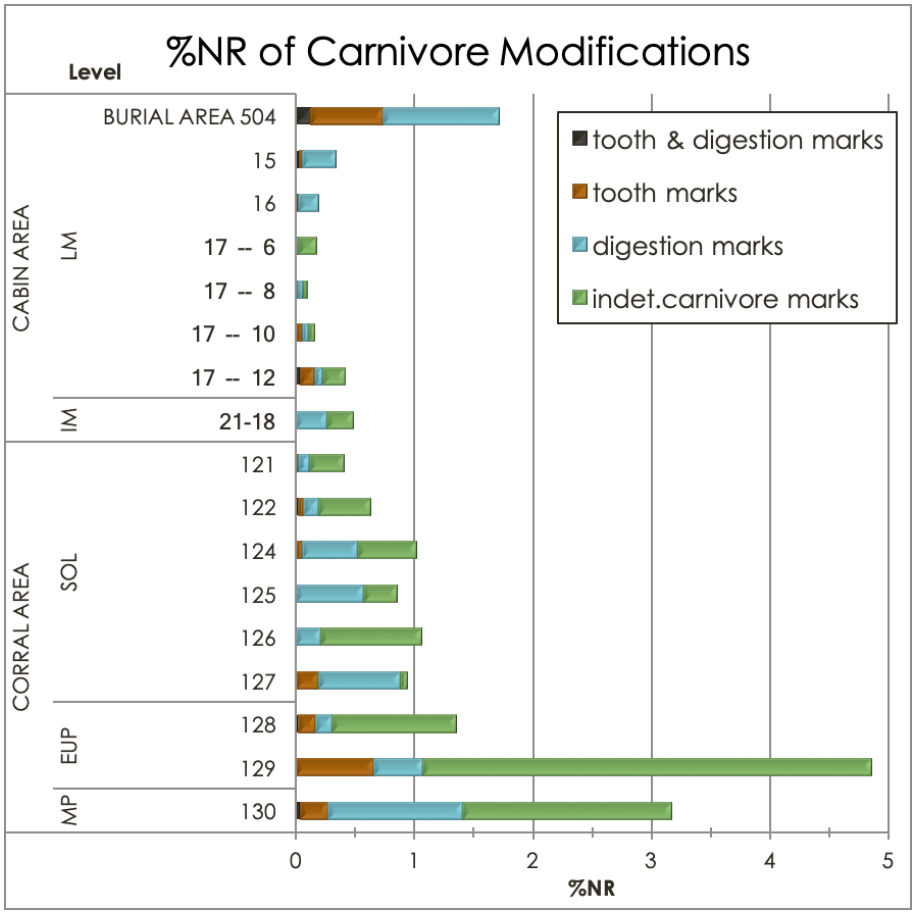


Figure 4.7: Carnivore modifications recorded by levels and periods. Codes: MP=Late Middle Paleolithic, EUP=Early Upper Paleolithic, Sol=Solutrean, IM=Initial Magdalenian, LM=Lower Magdalenian.

While percentages are greater in the oldest levels, the highest number of carnivore marks have been found in the Lower Magdalenian levels, presumably because their richness in numbers of total remains. The carnivore actions can be further subdivided (as explained in methodology) into different carnivore action patterns of: pitting, puncturing and scoring (Type A), furrowing, gnawing and chewing (Type B) and digestion marks (Type C).

Figure 4.8 shows their distribution. Type A modifications are the most common found, distributed mainly on the shoulder and pelvic girdle, followed by feet, axial parts and long bones and these represent 50% of the carnivore modifications of the Late Middle Paleolithic, 53% of the Early Upper Paleolithic, 78% of the Solutrean and 55% of the Lower Magdalenian fauna. 40% of type B modifications are found on the Late Middle Paleolithic and Early Upper Paleolithic long bones and carpal and tarsal bones. Type B marks represent 22% in the Solutrean and 26% in the Lower Magdalenian levels. Type C marks, containing both tooth and digestion marks, were mostly found in the axial, long bones and feet of the Lower Magdalenian levels. These are hardly represented in the Middle and Early Upper Paleolithic and Solutrean levels.

Although, the quantity of the carnivore marks hardly varies among the studied faunal units, they are mostly dominated by type A (from defleshing and transport of bones), followed by type B (from disarticulation and eating) and C (regurgitation or excretion), which might indicate rather short and/or occasional stays of carnivores in the cave vestibule.

According to the size of tooth marks diameter identified previously, in particular on the human tibia in the Lower Magdalenian levels in the burial area, one of the agents was possible a wolf (compare MARÍN-ARROYO 2015; MARÍN-ARROYO ET AL. 2018a). Most of the few clearer carnivore pitting marks (n=6) on the skeletal elements are smaller and indicating small carnivores such as marten, fox, or lynx. However, among the taxa were only identified beside wolf, red fox and lynx remains.

In summary, the impact of carnivore modifications is low and they seem to have played generally a small role, especially during the Late Glacial accumulation of the faunal deposits at El Mirón cave, with activities more pronounced in bone surface modification. Possible scenarios are human-carnivore alternating cave use (see STRAUS 1982) and faunal deposits being more carnivore dominated in the Late Middle and Early Upper Paleolithic layers, generally low during the Solutrean and more numerous during the Lower Magdalenian. If declined presence of carnivores in this montane site during the Solutrean was due to climate is yet difficult to determine. This higher impact of carnivores during the Lower Magdalenian is remarkable, which surprisingly include the period of most frequent human occupations. The frequency, however, is low regarding the high NISP of those occupations. It might be possible that a more recurrent human presence, and subsequently more frequent accumulation of food leftovers, attracted small carnivores for scavenging activities. Such noticeable use by carnivores, however, would also imply repeated use and abandonment of the cave, maybe between regular seasonal occupations. Or, these human occupations were specifically associated with carnivore presence in terms of 'early' signs of domestication as a wolf or dog (?) as has been suggested as responsible for the gnawing marks on the human tibia found in the Lower Magdalenian burial (MARÍN-ARROYO 2015). There is one other hint of possible early domestication in the region found by a humerus in contemporary occupations in Erralla cave, with a morphology and size more similar to a dog than a cuon (ALTUNA & MARIEZKURRENA 1985: p. 111).

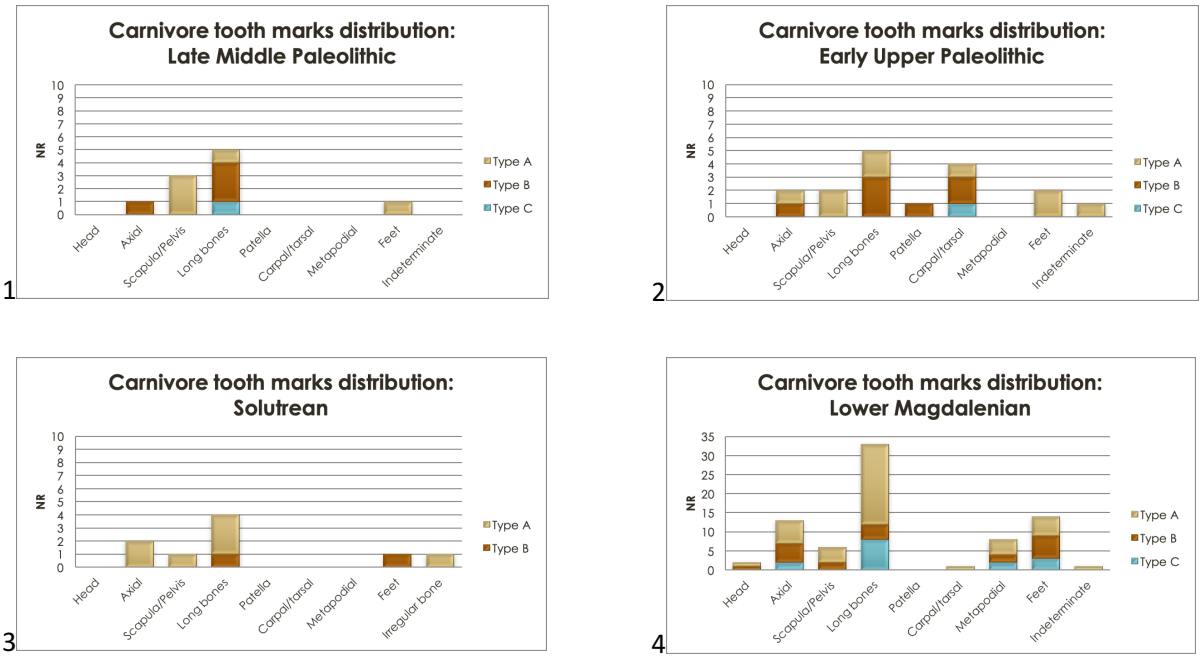


Figure 4.8: Distribution of carnivore modifications by periods and skeletal representation. Type A = pitting, punctures, scoring; Type B= furrows, gnawing, chewing; Type C= digestion.

Digestion marks are the second most important category to characterize carnivore activities. The Middle Paleolithic faunal remains, several skeletal elements are altered by digestion marks, but concentrated on teeth and feet elements, while the Early Upper Paleolithic levels show fewer bones affected. Within the Solutrean, only metapodial and feet are affected. For the Initial Magdalenian, only foot elements show digestion marks. The Lower Magdalenian occupation contains the highest number of digested faunal remains (Figure 4.9).

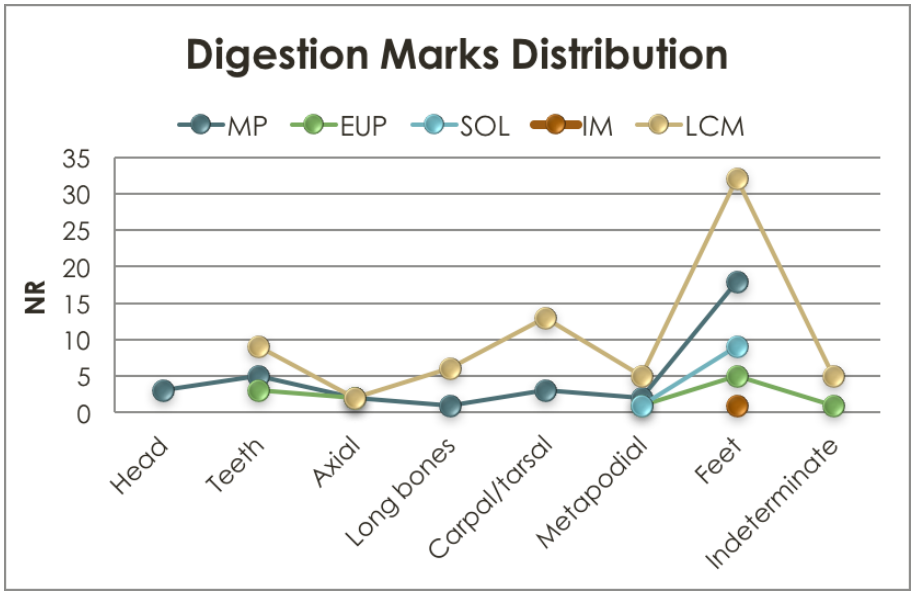


Figure 4.9: Number of digested bones by body part and cultural unit. MP=Late Middle Paleolithic, EUP=Early Upper Paleolithic, Sol=Solutrean, IM=Initial Magdalenian, LM=Lower Magdalenian.

Among all these levels, the feet are the elements mostly digested, followed by carpal/tarsals, teeth, long bones and metapodia. Despite the different quantities of digested bones between levels, the skeletal profile remains similar with the highest peak resembling the feet, followed by teeth and carpal/tarsal bones and later, long bones. This profile is similar to what was observed in previous studies on bearded vulture activities in El Mirón cave (MARÍN-ARROYO ET AL. 2009; MARÍN-ARROYO & MARGALIDA 2012), where the bones preferentially ingested by vultures are the ones including the most oleic acids (MARÍN-ARROYO & MARGALIDA 2012). Many of the bones showing digestion and lacking gnawing marks encountered display typical similarities to those produced by vulture activities, such are thinned edges, smoothed surfaces and perforations of compacta (DAVIS ET AL. 2007; MARÍN-ARROYO 2010; LLOVERAS ET AL. 2014; SANCHIS ET AL. 2014). Evidence of such proposed vulture activities are abundant in Level 17, which also contained identified vulture bones (see Appendix C) as well as egg shells from bearded vulture who brooded in the cave (DEMARCHI ET AL. 2019).

These data confirm again a probable sporadic presence of carnivores, i.e. vultures within the cave, which, therefore, implies an alternating use by humans and other predators. Thus, a discontinues presence of humans occupying El Mirón cave is implied. The results obtained here indicate that bearded vulture was repeatedly present in El Mirón cave, while their cave use started, at least, during the Late Middle Paleolithic and lasted until the Holocene.

In the Figure 4.10, a comparison between indirect and direct anthropogenic modifications (which detailed description follows in the next paragraphs) with carnivore modification is shown. Indirect anthropogenic modifications are burned bones. Only when these items had cut marks or anthropogenic impacts they were included among direct indicators of human activities. The Solutrean and Lower Magdalenian levels contain ca. 10% of anthropogenic alterations, while the amount is less in the MP and EUP levels. Because Level 504 includes only individual finds, it is not directly compared here in the graph, but it has therefore generally higher percentages of 18.7% direct and 1.7% indirect anthropogenic marks as well as 1.6% carnivore marks.

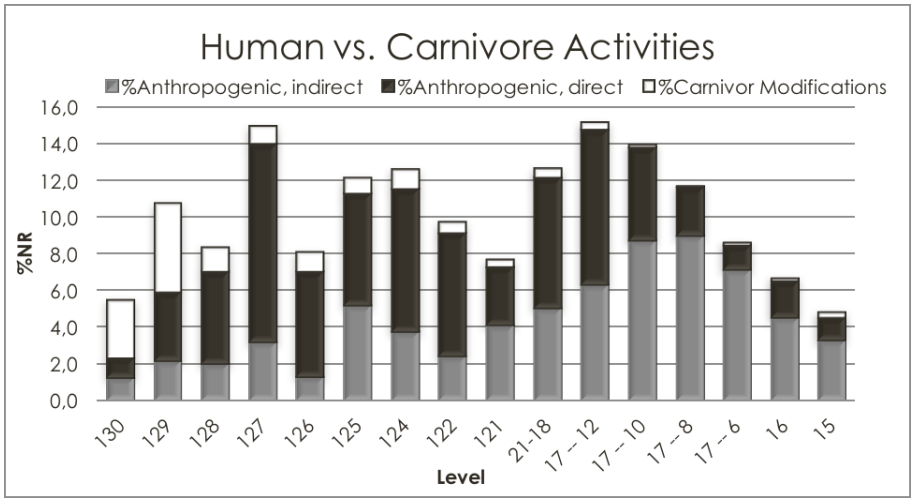


Figure 4.10: Anthropogenic (direct= cut marks and impacts, indirect= burning) and carnivore activities.

In summary, it is remarkable that in every archaeological level significant evidence of human activities have been found, unlike carnivore activities, which occur sporadically across the studied units. In general, anthropogenic activities dominate most of the studied units, despite the Late Middle Paleolithic Level 130 and its overlying-transitional Level 129, where carnivore presence overbears sporadic human presence. Carnivore modifications make up only around 1% of the complete fauna in the present study.

4.1.3 Human activities related to diet

Human activities are in focus of this analysis and will be further discussed in detail considering (A) butchering processes, (B) bone cracking and (C) thermo-alterations as modifications related to diet in differentiation to osseous industry and trampling. They will be presented in this order as they represent the consequent steps of human actions.

An overview of human activities is given in Figure 1.11. Butchering activities that leave cut marks and broken bones, recording as the positive bone flakes and the negative impact marks, are the most common anthropogenic marks found on the animal bones. It is remarkable how the quantity (%NR) of cut and impact marks changes throughout the different time periods.

Firstly, the numbers of flakes increase from the Middle Paleolithic to the Solutrean (Level 126=76.7%) occupations to decrease slowly from Level 125 onwards. Level 17 have a stable representation (13.4%-17.6%) of flakes within its subunits. Cut mark frequencies are highest in the early Lower Magdalenian levels (compare Sample 17-12=17.4% and Sample 17-10=12.1%) compared to the other ones.

Secondly, the number percentage of bones with impact marks, as a result of breakage to extract marrow/grease, is highest in the Initial and early Lower Magdalenian levels, 19.8% and 22.9%, respectively. This implies that, despite the different densities in occupations, prey animals were explored on a similar way by accessing at intensively meat and bone marrow.

Thirdly, the frequency of bone and antler tools starts to increase during the Solutrean with very limited presence in the former cultural periods. These categories include antler and bone points, needles, wedges, retouchers (billets) and 'used' bones, and similar finds, some of them being recently summarized by Straus et al. (2018) in a description of the osseous industry of Level 17 in El Mirón cave.

The studied Level 504 faunal material is comprised of only individual (piece-plotted) finds, thus as a consequence it is missing a majority of the flakes and burnt bones from the general bags, as is visible in the graph (Figure 1.11).

Burning is well represented, but this modification changes throughout the archaeological sequence and it is generally overrepresented due to its easy identification on the small fragment sizes. Burnt faunal remains evidence some kind of elaborated human visits in every studied unit, including at least a hearth.

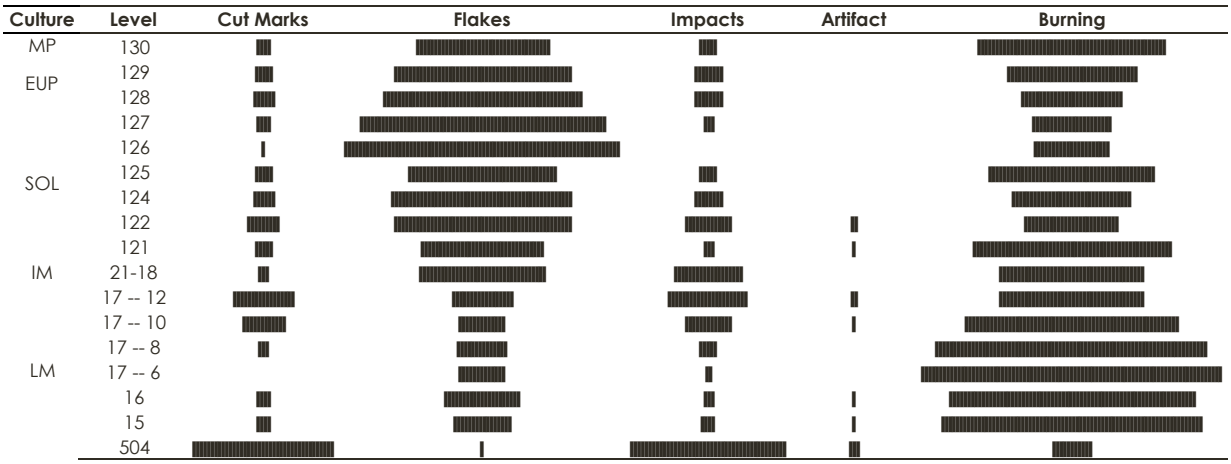


Figure 4.11: Representation of Bone modifications, along the sequence, as a result of anthropogenic activities (%NR). MP=Late Middle Paleolithic, EUP=Early Upper Paleolithic, Sol=Solutrean, IM=Initial Magdalenian, LM=Lower Magdalenian.

A. Butchering Activities are manifestations of human modification on faunal remains. Varied Human activities can be interpreted from cut marks frequency and patterns. Cut marked bone frequencies vary among the main prey species and their skeletal part representation along the studied levels (Table 4.2).

In red deer, the majority of cut marks have been recorded on long bones, most abundant in metapodia. This pattern is especially repeated in Levels 130, 127, 124, 121, 17-12, 16 and 15. The femur is the second bone with the highest amount of cut marks in the Levels 128, 122 and 17-10, followed by tibia, which show the highest density of cut marks in Levels 124, 121 and 17-18. After that, humerus is next-best- represented. Cut mark densities decrease further among the rest of the skeletal part representation, continuing with the lower front, antler, head, axial, and feet element, with the latter having the lowest quantity on cut marks observed.

Table 4.2: Cut mark frequencies by anatomical parts found, along the sequence, in red deer.

LEVEL: BODY PART	130	128	127	125	124	122	121	18	17				16	15
									12	10	8	6		
ANTLER									14	11	12	3	1	
HEAD		1		2		2	1		26	6	1	1	1	
AXIAL			1						15	11	4		1	
UP FRONT		1				4	3	1	24	28	8		2	1
UP HIND		2				4	3		31	44	14	2	2	
LOW FRONT		1			1		1	1	15	18	5	4	2	
LOW HIND			1	1	1	3	6	1	19	31	18	2	5	2
METAPODIAL	1		2		1	3	4		38	39	12	2	10	3
FEET		1				1			7	5	4			
LONG BONE				1		1	2		7	9	3			1
TOTAL	**1**	**6**	**4**	**4**	**3**	**18**	**20**	**3**	**196**	**202**	**81**	**14**	**24**	**7**

In the Lower Magdalenian found in the Cabin area, the distribution of cut marks in red deer shows (Figure 4.12), first, a very similar pattern of low densities in cut marks for the Levels 17-6 and 15 and Level 16; and second, differences between the lower front limb and the metapodial elements. A shift in the spatial separation of the discarded bone elements in Level 17-6 might be a possible explanation for a dominance of lower front limbs or differences within the applied slaughtering techniques producing more cut marks would be possible explanations for these observations. The concentration of cut marks on metapodia in Level 16 and 15 might be due to the further use of only these skeletal elements for osseous industry production or to identification bias by altered bone surfaces.

Further circumstances that could have altered the pattern of abundant cut marks in Samples 17-8, 17-10 and 17-12 might be correlated with the higher number of faunal remains within these units. Levels 17-12 and 17-10 show a very similar cut mark distribution, while the oldest is having the highest amount of cut marks on the cranial elements. The reason for this observation is, presumably that, red deer head elements are most abundant within this unit.

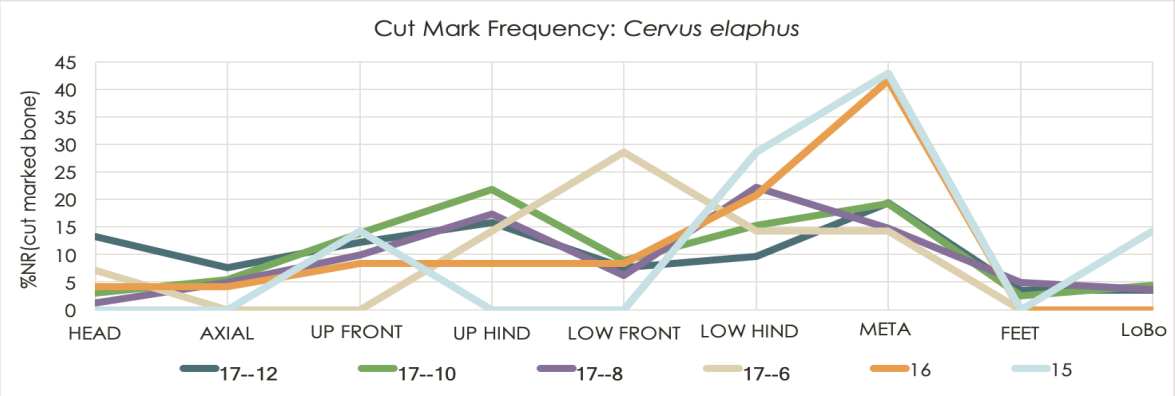


Figure 4.12: Cut mark frequency by skeletal body parts in red deer.

In ibex, in the upper front (shoulder and humerus) skeletal elements there are more cut marks than in the rest of the skeleton, especially observed in Levels 124, 17-12 and 17-10. The upper hind limb is where the second highest amount of cut marks was found, similar to the observed in Levels 18 and 17-6. The lower hind (tibia) skeletal part representation have the third most frequency of cut marks; this part is most frequently modified in Levels 128, 122, 18, and 16. Cut mark densities decrease subsequently in the axial, lower front, metapodial, head, feet and horn (Table 4.3).

Due to the different quantities of cut marks in red deer and ibex it is difficult to compare its pattern among the levels. However, we can conclude that the variation in cut mark density is higher between the Early Upper Paleolithic and Solutrean between the species than between the Solutrean and the Magdalenian, while the final Solutrean is very similar to the Initial and the early Lower Magdalenian.

Table 4.3: Cut mark frequencies by anatomical parts found, along the sequence, in ibex.

LEVEL: BODY PART	130	129	128	125	124	122	121	19	18	17				16	15
										12	10	8	6		
HORN											1				
HEAD					1	2	1			19	17	3		2	
AXIAL			1							11	32	7		3	
UP FRONT					3	1	1			22	30	7		1	1
UP HIND				1			1		2	15	25	9	2	6	
LOW FRONT			2	1	2	1	1		1	14	16	7	1	5	1
LOW HIND			4			4	1	1	2	19	9	9		9	1
META	1	1			1	1			1	9	23	9	1	2	1
FEET				2	1					7	13	13	1	1	3
LONG BONE					1						3				
TOTAL	1	1	7	4	9	9	5	1	6	116	169	64	5	29	7

Cut mark frequency in ibex during Lower Magdalenian occupations also vary (Figure 4.13:). Similar to what was observed in red deer, Levels 17-6 and 15 have the lowest quantity of cut marks and variation on skeletal part elements, possible due to diagenetic preservation. On the other hand, ibex bones in Level 16, have a higher concentration of cut marks with marks concentrating on long bones. The frequency of cut marks is

more evenly distributed on the body part of the sample 17-8, but with a high peak on feet bones. Level 17-10 is characterized by a high amount of cut marks at the axial, upper front, upper hind and metapodial skeletal representation. These imply cutting activities primarily located close to the center of the body of ibex and on metapodia. Level 17-12 shows, again, an even distribution of cut mark frequencies among the skeletal part representation, similar to what was observed for Level 17-8, but in higher quantities.

Cut mark patterns on ibex (Figure 4.13) are more evenly distributed throughout the skeleton than in red deer. They concentrate on axial skeleton and head during the older phases (Levels 17-12 and 17-10) and lower in the younger periods (levels 17-8, 17-6, 16 and 15). Whereas, the cut marks in red deer concentrated on the metapodia, upper hind and on the lower hind body parts. The differences in cut mark patterns, and thus in butchering techniques, among the ibex and deer might be due to the differences in size, indicating that the two species were generally exploited in different ways. This pattern might be biased, however, by the skeletal profile represented as absence of bones also mean the absence of cut marks. For example, if the occupants after deposit of Level 17-10 started to deposit ibex heads somewhere else in the cave, they won't appear in the cut marks pattern anymore.

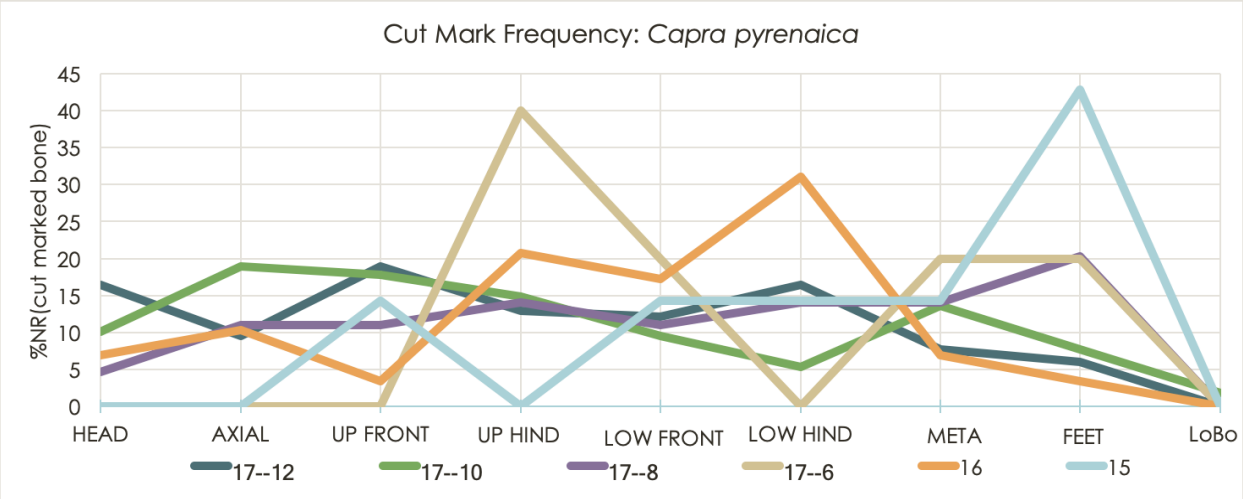


Figure 4.13: Cut mark frequency by skeletal body parts in ibex.

Orientations of cut marks on long bones from each of the main prey species, red deer and ibex, indicate different activities related to butchering, including skinning, disarticulating and defleshing; main orientations and directions of cut marks identified on bones is explored following. Those can be parallel and close to the articulating facies (FA), right angle to the shaft (RI), longitudinal (LO) and oblique (OB) (Figure 4.14:).

Cut marks are rare on the Late Middle Paleolithic faunal remains: only three, and thus an insignificant amount for further interpretations. They were found on a deer metatarsal, an ibex metacarpal and a lumbar vertebra from a medium sized artiodactyl.

Red deer and ibex, the main prey species of the Early Upper Paleolithic occupations present a dominance of oblique cut marks (Figure 4.14: .1-2). On red deer cut marks identified indicate early stage dismembering and skinning activities. These are exemplified by two left femur shaft fragments that resemble the cut mark pattern Fd-4 described by Binford (1981: p. 132), several filleting and defleshing activities are implied. Also within the Early Upper Paleolithic levels, ibex long bones carry cut marks and chop marks implying disarticulation activities. Varied cut marks pattern were identified indicating disarticulation, such are mark MTp-1 of Binford (1981: p. 122), central tarsal bone (TNC-1 after BINFORD 1981: p. 122), second and third tarsal (TE-1) and on a rib (RS-3 after BINFORD 1981: p. 137).

The Solutrean bones show a more complex cut mark orientation pattern than what was observed in the previous cultural occupations at El Mirón cave. The cut marks on the red deer remains of the Solutrean Levels 121-127 are dominated by filleting marks (longitudinal and oblique), while only four resemble disarticulation marks (humerus, ulna and metapodial). Following patterns were identified: a disarticulation mark MTp-1 (after BINFORD 1981: p. 137), two metapodia show skinning marks on the shaft and filleting cut mark pattern Fp-9 (after BINFORD 1981: p. 131). Other bones than the long bones that are carrying cut marks are antler, atlas (disarticulation), mandible and calcaneus disarticulation - TC-1 (after BINFORD 1981: p. 120). On Solutrean ibex bones, in comparison with red deer ones, fewer cut marks have been determined, while also dominated by filleting marks. Humerus, ulna, tibia calcaneus and a second phalanx carry marks that could be associated with disarticulation. Defleshing marks were observed on humerus, radius and ulna fragments. Cut marks were also detected on cranium, mandible, atlas, carpals and sesamoids.

The Initial Magdalenian cut mark observations are limited and don't allow further interpretations (compare Figure 4.14: .5-6).

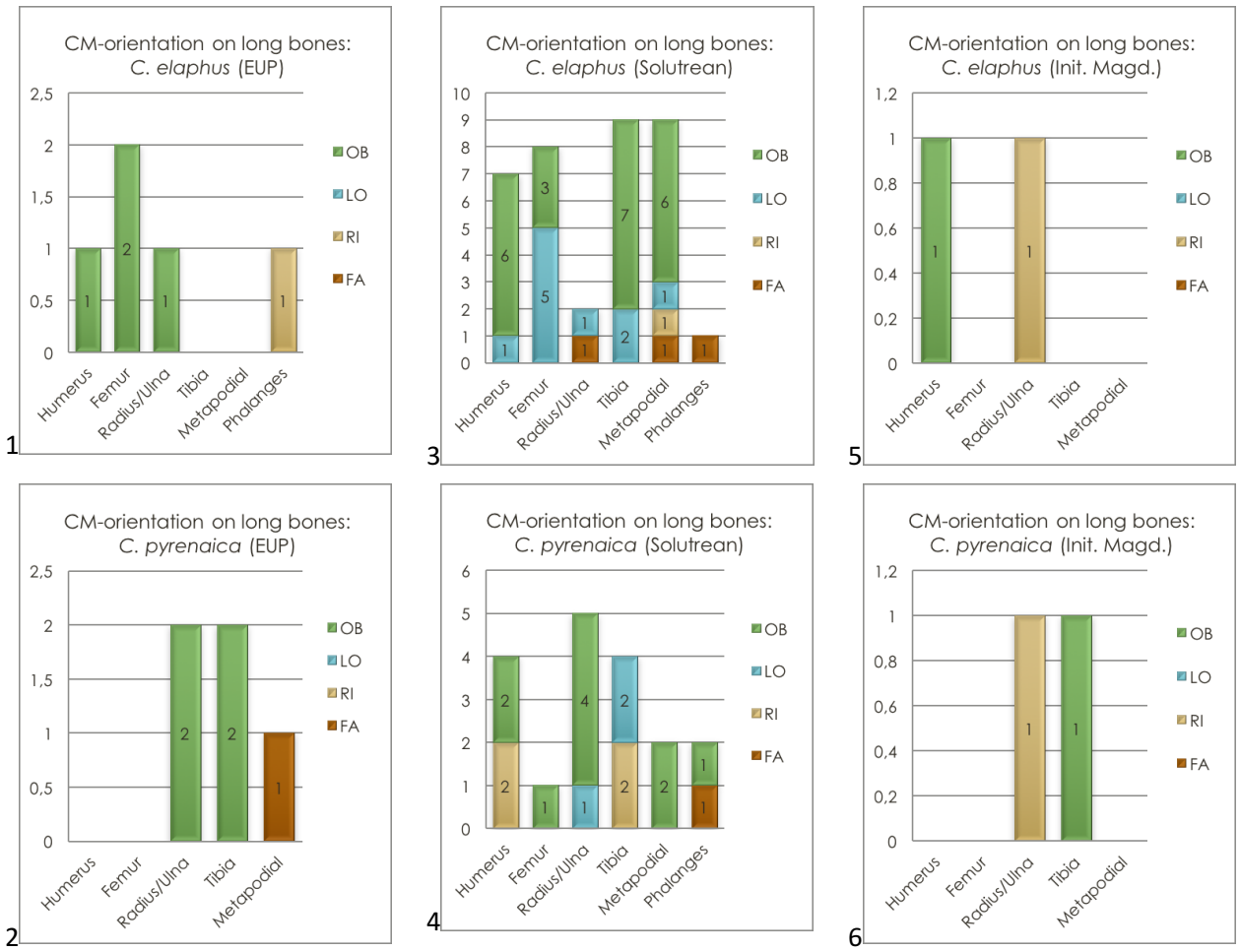


Figure 4.14: Cut mark orientation on long bones of red deer (1,3,5) and ibex (2,4,6) during the Early Upper Paleolithic (EUP), Solutrean and Initial Magdalenian (Init.Magd.).

In red deer, during the early Lower Magdalenian Level 17-12 dominate oblique marks in long bones (Figure 4.15: .1) also in Level 17-10 (Figure 4.15: .3-4). Ibex long bones, though have generally less cut marks represented, which are also dominated by oblique cut marks and those close to the articulating surface, both indicating disarticulating activities.

The cut marks on the long bones from red deer in the Lower Magdalenian Level 17-8 (Figure 4.15: .5-6) are oriented mostly oblique, with less longitudinal and right angle to the shaft ones. In ibex, the same distribution of cut marks was observed, however, the different kinds of marks are more equally spread among the long bones when compared to red deer bones.

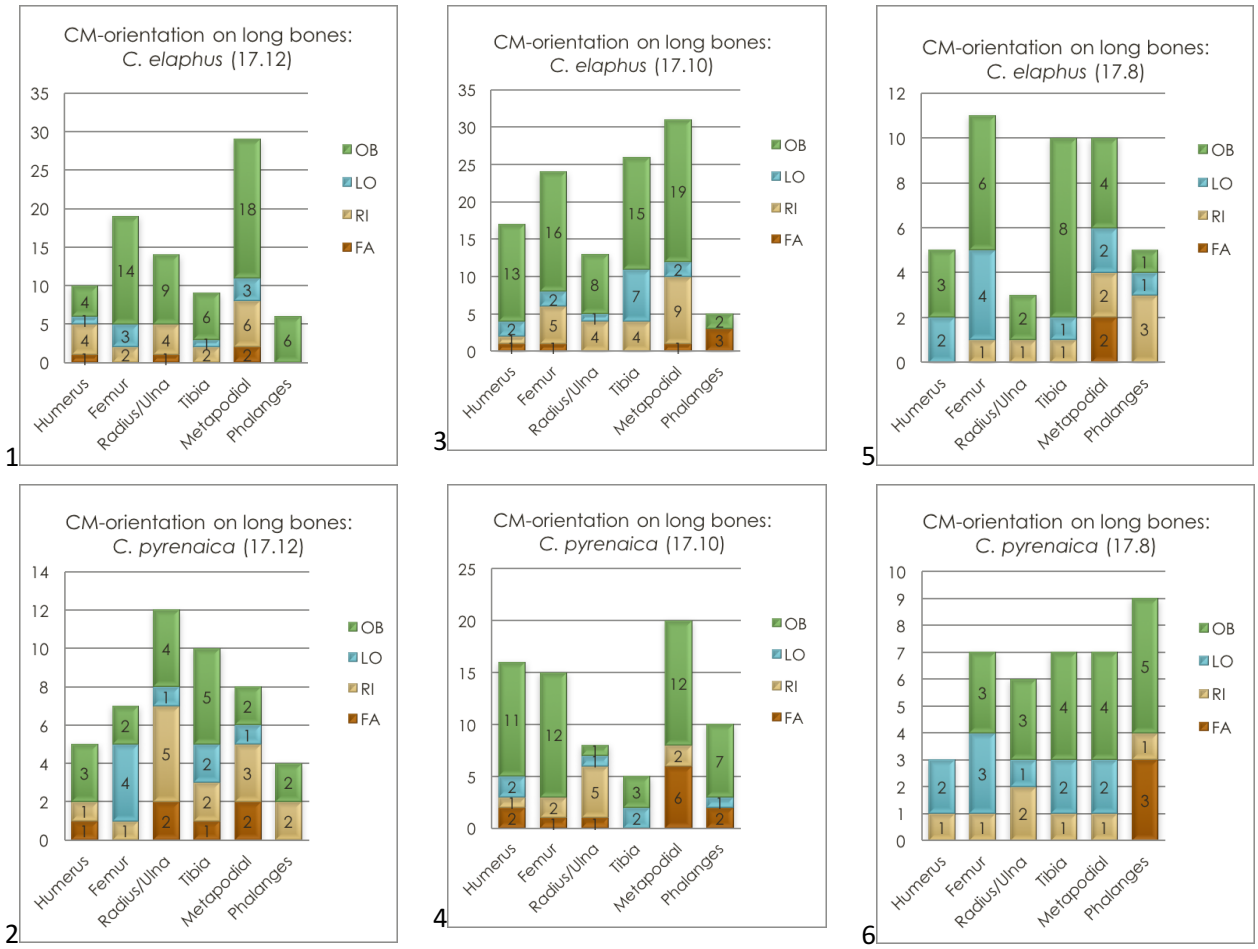


Figure 4.15: Cut mark orientation on long bones of red deer and ibex during the early and middle Lower Magdalenian.

Level 17-6 (Figure 4.16: .1-2) has remarkably fewer cut marks than the underlying levels in the same area. Most cut marks on the red deer long bones in Level 16 (Figure 4.16: .3-4) are dominantly located on the distal extremities, while just a few cut marks were observed among the long bones in Level 15 (Figure 4.16: .5-6).

Of note is that during the Lower Magdalenian, the cut mark orientations are evenly distributed for long bones of ibex. Red deer and ibex bones are dominated by oblique cut marks. In ibex, however, cut marks are oriented on a right angle to the articulating phase they are most abundant in the earlier occupations and decrease in any later sublevel studied. Thus, disarticulation marks were observed less on ibex bones as time progressed from the early to middle Lower Magdalenian occupations. In the same manner increase longitudinal cut marks throughout the skeletal elements. These results may imply an adaptation in the intensity of butchering techniques to the ibex species. Maybe ibex started to be systematically exploited by these groups of people that began to inhabitant El Mirón cave during that period (see STRAUS 1987: ibex hunting in SW Europe was an especially late UP phenomenon). It seems that the red deer butchering activities

were a familiar task to the people since the beginning of the Lower Magdalenian occupations of this site and did not change too much, where they left continuously a low frequency of disarticulation marks on the animal bones. More systematic analysis in the butchering techniques especially between these two species would be helpful to be tested experimentally in future work.

The unit 17-6 (uppermost end of the massive Level 17 horizon) shows fewer cut marks than the older Lower Magdalenian levels, which seems to be the trend followed by the next faunal units of Level 16 and 15, which in turn show intense diagenetic modification that may have overprinted many cut marks.

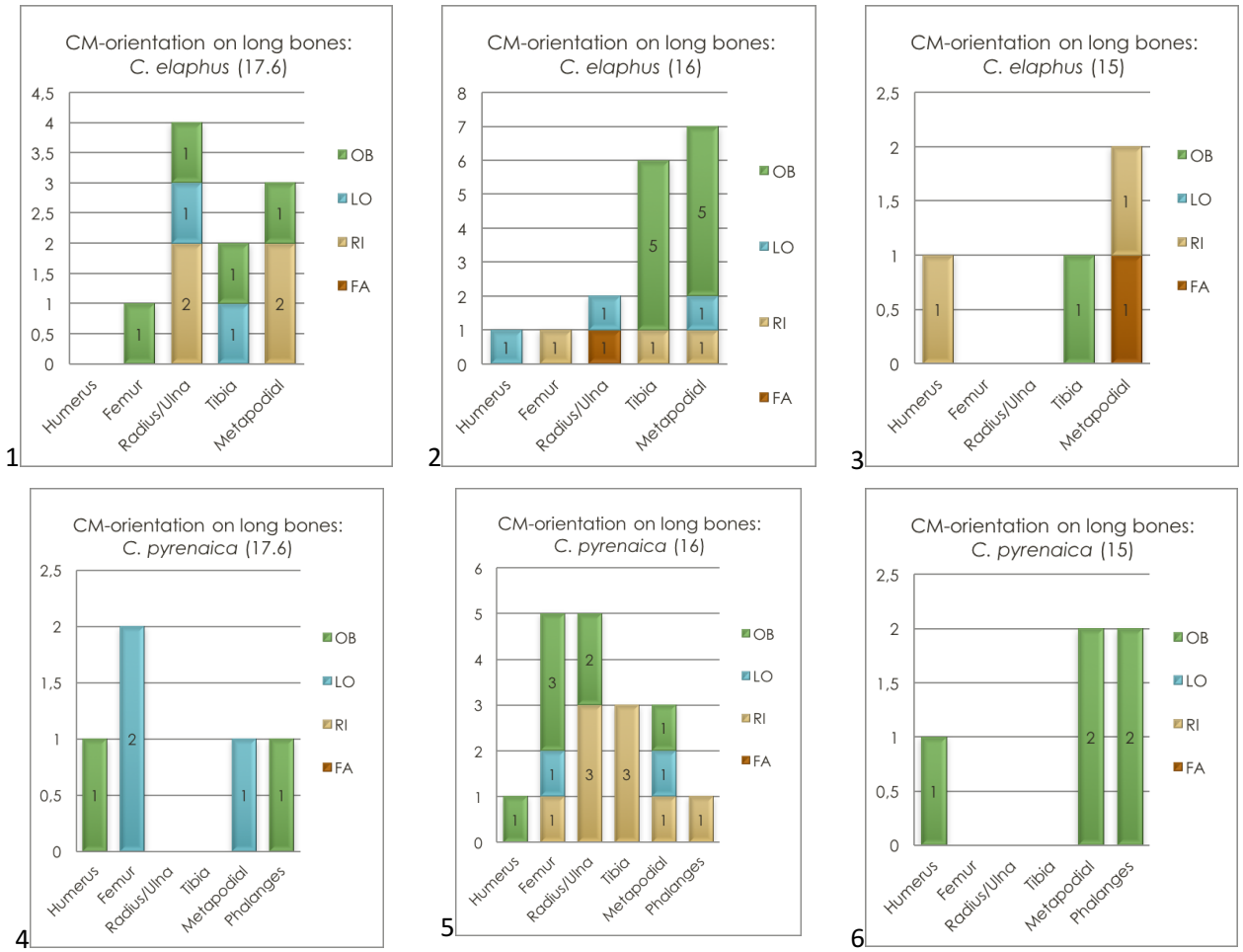


Figure 4.16: Cut mark orientation on long bones of red deer and ibex during the Late Lower Magdalenian.

In general, it is worth noting that most of the cut marks observed could not be classified as specifically contributing to one of the three common butchering activities (skinning, disarticulation, and filleting) and they are, therefore, indeterminate. Additional cut marks related to osseous industry manufacturing or artificial works are summarized within the category of 'others' and were not included here for analysis of butchering activity.

Despite the above mentioned interpretations, for the Lower Magdalenian (Figure 4.17), the following cut mark pattern were recorded on red deer remains in reference to the butchering processes recorded by Binford (1981):

- Level 17-12: disarticulation in humerus (Hd4) and radio (RCp4)

- Level 17-10: disarticulation in humerus (Hd2, Hd4), pelvis (PS7), calcaneus (TC1), metapodia (MCd1, MTp3)
- Level 17-8: disarticulation in mandible (M2), tibia (Td1) and calcaneus (TC1, TC3)
- Level 504: disarticulation in thoracic vertertebra (TV1), humerus (Hd7) and metapodia (MTp1); filleting in femur (Fp8, Fp9)

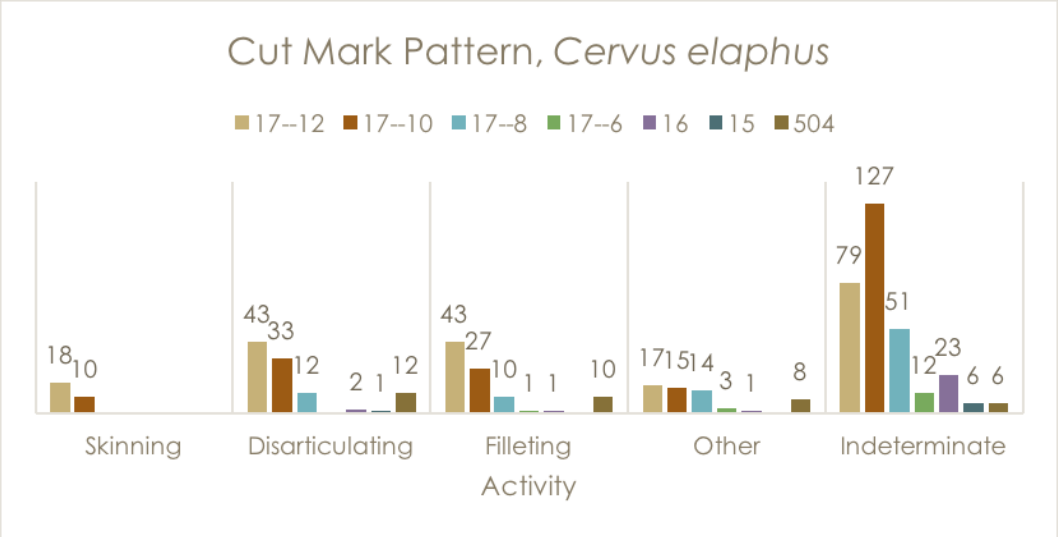


Figure 4.17: Cut mark pattern, red deer. Lower Magdalenian.

The cut marks observed among the Lower Magdalenian ibex bones (Figure 4.18) refer in a lower frequency to skinning activities. It is remarkable for both activities, disarticulation and filleting, that the number of cut marks decline with time, but the latter here are less commonly represented than the previous ones.

The following cut mark pattern on ibex bones observed have been compared to published cut mark patterns of butchering processes (BINFORD 1981):

- Level 17-12: disarticulation in humerus (Hd2)
- Level 17-10: disarticulation in mandible (M4, M5), pelvis (PS7), astragalus (TA2), radius (RCd1), metapodia (MCd2), skinning in skull (S6);
- Level 17-8: disarticulation in mandible (M5), cerv. vert. (CV6), tibia (Td3, TE1), skull (S2), filleting in tibia (Tp5)
- Level 16: disarticulation in mandible (M2), pelvis (PS7), radio (RCd2), femur (Fd3), radio (RCp2)
- Level 504: disarticulation in carpal (C1), mandible (M2), metapodia (MCd4, MTp1), tarsal (TNC1), skull (S6), skinning in mandible (M1), filleting in tibia (Tp4)

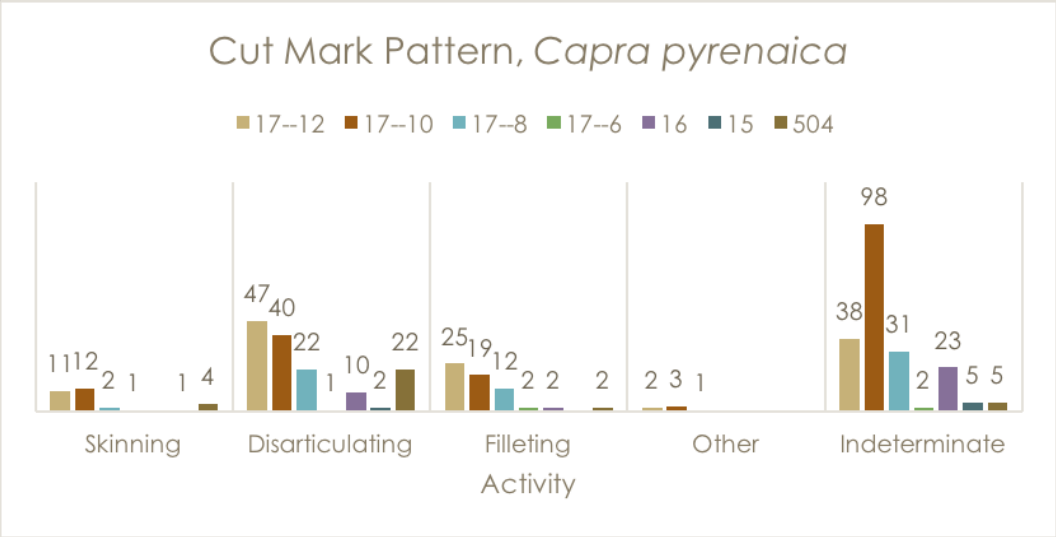


Figure 4.18: Cut mark pattern, ibex. Lower Magdalenian.

The results of correspondence analysis show that the cumulative variation of 82.2% is explained by the first four axis from seven for the archaeological faunal assemblages. For both species, red deer and ibex, explain Axis1= 36.5%, Axis2=20.9%, Axis3=15.8% and Axis4=9.1% of the variation, they are illustrated below (Figure 4.19). As explained for the human activities datasets in the method section (Chapter 3), a set of cut marks pattern retrieved from defined activities of 'skinning', 'disarticulation & filleting', 'filleting' and bones used as 'raw material' are examined next. 'Skinning' activity can be distinguished from the others, here on Axis 1, but only 'filleting' from 'filleting & disarticulation' on the second last Axis 6. Axis 2, 3 and 7 reflect an abundance pattern, where 'raw material' use and bone density are reflected in equifinality. These result show that also other patterns than human behavior explain the distribution of cut mark pattern observed, which could be possible related to skeletal element selective transport and preservation of bone material or other unknown variables (Axis 4 and 5). Skinning and filleting activities are clearer to be differentiated in ibex than in red deer. Red deer cut mark pattern distribution seems to follow another factor, maybe skeletal presence in the faunal assemblage related maybe also to spatial distribution of elements, transport, or preservation.

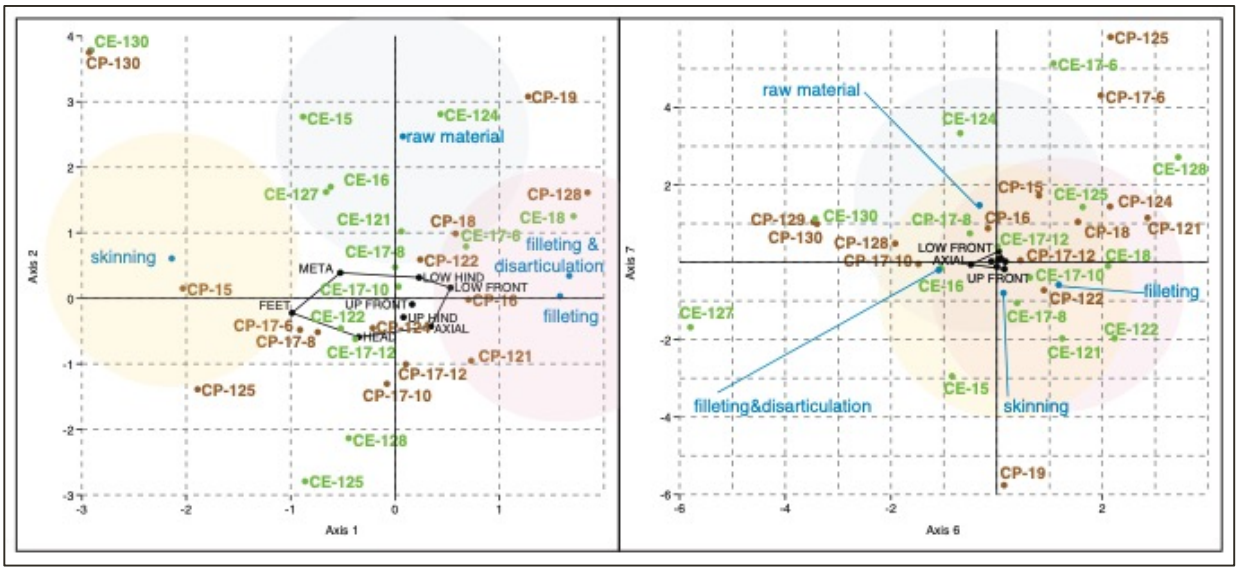


Figure 4.19: Relative composition of cut marked body parts, shown by Axis 1-2 and Axis 6-7 from correspondence analysis for species red deer and ibex. Highlighted are areas of cut mark patterns related to skinning, filleting or raw material use.

Based on the correspondence analysis, a summary of results of tendencies in human activities are shown in Table 4.4.

Table 4.4: Summary of inferred human activities by cut mark patterns.

Cultural attribution	Level	Red deer	Spanish ibex
Lower Magdalenian (LM)	15	raw material	skinning
	16	raw material	filleting
	17--6	filleting	skinning, filleting
	17--8	raw material	skinning, disarticulation, filleting
	17--10	all	all
	17--12	skinning	all
Initial Magdalenian (IM)	18	/	filleting
	19	/	raw material
	121	raw material	filleting
Solutrean (SOL)	122	skinning, filleting	/
	124	raw material	filleting
	125	/	skinning
	127	raw material	/
	128	filleting	disarticulation, filleting
Early Upper Paleolithic (EUP)	129	/	raw material
Late Middle Paleolithic (MP)	130	/	/

The results also suggest that differences between ibex and red deer, in terms of variation in bone modification patterns, is also related to size differences in butchery effort and utility-related differences in skeletal element treatment (similar to what was observed by STEWART'S 2010 butchering analysis of smaller and larger bovid).

On bone remains from Level 504 it was more often possible to correlate the cut marks to their original activity than in the other studied units from the Lower Magdalenian, probably due to their really well preservation and only individual finds were studied.

In summary, about the cut marks found in bones of deer and ibex from the Late Middle Paleolithic to the Lower Magdalenian levels of El Mirón changing pattern of human behavior throughout time is observed, specifically as follows:

- During Late Middle Paleolithic occupations, a few cut marks were only observed on red deer and ibex bones. Humans were almost or entirely involved in the accumulation of all the remains, but further behaviorally implications are difficult to retrieve from the scarcity of data.
- While disarticulation activities were prominently recorded in the Early Upper Paleolithic, inhabitants of the cave produced some filleting marks on bones, too. Preparing food for further transport could be a reasonable interpretation for the pattern observed. It was also observed skinning marks.
- Solutrean people left cut marks patterns that are dominated by filleting marks with fewer disarticulation activities showing consumption of food by people just stopping over for short stays.
- For the Initial Magdalenian activities, the few data available allow no further interpretations for the moment.
- From the rich Lower Magdalenian, disarticulation and filleting activities are abundantly present within all the studied levels, but especially disarticulation marks become notably fewer within the upper levels. Level 504, separated from the other Lower Magdalenian levels, is comparable to Level

17-8 in terms of quantities in disarticulating and filleting marks. This is interesting as radiocarbon dates suggest contemporaneity of these assemblages.

Butchering pattern already gave many insights into the site function. The other direct human activities, of bone open cracking, is explored in the next paragraphs.

B. Bone cracking activities is a common phenomenon in archaeological contexts. The acquisition of the bone marrow nutrient by humans is visible on the marks produced during its breakage in the different cultural periods. Impact marks or percussion notches are semicircular- to arcuate- shaped scars on bone fractures with negatives, often on medullary surfaces (BINFORD 1981; CAPALDO & BLUMENSCHINE 1994; PICKERING & EGELAND 2006).

The Late Middle Paleolithic contains only four bones with impact marks (one on a red deer metatarsal, a chamois tibia and ibex radius and a medium to large sized tibia) and two bone flakes (on medium to large sized long bones). The impact frequency is also relatively low during the Early Upper Paleolithic occupations and Initial Magdalenian, but intensified during the Solutrean and Lower Magdalenian.

The most impact marks were observed during the Lower Magdalenian occupations; this pattern of impact frequencies is summarized below (Figure 4.20) by number of impacts for each part on long bone locations proximal-mid-distal and anterior-medial-posterior-lateral:

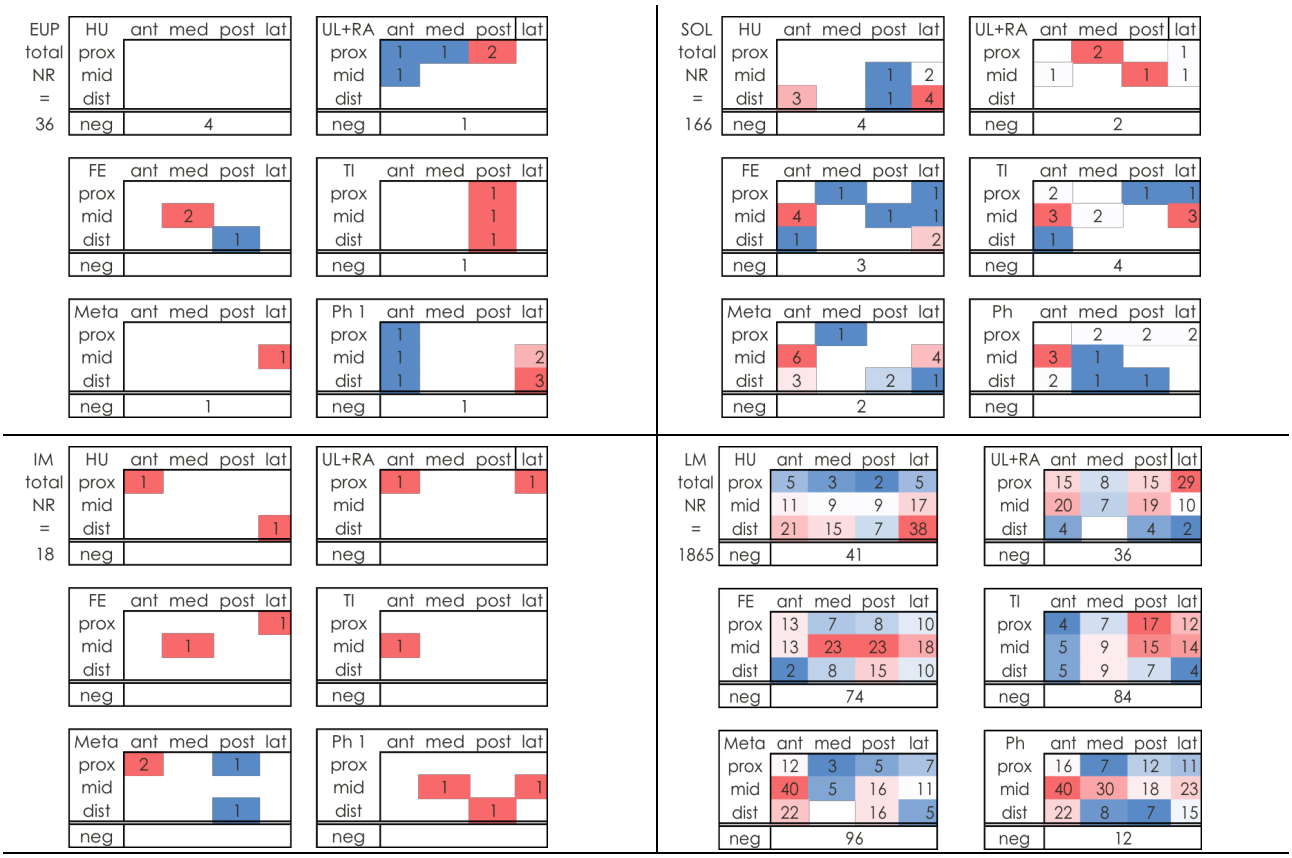


Figure 4.20: Distribution of impact marks on long bones of ibex and red deer (Hu: humerus, UL+RA: Ulna and radius, FE: femur, UL+RA= Ulna and Radius, TI= Tibia, Meta= Metapodial, Ph1=First/proximal phalange) by cultural periods. EUP-Early Upper Paleolithic, SOL-Solutrean, IM-Initial Magdalenian, LM-Lower Magdalenian. Blue color indicates low and red high quantities.

The impact patterns for Solutrean long bones show higher values but similar locations as in the Lower Magdalenian, thus, both exploited bone marrow from long bones in a very similar way. The patterns observed during the Solutrean are repeated and intensified during the Lower Magdalenian at El Mirón cave. In the Cantabrian Region, especially the Lower Magdalenian cultural period is recognized by the efficient exploitation of animal resources including an intensive use of within bone nutrients (FREEMAN 1973; STRAUS 1992; QUESADA-LÓPEZ 1995; MATEOS CACHORRO 1999; MARÍN-ARROYO 2010). Comparable exploitation strategies, of less intensity, might describe the (possibly emerging) Solutrean skills of coping with the environment. The Initial Magdalenian within-bone exploitation is also similar to the Lower Magdalenian pattern. The EUP, though, show a different, more random pattern of impact marks.

Another measure, the Density Index of bone flakes by level shows the amount of bone flakes within each sediment units (Figure 4.21:), being highest during the Solutrean. The late Initial Magdalenian levels and early Lower Magdalenian levels contain high amounts of bone flakes, but bone flake intensity decreases in the Levels 15 and 16. The pattern manifests a more intensive exploitation of within-bone nutrients for the Solutrean and the Lower Magdalenian compared to the Middle Paleolithic and Early Upper Paleolithic periods. Here especially there was much contributed by many of the rather smaller sized bone flakes that resulted from smashed bones that were recovered from general bag collections.

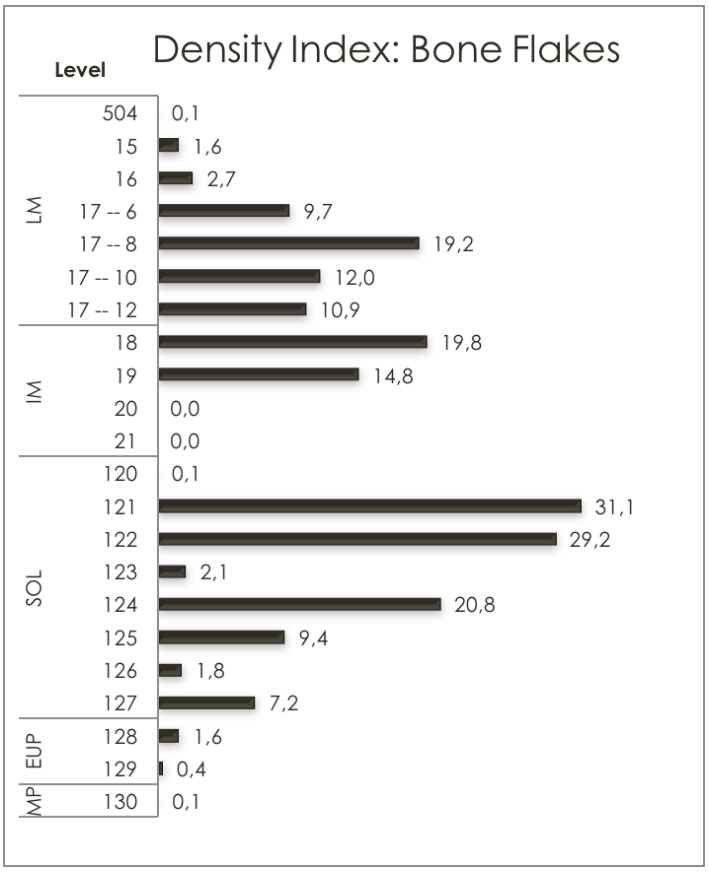


Figure 4.21: Density variation of bone flakes, per 0.01m^3, along the sequence.

To evaluate the activities of bone breakage for marrow extracting, the frequency of impact notches used per impact location is recorded. During Paleolithic, bone marrow exploitation was done as an important nutritional resource and complemented the meat provided from the hunted prey animals, also evidenced in ethnographical data (O'CONNELL ET AL. 1988; YELLEN 1991; BINFORD 2012). Additional activities involved for bone cracking require extra energy costs. It is known that the process of opening bone medullar cavities was

usually done with a hammer (stone) and placing the bone preferentially on an anvil (also stone, bedrock, maybe other bones or soil surface) (BLUMENSHINE & SELVAGGIO 1988; CAPALDO & BLUMENSCHINE 1994; OUTRAM 2001: p. 200; PICKERING & EGELAND 2006; GALÁN ET AL. 2009), such were found at El Mirón (NAKAZAWA 2007; NAKAZAWA ET AL. 2009). The energy cost increase with the number of impacts needed to open a bone cavity or smashing cancellous bone. Thus, the number of impacts should be relative to the amount of costs to obtain the extra nutrients (benefit) (BINFORD 2012). Impact marks are defined as hammerstone-inducted conchoidal flake scar marks (FERNANDEZ-JALVO & ANDREWS 2016: p. 298). If later bone grease is also extracted, further processing steps will increase the cost of work load as discussed later.

If this is related to the present fauna, the percentage of bones affected by impacts and the resulting flakes varies among the studied faunal assemblage. Generally high fragmentation of the faunal material associated with these bone cracking activities happen to be normally identified only to the low level of precision as 'long bone shaft fragments', often only classified by size class categories. During the Late Middle Paleolithic only 4.8% of the faunal remains show impact marks and the value increase to 11.8% during the Early Upper Paleolithic period. During the Solutrean the results increase to 23.3% and during the Initial Magdalenian to 24.7% in the vestibule front area. During the Lower Magdalenian decreases to 18.2% in the vestibule front area and to 11.5%, in the Level 504, in the vestibule rear.

I found it useful to relate bone flakes and impact marks on bones to each other and calculated the BCE (Bone Cracking Efficiency; see methodology) index that measures the efficiency of bone cracking activity. The BCE Index of 1.0 corresponds to the fact that every impact on bone leave, at least, one impact mark. Instead, in general, the results show that the frequency of broken bones with impact marks increase steadily by time (Figure 4.22). The BCE varies with the percentages of impacted bones and bone flakes, showing value 1.0 for the Middle and Early Upper Paleolithic occupations. Already during the EUP the frequency of bone flakes increase, simple impacts are dominant. This pattern continues during the Solutrean and Initial Magdalenian and slightly decrease for the Lower Magdalenian levels, with multiple impacts being commonly found on the bones. These results imply either, during the earlier occupations persons controlled better bone cracking and later several people of various experience contributed to this activity. Or, more impacts indicate an intentional smashing of bones into smaller fragments, maybe in preparation for the grease rendering process (JANZEN ET AL. 2014), dismantling of bones via two processes of activities. Outram (1998) has shown in experiments that the fracture of fresh bones requires, on the whole, just a single sharp blow opposed to one-hour heat treated ones, which were distinctly harder to break and after no impact points were present. A higher BCE would then infer that more blows were used to open bones, which might correspond to previous heat treatment of the elements. The existence of more blows and change of the fracturing behavior of heat treated bones (OUTRAM 2001) also would produce relatively more bone flakes.

In these terms, heat treatment of bone elements might be evidenced through the relationship of an increasing %NR of bone flakes and an increasing BCE index reflecting more number of notches per impacted bone. The obtained results infer that during the Late Middle Paleolithic, bones were cracked in fresher condition than later. The following Early Upper Paleolithic assemblages show an increase in bone flakes indicating more bone shatter maybe due to initial or partial heating of the bones, for example during roasting activities. From the Solutrean onwards, the observed pattern in changes in the fracture pattern at a whole then might be likely linked to cooking activities effecting the bone throughout. These bones would be more difficult to crack open and so they produce more bone flakes than fresh bones (OUTRAM 2001).

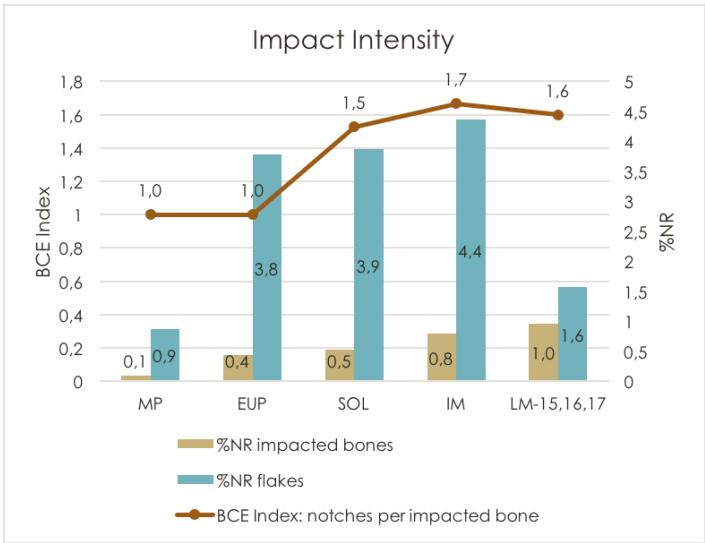


Figure 4.22: Bone Cracking Efficiency Index is compared with the %NR of impacted bones and bone flakes along the sequence.

While studying within-bone nutrient exploitation, "knowing element and taxon is useful but not essential" (OUTRAM 2001: p. 403), the results indicate a general intensified exploitation already beginning during the Solutrean and Initial Magdalenian. The proportion of this activity, though, decreased during the late Lower Magdalenian in a way that the percentage of impact bones decline even when this period shows the highest amount in numbers. This phenomenon could be explained by either complete carcasses brought into the cave that left more unused (in terms of within-bone nutrients) bones behind. Another explanation could be that a higher fragmentation rate within these levels left impact points further distributed over the fragments.

Those data imply also that during the Late Middle and Early Upper Paleolithic, when people exploited within-bone nutrients, they spend less energy (in terms of how often the bone was struck) for obtaining additional nutrients. This also might correspond to the circumstances that the exploitation mainly considered bone marrow, where it is possible to open bone cavity just with a few strokes, or even one stroke. It could be a possible sign of absence in economic stress until then. Bone grease rendering via cooking instead requires an intensively smashing of the cancellous bone parts to extract fats effectively (BINFORD 1981; DAVIS 1995; BRINK 1997; OUTRAM 2001, 2004; STINER 2002; CHURCH & LYMAN 2003, 2003), which is a elaborated human activity which get further analyzed within the next paragraphs.

The distribution long bone shaft fragments vs. spongy bones might be relevant for further interpretations. The fragment sizes (FSI) of long bone shaft fragments and spongy bone ones is explored here. The studied levels show a low percentage of long bones shafts compared with spongy or cancellous bone fragments, which is close to the actual distribution of these parts in the animal body. The fragments of parts containing spongy structures are much smaller than the long bone shafts in the skeleton (LAM ET AL. 2003); the compact bone in the epiphysis are normally very thin when compared to the diaphysis or long bone shaft. Nonetheless, several impact negatives were found on long bones shafts as well as on cancellous parts, where they were presumably intentionally cracked or smashed into smaller pieces by humans.

The fragment size (FSI) variation of the different cultural periods from the Late Middle Paleolithic to the Lower Magdalenian show how the long bone shafts get larger; normally one would suggest after the standard model that the younger the material the larger the fragments (Figure 4.23-A). Long and spongy bone fragment size increase from the Middle Paleolithic (MP), to Early Upper Paleolithic (EUP) and to Solutrean occupations (SOL) following this standard rule (Figure 4.23-B). However, FSI of spongy bone parts decrease

from there on to the Lower Magdalenian. There could be varied reasons. There could be a higher attrition of cancellous bones compared to shaft fragments in younger levels due to trampling or intentional fragmentation, or the progressively stronger incorporation of large ungulates resulting in larger long bone fragments or other reasons.

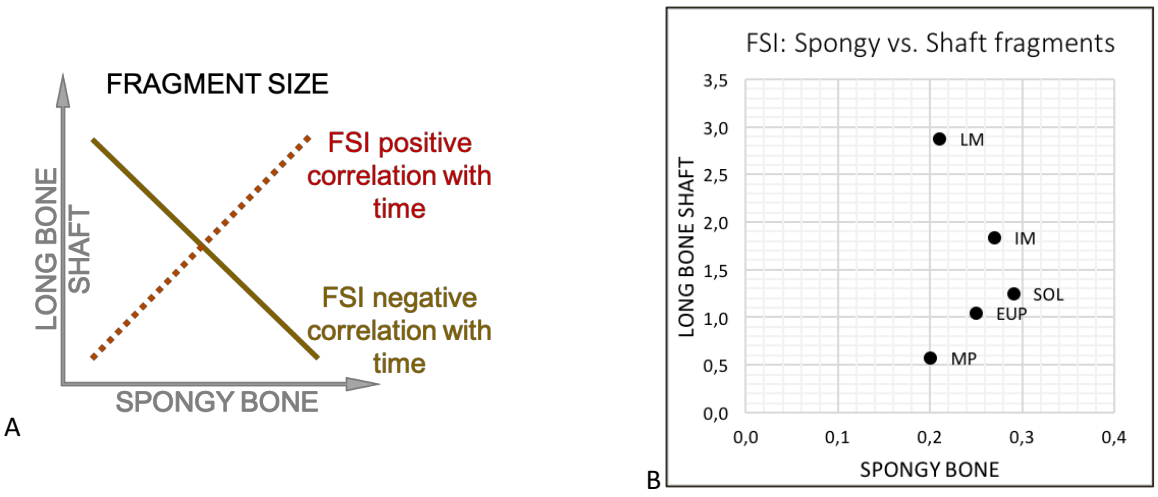


Figure 4.23: Long bone shafts vs. spongy parts compared by FSI (fragment size index). A-Model Fragment size correlate with time. B- El Mirón FSI development.

This turnover in the size association of long versus spongy bones might be also related to an intense fragmentation of the epiphysis and spongy bone parts (DAVIS 1995; BRINK 1997; CHURCH & LYMAN 2003; JANZEN ET AL. 2014). From the observed high fragmentation of cancellous bone could be implied grease rendering processes as the crushing of spongy bone is thought to improve the efficiency in extracting the bone fats through cooking (JANZEN ET AL. 2014; MORIN & SOULIER 2017), although this pattern might be in equifinality to trampling or attrition. If practiced, these activities might correlate with the fire-cracked stones and several shallow hearths as found in El Mirón Cabin (NAKAZAWA ET AL. 2009; BINFORD 2012: p. 159). Grease-rendering activity, however, would then begin with the Initial Magdalenian, and be a true Magdalenian occurrence. Bone cracking activities might have also a spatial element with defined areas of hearth, marrow extraction and grease rendering processes (BINFORD 1983: p. 153). A further detailed discussion on evidence for grease-rendering activities is given in the next chapters: 4.2 about El Mirón economy and in 4.3 about spatial distributions.

C. Thermo-alterations on faunal remains in cave sites are direct and indirect signs of human activities. Different levels of burning were identified during the analysis of the faunal remains. A brief exposition of the burning degrees identified per skeletal part elements and species is presented. The burning degree is estimated based on the element coloration that the effect of burning left on the bones by alteration.

Burnt bones are at least indirect indicators of human presence, however, their density can be also related to the location of certain human activities of direct fire use or even sanitary surface cleanings. The amount of burnt remains is described for the levels (Figure 4.24), based on the Density Index of burnt remains.

Levels 121, 17-10, 17-8 and 17-6 show the highest frequencies of burnt remains, Levels 125, 124, 122, 18, 17-12 show moderate frequencies and Levels 130-126, 120, 21-19, 15, 16 and 504 have low ones.

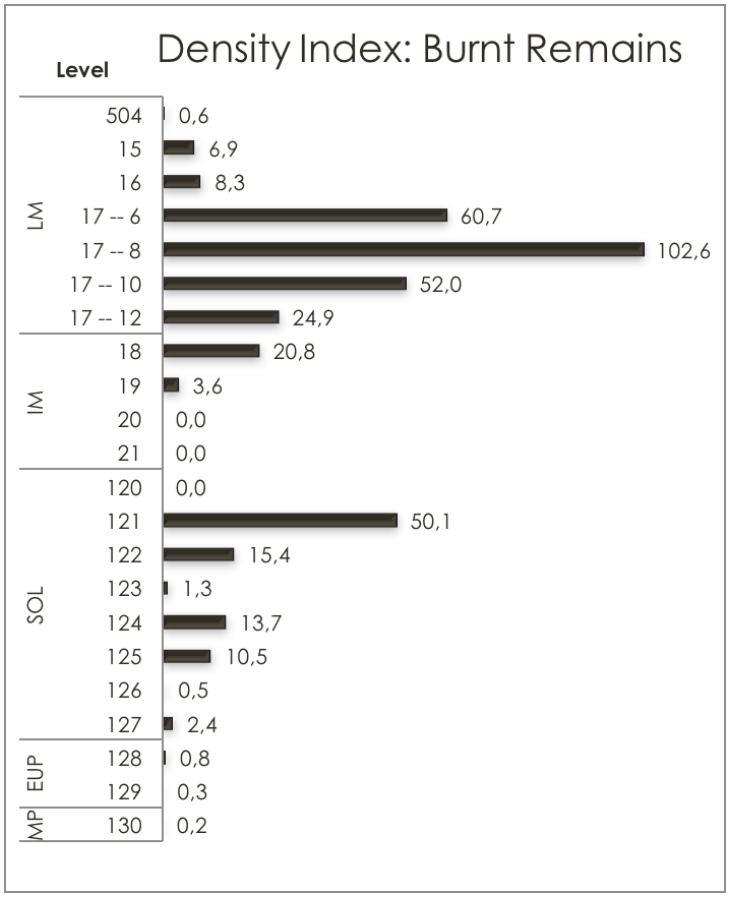


Figure 4.24: Abundance of burnt bones.

The initial results on thermo-alterations according to the burning degree are summarized in the figure below (Figure 4.25). The distribution of the amount of burnt individual bones vary highly between the studied levels, while Levels 17-12, 17-10, 17-8, 16 and 504 show the highest quantities of burnt faunal remains; they all belong to Lower Magdalenian occupations. The main difference between the vestibule front Levels 17 and 16 to the vestibule rear Level 504 is that in the former one the main bulk of burning modification are reddish colorations, while in the latter one more brown-grey colored (presumably) burnt bones were observed. The most intensive burning activities seem to be practiced during the accumulation of Level 17-10. It is noticeable that advanced burning degrees (white-blue colors, i.e., calcined) are less represented than earlier stages of heat treatment (reddish to black). It has to be kept in mind that advanced burning stages might lack of presence, due to their higher fragmentation grade and disintegration of the bone element. It was demonstrated that especially burning fresh bones (for example, used as fuel) do crack them into smaller pieces as the loss of humidity and collagen is more extensive (COSTAMAGNO ET AL. 2005). The smallest remains were not recorded individually during excavation, but were collected in general bags after wet and dry sieving. The spatial distribution of density in burnt bone micro-fraction is further analyzed in the section about faunal spatial analysis (2.3) at El Mirón.

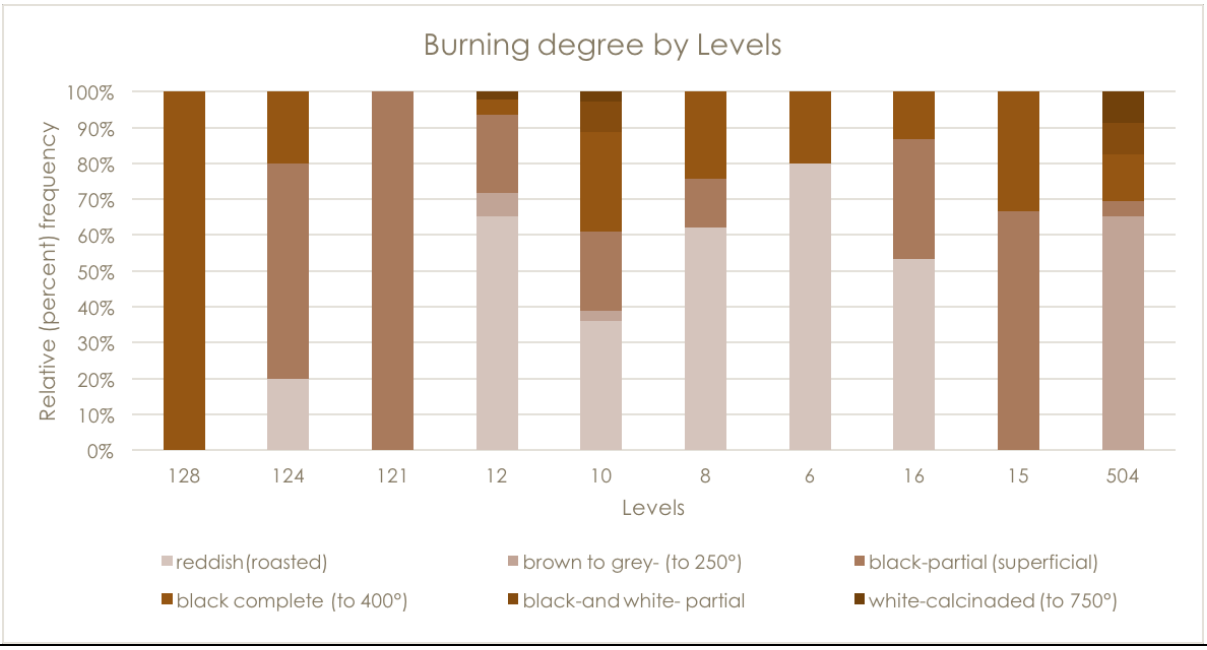


Figure 4.25: Distribution of the burning degree on bones larger than 2 cm, percentage by number of total bones.

Possible implications from the thermo-alterations on bones can be made, although they are mainly identified only at the anatomical level, not allowing further species-specific interpretations. Burning seem to be quite evenly distributed among the skeletal part representation of the preys consumed (Figure 4.26). The Lower Magdalenian Levels 17-12, 17-10 (in the vestibule front) and 504 (in the vestibule rear) are rich in burnt remains, which could be the results of food preparation (roasting). An alternative interpretation is that new hearths were made on the surface of the cave, where bones already were lying on the surface; these would then be affected by the fire. The overlying Level 17-10 shows a slightly higher number of completely burned bones. The complete combustion of the bones could indicate that faunal remains were used as fuel or were simply disposed into the fire, possibly for 'cleaning purposes'. Level 504 shows also a high number of animal remains that are completely burnt, they seem to be the results of discarding production waste from antler working activities into the fire. The similar high frequency of other skeletal representation having experienced intensive burning was not observed.

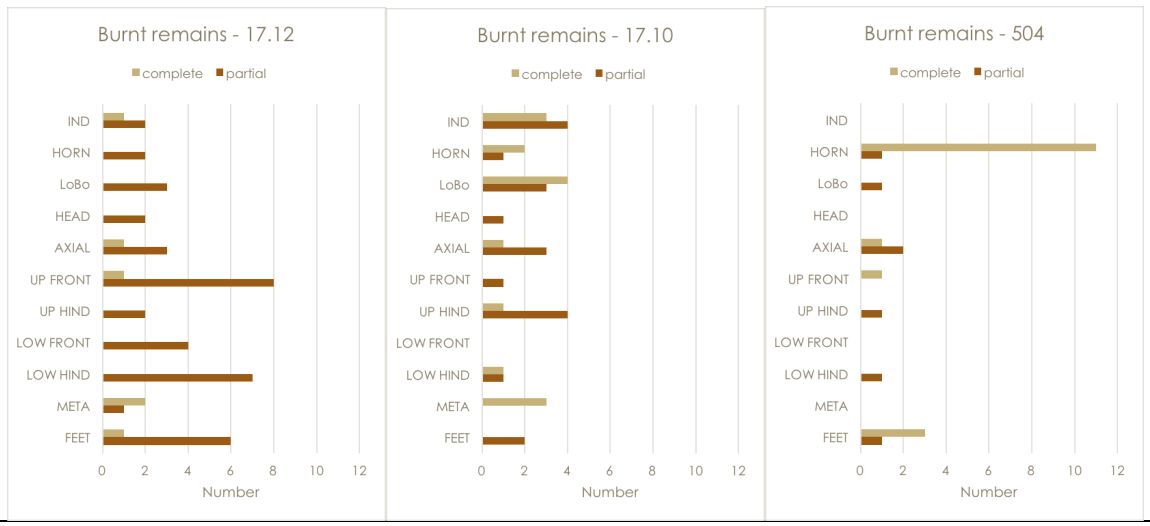


Figure 4.26: Distribution of burnt remains by skeletal part elements in Levels 17-12, 17-10 and 504.

The number of burnt remains is generally low among the studied faunal units, which imply that each of the inferred activities that producing burnt bone remains are explored neither regularly or intensively and more occasionally. Actually, if meat seemed to be stripped of from bones before cooking, long bones were cracked open for marrow extraction and comminuted cancellous bone were cooked with heating stones, the burning features of bones might have been lowered.

4.1.4 Human activities beyond diet

Some taphonomic alterations are special as they provide beside their direct also indirect evidence of human activities, such are the study of (A) osseous industry and (B) trampling. Since taphonomic studies, and specifically cut marks analysis, comprise also intentional shaping of osseous remains, the evidence found regarding the osseous industry is presented before further attrition modification being discussed following the logical consequent steps of animal processing activities.

A. The diverse osseous industry that appeared during the study of El Mirón faunal remains are described here primary under a taphonomic aspect by sequence of modification activities. It is exemplified how multiple human activities and behavioral implications can be derived from the analysis of such osseous artifacts from the Lower Magdalenian levels at El Mirón, as they show the richest and most complex of such kinds.

Osseous raw material processed directly in case of antlers, or was taken either after skinning and butchering, but before intensive cracking of long bones. Antler as raw material is described first, followed by bone artifacts and their by-products. Examples of these objects are bone flakes, bone tools (awls, points, needles, smoothers/spatulae, wedge, retouchers/billets, used bones, etc.), antler tools (mainly sagaies—projectile points), antler blanks, as well as osseous production waste.

All red deer antler pieces at the cave were fully developed, some even presenting a rosette of a shed antler, although Level 17 contains also three unshed head-antler fragments. This circumstance makes clear that most of them were brought to the cave primarily as a raw material resource rather than as leftovers from food resources, and indicate specific human activities, distinguishable from the other activities. The find category of antler remains (Figure 4.27) shows a higher amount in the earlier Lower Magdalenian levels than in the later ones by numbers. This indicates a higher input of antler during the earlier Lower Magdalenian phases of the occupation as opposed to the later ones. Another explanation could be a more intensive production of antler tools was applied that produces more small fragments during that time periods.

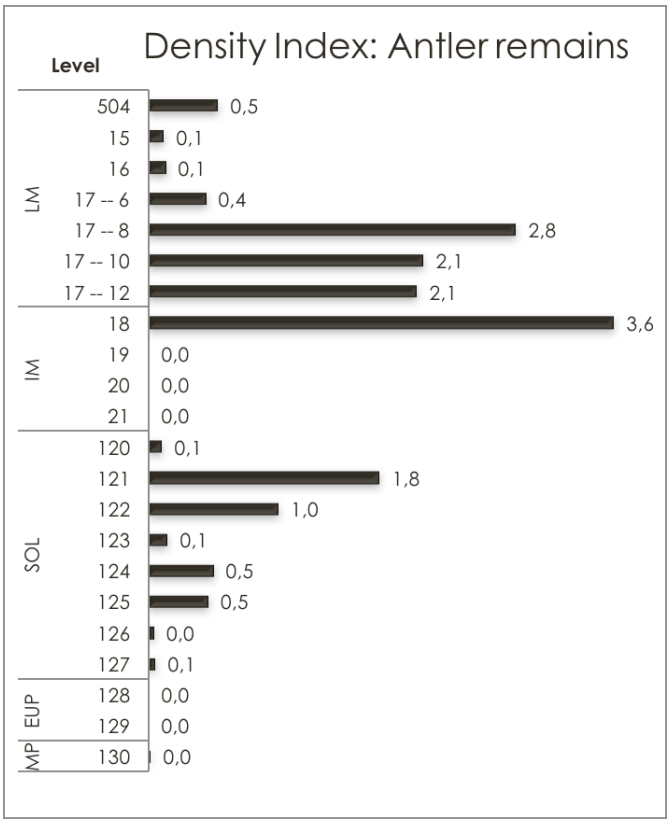


Figure 4.27: Frequency of red deer antler identified at El Mirón in studied levels.

Antlers were abundantly used as raw material. Worked antler remains (Table 4.5) are found frequently within the Lower Magdalenian Levels 15, 16 and 17 in the vestibule front of El Mirón, with sometimes very abundant antler blanks and splinters in the Lower Magdalenian levels (as were already observed during excavations by L.G. Straus and M.R. González-Morales). This is not surprising considering antler tools are a typical archaeological find category and component of the Magdalenian culture (GONZÁLEZ-MORALES & STRAUS 2005; STRAUS & GONZÁLEZ-MORALES 2012; LANGLEY ET AL. 2016). But for what did people use the antler remains? It seems that the studied occupations throughout the region commonly contain antler remains that are the results of specific antler point production, named '*sagaies*' or in Spanish "azagayas" (BARANDIARÁN 1967: p. 285). Antler working at El Mirón seemed to focus on *sagaies* production with the dominance in finds of antler *sagaies* and their production waste.

Table 4.5: Categories of antler usage identified in Lower Magdalenian Level 15, 16, 17—6, 17—8, 17—10 and 17—12). *(Additional worked antler-beam fragments belonging to those samples were found by L.G. Straus in July 2019, they are not included in total numbers.)

Artifacts	Number
Antler blank (by grooving)	1
Antler blank production waste (by grooving)	22 *(+6)
Antler core	1 *(+4)
Antler flake	4
Antler production failure	4
Antler *sagaie*	18
Antler tool	2
Total	**52**

With the help of the various pieces that were identified in relation to published references, it is possible to detect the production order of this artifact category during the Lower Magdalenian at El Mirón cave (compare Figure 4.28). A (double) groove and splinter technique (GST) is used to extract blanks (TEJERO ET AL. 2012) from red deer shed antlers (ASHBY 2013). The blanks were extracted through direct percussion impacts found on the antler roses. Whether larger blanks (rods) were formed by cutting-percussion with wedges (longitudinal cleaving) into smaller sections is not possible to differentiate, but many bone wedges were found in the same levels. This preparation step produced blanks which after trimming and shaping (whittling) were transformed by smoothing into the finished product. Finally, they were 'decorated' mostly on the base with parallel or crossed lines with sharp-edges stone tools.

The sequence of grooving – percussion – cleaving – shaping – smoothing (compare CLARK 1953), seems to have been the system of manufacture for producing the *sagaies* of Lower Magdalenian levels, as leftovers of each of these production steps are frequently found among the faunal material. This manufacturing is equivalent to what has been explained from experiment of production of square-section antler points and what has been observed in Lower Magdalenian levels at El Cierro Cave (Asturias) (TAPIA ET AL. 2018), for example.

Some antler flakes were also found among these worked antler items. Flakes might origin from initial chopping/ percussion gashing to prepare blocks for blanks or simple occurred during leverage of antler blanks, and no sign of clear flaked antler blank was found, in sense of the reported flaking technique used during the French Badegoulian occupations in Couzoul de Vers (PÉTILLON & DUCASSE 2012; AVERBOUH ET AL. 2016).

Point-tip fragments broken off from the projectile (Figure 4.28) present mostly beveled fractures as they occur by use (PÉTILLON ET AL. 2016). They display one of the ultimate end-products of a *chaîne opératoire* of animal carcass exploitation, which might nearly include all the activities of raw material search, point production, hunting, and finally consumption where the broken points got recovered from inside the carcass and later discarded (LANGLEY 2015). In case of broken antler point tips (which are relative abundant in the collections), this sequence also applies, while the raw material source origin presumably from fully grown-shed antlers, possible collected in the landscape.

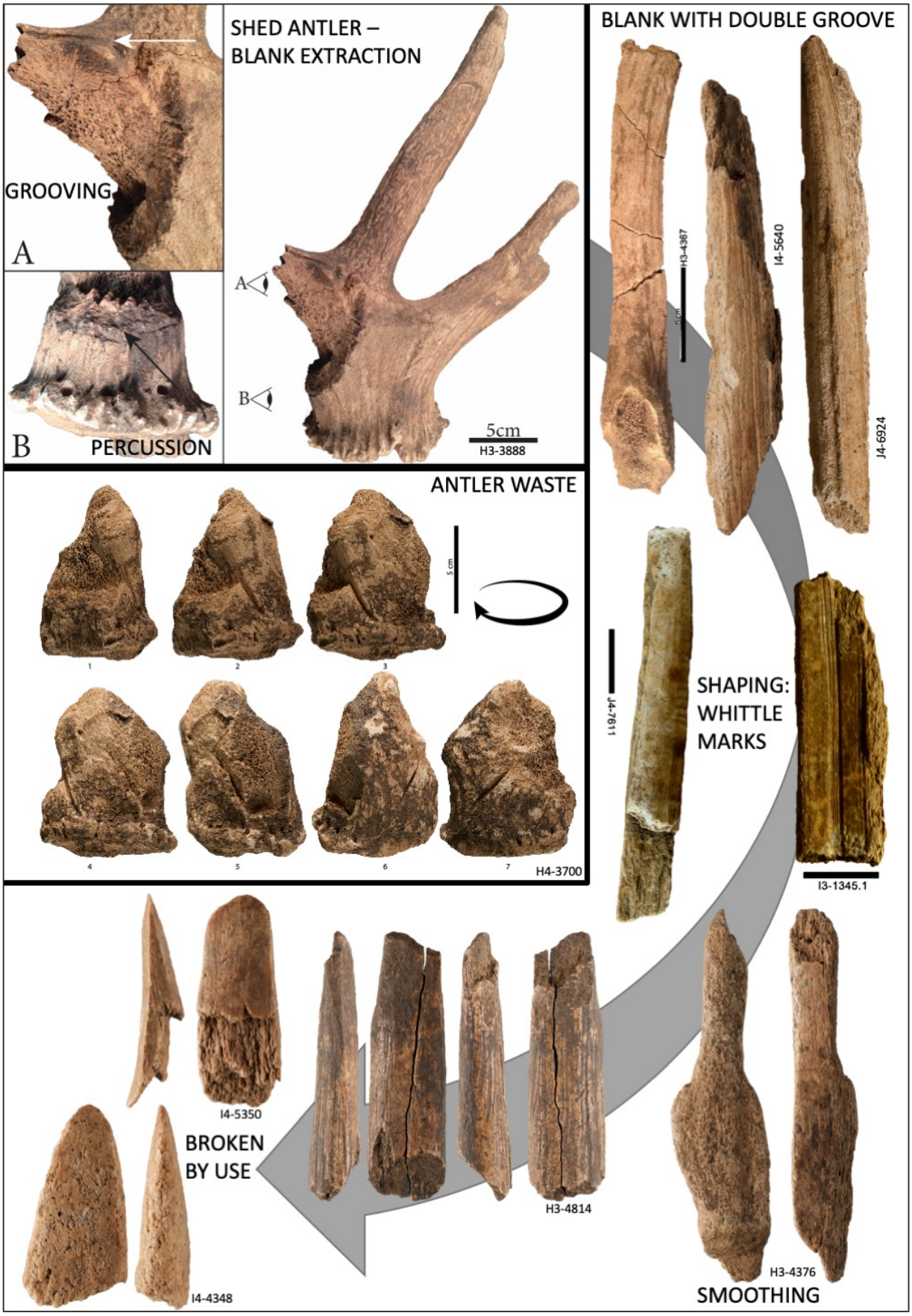


Figure 4.28: Possible *Chaîne opératoire* of antler object usage during Lower Magdalenian at El Mirón, beside common *sagaie* finds.

These finds fit well into the context of the Cantabrian Lower Magdalenian having one of the hallmarks the antler points (often bevel-based and quadrangular in section with engraved marks—both functional and decorative) and striation-engraved scapulae (BARANDIARÁN 1967; UTRILLA-MIRANDA 1981; CORCHÓN-RODRÍGUEZ 1986; and many others). Some highlights of these antler remains and important osseous finds from El Mirón cave identified previously to this faunal study are published available (GONZÁLEZ-MORALES & STRAUS 2005, 2009; STRAUS ET AL. 2014; FONTES ET AL. 2015); especially the Lower Magdalenian levels including points with often quadrangular cross-section that are sometimes decorated with complex, incised, geometric (or 'tectiform') motifs (STRAUS ET AL. 2018), as the one displayed in Figure 4.29. However, large round-sectioned sagaies were identified also in the Solutrean levels, here are shown two examples from Level 122.



Figure 4.29: Antler *sagaies:* quadrangular with parallel incisions on single bevel base from Lower Magdalenian Level 17 and round-sectioned with incisions on base from Solutrean Level 122.

The Lower Magdalenian levels in the Cabin show a great abundance of worked objects by ±1 osseous artifact per 0.01m^3, which might reflect longer habitational stays and more domestic activities than in previous or

later periods. Beside antler artifacts, among the Lower Magdalenian domestic activities at El Mirón were involved a great number of bone artifacts. During the late Solutrean, occupations show already a similar amount of these objects (compare Figure 4.30), thus also implying the beginning of longer residential uses or change of site function at that time.

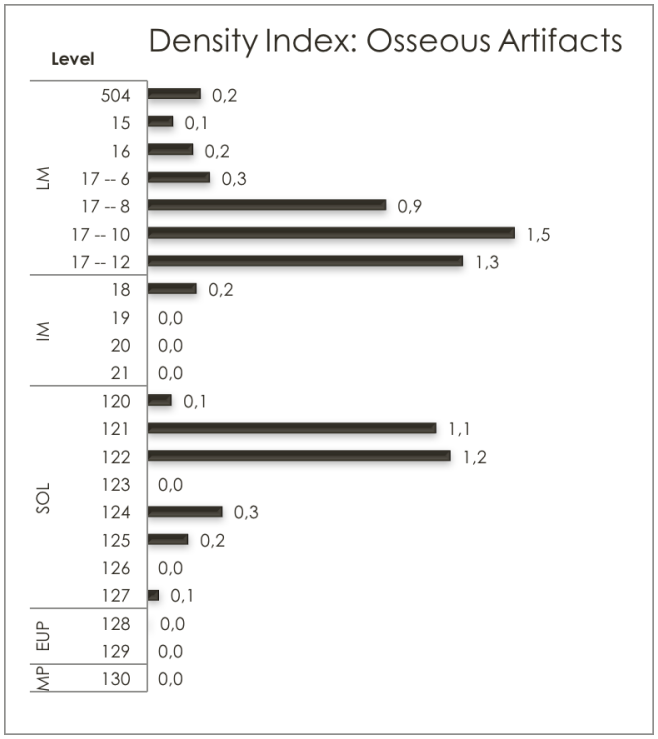


Figure 4.30: Density of Osseous artifacts (bone flakes excluded), per 0.01m^3.

The quantity of elements probably manufactured and used at site are summarized to the skeletal elements identified (Table 4.6:). The different categories of osseous artifacts are described below.

Table 4.6: Bone elements results of manufacturing bone industry.

Skeletal element	Bone flake	Production rest	Bone tool	Bone point	Used bone	Sum
Mandible	1					**1**
Cervical vert.	1					**1**
Thoracic vert.	1					**1**
Lumbar vert.	1					**1**
Rib			1			**1**
Scapula		2	1			**3**
Humerus	12		2			**14**
Radius	9		5			**14**
Ulna		1				**1**
Ulna-Radius	1					**1**
Metacarpus	12	2	2			**16**
Pelvis	1					**1**
Femur	10		11			**21**
Tibia	12	1	17			**30**
Calcaneus	1					**1**
Tarsal bones	1					**1**
Metatarsus	6	7	9			**22**

Metapodial	11	2	1			**14**
Prox. Phalanx	4					**4**
Humerus-Femur	4		2			**6**
Long bone	59	11	24	4	2	**100**
Flat bone	1					**1**
Indeterminate	2842	3	8	5		**2858**
Total	**2991**	**28**	**83**	**9**	**2**	**3113**

Flakes are a typical find category in Paleolithic archeology, one better known from the terminology of lithic stone tools (HAHN 1991; INIZAN ET AL. 1999). Flakes of bones, though, origin from bone-cracking activities. The frequent exploration of within-bone nutrients results in a high fragmentation rate through intentionally cracked bones; a common observation among Paleolithic bone/faunal assemblages. Bone flakes dominate the bone artifacts at El Mirón cave (Table 4.6:), because they are simply the debris of bone opening cracking activities, and, thus, an accurate marker of these activities performed with this occupation area and periods (CAPALDO & BLUMENSCHINE 1994). Most of the bone flakes (Figure 4.31) originated from long bone shafts (presumably for marrow extraction from bone cavities), but the presence of bone flakes (as well as impacts) on irregular spongy bone parts also infer the application of grease-rendering techniques.



Figure 4.31: Example of a typical bone flake from a long bone (Level 504).

Bone tools were found frequently (Table 4.6:); while some are clearly elaborated tools others seem to fall more into a category of 'used bones' as tools. The main category of clearly identifiable bone tools are bone points and bone needles. Bone points can be subdivided into two groups according to the stage of human activity where they were involved in and were deposited; bone points during or at the final stage of production and broken tips from used bone points. The bone point production itself include the use of raw materials and selection presumably from bones of previous butchered animals. Some long bones from the main prey animals have been set aside as raw material sources as indicated by various waste products of bone blank production (Figure 4.32). Similar kinds of these production remnants have been identified, for example at Cueva de la Pila (Cuchía, Cantabria) on display in the Museo de Altamira. Bone artifacts were preferentially made from long bones with a thick compact shaft such are tibia or metapodia. Testing for the proper bone is recorded by some superficial, but clearly visible cut-mark bundles or deeper, unfinished grooves. These marks imply some kind of problem or failure at the early stage of blank extraction, which were found mainly from metapodial shafts. The high frequency of bone blank production waste attest that the production of (at least some of) the bone tools happened at this living place, as demonstrated here.

Bone needle fragments (total NR=14) were identified during sorting of the general bag material from different levels (Level 15=1, Level 16=4, Level 17--6=2, Level 17--8=2, Level 17--10=5) (Figure 4.32). They show long, parallel whittle marks and smoothing along the shaft, which are the results of a global thinning of the blank diameter to a needle form. Needles are especially abundant in the Lower Magdalenian levels and

some are eyed. They come in a variety of thickness calibers in conformity to the ones already described from the site (STRAUS ET AL. 2018).



Figure 4.32: Bone blank leftovers or failure for fine bone point and needle production. Finished needle with needle eye on the right from Level 17 (Photograph by L.G.Straus).

Bones used as wedges (NR=23) [(BARANDIARÁN 1967: p. 314): "cuña" or "cincel", also (BALDEÓN 1993: p. 24)] are made on long bone shafts that have on one or two longitudinal end flake removal scars and sometimes a used end (crushing, use retouch), compare (TARTAR 2012b). The negatives are oriented longitudinally, which is to say that they are sometimes unidirectional and sometimes bidirectional. Some of those longer negatives might represent more force spend, maybe while using them also as soft hammer (Figure 4.33). Retouch negatives seem to be the results of using the long bone shaft (often red deer tibia or metapodia), for example, for levering out bone or antler blanks along the incised grooves from the raw material form (STRAUS 1976). Thus, these tools seemed to be used for the producing and extracting blanks and /or bone open cracking or soft percussion.



Figure 4.33: Bones (often red deer tibia or metapodia) used as wedges. They commonly have unidirectional negatives and sometimes rounded edges.

Bone retoucheur or billet [(BARANDIARÁN 1967: p. 315); this is “retocador”, “compresor”] are bones used as tools in the lithic production process (TARTAR 2012a; MALLYE ET AL. 2012; ABRAMS ET AL. 2014; ROMANDINI ET AL. 2015; COSTAMAGNO ET AL. 2017; JÉQUIER ET AL. 2018). The intended working edge of lithic flakes are pressed against the bone surface that would otherwise break during the actual cutting with these objects. These activities leave little impressions (scars, notches) normally on bone shafts that are more or less parallel-oriented, possibly due to the performance of this activity, which is repeated along the working edges of the tool and performed in one movement. Figure 4.34 shows one of three bone retoucher (or ‘flaker’) which were identified within the Lower Magdalenian Level 17 (one in Level 17-10 and two in Level 17-8), which use actually created bone flakes.



Figure 4.34: Example of bone retoucher (or ‘flaker’) of bone with grooves, with pressure flake negatives along the edge.

Some bones seem to have a smoothed working edge and show a specific polished surface (MOZOTA-HOLGUERAS 2012: p. 240), but a systematic identification and interpretation of these used bones would only be possible in conjunction with a series of experiments testing their possible production and use as well as further microscopic analysis, but they were recognized here. Similar objects have been described as “Los útiles óseos «poco elaborados»” (MOZOTA-HOLGUERAS 2014: p. 17) = ‘less elaborated’ bone tools (TARTAR 2012b) in different cultural periods of the Paleolithic. Further investigations (experimental and microscopic future work) are needed to further elaborate the definition of this tool category. They were possibly used as polishers, burnishers or hide-smoothers. Similar elements have been found in the Mousterian levels of Letzexiki site on large bovine bones, although in small quantities (BALDEÓN 1993). Figure 4.35 shows an example from Level 17.



Figure 4.35: Smoothed-used working end on bones.

Outstanding are osseous objects that are possibly decorated. A varied number of possible decorated objects (possible art) and ornaments have been found among the faunal remains. Those objects were distinguished from ones with normal cut marks pattern, if cut marks were placed outside of reasonable butchering cut marks locations, they were elaborated organized, complex and seemed intentional (see Table 4.7).

Table 4.7: List of decorated bones.

Skeletal element	Decorated bone	Possible decorated bone
Indeterminate.	2	
Viscerocranium		1
Long bone	2	
Scapula	4	
Pelvis	1	
Femur	3	1
Tibia	2	
Humerus/ femur	1	1
Thoracic vert.	1	
Rib	4	
Total	**20**	**3**

Simple decorated bones often show parallel cut marks (Figure 4.36), whose meaning is unclear. Twenty decorated bones were identified, most belong to red deer and ibex. Only in Level 17 long parallel cut marks were observed on long bones, which seem precisely placed in the same distance to each other, made by the same tool and display some kind of decoration pattern, for example two long cut marks on the lateral side and 19 on the medial side of a metatarsal combined with 66 short cut marks (Figure 4.36-1). This kind of decoration is similar to ones found at long bones in El Juyo Lower Magdalenian Level 6 (BARANDIARAN MAESTU ET AL. 1985: p. 168 Fig.3). Another bone has similar parallel cut marks on its bone cavity inside (Figure 4.36-2).

More seldom were found pieces with parallel incised borders (Figure 4.36-3), which were found only once to be relatively deeply incised (Figure 4.36-4). Some similar incised pendants have been found in Las Caldas, Altamira and La Garma may be indicating that these pieces were part of such objects. Due to the polished surface and horizontal engravings along the edges, the small fragment may be also part of a atl-atl similar to the one found in the same level. The already published atl-atl from Level 17 also carries horizontal, parallel engravings on its back (GONZÁLEZ-MORALES & STRAUS 2009), which was found similar to ones found in Placard and Roc de Marcamps (France).

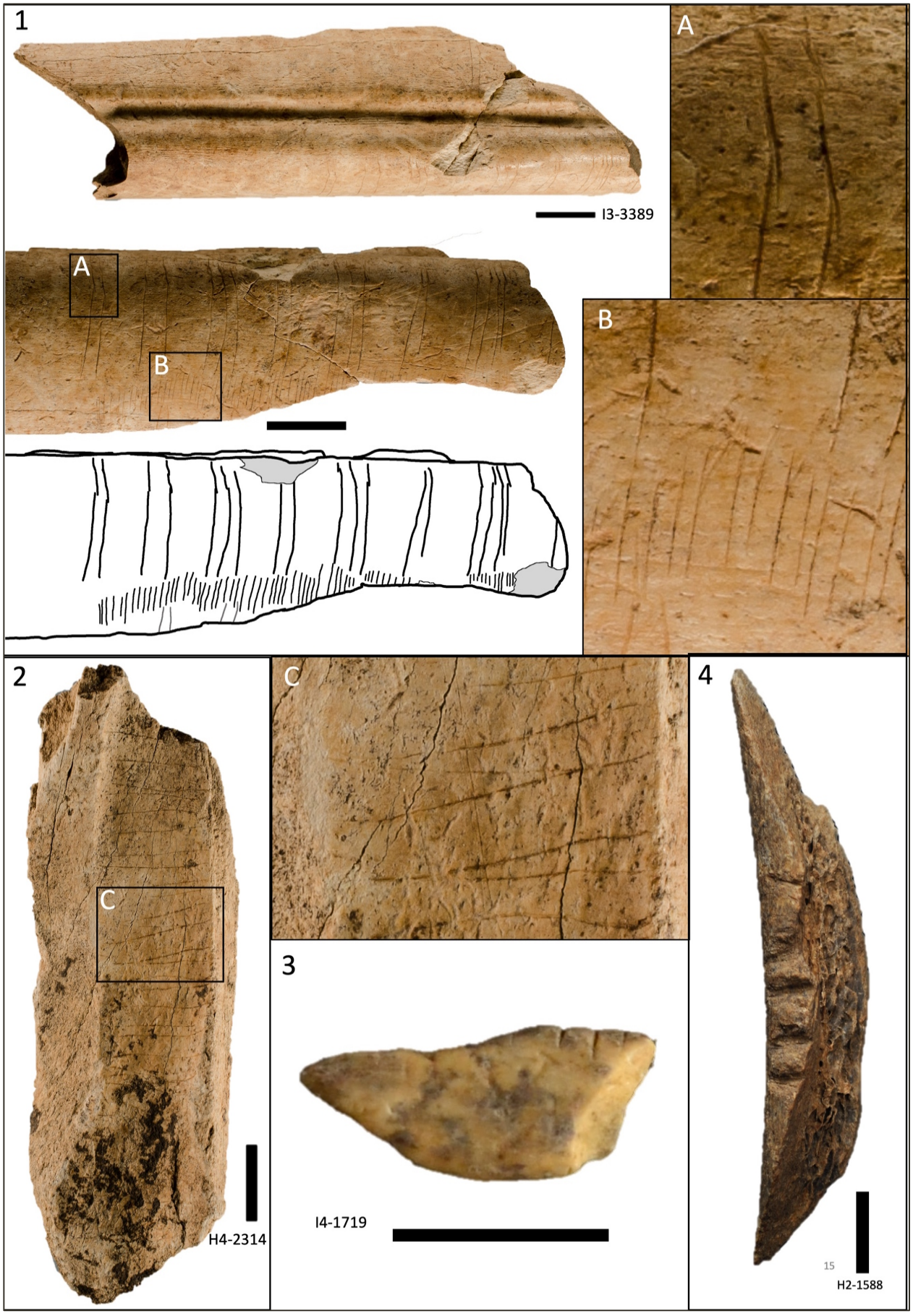

1
I3-3389
A
B
A
B
2
C
H4-2314
C
3
I4-1719
4
15
H2-1588



Figure 4.36: Decorated bones with horizontal engraved lines (1,2), with polished and incised borders (3) and deep sawing incisions (4). Horizontal engravings have been also found along the edges of the atl-atl found in the same level (5; Photograph by MR González Morales, drawing by L.Teira, Figures 6 and 7 from González-Morales and Straus, 2009; modified by JMG).

Further elaboration of osseous decorations are figurative engravings. The red deer scapula (specimen H2-1981) with a red deer hind engraving was found in Level 17 (pits 52-54 of subsquare H2b) and was described and studied in detailed previously (GONZÁLEZ-MORALES ET AL. 2006; GONZÁLEZ-MORALES & STRAUS 2009), (Figure 4.37-A). Figure 4.37-B shows some other scapula fragments that also contain cut marks, but perhaps not of figurative origin.

A



B



Figure 4.37: Level 17: (A) Red deer scapula with hind engraving (Photograph by M.R. González-Morales) and (B) bundle of cut marks on other red deer scapula fragments refitted (Level 17, H4-3577).

A few special objects (Figure 4.38) carry engraving of a non-figurative, abstract pattern where the outlines are multiple incised and in the inner surface of a triangle like symbol are filled with crossed striations. Two were found on red deer long bone (H3-3434 and H2-1784; Level 17), in stratigraphic position related to the red deer hind engraved scapula mentioned above. A Lower Magdalenian (Level 113, square T8) pebble rich in iron oxide with engraved cross-hatching was also found at El Mirón, whose grid-design has close parallels among Cantabrian cave art (ARIAS-CABAL & ONTANÓN 2004: pp. 174, Cat.Nr 13; GONZÁLEZ-MORALES & STRAUS 2005). Many of the parietal art engravings at the northern ("Unidad gráfica 2" GARCÍA DÍEZ ET AL. 2012: pp.26) and southern ("Conunto gráfica 3" GARCÍA DÍEZ ET AL. 2012: p.28) cave wall as well as the engraved block from the burial ("Conjunto gráfica 6" GARCÍA DÍEZ ET AL. 2012: p.29) contain similar cross-linked signs, the latter well

placed in a Lower Magdalenian chronology (GARCÍA DÍEZ ET AL. 2012; GONZÁLEZ-MORALES & STRAUS 2015), which are probably all manifestations of the same cultural-social-artistic unit.

Similar multiple striations are frequently observed among the red deer hind engraving from portable and parietal art at El Cierro, Tito Bustillo, Llonin, Altamira, EL Castillo, Pasiega, El Juyo, Rascaño, El Pendo, La Garma, Cobrantes and El Mirón, typical for the Lower Magdalenian in the Cantabrian Region (GONZÁLEZ-MORALES ET AL. 2006; RIVERO VILÁ 2010; RIVERO VILÁ ET AL. 2019), but cross-hatching are more seldom reported in these context, for example from Altamira or Las Chimeneas (MOURE-ROMANILLO ET AL. 1996). However, the ears of an engraved deer on a rib from Lower Magdalenian El Juyo Level 4 (ARIAS-CABAL & ONTANÓN 2004: pp. 108, Fig.2), a decorated stone plaquettes from La Paloma Level 6 (ARIAS-CABAL & ONTANÓN 2004: pp. 202, Cat.Nr.54) and an engraved pisiform rib spatula from El Pendo (ARIAS-CABAL & ONTANÓN 2004: pp. 170, Cat.Nr.8) also carry cross-hatching. Which implication they could have - we don't know it yet. However, they may also show a cultural-social-artistic connectivity.



Figure 4.38: Abstract engravings on long bone shafts: triangle like symbol are filled with cross-hatching.

Different teeth were identified having a very similar modification pattern: the root was whittled into a double bevel base, some more intensively than others in varied stages of production. In this way, the root was prepared to facilitate to place a hole that using the cavity of the pulpa. Additional modifications marks can be found, such are polishing and perforations, which are described in detail among the objects found (Table 4.8).

Table 4.8: Characterization of the tooth ornaments and semi-finished products.

Identification	Ornament description
H3-3391, Level 17-10, *Rangifer tarandus* lower I3 incisor	The reindeer tooth was two times deeply incised on the frontal surface from the lateral and mesial side that the incisions meet with a slight angle to each other. The labial part appears to be smoothed. The lingual part presenting oblique striations all over its root and enamel surface as evidence of smoothing.
H3-5275, Level 17-10, *Capra pyrenaica* lower I2 incisor	The ibex milk incisor has been flattened on its lateral surface and deep incisions were made on the frontal area, these are not as elaborated as the ones form the reindeer tooth. These marks do not seem to origin from common skinning marks, because the root has incisions that reach from lateral over frontal to the mesial surface of the root.
I4-3224, Level 17-12, *Capra pyrenaica* lower deciduous incisor, dI2	This tooth was just whittled, but with very rough, clear carving marks from both sides, mesial and dorsal. The root was thinned by radiating motions. It seems to be discarded during preparation.
J3-5812, Level 17-12, *Cervus elaphus* lower incisor, I3	Whittled and a hole was drilled into the lower part of the root from mesial to dorsal. The edges of the hole seemed to be rounded and somewhat polished like it was used.
J4-7637 Capra pyrenaica, incisor	Strong whittle marks on the mesial and dorsal side of the root.
J4-5706 Capra pyrenaica, incisor	Strong whittle marks on the mesial and dorsal side of the root.
H3-2620 Capra pyrenaica, incisor	Strong whittle marks on the mesial and dorsal side of the root. Polished and oblique engraved lines, similar to what is seen in the beveled bases of *sagaies*.
H4-2066 Large bovid, lower incisor, left	Mesial and dorsal deep and clear carving marks seem to be placed over the weathering marks, thus, the collection of this item during a stage of beginning weathering is implied (maybe from an open-air site). Weathering and root activity on the surface, as well as grey-white discolorations are visible, this item was lying on the surface where it was exposed to weathering.
H3-1550 Cervus elaphus, lower incisor	Weathering over deep whittle marks.

The flattening of the mesial and dorsal side of the tooth root (as exemplified on ibex and large bovid teeth on the left side in Figure 4.39) are preparations possible for placing a hole through the root of the tooth. Very similar manufactured items are reported from Lower Magdalenian contexts in the region, one horse incisor from Altamira (Inv.Nr.2341) and large bovid incisor from El Castillo Level 8 (Inv.Nr.190) (ARIAS-CABAL & ONTANÓN 2004: pp. 232, Cat.Nr.113 & 115), or Nr.1769 and Nr.1757 in Level E in Cualventi (DE LAS HERAS 2016: p. 651,654), for example. This preparation technique as also seen in the red deer canine (right corner) and is known from perforated red deer canines found in Amalda, for example (ALTUNA ET AL. 1990; D'ERRICO & VANHAEREN 1999). One worked tooth might be discarded for another reason. The same has an already drilled hole, seems to be used and then broken. In the Cantabrian Region were similar pierced teeth found like the one observed at El Mirón to the west in Las Caldas (CORCHÓN-RODRÍGUEZ 1986: pp. 253, 309) and to the east in Aitzbitarte and short Lower Magdalenian occupations at Praileaitz (D'ERRICO & VANHAEREN 1999; VANHAEREN & D'ERRICO 2017). Such small bovid teeth with modifications and perforations were found in the Lower Magdalenian of El Castillo and the previously- considered Evolved Aurignacian (but newly dated as Magdalenian) in El Otero (MARÍN-ARROYO ET AL. 2018b). The worked teeth found might be discarded for possible failures as one has a very thin root left or others proximal end broke off. Actually, those many

different stages of ornament's life-history suggest the idea of El Mirón being a multipurpose site with production, maintenance, wear and loss all at the site.

The flattening through whittling seems a common technique for processing teeth during the Lower Magdalenian in the Cantabrian Region, which connects several sites in the classic Lower Magdalenian territory. Another, more seldom type of tooth modification is sawing incisions into the root, as have been identified on the only reindeer tooth identified at El Mirón (see right upper corner Figure 4.39). This ornament lingual side was flattened and the labial root end carries polish by use. One milk incisor from ibex also shows sawing marks and flattening of the root. These sawing marks on the labial root side, however, also can appear when incisors were intentionally extracted from the mandible or even during skinning of the animal.

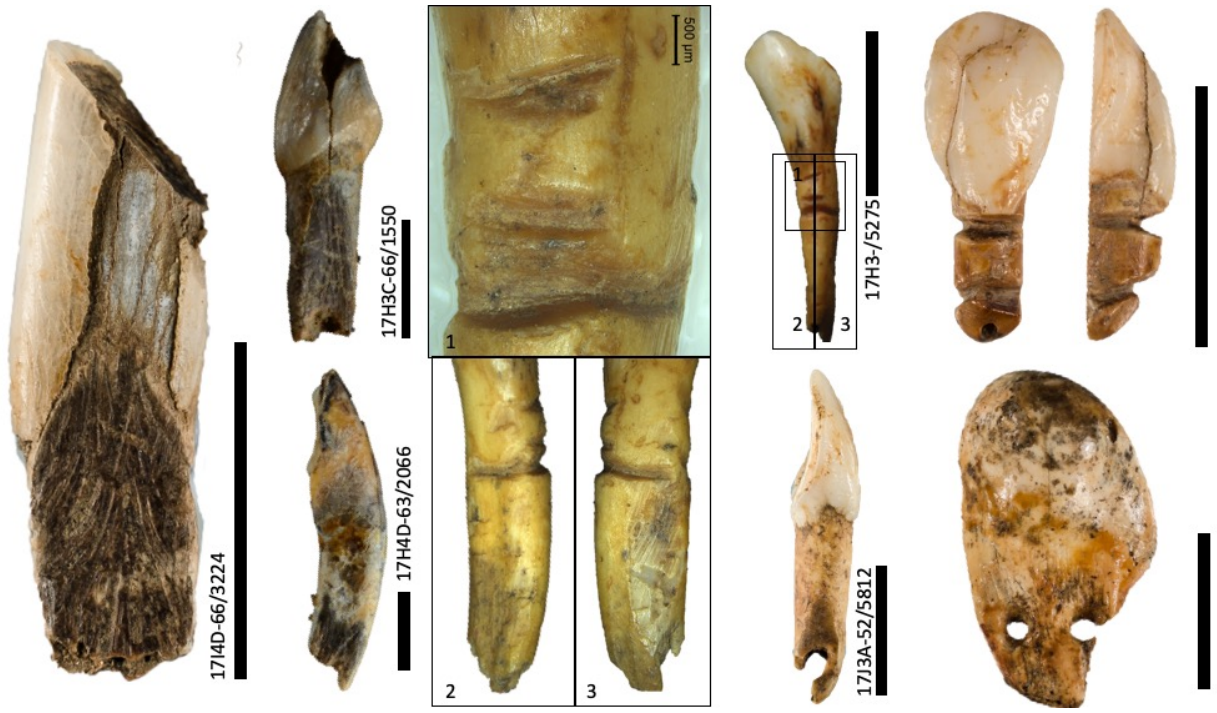


Figure 4.39: Modifications on teeth. Left: whittle marks thinning the root on ibex, large bovid and red deer incisors, middle: ibex milk tooth with whittled and incised root (microscope photo) similar to the reindeer incisor, and right, bottom: perforations on whittled roots on ibex incisor and red deer canine (ID:J3/1246).

It should be highlighted that the modifications of the reindeer tooth ornament are different and thus, a distinct manufacture and production mode is indicated. The local, Cantabrian, production or tradition of such tooth ornaments, hence, might differ from the one which was used for the reindeer tooth. More importantly, the reindeer tooth is the only piece of evidence of reindeer in El Mirón cave. The different manufacturing style, the rareness of the species reindeer in Cantabria and the fact that it is the only object of its kind so far might suggest that this ornament was brought into the site rather than being produced here. It is known the Lower Magdalenian people had connections or trade contacts with Aquitaine and the French Pyrenean regions, where reindeer were much more common within the archaeological sites of that time period. For example, long distance contacts or travel are shown for lithic raw material resources exploitation along the Cantabrian coast, the more inland mountainous area and reaching up in to SW- France (FONTES ET AL. 2016). Very similar grooved reindeer incisors have been found in Roc de Marcamps, a site near Bordeaux with atl-atls virtually identical to the one from El Mirón Level 17 (GONZÁLEZ-MORALES & STRAUS 2009; KUNTZ ET AL. 2015).

Social contacts through a long-distance network connecting Cantabria and Southwestern France is very likely shown by this artifact, which infer over-regional connectedness of these foragers.

B. Trampling is a taphonomic alteration categorized as a measure of indirect activities. In El Mirón, in absence of meaningful carnivore activity, trampling activity was considered as a reflection of human activities affecting surface finds, mainly due to the repeated and dense human actions within specific cave areas. A general higher amount of trampling marks was recognized in Level 17, but the frequencies in percentages in late Lower Magdalenian assemblages of Level 17-8, 17-6 and 16 do differ from these results.

During the Late Middle Paleolithic and Solutrean occupations low frequencies of trampling marks were recognized, though a slight increase is noticeable in Level 121, here possible to the post-Paleolithic looter activities that took place in on top of those level as described by the excavators. The trampling amount for the Lower Magdalenian levels varies, with the earliest occupations presenting the fewer trampling marks. Level 17-8 shows the highest among all studied units. With the transition to the late Lower Magdalenian occupations, Level 17-6, is still high in trampling marks with a decrease of these modifications in Level 16. Bones in Level 15 does not show these marks (Figure 4.40). The increase frequency of trampling marks for Level 17-8 indicates that during the accumulation of this assemblage, more activities were realized in this area, while before and after the area was used less frequently. Despite the fact that many squares have been excavated, the excavation areas in El Mirón cave only cover a part of the possible living surfaces. Human activities, therefore, could shift around within the large cave vestibule during or between different occupation phases.

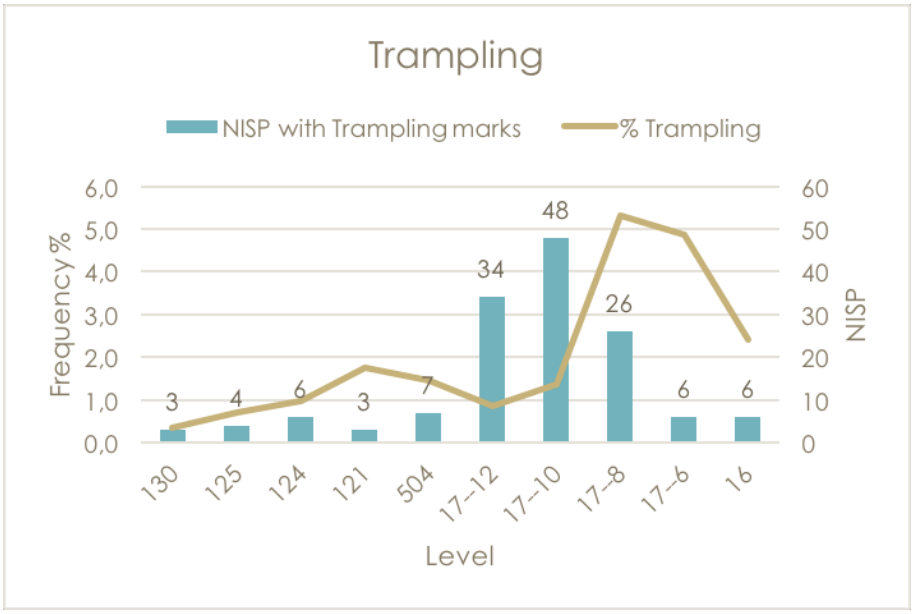


Figure 4.40: Distribution of Trampling marks among the studied levels.

4.1.5 Site diagenesis

Post-depositional components that alter the archaeological or paleontological record are collectively referred to diagenesis (LYMAN 1994). The effect of diagenetic changes affects primarily faunal remains on the surface and levels underneath, where subsequent sedimentation and depth buffers the effects. The observations of the diagenetically-produced conditions are discussed for the two main prey species -red deer and ibex. It is the purpose here to test whether there are depositional differences between the main prey species that would imply different accumulation or preservation conditions, applied throughout the

accumulation sequence, from the Late Middle Paleolithic until the late Lower Magdalenian levels. In the following paragraphs will be explored (A) bone weathering, (B) carbonate concretions, and (C) root and fungi activity. Bone coloration is separately discussed in the following subsection.

(A) The evolution of the weathering index (W0=well preserved to W5= falling apart) was analyzed among red deer and ibex along the levels. First, it is observed that the weathering stage varies between the levels, but in general, however, all faunal remains have a good preservation with an average of Weathering Stages 0 and 1. It should be also noted that the two main prey species show very similar indices, which have a higher offset only in Levels 121, 17-6 and 15, according to the observations made (Figure 4.41).

The weathering degree drastically decreases from Level 130 onward and increase with the Level 127. Level 121 show an even more drastic increase in weathering among the faunal remains. A similar increase is visible between Level 18 and 17, though, this observation might be influenced by the circumstance that faunal remains from Levels 18 to 21 were only excavated in one square close to the cave wall, where more advantageous preservation conditions might have existed compared to the whole outer vestibule excavation area. Red deer remains have a similar weathering stage as the units 17-8, 17-6, 16 and 15. Ibex remains, however, alter more between these levels in their preservation condition.

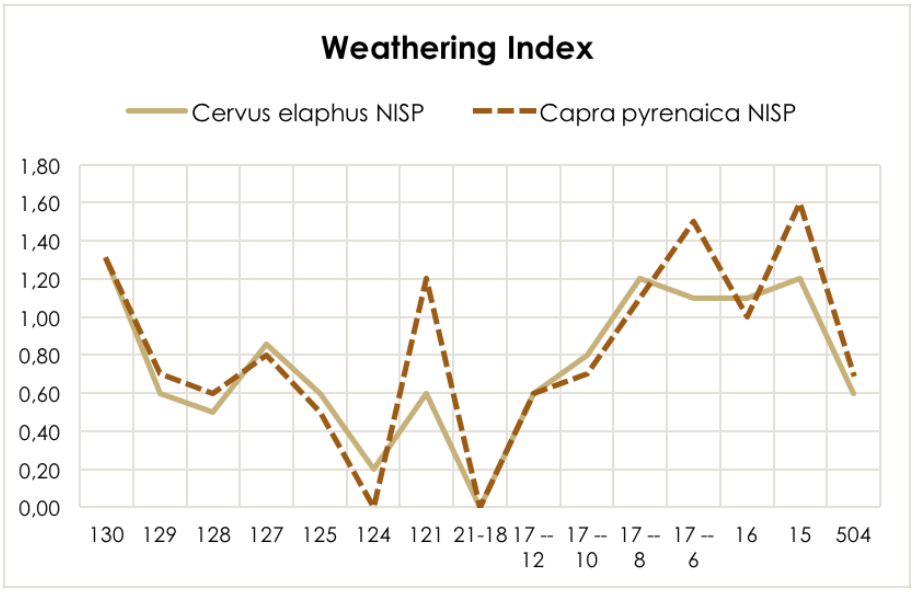


Figure 4.41: Weathering index variation among levels.

The variation of weathering stages between the species might indicate a difference on the exposure to surface environmental conditions in-between the two species, such as would be expected in a time offset to the accumulation of the bones before they got buried within the sediments. Different hunting seasons for species could be one possible explanation that suggest different occupations and prey consumption at the cave for the hunting of each of these animals. The results might be the case for Levels 121, 17-6 and 15. An alternative scenario would imply diagenetic conditions affecting the two main prey species differently, which seems less plausible when only some levels are affected within the same site.

(B) Carbonate Concretions were observed on teeth and bones. In the Corral area, the degree of calcite crust on faunal remains is variable throughout the studied sequence (Figure 4.42). Encrustation processes can be observed in Levels 130, 128, 125, 124 and 121 in varying degrees. The repeated building of calcite crust implies dry out events of previous percolated waters. In Levels 125 and 121 more than 5% of the bones, thus, were affected by these drier periods.

In the Cabin area, faunal remains from the Lower Magdalenian occupations show more intensive drying out events, presumably in relationship with rapid superficial water evaporations. Only Level 16 contains less than 5% of encrusted bones. This process has not been observed on the Initial Magdalenian Levels 18 to 21 and, in much lower quantities in Level 504 in the burial area.

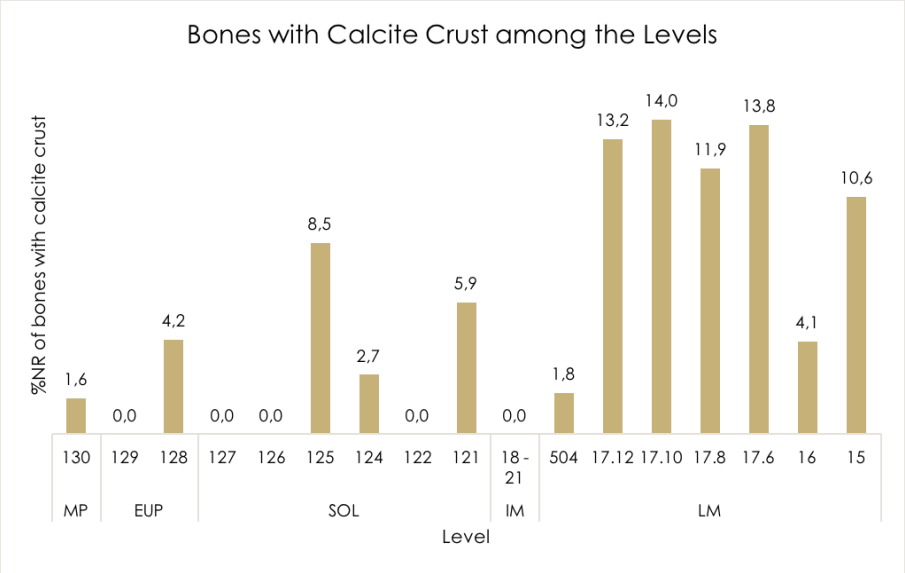


Figure 4.42: Distribution of the bones with calcite concretions.

Two kinds of secondary carbonate concretions on the bone surface were observed. 1) some bones had a calcite crust that developed within the sediments, thus, carbon rich water penetrated through the sediment, the calcite precipitated and water evaporated there later leaving a calcite crust, more or less homogenous in thickness and with sediment-particle-inclusions from the surrounding sediment of varying colors. And 2) bones with 'pure' calcite crust on their surface were presumably lying on top of the cave sediments as superficial waters evaporated, sometimes root shadows are included, varying thickness and with no or locally sediments included. These represent cave surface waters and calcite precipitation and they are mostly grey in color. The former was found on bones in the inner vestibule and the latter in the outer vestibule of El Mirón cave.

Within karstic systems rain water may permanently dripping through the cave walls, but its density may vary seasonal or with major climatic changes. Despite the different origins of water in the cave, it is clear that there is generally more water percolating through the lime stone matrix after rainfalls. Nowadays, superficial dripping water appear especially in the cave vestibule front with an offset of a few days after heavier rain falls. Similar scenarios are suggested for Paleolithic time periods, though, with presumably varying location and intensity of the dripping zone. Rain water that dripped on the cave surface possibly dried quicker and earlier in the sunlit outer part in contrast to the inner vestibule area, possible resulting in ponding. This implies that superficial waters might have staid longer on the surface, suggesting the existence of ponded water, penetrated deeper into the sediments and dried out slowly in the inner vestibule. Additional superficial waters might have run into and has gathered in this area, which is located at the base of the steep ramp reaching to the inner of the cave, where the cave sediments originate from (STRAUS ET AL. 2001; FARRAND 2012).

(C) Root and Fungi Activity were found in varied degrees on faunal remains from El Mirón. Modification marks from plant and moss roots and fungi activity (FERNANDEZ-JALVO & ANDREWS 2016: pp. 85–93) result from these organisms occupying the sediments where the bones are buried or superficially deposited on. Especially root

marks are seen in high percentages in the Cabin area where plants still grow today, particularly where water is dripping. Figure 4.43 shows plant cover in the cave vestibule before excavation season.



Figure 4.43: Plants in the front vestibule area of the Cave today (Photo taken by excavators in June 2010).

Root marks (Figure 4.44) were also observed on the Solutrean levels, with higher percentages in Levels 125 and 127, at the rear cave vestibule. Level 504 also contains root marks. In this area, today the sunlight reaches during the evenings and covers the engraved block that separates this level from the other part of the cave (GONZÁLEZ-MORALES & STRAUS 2015). The constant high amount of surface modification on organic remains in El Mirón suggest, a continue and repeated growth of plants within the cave vestibule throughout the Magdalenian occupations, as all stratigraphic levels and sublevels show root activity. Also, the continuous availability of cave dripping water favors plants growing inside the vestibule.

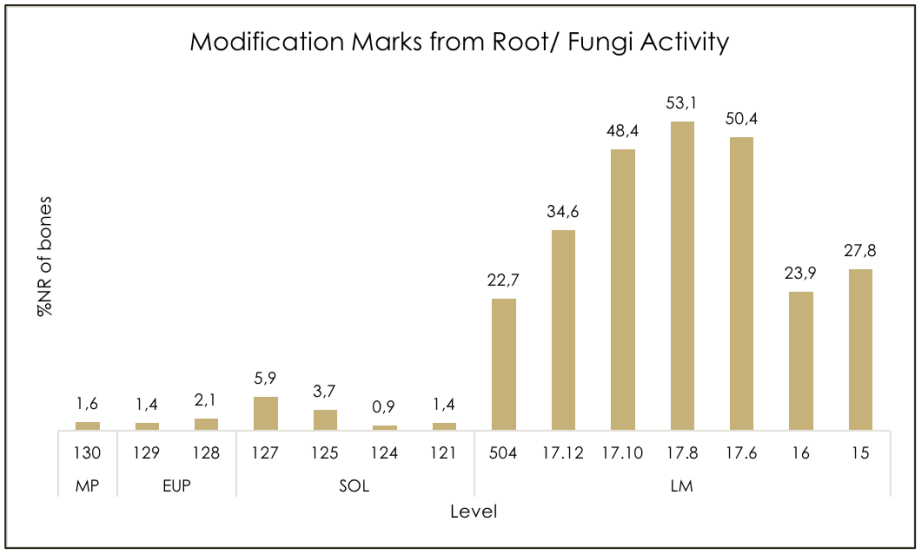


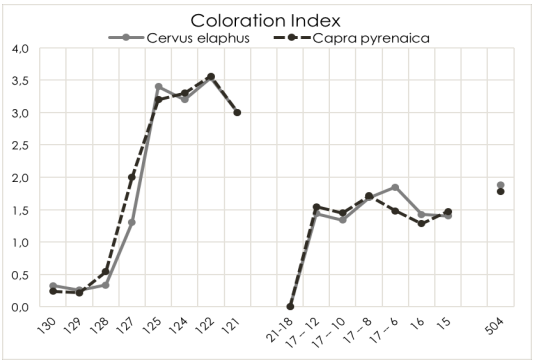
Figure 4.44: Presence of root and fungi activity on bones.

4.1.6 Bone coloration and project "ColoMiron"

Bone coloration determines the degree of bone surface coloration is measured with the coloring index, which measures the degree of color change among the bones, ranging from their natural white-beige (value 0) color to black (value 4). The variation of the coloring index among the studied fauna is presented only for red deer and ibex (Figure 4.45: .A). Both species show a very similar coloring index throughout the different levels, which indicate very similar accumulation, long-term depositional conditions and no great admixture of sediments.

The Middle Paleolithic and Early Upper Paleolithic levels at the rear vestibule show a low coloring index that indicates none or only very light bone colorations (MARÍN-ARROYO ET AL. 2018a). Beginning with Level 127, the coloration of the bones increases steadily, these bones are mostly yellow-brown. The bones from the Solutrean Levels 125 to 121 show a quite dark staining with coloration of chocolate-brown to black-brown. This dark coloration type (an index of 3 and higher) is very similar to what has been observed before (Figure 4.45: .B) in studies of the Middle to Late Magdalenian levels in the same area (MARÍN-ARROYO ET AL. 2008). The Initial Magdalenian finds from the outer vestibule excavation area show no such shading and bones kept their natural white-beige color. The Lower Magdalenian levels contain bones mainly of the colors yellow-ochre, yellow-grey to yellow-brown, which again is a distinctive color type compared with the other cultural levels. So far, it can be seen that coloration types vary with (broader) cultural periods, but with caution to the different excavation areas where the faunal remains are originating from. As these coloration and staining processes are associated with environment/ sediment/ accumulation conditions, it will be discussed in the following paragraphs which kind of climatic or biological influence could have affected these deposits in its different kind.

A - this study



B – published data

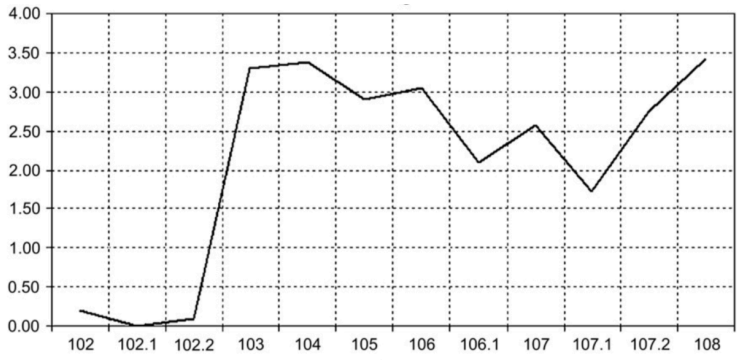


Figure 4.45: Color index variation by cultural periods (El Mirón Levels): A) at Late Middle Paleolithic (130), Early Upper Paleolithic (129,128), Solutrean (127-121) in the Corral area, Initial (21-18) and Lower Magdalenian (17-15) levels in the Cabin area and Level 504 in the burial area from this study ; B) and in reverse order at Middle (107, 107.1, 107.2,108), Upper (103,104,105,106) and Final Magdalenian (102.1-102.2), Azilian (102) levels in the Corral area form previous studies (Marín-Arroyo et al. 2008).

The current interpretation of the dark to black coloration in the Corral area (MARÍN-ARROYO 2010) is the following: the black color origins from high frequencies of manganese (Mn) oxides of the surface of bones in the corral area. Sediment analysis showed higher proportions of organic matter coherent with intense organic garbage accumulation such as animal and plant remains. High humidity and limited sun-exposure favor the growth of saprophyte microorganism that are responsible for the decomposition and mineralization

of organic materials, meaning the degradation of organic materials (plant or animal residues, living soil organism, plant roots, etc.). They are breaking down organic matter and give rise to a number of substances, among others are humic substances of yellowish-brown to black color. The process of biolixiviation makes complex metals (for example, iron and manganese) much more soluble and more mobile; a decrease in pH reduce the manganese and increase its solubility. Free Mn ions would be attracted by a more basic medium (such are bones) and by osmotic phenome that fix it to the osseous remains that mobilize the ions. Two further phenomena, then, could mobilize the Mn: 1) by time, the pH of the initial acidic surface of the cave would get increased by percolating carbonates from karstic waters, in consequence slowing down humification processes and causing the precipitation of Mn, and 2) the additional intensification of oxidizing conditions (dry, well-aerated soils) favor a change in manganese towards insoluble forms. Importantly, the origin of mineral manganese from the use as cave painting can be excluded as the mineral has not been found in the dripping water of the cave. Both areas (Corral and the Cabin), nonetheless, are "susceptible to harboring saprophytic organism communities although the conditions at the back of the vestibule are better, as this is a more stable and shadier zone." (MARÍN-ARROYO ET AL. 2008: p. 810).

Thus, humid sediment conditions, low insolation and high amount of organic materials at the rear vestibule due to the repeated process of lixiviation-oxidation seen in archaeological levels from the Solutrean to the late Magdalenian would be implied when considering previous studies. An inconsistency in color variation throughout the stratigraphic sequence, such as the one in the Corral, if observed in the Cabin area would indicate a difference in intensity of these staining processes and a fluctuation of either humidity or organic material input. This aspect was considered relevant to understand the diagenesis leading to bone coloration in the Cabin area and then was investigated in more detail, with archeometric analysis also conducted to improve our understanding of this processes based on the above described. This is the reason for the rise of the dissertation integrated project named "ColoMiron".

The project: "ColoMiron" (Coloration of El Mirón bones) was proposed to investigate the varied coloration identified during the present zooarchaeological analysis on the macromammals remains from the Vestibule Front and Rear in El Mirón cave. While a few specimens have typical bone coloration (white-beige), a varied palette of red, brown, grey and black shade coloration of bone surfaces was recorded, mainly in the front cave vestibule.

Two main objectives were addressed. First, geochemical analyses to explore and identify what caused these types of bone coloration. Second, to identify the stratigraphic and spatial location of varied bone coloration and their combinations. For this reason, Color Cluster Codes (CCC) were created, which group similar colorations of bone specimen together and, the frequency of each CCC-group is explored spatially.

Geochemical and microscope analysis of varied colored bones has been kindly realized by specialist in this field of analysis (Dr. Romualdo Seva Román, Dra. Mª Dolores Landete Ruiz and Cristina Biete Bañón who analyzed bone samples in the Archeometry laboratory at the University of Alicante, Spain and provided the analytical report (SEVA ROMÁN ET AL. Unpub.)). Bone samples of the different color types from Level 17 have been analyzed with established methods (MARÍN-ARROYO ET AL. 2008, 2014; SEVA ROMÁN ET AL. 2015, 2019). The methodology achieved included sediment analysis, bone surface exploration, scanning electric microscope (SEM-EDX) raman spectroscopy, infrared spectroscopy with Fourier transform, and X-ray photoelectron spectroscopy as explained in the method chapter.

Seva Román et al. (SEVA ROMÁN ET AL. Unpub.) described that the results from the sediments analysis from Level 17 do not reveal a different granulometry or texture with respect to the other strata of the cave, previously analyzed (STRAUS ET AL. 2001; MARÍN-ARROYO ET AL. 2008; FARRAND 2012). These are sediments with

abundant gravel and free (frank) sands that facilitate the vertical percolation and transit of water with the elements in solution. The percolation (lixiviation/ leaching) is favored during humid periods and to the contrary, during dry stages of the surrounding environment. The same phenomenon is responsible for the low content of carbonates. The pH in Level 17 is lower than basic, unusual, but it could be explained with the active lime stone dissolution in this environment and the organic matter (also plant growth in the cave surface) that could acidify the stratum.

Seva Román et al. (SEVA ROMÁN ET AL. Unpub.) also reported that during the binocular investigations and Fourier Transform Raman and Infrared Spectroscopy (FT-IR) of Level 17 bones, on some of the bone surface dark spots were observed (Figure 4.46), which are different to MnIV and carbon deposits, they are of non-crystalline structure and amorphous. It appears to be decomposed organic material with long C-H chains (bands between 2849 and 2958 cm-1 and a C=O group 1732 cm-1), so it could be some residue of a mixture of fatty acids or resin. The discovery of resin in El Mirón would be not surprising as the Lower Magdalenian is rich in bladelets, which were hafted and sagaies with presumed functional line engravings probably also aided in the security of hafting (FONTES ET AL. 2015; STRAUS ET AL. 2016, 2018). On the other hand, such mixture of fat could be residues of fat-burning lamps. Since cave art appear often beyond the daylight zone in caves, for example at Covalanas Cave located just above El Mirón, we assume those people had some portable means of lightning. However, this would be the first direct evidence of such hafting resin or fat-burning preserved at El Mirón, and importantly obtaining that fat requires some sort of grease rendering activity and cooking. These dark spots, then, are equally can serve as a criterion for cooked bone.

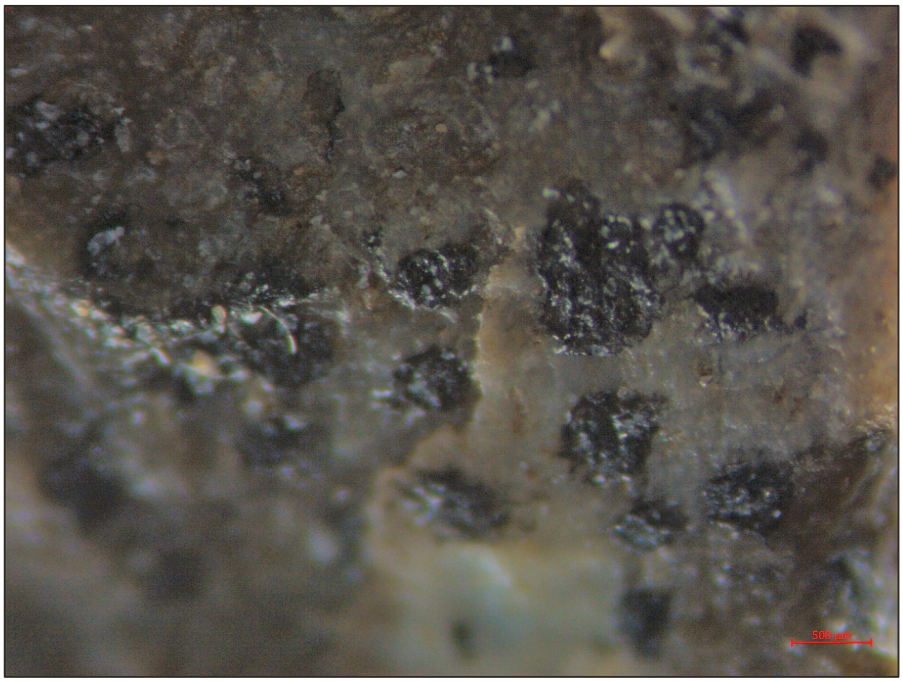


Figure 4.46: Dark spots on the bone surface were identified as residue of a mixture of fatty acids or resin. (Photograph by Seva et al.)

The scanning electron microscopy analysis reveal that in some bones titanium oxide (anatase) appears. This is a material that is clearly associated with ochre. Given the archaeological context of Level 17 and the timely and culturally associated burial of the 'Red Lady' that contained red ochre (SEVA ROMÁN ET AL. 2015, 2019), ochre may be distributed across the living floors in trace quantities or by adhering remains to artifacts

attesting contemporaneity. Beside the burial area, ochre use is not yet testified directly in the main living area of the Cabin may be highlighting its special use for burial activities at El Mirón. Especially the red ochre and crystal hematite used for the covering the human burial was transported from the Monte Buciero, some 27km from El Mirón, as recent analysis by Seva et al (2019) had shown. They also found that the engraved block next to the burial was painted not only with the same red ochre, but with a mixture containing also bone micro-fragments and fat – an aspect worth of attention in context of following animal processing activities and use of animal products.

The phenomena of (black) manganese coating are clearly detectable in the cross sections of the bones where only the external surface is stained (Figure 4.47-two lower pictures). The black staining does not occur in the bones related to the main fireplaces located in the squares H2, H3, H4 and partially in I2, and I3 of Level 17. The organic remains from the fireplaces would not release MnII for subsequent oxidation to MnIV, since they are carbonized and mineralized. On the contrary, the bones with the most manganese content correspond to the areas that do not coincide with hearths (J3, and partly I2). This location would have had more organic matter, sufficient humidity and lightning conditions (preferentially low insolation) to produce the process of staining bones black by oxidation and precipitation of Manganese IV (MARÍN-ARROYO ET AL. 2008).

Different conditions, in terms of archaeological and/or environmental context must be given in square J2 since manganese is not evidenced. Compared to other parts of the cave sediments appear relative dry, which possible did not support geochemical staining processes as the transmitting media water was missing. This highlights again that water as manganese, iron, etc. transmitter is key for any coloration of bones.

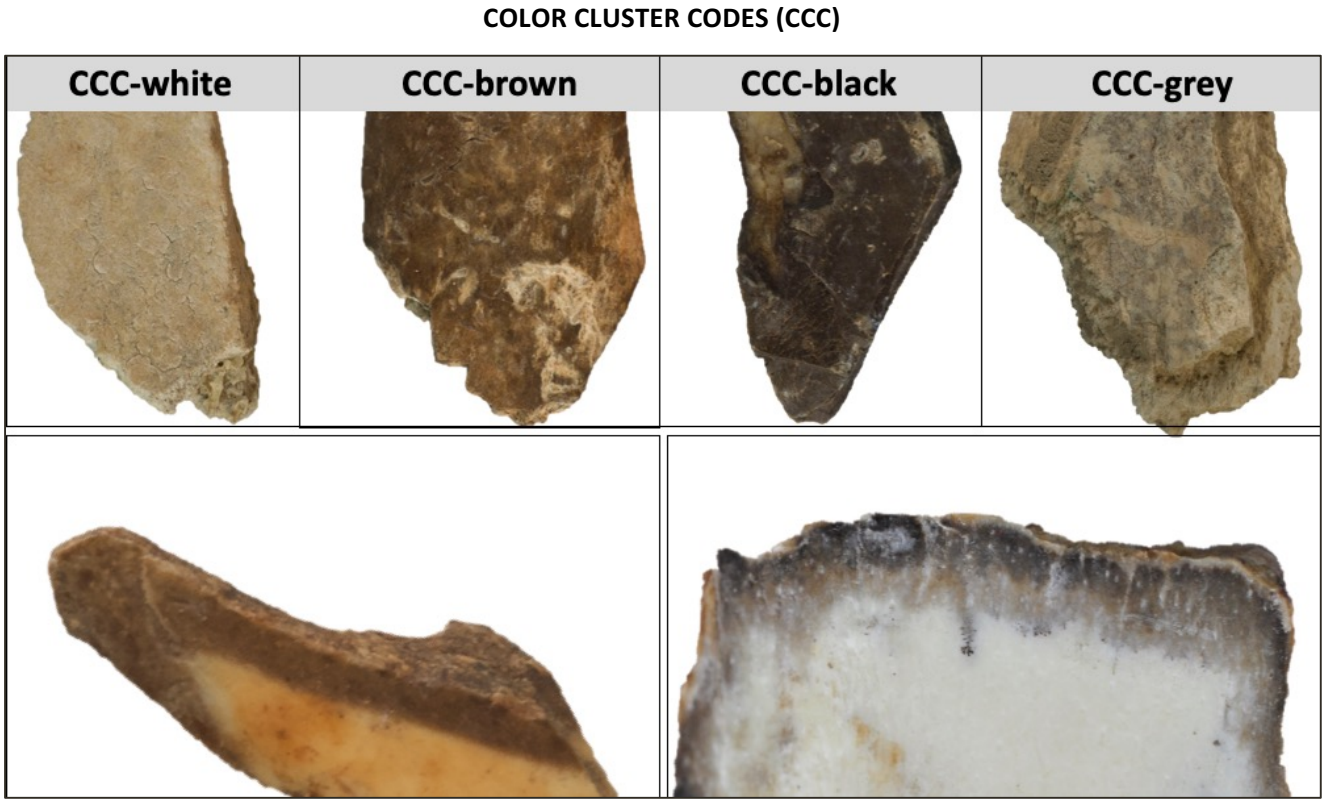


Figure 4.47: Varied coloration of bones because of manganese (Mn) and iron oxide coating (Fe). The main staining and associated color cluster codes (CCC) are indicated in above row. The two pictures of bones cross section in the lower row show that color staining occurs from the outside to the inside of the bone with different intensities. The lower right shows even two phases of staining.

For further analysis were combined the reports of origin of staining process from Seva et al. (SEVA ROMÁN ET AL. Unpub.) to Color Cluster Codes (CCC) and analyzed how the frequency and distribution of CCC varies among the studied levels (Figure 4.48). The occurrence of CCC-white and CCC-black presences is changing greatly within the rear vestibule, or corral area. The Late Middle and Early Upper Paleolithic bone colors are dominated by white and grey colorations, where brown colors play a minor role and black colors are absent. The older the levels, the more greyer shadings they have. With the beginning of the Solutrean occupation, in the Corral area, the coloration of the bones changes dramatically. Level 127 is dominated by over 70% of CCC-brown, but still some white colorations were observed. Level 125 continues to have a high percentage of CCC-brown, but what it is prominent there are bones in black shadings. These black colorations are decreasing with the next-uppermost levels, but still are present to over 25%. Later in the Solutrean levels, brown colors, again, make up the largest amount within the faunal remains.

On the Cabin area at the front cave vestibule, the color cluster varied mainly between brown and grey shadings. Brown colors are found in the highest amounts in levels 17-12 and 17-10 with over 60%. Grey shades made up ~20% within these two units. This changes with the upper next levels 17-8 and 17-6, which have a more or less equal distribution of CCC-brown and CCC-grey. Level 16 faunal remains show a slight increase of brown colorations against the grey ones, while Level 15 show again a similar amount of the two colors.

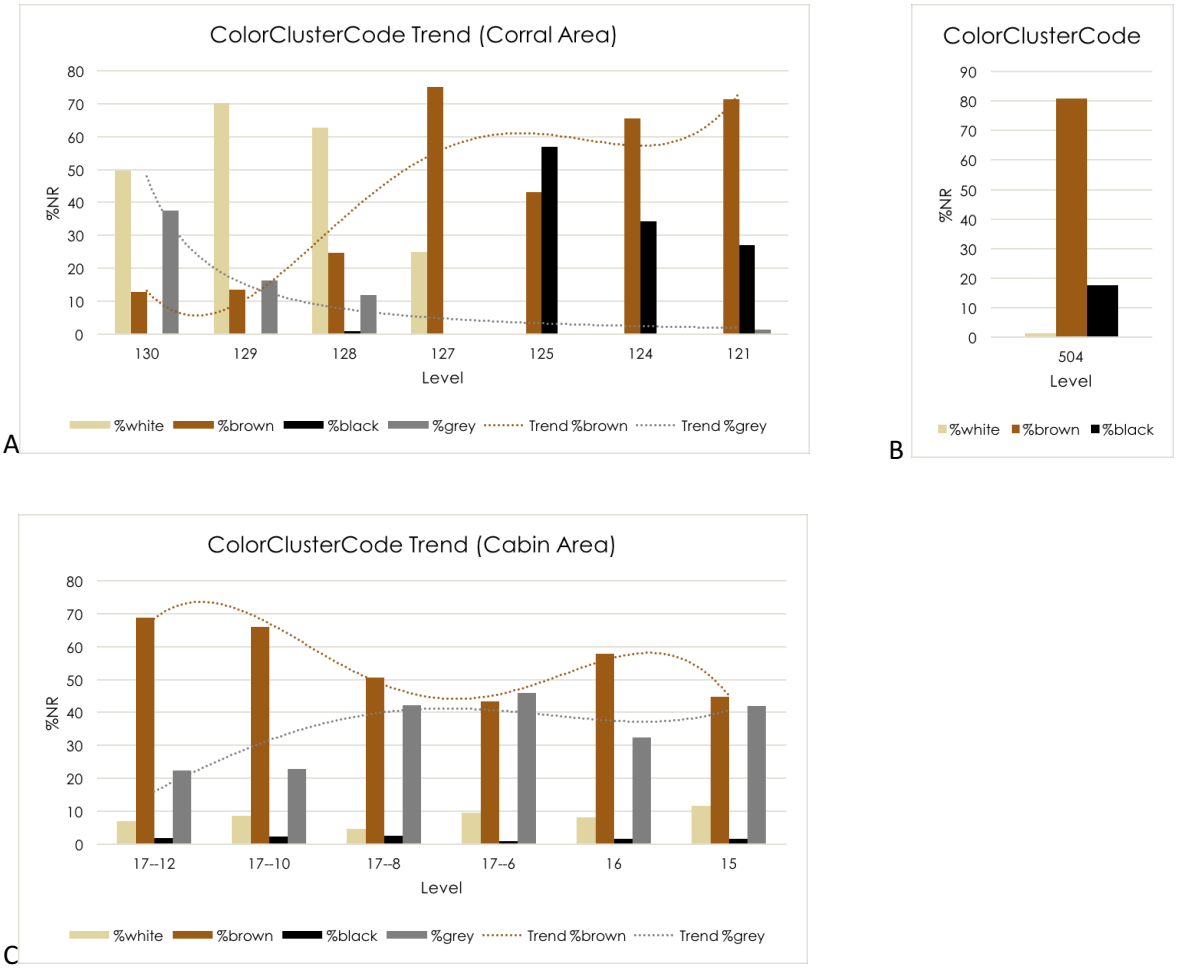


Figure 4.48: Distribution of each Color Cluster Code in the different areas within the cave vestibule: rear vestibule or Corral (A), in the burial zone and the front cave vestibule or Cabin (B) area.

In summary, the Project "ColoMiron" revealed some interesting results. Thanks to the geochemical analysis achieved by Seva et al. this research reveals that the coloration on the bones found in the front vestibule area was due to different oxidation processes from Manganese II to Manganese IV, following the same pattern as the one identified previously in the rear cave vestibule (MARÍN-ARROYO ET AL. 2008), however, in the Cabin area due to higher insolation, its spatial location close to the cave mouth, these diagenetic processes occurred with less intensity.

The solubility of Manganese++ and Iron++ together depends on the pH of the soil and the redox conditions, which vary with particular environmental conditions (SEVA 2006). The sediments in El Mirón cave have a low pH and redox environment which allowed percolation of water and its soluble elements, thus letting Mn++ and Fe++ to be mobile. When sedimentological conditions change, these minerals oxidized and attached to bones which are highly porous.

By means of this project, the CCC changes infer depositional environmental variation between the diagenetic histories of the faunal remains, which I refer to as nano-environments from here onwards in contrast to micro-environments that comprise local site surroundings. Such diagenetic processes have to be considered separately for the Corral and Cabin area, because of their location in El Mirón caves vestibule rear and front area, respectively.

- Corral area: The white-natural colorations of the Middle and Upper Paleolithic bones might indicate the absence or low presence of organic remains and minerals in the deposits. Brown colorations in bones, high since the begin of the Solutrean occupations, appear to be influenced by iron minerals and humic acids. Level 127 indicate the first moment of more organic input into the caves sediments. The black color types, found mostly in Solutrean levels and being highest in Level 125, suggest an increase in either the amount and the frequency of organic materials deposited (also in above Magdalenian levels) and humid sediment conditions. Oxidizing bacteria need to be present to mobilize a derivate of the non-water-soluble manganese (MnII) that stains bones black (to MnIV). The presence/ absence of these bacteria might be influenced by temperatures, humidity and/or the availability of feeding grounds, which would be organic leftovers in the case of El Mirón. Thus, with early Solutrean occupations was a nano-environment created that include higher input of organic remains. Grey colors, often found before and after the Solutrean, might be associated to humid conditions and the presence of organic remains in less intensities.
- Cabin area: Bones from the Lower Magdalenian sequence contain mainly brown and grey colors. In the early phases are dominant brown colors and in the later phase grey colors. The conditions that results in CCC-grey still need to be enciphered completely in future research. But likely due to close location of the Cabin area to the cave mouth, sediments seemed more affected by the seasonal climate fluctuations with less stability supporting only limited presence of oxidizing bacteria, thus, limited staining. Especially sediment humidity, necessary for mobilizing manganese, seem to be an unstable factor in this area of the cave. Alternating conditions of insolation, humidity and temperature, may have influenced the grey types of bone colorations. Some cross section of bones even show like two staining phases may be reflecting seasonal fluctuation whilst still deposited in sediments on or near the surface (compare the lower right picture in Figure 4.47).
- The different characteristic that cause such varied types of colorations represented in each CCC, thus, stand for a different nano-environment in stratigraphic units. In consequence CCC- white refers to generally more dry conditions, CCC-black for more humid ones, with the presence of organic materials in the sediments and CCC-brown would be in an intermediate stage and presence of iron minerals (compare the upper pictures in Figure 4.47).

Then, the varied coloration of the bones among the studied levels would infer, thus, changing conditions in either natural and anthropogenic accumulation processes, temperatures, humidity and insolation on the sediments in El Mirón cave. It is suggested that the staining of the bones comes from authigenic minerals that they are found where they were formed, instead of being transported there. Therefore, this reflect the tendency of sedimentary materials to achieve chemical equilibrium when new environmental conditions are imposed, indicating the conditions that prevailed at the time of formation (KARKANAS ET AL. 2000). However, extensive precipitation that increase water presence and activity in the karstic cave system could favor mineral percolation also through sediments of archaeological layers. When chronological later intensive deposits of organic remains were decomposed by oxidizing bacteria mobilizing manganese, those minerals can also be transported to archaeologically older levels. Whether the dominance in staining of Magdalenian and Solutrean bones from the Corral area of El Mirón might be originating mainly from rich Middle/Upper Magdalenian organic deposits and downwards percolation or repeated organic input could be further investigated. More detailed spatial analysis of those coloration variation in time and space would be helpful for further insights on environments-human relationship.

4.1.7 Conclusions on taphonomy at El Mirón

Humans were the primary accumulator of the El Mirón faunal assemblages. Carnivores played only a limited role, although which was more relevant during the Late Middle Paleolithic and the transition to the Early Upper Paleolithic. The frequency of carnivore activities was generally low, with gnaw marks and digestions traces, presumably from small carnivores such fox, but also bigger ones, of wolf size. Repeatedly, throughout the different archaeological levels, digested bones reflect a pattern in body part representation, similar to bearded vulture activities during the Late and Middle Magdalenian in the same cave. These items are distinctively modified and easily separated from the other faunal remains.

While the Late Middle Paleolithic and Level 129 faunal remains show a mixture of human and carnivore activities, dominated by the latter, the main accumulation agent of the studied units from the Early Upper Paleolithic, Solutrean, Initial and Lower Magdalenian were humans. They mainly accumulated ungulates such as horse, bison, red deer, ibex, and chamois. Small birds, mice, rats, frogs, and small carnivores seem to belong to the general background fauna of these faunal assemblages.

Fresh fractures, followed by cut and impact marks, were the most common anthropogenic modifications. The pattern of butchering activities interpreted form the cut marks were related to skinning, disarticulation, filleting, and bone working activities. Both red deer and ibex, show intensive modifications that refer to the exploitation of meat as well as within bone nutrients such are bone marrow (bone cavity cracking) and bone grease (with a stone cooking technique implied). The activities of butchering, marrow, and grease extraction were reconstructed and compared for the different species and levels. Remarkably, generally cut marks pattern for ibex are dominated by skinning and filleting activities, while red deer by raw material use, a pattern presumably resampling different transport selection of the game species by human hunters.

Reconstructed butchering activities differ slightly among the excavation areas. A possible explanation might be that the burial area was a place that people used to dump the ‘garbage’ as opposed to where humans lived in the vestibule front area. For this area, behind the engraved block in the vestibule rear, thus a more undisturbed accumulation was found where bone surfaces are mostly perfectly preserved. The sediments of Level 504, that contained the human remains of a primary burial, were partially disturbed during the extraction of bones for possible reposition elsewhere (STRAUS et al. 2015a). The sunlit vestibule front area, in comparison, was repeatedly occupied. The movement of people and, thus, bones accumulated within this living and working space suffered more trampling and movement, which attacked all bone surfaces.

Based on the taphonomic data it was possible to rebuild the sequence (*chaîne opératoire*) of animal exploitation and to reconstruct the depositional history for the studied units. During faunal analysis were identified different categories of worked bone remains, they can be summarized as it follows: bone flakes, production leftovers from bones (blanks, blank production waste, production failures and production remains), bone tools (needles, wedges, retouchers), bone points and 'used bones' (of yet undetermined usage). Especially interesting are point-tip fragments broken off from the tool that present mostly a beveled fracture (PÉTILLON ET AL. 2016). They display one of the ultimate end-products of a *chaîne opératoire* of animal carcass exploitation, which might nearly include all the activities of raw material search, point production, hunting, and finally consumption where the broken points got recovered from inside the carcass and later discarded (LANGLEY 2015). Antler materials belong to the category with a firmly raw material character, showing intensive exploitation during the Lower Magdalenian and the flourishing of the osseous industry during this period. A groove and splinter technique is used to extract blanks from red deer shed antlers (ASHBY 2013). The sequence of grooving – chopping – shaping – smoothing (compare CLARK 1953), seems to have been the system of manufacture for producing the *sagaies* of Lower Magdalenian levels, as leftovers of each of these production steps are frequently found among the faunal material. Nevertheless, a high number of intentionally modified bones within the levels were found, many were used as raw materials (especially during the Magdalenian), for the manufacture of tools, and possibly symbolic objects.

Some post-depositional alterations gave further information on human activities. Such human related results include trampling intensity, residue of possible fat on bones, ochre traces passed from the burial along Level 17, and manganese staining of bones occurred at locations of organic matter, but not at hearths. Initially thought to be diagenetically alterations, dark spots on bones found are determined as a criterion for grease rendering and cooked bone.

The post-depositional alterations observed on the bones indicate several changing environmental conditions as well as certain human activities. Weathering processes affected bones in the front vestibule more than in the ones deposited on the rear vestibule, while red deer and ibex are affected in similar ways, which indicate related accumulation and depositional conditions. Levels 121, 17-6 and 15 show a separation of the Weathering Index between the main two prey species, which infer a timely separated deposition, for example a possible explanation is a deposition in different season. The coloration of the bones varies among levels, from light colors in the Late Middle Paleolithic and Early Upper Paleolithic deposits, brown to dark ones within the Solutrean and yellow-brown-grey ones in the Lower Magdalenian of the Cabin area. Different chemical processes seemed to be the origin for these various tones of bone staining, which could be tied back to the degree of humidity and organic matter within the deposits. Secondary calcite percolated the sediment in both the rear and front vestibule. Especially in the rear vestibule, $CaCO_3$- encrusted bones, which infer changes in humidity within the cave are indicating meteoric water in the environment. Dripping water seems to have constantly affected the sunlit front vestibule where plants have grown and left several root marks on the faunal remains of this area.

The taphonomic history of a sample allows the faunal analyst to know factors that modified the faunal assemblage by evaluating the degree of additive (i.e. human or carnivore marks, coloration) and reducing (i.e. attrition, bone eating) alterations. After knowing the degree of human alteration that modified a faunal assemblage, the analyst can go further towards human behavior interpretations. In conclusion, the results collected during the taphonomic analysis provide a solid dataset for further interpretation of human activities. A broad analysis of pre- and post-depositional processes enabled to decipher the integrity of the faunal assemblage for further economic analysis presented and discussed within the following Chapter 4.2.

4.2 Human subsistence strategies

Archeozoological analysis was applied to investigate human subsistence strategies, in terms of prey species contributions into the human diet and what the skeletal profile of prey animals revealed about site function. In this case, paleoeconomic faunal studies address a series of questions that can help to untangle the functionality of a site and capture the patterns of human behavior. Understanding site use and function allow researchers to place the site's role within the local settlement and subsistence systems of the hunter-gatherer societies that occupied El Mirón Cave, and more broadly, the Cantabrian Region as a whole during the Paleolithic.

Faunal material from Levels 130-120 (Late Middle Paleolithic [MP], Early Upper Paleolithic [EUP] and Solutrean [SOL]) from the Vestibule rear ('Corral') area, Level 504 (Lower Magdalenian) from the burial area, Levels 21-15 (Initial Magdalenian [IM] and Lower Magdalenian [LM]) from the 'Cabin' area in the Vestibule front of El Mirón cave were studied. Archeozoological analyses were organized according to the paramount objectives of understanding paleoeconomic behavior.

- Which were the patterns of species frequency in the archaeological faunal assemblages and, how can be explained?
- What human behavior reflects the faunal skeletal profiles preserved?
- How does the exploitation of animal resources vary through time?
- How does the site function change throughout time? What does it imply for the settlement and subsistence systems?

4.2.1 Faunal quantification

Quantification methods for the faunal specimens are described by the number of studied remains, degree of anatomic and taxonomic identifications, and re-articulation.

The faunal assemblage studied comprises 241,285 faunal remains, of which a total of 232,682 are bones and 8,603 dental elements. All obtained quantifications are described in Appendix C for each level studied, including in Appendix E NISP, MNE, MNI and age determination, when possible. The highest numbers of MNE and MNI were recovered from the Vestibule Front Level 17 Lower Magdalenian, specifically in samples 17-8 and 17-10. All records from the present faunal analysis are summarized in the following table (Table 4.9).

Table 4.9: Summary of the studied faunal materials originating from different periods: MP-Late Middle Paleolithic, EUP-Early Upper Paleolithic, SOL-Solutrean, IM-Initial Magdalenian and LM-Lower Magdalenian.

Cult.	Level	NR	Total weight	NISP	MNE	MNI-ungulates	MNI-carnivores	MNI-others
MP	130	2995	935.6	301	61	8	3	4
EUP	129	1215	418.5	132	44	5	0	4
	128	5531	2096.11	1096	128	7	2	8
SOL	127	1595	1157.2	92	37	5	0	8
	126	982	748.9	58	23	6	1	1
	125	4942	2087.9	271	100	10	0	3
	124	3650	1630.9	234	73	11	0	2
	123	381	133.2	37	16	3	1	0
	122	6371	3936.8	410	127	11	0	2
	121	17370	6264.38	350	89	11	0	3
	120	59	30.9	1	1	1	0	0
IM	21	9	48.8	9	6	2	0	0
	20	4	16.7	4	4	2	0	0
	19	508	268.7	14	12	2	0	0
	18	1751	996.7	64	35	6	1	0
LM	17 (12)	15214	15189.7	2177	388	31	2	2
	17 (10)	28252	20560.8	2581	484	36	1	3
	17 (8)	54306	22054.8	2419	506	38	0	4
	17 (6)	40622	8251.7	686	190	17	1	1
	16	34720	11905.9	1366	393	26	1	3
	15	19989	8501.5	1132	262	21	2	2
	504	819	/	817	213	14	2	0
Total		241,285	105,147.79	14,251	3,192	273	17	50

In every level or sublevel studied, NISP increased when including identifiable general bag items. This is especially true for the smaller assemblages such as Levels 130 to 125, but also for 16 and 15. An average of 40% of NISP of the individual identified bones from all levels come from general bags (mostly small items collected in the field without piece-plotting and especially items found in the screen, these are macro-faunal remains generally smaller than 3cm, often taxonomically and anatomically non-identifiable). For example, for Level 17, by far the richest level of the assemblages studied, 28% of the identified remains come from general bags.

Such an observation implies to include all the available archaeological record, regardless of any pre-sorting of materials done during excavation. This procedure holds true for any novel material-related research question, which typically pre-concludes that nobody has studied and sorted the material from this perspective before. A holistic study approach is meant for the excavation unit addressed, for example, squares or spits, rather than a whole site.

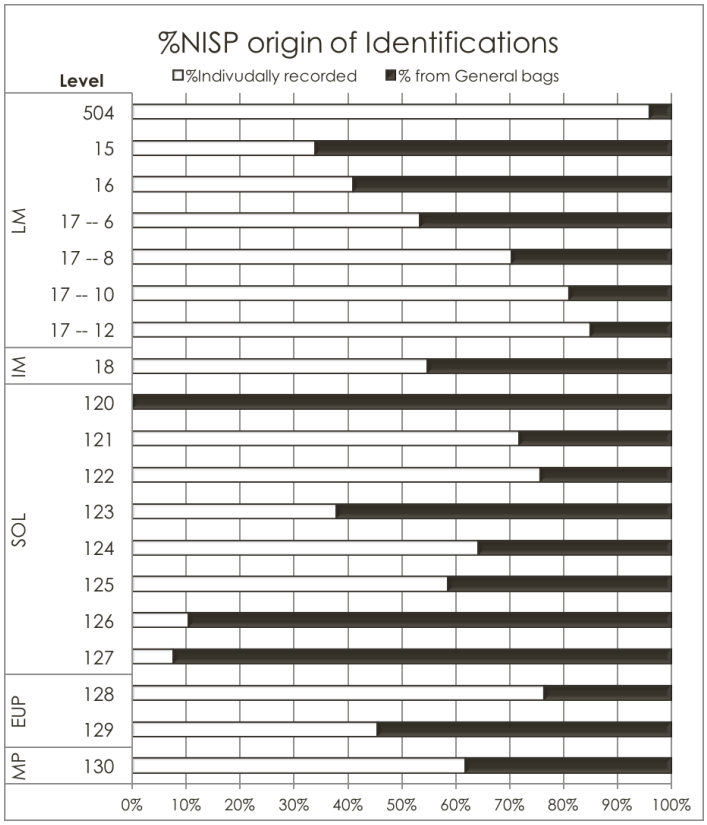


Figure 4.49: Frequency of identifications of different origins: individual records and general bag finds.

The identified fauna is primarily represented by artiodactyl species (=ungulates) and various carnivores. Other species besides the main ones were identified (see faunal spectra in Table 4.10) notable reindeer (one tooth), bearded vulture, or lynx.

Table 4.10: Identified species according to their order and family.

PROBOSCIDEAE Mammuthus primigenius (Blumenbach, 1799) **PERISSODACTYLA** (Owen, 1848) *Equus ferus* (Linnaeus, 1758) **ARTIODACTYLA** (Owen, 1848) Bovidae *Bison priscus* (Bojanus, 1827) *Bos/Bison* (Linnaeus, 1758) *Capra pyrenaica* (Schinz, 1838) Rupicapra rupicapra (Linnaeus, 1758) Cervidae *Cervus elaphus* (Linnaeus, 1758) *Rangifer tarandus* (Linnaeus, 1758) Capreolus capreolus (Linnaeus, 1758)	**CARNIVORA** (Gray 1821) Felidae *Panthera pardus* (Linnaeus, 1758) *Lynx sp.* (Kerr, 1792) Canidae *Canis lupus* (Linnaeus, 1758) *Vulpes vulpes* (Linnaeus, 1758) Ursidae *Ursus arctos* (Linnaeus, 1758) **LAGOMORPHA** (Brandt, 1855) Oryctolagus cuniculus (Linnaeus, 1758) *Lepus sp.* (Linnaeus, 1758) **PRIMATES** (Linnaeus, 1758) *Homo sp.* (Linnaeus, 1758) **AVES** (Linnaeus, 1758) *Gypaetus barbatus* (Linnaeus, 1758) **AMPHIBIA** (Gray, 1825) **PISCES**

During identification of faunal remains, commonly, one identifies first the anatomy of a specimen before the taxonomy can be determined. A norm is that all taxonomically identified pieces are also anatomically recognized, but not necessarily *vice versa* (KLEIN & CRUZ-URIBE 1984; REITZ & WING 2008). The anatomical identification rate is relatively high, between 80% to 100%, throughout all studied units (Figure 4.50-A). Similar rates were achieved in terms of %NISP and %weight. A higher difference between the quantification of %NISP and %weight is shown in the taxonomic identification rate. Normally, %weight is higher than %NISP, this might originate in the fact that the bigger the specimen is, the more likely it is to be identified. The taxonomic identification rate varies throughout the studied units (Figure 4.50-B). While the middle-sized faunal assemblages have the lowest identification rate, the smallest ones of Levels 21 and 20 and the largest ones of Level 17 show the highest taxonomic identifications. Level 504 also shows again a high number of taxonomically determined remains, probably due to the fact that within this layer, the general bag (smaller) items were not included in the study.

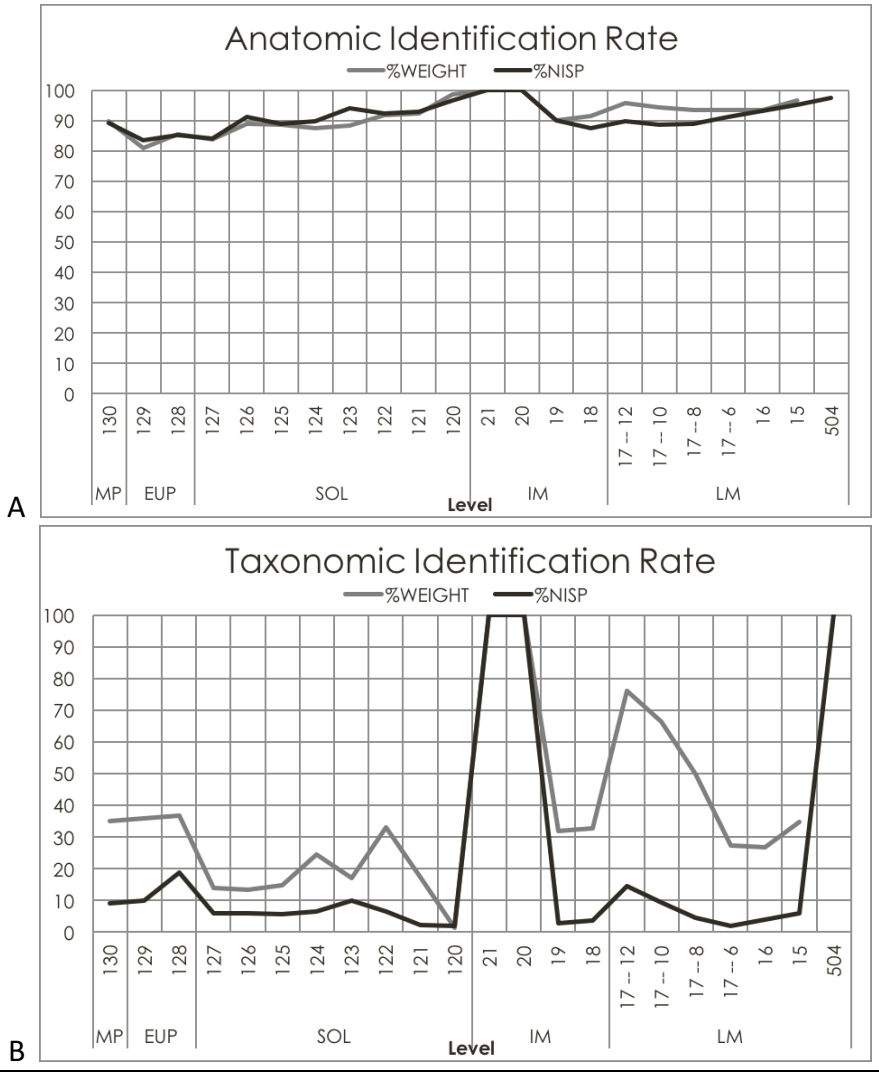


Figure 4.50: Frequency of anatomic (A) and taxonomic (B) identifications.

The %NISP from the studied faunal material indicates that the most represented animals in the overall assemblage are ungulates, dominated by red deer (%NISP=10%) and Spanish ibex (%NISP=21%), but these also include large bovids (*Bison/Bos*), horse, roe deer, and chamois. An isolated tooth from the reindeer was also identified. Together comprise the ungulates comprise 77% of the entire studied collection. The

frequency of carnivores, other species (birds, fish, amphibians and rodents), and anatomically identified bones in size classes is summarized for each level in the table below (Table 4.11).

Table 4.11: %NISP for ungulates, carnivores, and other taxa such as leporids, birds, and fish identified taxonomically (%ID_{taxa}) are given with respect to percentage of remains identified anatomically by size classes.

Level							
$\%ID_{taxa}$	%Ungulates	15	16	17 -- 6	17 -- 8	17 -- 10	17 -- 12	504
	%Carnivores	84.2	81.7	82.8	78.4	79.6	84.9	99.8
	%Others	85.8	83.4	83.7	79.0	80.2	85.3	100
		0.8	1.0	0.4	0.1	0.1	0.2	0.2
		0.8	0.7	0.4	0.6	0.5	0.2	
		14.2	16.6	16.3	21.0	19.8	2,1	
%ID by size classes		100	100	100	100	100	100	100
%NISP total		18	19	20/21	120	121	122	123
		96.9	85.7	100	100	80.0	72.8	97.3
		98.4	85.7	100	100	81.7	74.5	100
		1.6				1.7	1.7	2.7
		1.6	14.3			18.3	25.5	
		100	100	100	100	100	100	100
		124	125	126	127	128	129	130
		89.3	90.7	77.6	55.4	15.1	311	33.6
		91.5	93.3	100	95.7	32.4	63.6	61.5
		2.1	2.2	20.7	40.2	16.9	32.6	26.6
		8.5	6.7		4.3	67.6	36.4	38.5
		100	100	100	100	100	100	100

In El Mirón Cave, large carnivores might have entered the cave at any time when humans were not in residence; however, small carnivores, presumably mainly foxes, seem to have used the cave more frequently. The dominant non-human agents identified at the site are birds of prey, which seemed to have used the cave for breeding. This was recently confirmed on egg shell remains (DEMARCHI ET AL. 2019), implying only a low frequent use of the cave, probably always only one single breeding pair at time. Bearded vulture activity, is confined to either accumulate certain skeletal parts or select from carcasses especially grease rich parts, but not to accumulate extended parts of the body (MARGALIDA 2008). Fortunately, the taphonomic modification pattern of digested bones is characteristic and faunal remains can be securely distinguished by accumulating agent and not influence further interpretations of human activities (MARÍN-ARROYO & MARGALIDA 2012).

The species distribution shows a constant high number of ungulate species identified among all faunal remains. The high percentage of large ungulates (mainly big-game species) might constitute a phenomenon typical of the product of Paleolithic human activity in general (GAUDZINSKI 2000), along with that of large carnivores, as to the steep entrance to El Mirón cave non-mountain species-ungulates would not enter

naturally. A similar pattern of species representation was observed in previous faunal studies for El Mirón during Middle and Upper Magdalenian time periods (MARÍN-ARROYO 2010).

Since the depositional history of the assemblages can be reconstructed by cross-connecting bones (ENLOE 1995), objects were refitted directly across old fractures (NR=19, NISP=42) and by rearticulation or reunion of physiological pairs (NR=45, NISP=112) for fauna. During this study, in Level 504 was found one refit of a first ibex phalange and nine reunions (NISP=24). In the Vestibule rear (%NISP=2.5) more items were reunited than in the Vestibule front (%NISP=0.1) as a few examples show in Figure 4.51. Since the sediments surrounding the burial area seemed relatively intact, forming of a bathtub like deposit (GEILING & MARÍN-ARROYO 2015), a general distinction among the different areas of cave may be suggested in terms of area use. Intensive human activities, such as transport/displacement, cleaning, destruction, etc., can disperse faunal remains through trampling and other activities in living areas (see also the result Chapter 4.3 in regard to spatial analyses of faunal remains). The higher number of re-articulations and less trampling observed in the Vestibule rear behind the block suggest that this area might have been primarily a spatially and functionally separated area for perhaps refuse deposition rather than a living space. It can be remarked that in the northern part of the Vestibule rear (Corral area) have been identified hearths, pits, pavements, and a possible wall creating relatively complex site structures, perhaps in the whole Vestibule (STRAUS & GONZÁLEZ-MORALES 2018). Definitively could the direct comparison of the 'same' moments of occupations from the different excavation areas accomplished to verify this hypothesis, with the caveat that most of it is still unexcavated. The following economic analysis, however, will reveal manifold insights to which degree especially the Vestibule front area has been heavily involved in human activities in El Mirón.



Figure 4.51: Refit and rearticulation examples from Level 504.

4.2.2 Hunting strategy and game diversity

The skeletal remains of identified species are investigated to elucidate hunting strategies of Paleolithic humans who occupied El Mirón Cave, including prey species preferences, demographic composition, biomass obtained and seasonality of kills (and hence occupation of the cave).

When comparing the frequency of the main game species represented in the fauna, the dominance of red deer and Spanish ibex averages out to 22.7%NISP and 27.9%NISP, respectively (Figure 4.52-A). According to %NISP, ibex remains are more frequent than red deer remains in most of the levels, except Levels 126, 121, 120 (Solutrean) and 18 (Initial Magdalenian). Such levels of low NISP show skewed identification rates biased towards larger fragments from red deer, which display higher percentages of those remains. Among the

samples of high or moderate number of faunal remains (more than 10,000), only Level 121 has a greater portion of %NISP of red deer than ibex.

The third most common species is chamois represented with an average of 2.1%NISP, although this average is inflated by Level 126. This species is better represented in Late Middle Paleolithic, Solutrean than in the Lower Magdalenian, but also later during the Middle (Level 108) and Upper Magdalenian (Levels 106, 307, 308) studied by Marín-Arroyo (2010), but was sparse overall. According to MNI (Figure 4.52-B), whether this prey species of smaller body size, but as agile than ibex in steep-rocky terrain was selection to be killed for certain purpose, due to economic stress or climate changes favored this species temporary in the surroundings of the cave are not fully understood. Some of these events are contemporary to short climate ameliorations shown in the GISP2 core observed for Solutrean and Middle Magdalenian levels, and the Upper Magdalenian abundance of chamois in El Mirón fauna occurred during DO1 event. Temporary abundance of chamois in the El Mirón catchment area could either be favored by population growth or habitat shifts.

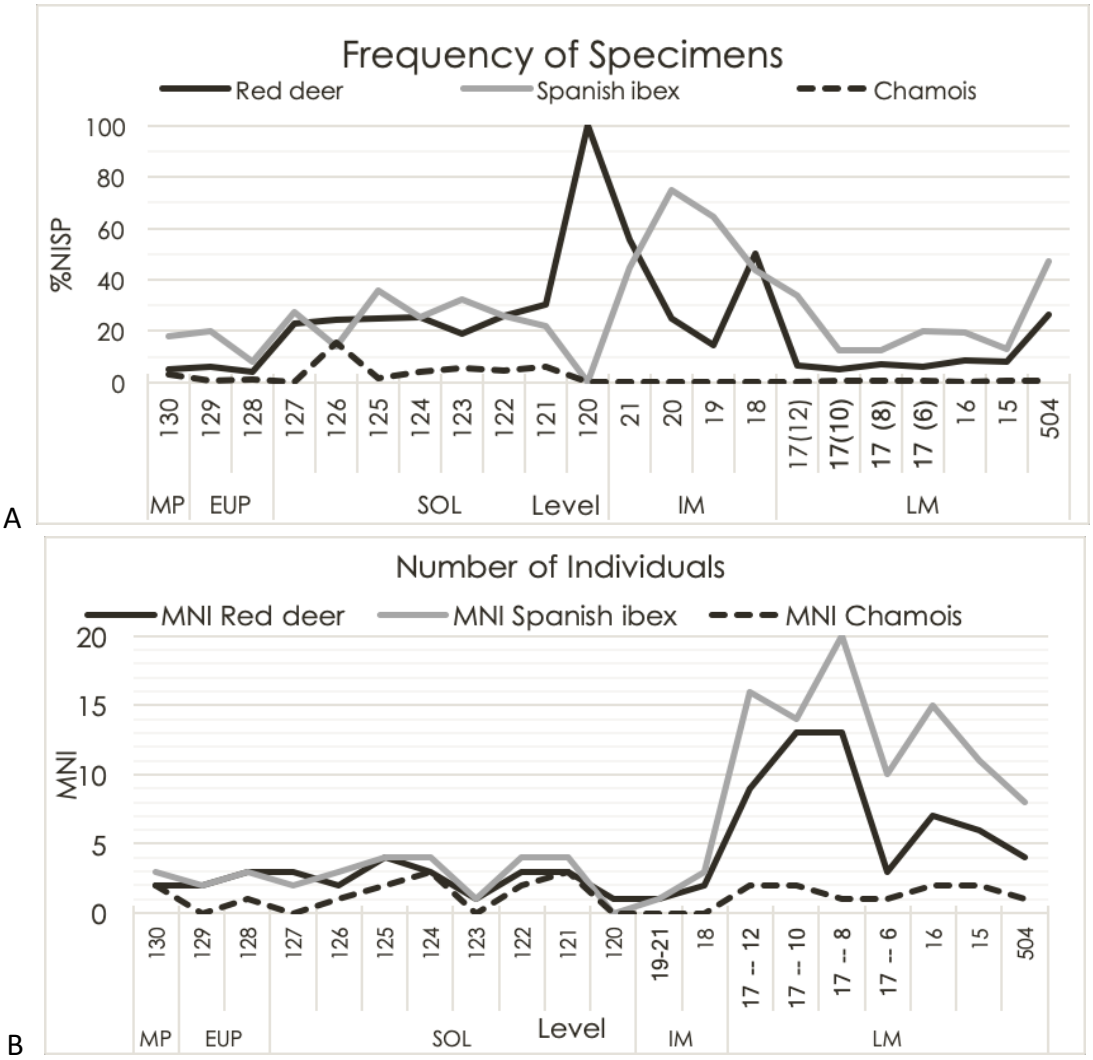


Figure 4.52: Frequency (%NISP) of main prey species (A) and minimum number of individuals (B): red deer and Spanish ibex.

According to the number of individuals, ibex mostly outnumber red deer, especially in the Lower Magdalenian occupations, which for Cantabria have been referred to as being hunters specialized in red deer (FREEMAN 1973). Although, red deer only exceeds ibex in Level 127, by one individual, it is equally well

represented. However, based on the steep, rocky mountain terrain around E Mirón, one would be expecting a specialization in montane species (ibex and chamois) hunting, such is seen in other comparable mountain sites like Rascaño, Collubil or Bolinkoba in the Cantabrian Region and Les Eglises or La Vache in the French Central Pyrenees (STRAUS 1987). This highlights the special character of El Mirón site and its catchment area that include habitats of all those game species as demonstrated before by topographical analysis (MARÍN-ARROYO 2009). However, a dominance in numbers of remains should not be confused with what could have been the relatively contributions of these two animals to the human diet, since red deer is larger than ibex. Moreover, before estimating the biomass contributed by each game species to evaluate the roles they played in the human diet, the mortality profiles of hunted species through ageing and sexing of identified individuals should be determined.

4.2.3 Demography of main game species

When possible, individual animal age was determined based on dental root maturity, dental eruption and wear stage and on the stage of long bone epiphyseal fusion as explained in the methods section. A list of osteometric measurements recorded are given in Appendix D.

In the Lower Magdalenian (Levels 15, 16 and 17), red deer and ibex molars often do not show roots during the period of mineralization (VIGAL & MACHORDOM 1985; BROWN & CHAPMAN 1991a), but rather they mostly display a normal developed root or roots showing advanced maturity signs of massive cementum growth ('massive root'), see Figure 4.53. These results indicate a dominance of adult (prime age) individuals. They also show that 'massive roots' (from adult or older individuals) were observed more often in the upper than in the lower molars and more often in ibex than in red deer. The underrepresentation of very old upper M3 in ibex might originate in either massive root development being generally less common in upper M3s. Either very old ibex skulls, including maxillary bone were not brought to the cave, or very old skulls were deposited spatially in some different areas of the cave. The results indicate, however, that a broad spectra of animal ages are present among the hunted animals, some of them of relative old age.

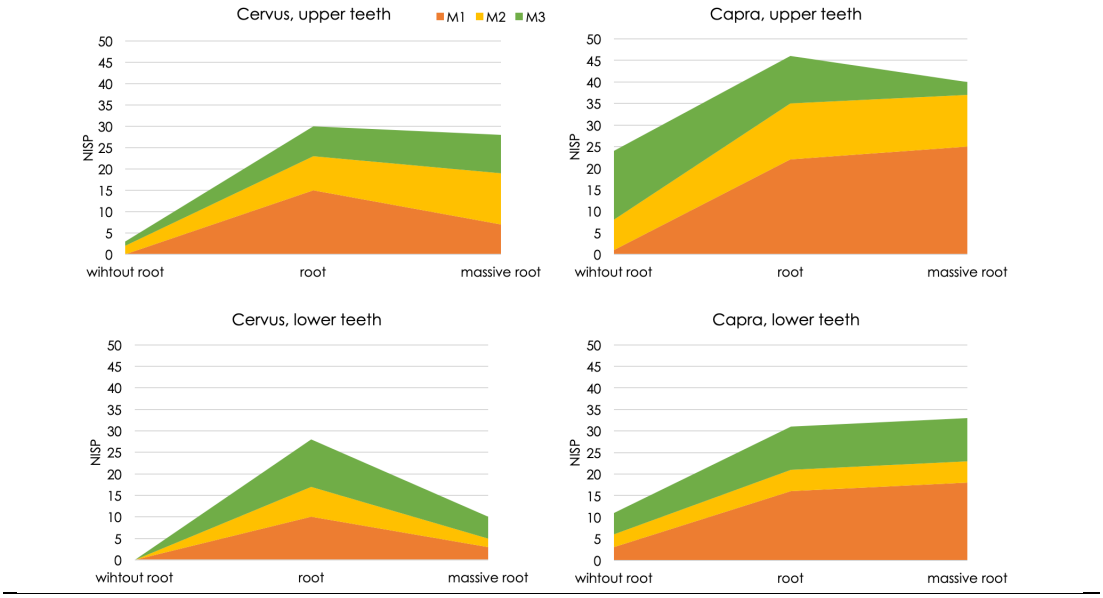


Figure 4.53: Tooth eruption pattern indicated by root development on individual teeth.

Crown height measurements (after KLEIN ET AL. 1981) reflecting abrasion degree and wear stages were compared across the Lower Magdalenian sequence for red deer (BROWN & CHAPMAN 1991b, 1991a; AZORIT 2011) and ibex (VIGAL & MACHORDOM 1985; PÉREZ-RIPOLL 1988). For improving estimations by crown height

measure, first is tested which crown height variation is present in general. For lower and upper ibex teeth, the most commonly represented teeth (i.e.; deciduous fourth premolar-dP4, first-M1, second-M2 and third molar-M3) were grouped by their wear stages. The numbers of teeth contributing to each wear stage are given and the variation of crown height is shown in the following figure for each tooth (Figure 4.54). As a result, among the faunal remains the different groups of crown heights and their variability among different tooth wear stages are clearly apparent.

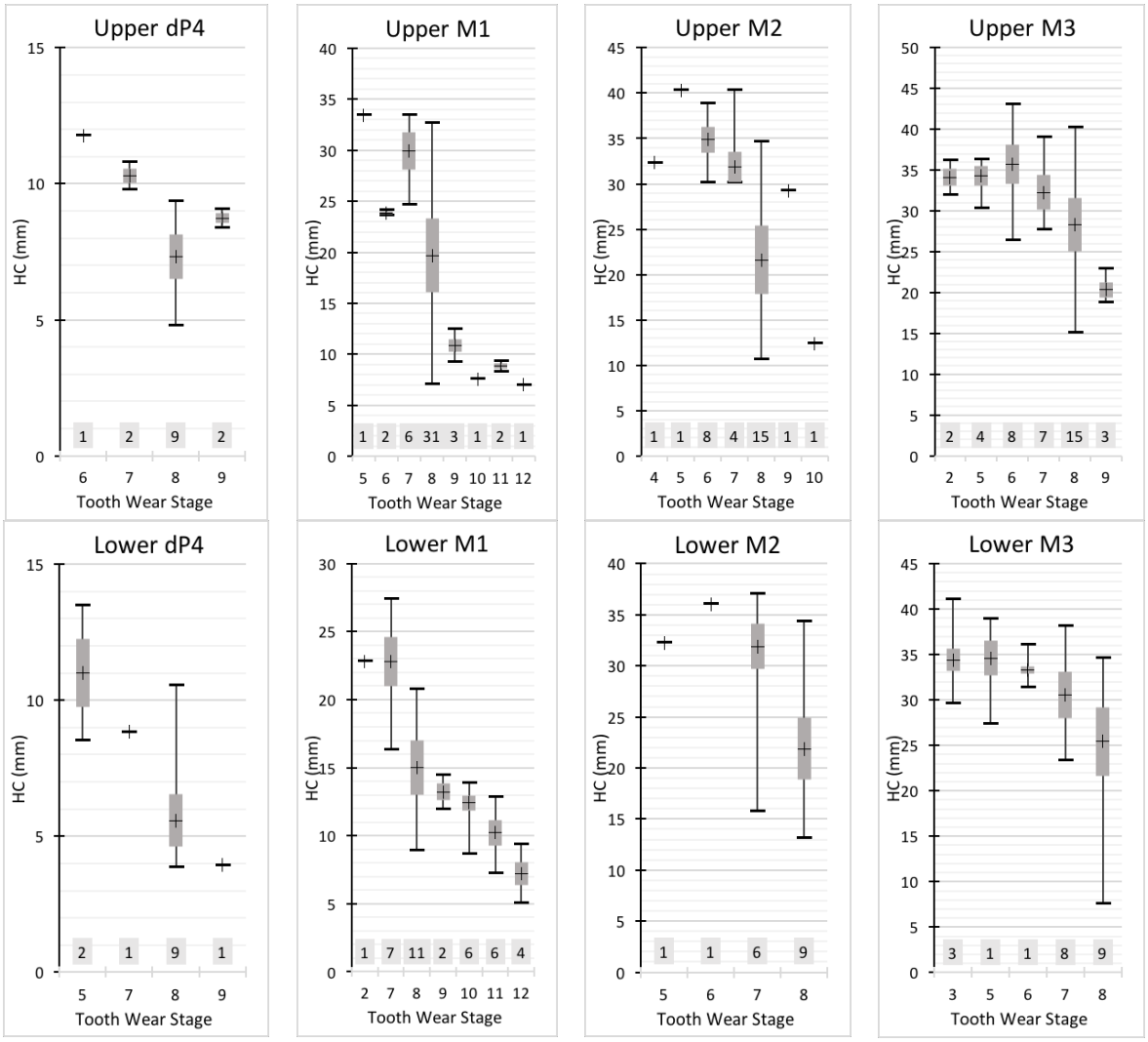


Figure 4.54: Crown height (HC) variation according to different wear stages defined for Spanish ibex teeth. + average, grey box = range of standard deviation, - maximum and minimum; number at the base for each wear stage = number of observations.

The tooth crown height measurement was used for a correlation test against a normal distribution (Shapiro–Wilk test) to decipher the observation made on ibex teeth and to predetermine which crown height and abrasion stage correlate; a detailed interpretation level by levels follows later. Most of the results show that crown height observations follow a normal distribution, despite the upper M1's (U-M1 in Figure 4.54) and the lower M3's (L-M3 in Figure 4.54) that have values under the significance level p(normal)= 0.05. Those teeth repeatedly show a tendency towards a specific range of crown height, meaning that a dominance of a seasonal pattern or age group might be present. When ibex was repeatedly hunted seasonally their teeth should all follow similar patterns of crown heights and targeting specific age groups might also produce

clusters of the same wear pattern. An overrepresentation of 'Tooth Wear Stage 8' might originate in a long duration of this stage and difficulties to further differentiate this age period in ibex. This test shows that hunted animals exhibit a variety of age groups. It is thus the first results that implied there were multi-seasonal ibex deaths with a possible preference towards few age groups, which can be remarked for later interpretations.

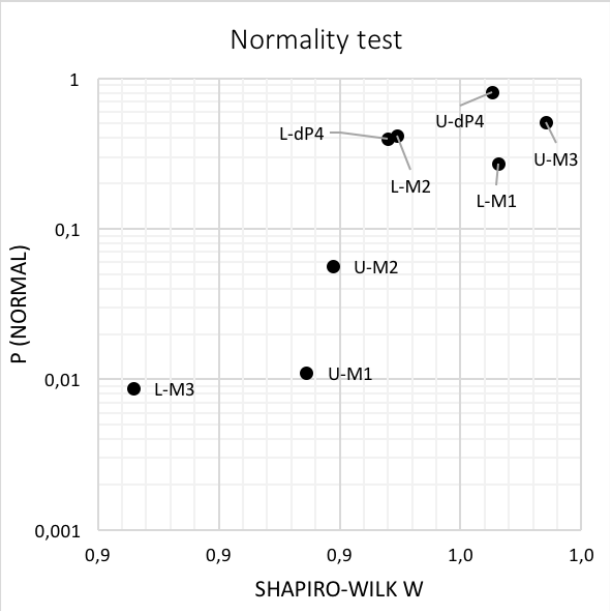


Figure 4.55: Test of normal distribution for ibex crown heights.

Next, crown heights distributions were compared to published crown height ranges from individuals of six months to three years of age (PÉREZ-RIPOLL 1988) via histogram plots (kernel density). Value overlaps represent higher likelihood, thus higher density that animals were hunted at that time/age. The crown height measurement on fully developed teeth of Spanish ibex and its kernel density curve shows a group of specific values with which age ranges can be associated (compare Figure 4.56).

The results show, in the upper dP4, the peak at 9mm crown height would then represent animals at the age of ~18months (2nd autumn-winter) and at 5-6mm ages of ~24-27months (3rd spring-summer). In upper M1 are two concentrations visible, one at ~27mm and another at ~12mm, corresponding to the ages of 32-36months (3rd winter-spring) and >60months (5 years old), respectively. The highest peak in M2 is located at ~33mm, corresponding to ~60months and a lower peak at ~15mm, analogues to individuals older than 5years. At around 33mm crown height is the peak in upper M3 teeth located, which can be associated with ~60months of age at death.

The milk teeth, lower dP4, show a peak center of the crown height at ~5mm, which indicate animals of ~18months (2nd autumn) at age of death. The lower M1 shows one great peak at 11mm (>36months) and two higher densities at ~17mm (32months, 3rd winter) and 23mm (27-30months, 3rd summer-autumn). The lower M2 shows two more equal peaks at ~34 and ~23mm, which can be associated to ages of 30months (3rd autumn) and >36months, respectively. The highest peak for the lower M3 is at ~35mm that correspond to ~36-month-old spring deaths.

These data obtained can be used further to decipher, the general age distribution of Spanish ibex.

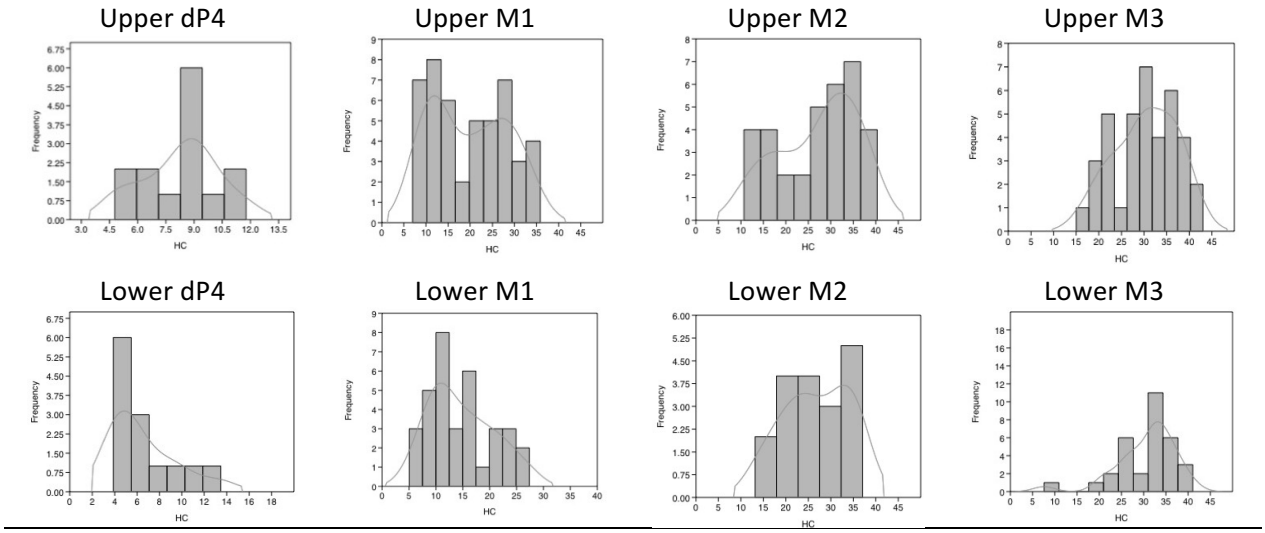


Figure 4.56: Spanish ibex crown height (HC) distribution of upper and lower dP4, M1, M2 and M3, Lower Magdalenian, Cabin area.

The different groups of wear stage show the variation of ages represented by the teeth found in the archaeological deposits. With this observation were derived the ages of animals at death, thus, the season of death, if animals were born late in June (ALADOS & ESCÓS 2012). With the results obtained, the different wear stages seen in individual ibex teeth can be correlated. For example, a dP4 with a wear stage 8-9 can be associated with an M1 with a wear stage of 7, thus, might represent the same animal or two animals of the same age, therefore, the same season of death. A summary of the varied wear stages correlated to the varied age ranges are collected in the following table (Figure 4.57).

| *Capra pyrenaica* | Neonate | | Infantile | | | | | | | | | | Juvenile | | | | | | | | | | | | Adult | | | | | | | | | | | |

Similar observations were made on red deer teeth (Figure 4.58). These teeth show normally one or more peaks of the Kernel density among the crown heights for red deer remains. The data suggest that two to three age groups were preferentially hunted. Red deer fawns are commonly born in May to June (CARRANZA 2011),

The upper M1 shows two peaks along the Kernel density curve of crown height distribution, one at ~13mm and another at ~9mm. Two peaks are visible at the upper M2 density curve at ~17mm and ~13mm and three peaks at the upper M3 one, at ~15mm, ~11mm and ~7mm. The lower M1 shows a peak at ~5mm and ~14mm, M2 at ~11mm and M3 at ~13mm.

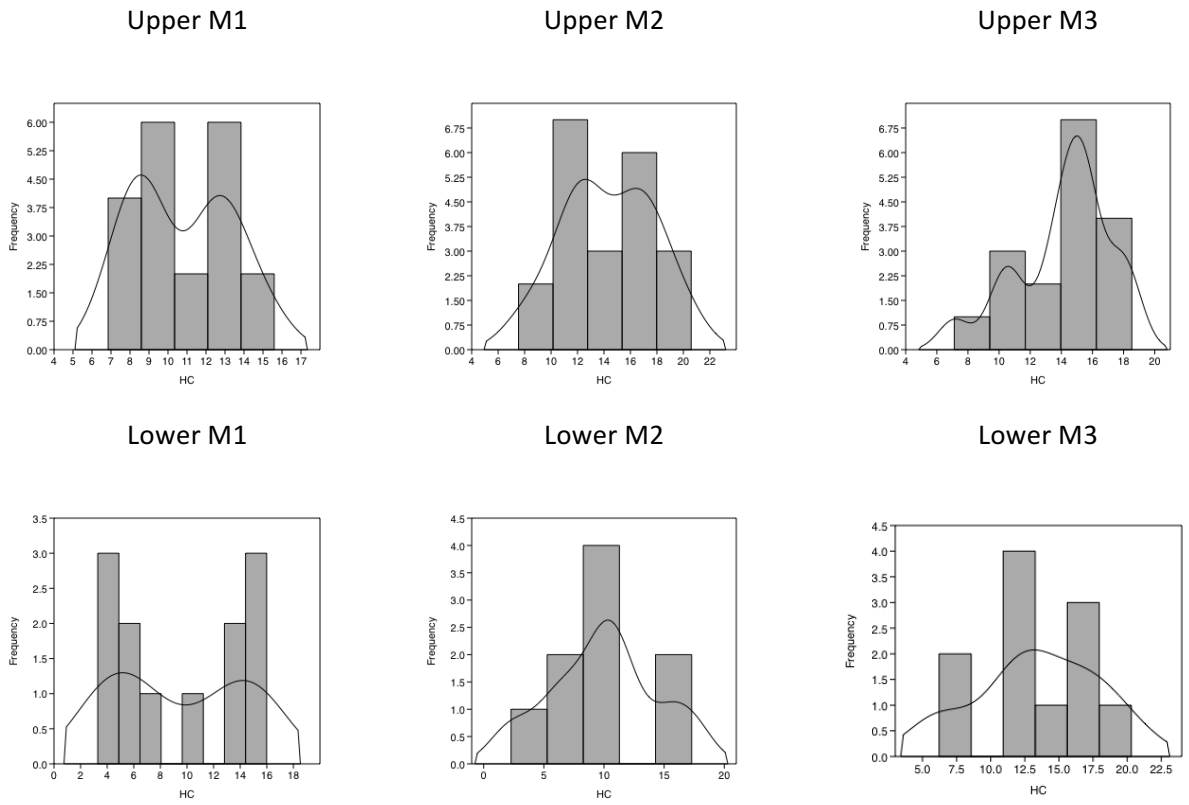


Figure 4.58: Red deer crown height (HC) distribution and kernel density of upper and lower M1, M2 and M3, Lower Magdalenian, Cabin area.

With this tooth height analysis was correlated age ranges and tooth wear pattern from El Mirón fauna, which is helpful when one wants to estimate the age at death and want to avoid over estimations when calculate MNI. Further was used osteometry to identify age and sex groups and also establish mortality profiles. The latter are used to further investigate whether a human demographic selection (i.e. juveniles, prime adults, or old individuals) existed among hunted prey.

Measurable faunal elements from El Mirón were consulted for osteometric comparison. Some osteometric dimensions of additional modern animals that were measured are *Capra pyrenaica* and *Cervus elaphus* bones from the Museo Natural Ciencias Naturales (MNCN-CSIC) in Madrid, the Laboratorio de Arqueobiología in the Centro de Ciencias Humanas y Sociales (CSIC) in Madrid and Laboratorio de Bioarqueología (LAB-IIIPC) Universidad de Cantabria in Santander. The size variation of Pleistocene and Holocene fauna is considered.

Table 4.12: Animal references for comparative measurements. Abbreviations see text.

Code	Collection	Skeleton-Nr.	Age	Notes
M1	MNCN-CSIC	18270	Modern	*Capra pyrenaica*, adult, female
M2	MNCN-CSIC	18167	Modern	Capra pyrenaica, adult, male
M3	MNCN-CSIC	18239	Modern	Capra pyrenaica, young
M4	MNCN-CSIC	17948	Modern	Cervus elaphus, female
LC	CCHS-CSIC	18184	Modern	Capra pyrenaica, old, female
LB1	LAB-IIIPC		Modern	Capra pyrenaica, young
LB2	LAB-IIIPC		Modern	*Capra pyrenaica*, adult, female, osteomyelitis
LB3	LAB-IIIPC	UC 061	Modern	Cervus elaphus, one year
CAL	Las Caldas Cave	varied	Paleolithic age	ALTUNA & MARIEZKURRENA 2017

How ibex measurements of archaeological samples scatter were compared with modern references and the sizes of Las Caldas Late Upper Paleolithic ibex remains in Asturias, some 250km West of El Mirón (ALTUNA & MARIEZKURRENA 2017). For ibex, analysis focuses on the dimensional comparison of the articular surface of the scapula, the distal humerus, carpals, and distal tibia.

Measurements of width and depth on the proximal glenoid surface of the scapula (Figure 4.59) show a grouping of three along the trend line. According to comparative data in the literature (ALTUNA 1978; FERNANDEZ 2001) these represents group A adult males and group B adult females, as well as young individuals.

The following age and sex representations are indicated by the osteometric study: Level 17-8 includes a minimum of one adult female, Level 17-10 at least two adult females from two left scapulae and a minimum of one adult male from a right and left side. Level 17-12 shows with seven the highest number of measurable scapulae, six located in group B of adult females. Five of them are from the left side, thus, a minimum of five adult ibex females is detected for Level 17-12. One juvenile is represented by the smallest measurements in group C.

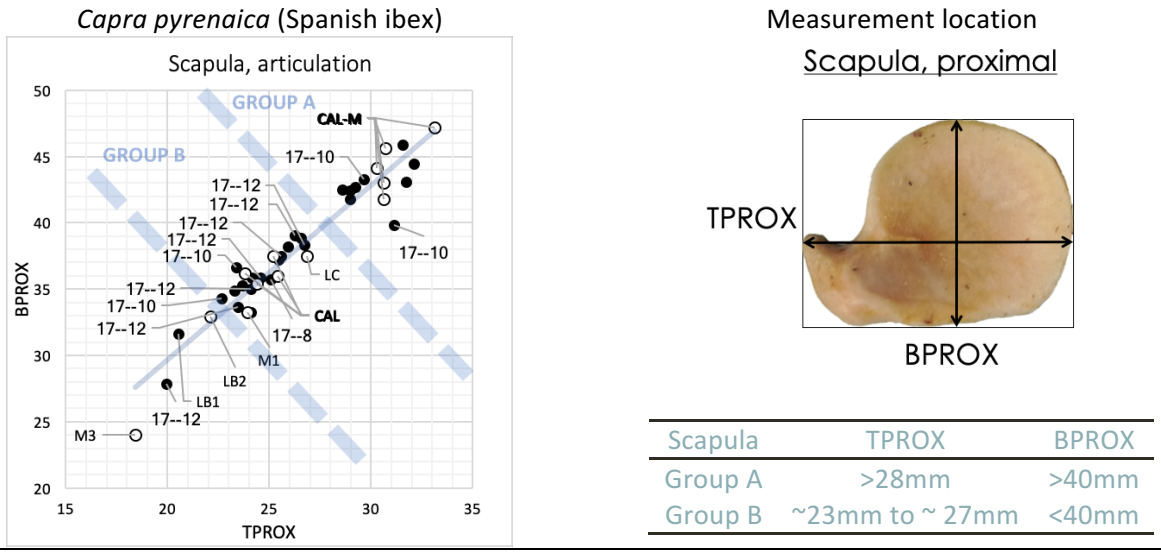
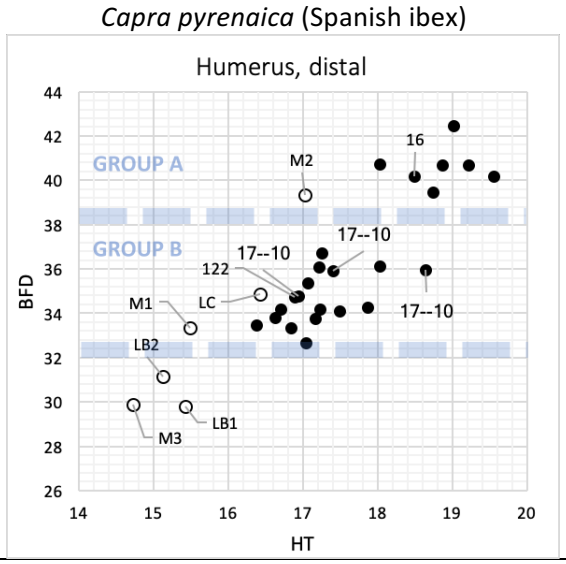
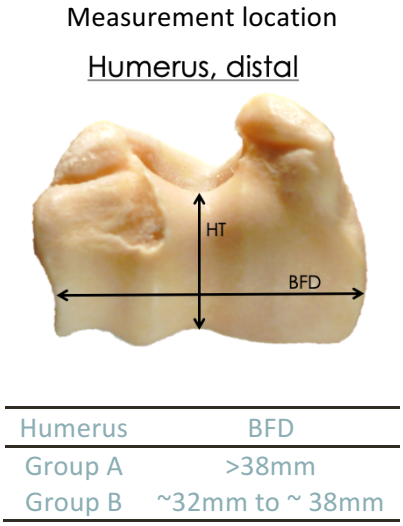


Figure 4.59: Ibex scapula wide (BPROX) and depth (TPROX) on articulation. Full circle= El Mirón; open circle=reference data; CAL=female from Las Caldas, CAL-M=male from Las Caldas.

On the humerus, three groups of dataset can be distinguished along the width of the distal articular face (BFD) (ALTUNA 1978). Based on distal humerus measurements, Level 16, contains an adult male individual (Group A). At least two adult females (Group B) are present in the Level 17-10. It is remarkable how the left humerus from a female adult represented in Level 122 has basically the same dimensions as one right humerus from Level 17-10.

Two measurements on the distal humerus of ibex (Figure 4.60), the height of the trochlea (HT) and distal width (BFD) show clear clustering of results. Especially in adult females, modern samples are smaller than those from the archaeological record as commonly agreed according to the Bergman's rule that ice age animals were bigger than their modern counterparts (MARIEZKURRENA & ALTUNA 1983; WEINSTOCK 2015). These lower values in modern reference animals also represent the evolutionary development of several subspecies of *Capra pyrenaica* from the Pleistocene to the Holocene and/ or their isolated survival in present day refugia regions in the Iberian Peninsula (PÉREZ ET AL. 2002). The modern reference animals are an adult male (M2), adult females (M1, LB2) and juveniles (M3, LB1).





Humerus	BFD
Group A	>38mm
Group B	~32mm to ~ 38mm

Figure 4.60: Spanish ibex distal humerus height of the trochlea (HT) and wide of the distal articulating face (BFD).

Small, irregular bones such as carpal and tarsal elements are commonly represented in the identified fauna, presumably due to the inclusion here of the general bag items. Carpal and tarsal bones are especially useful for osteometric studies as they are less likely to be intentionally broken during marrow or grease rendering activities, which are typical Paleolithic phenomena in archaeological sites with bone nutrient exploitation (STINER 2002: p. 28; NAKAZAWA ET AL. 2009). They are more robust than long bones due to their compact size, and have only one ossification center making them grow continuously until they are fully developed. Measurements taken on these elements, thus, can prevent a good demographic information on the death assemblage for each level. It is expected that osteometric data represent a continuous distribution from young animals to the fully-grown, adults stage. Especially in adult front limb body parts a sexual dimorphism should be observed as size differences, because males have to carry more weight of bigger horns and antlers than females, typically for animals of the infraorder *Pecora*. With the help of systematic measurements, adult males normally cluster in the area of greatest dimensions.

A sufficient number of measurements were available from the Lower Magdalenian (Levels 15, 16 and 17) carpal bones to investigate their dimensional distribution (Figure 4.61). The kernel density of measurements of the distal depth second & third carpal (C23) bones show a gradual increase up until ~18,5mm plus and a few bones with even higher values. This curve seems to represent at its first peak the adult females (and possible pre-adult males) and the second peak (~20,5mm) marks the adult male individuals. A twofold division also shows the kernel density curve of the fourth carpale (C4), radiale carpal (C.rad) proximal depths and ulnar carpal (C.uln) distal depth. These can be interpreted as the first peak (~12mm) in C4 are the adult females and the second peak (~13,5mm) are the adult males. For C.rad, the first peak for adult females is located at ~21mm and the second peak for adult males at ~24mm. The C.uln values group around ~17mm and ~20mm, for adult females and males, respectively.

These observations imply that especially the depths in carpal bones are a useful measurement to distinguish female and male adults as well as reconstruct the mortality profile within an archaeological assemblage. More importantly, carpal bones are often completely preserved. Best represented by C23 and C.uln measurements, these results imply that only a few adult males were hunted accompanied mainly with presumably adult female with younger animals; presumable matriarchal herds.

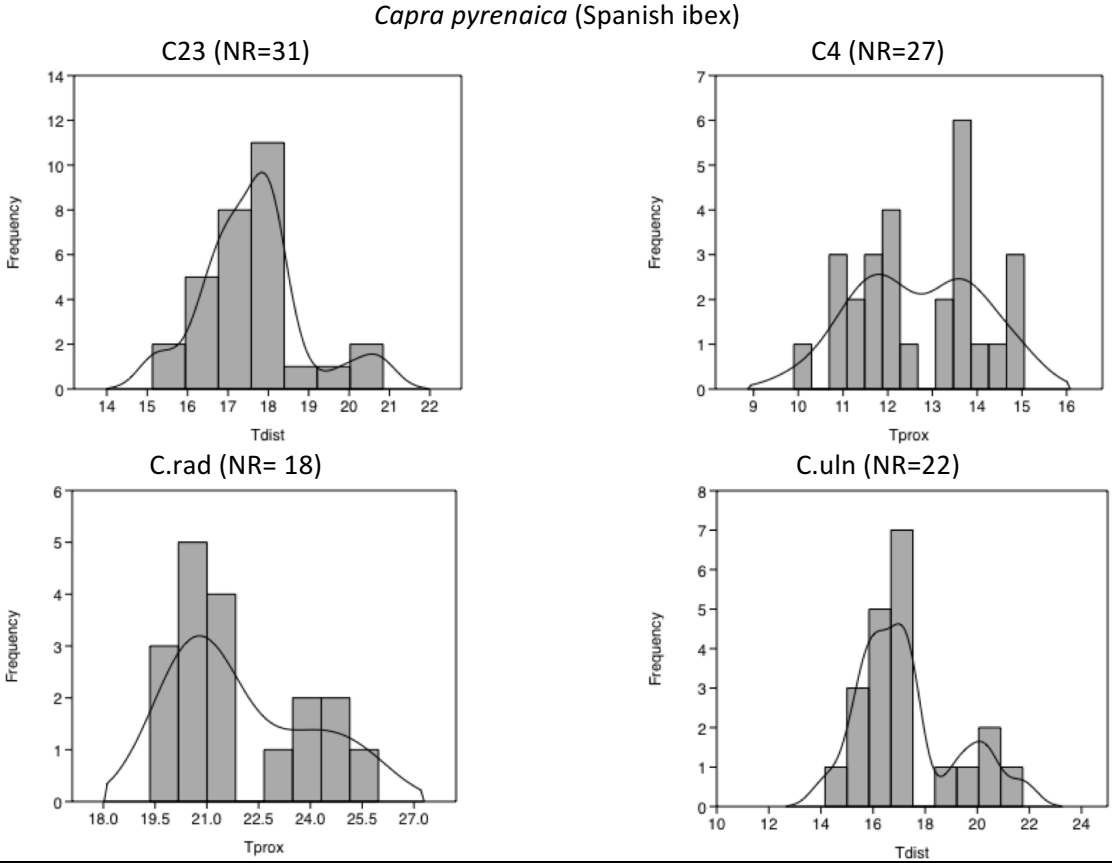
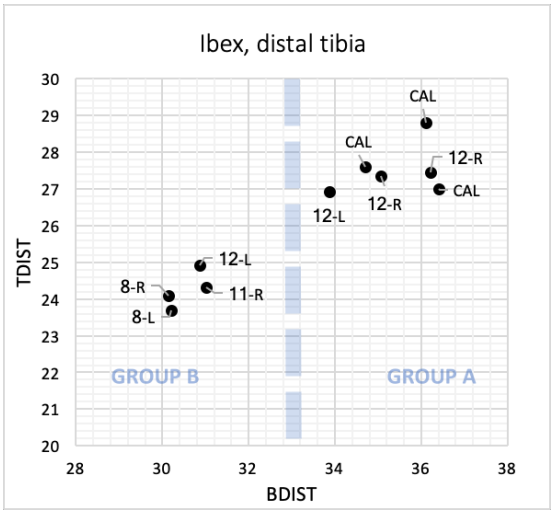


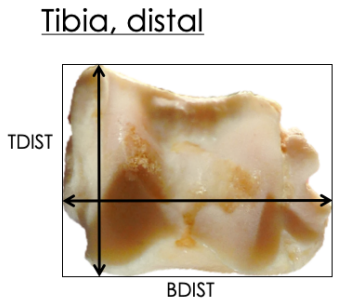
Figure 4.61: Spanish ibex distribution and kernel density curve of proximal depth (Tprox) on *carpale quartum* (C4) and *carpale radiale* (C.rad) and distal depth (Tdist) on *carpale secundum y tertium* (C23) and *carpale ulnare* (C.uln).

The distal part of the tibia is one of the few long bone fragments, which is often preserved and good to measure. This is also an element that is of great aid in sexing individuals. The following measurements are taken to explore this issue: the breadth and depths of the distal epiphyses (Figure 4.62). A separation in ibex measurements is possible by the largest dimensions in breadth (>34mm) reflecting adult males (Group A)

and females (Group B) with a range between 28mm and 33mm (ALTUNA 1978). An interesting observation made, is that data appear paired, which makes sense, if the two sides from one individual were measured. Here we can find a pair of bones corresponding to Sample 17-8 and 17-12 in the group of females. In the group of males only Level 17-12 is represented by two right and one left distal tibia. These results also imply that these distal tibiae were discarded together (spatially and temporally) in each level, at least for Group B.

Capra pyrenaica (Spanish ibex)





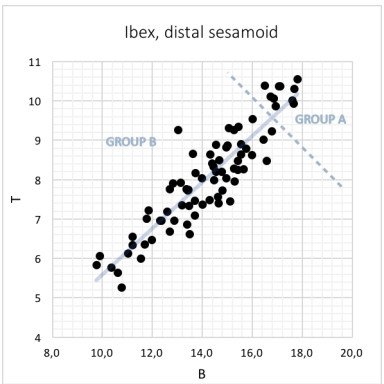
Tibia	BDIST	TDIST
Group A	>34mm	>26mm
Group B	>30mm	>23mm
Group C	<30mm	<23mm

Figure 4.62: Spanish ibex tibia: breadth (BDIST) and depth (TDIST) of the distal epiphyses.

The distal sesamoid data show also a possible separation of a group of adult male bones with the greatest dimensions in comparison with the other measured data, when looking at the breadth (B) and depth (T) of the individual bones. The measurements of depth (T) seem to be quite normal distributed, despite a little peak of higher values at the maximum end of the scattering, which might represent the largest, presumably male individuals (Group A) (Figure 4.63) compared with a group of females and possible young (Group B).

Capra pyrenaica (Spanish ibex)

A



B

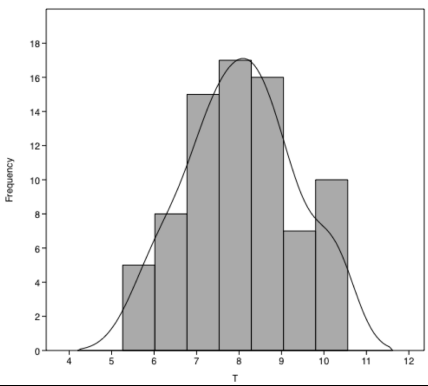


Figure 4.63: Spanish ibex distal sesamoid: A- breadth (B) and depth (T), B- distribution and kernel density of depth (T) values.

Red deer osteometry was explored analogously to the ibex measurements to obtain information on sexual dimorphism, while the measurements of identified unmodified canines and scapula were taken into account for comparative analysis.

Red deer atrophic canines have a relatively high degree of sexual dimorphism, where in lingual and buccal views, stag canines are wider than those of hinds. The measurements of the length (LC) and breadth (BC) on the column of the canine tooth is considered to sufficiently represent the size variations (D'ERRICO & VANHAEREN 2002). The ratio of these two values show clearly that males and females cluster separately (Figure 4.64). In El Mirón, according to the cluster plot male canines were identified only in the late Lower Magdalenian occupations of Levels 15 and 16. The generally smaller female canines were found in Levels 128, 121, 17-12, 17-10, 17-8, 17-6, and 16 in this study (beside other canines of ornamental character were found, but are not included here as they might have been independently brought to the site, i.e., not with carcasses).

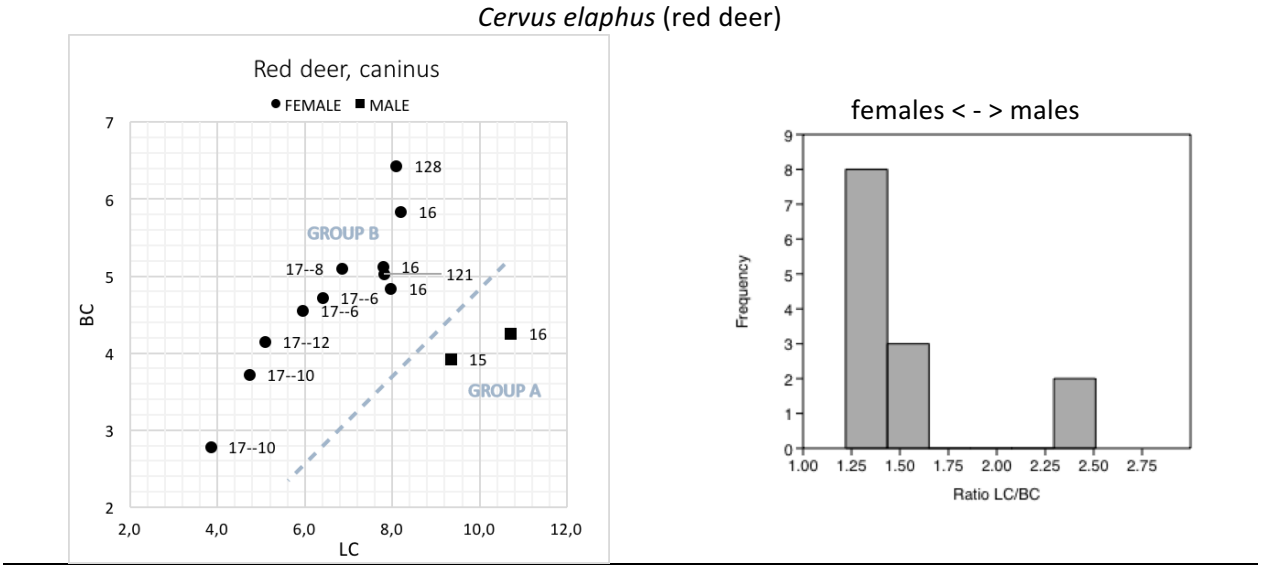


Figure 4.64: Red deer canines: measurements length on the column (LC) and breadth on the column (BC).

On the scapulae three measurements were taken on the proximal articulating facet, the glenoid fossa. The measurement of the width of the glenoid fossa is a useful indicator for sexual dimorphism, where females and adult male (larger than 45mm width) cluster separately (MARIEZKURRENA & ALTUNA 1983; GONZÁLEZ-MORALES ET AL. 2006). Two scapulae from Level 17-12 showed width of 43.04mm and 33.58mm representing a female and a young animal, respectively.

Only in Level 17—10 were found antler bases with attached skull indicating killed animals. Three adult male individuals were determined as antler beams were huge and antler bases had varied dimension of 60.2x50.1 mm (H3c/74-3280), 69.2x53.2 mm (H3d/74-3154) and 81.15x71.2 mm (H2d/57-2411). (Comments and Measurements were made by L.G. Straus).

When summarizing the osteometric analysis, it was possible to distinguish males from females or younger individuals based on their osteometry (Table 4.13). The results show that female and younger individuals are dominantly represented over males with the exception of Level 17—10. In Level 17—10 adult males seem to have been the focus of hunting, approximated during a period between late summer to early spring.

However, a different pattern was observed for all the other levels. Some would expect that males offer the most sufficient return rates in terms of cost and yield for hunting effort, but this might be misleading. Among many ungulates species, males tend to be more solitary most of the year, sometimes with riskier lifestyles or living in bachelor groups of a few young males (VILLARET ET AL. 1997). Males are, therefore, often more scattered across the landscapes. The Spanish ibex are another good example where young males tend to live in much higher altitude in the mountains or are found in smaller groups, as well as being generally more aggressive during attacks. Females live together with their offspring and tend to gather in larger matriarchal groups. Three main hypotheses are under serious debate to explain this sexual segregation in modern populations of Spanish ibex: the predation-risk, forage-selection, and activity budget hypotheses (LAVANDERA 2006). Assumptions about either a lactating female select safer habitats, different habitats being optimal for varied body sizes, or differing body sizes requiring a different activity budget are respectively under discussion, respectively for these theories.

The groups of females and young might be vulnerable to attack from the view of the predator as especially the juveniles-subadult individuals might have appropriate biomasses, but had not yet elaborated their escape strategy sufficiently; thus, the success rate of predators would be increased when targeting such groups. Carnivores also profit therefrom and prey on the youngest animals. Focusing on young ones would result in less energy expended per kill. Human hunters should target the most profitable prey such are male adults when optimal foraging theory is applied (FOLEY 1985). But the existence of matriarchal herds, however, might be an important factor in prey, especially when human gather in larger groups and focus on obtaining the most consistent food resource. On the contrary, such hunting pressure on mothers and their young could, in the long run, be catastrophic for the prey living population. Targeting of matriarchal red deer herds in Northern Spain's Magdalenian has been the subject of interpretation since the 1970s as part of the theory of subsistence intensification (FREEMAN 1973; BARANDIARAN MAESTU ET AL. 1985; STRAUS & CLARK 1986).

Table 4.13: Contribution of osteometry on sex and age determination. Y= young, F= female, M=male.

		MNI Spanish ibex																MNI Red deer				
		SCA			HU	C23			C4			Crad			Culn			TI		d- SES	**Ratio**	Caninus			Antler&skull	**Ratio**
	Level	Y	F	M	F	Y	F	M	Y	F	M	Y	F	**F:M**	Y	F	M	F	M	M	**F:M**	Y	F	M	M	**F:M**
Early Upper Paleolithic	EUP 128											**1:0**											1			**1:0**
Solutrean	SOL 122																	1			**1:0**					
	SOL 121											**1:0**											1			**1:0**
Lower Magd.	LM 17--12	1	5			1			1			**1:0**			2	2		1	2	1	**5:2**		1			**1:0**
	LM 17--10		2	1	2	1	1		1	1	1	1	**1:0**	1	1	1	1				**2:1**	1	1		3	**1:3**
	LM 17-- 8		1			1		1	1	1		**1:0**		1	3	1		1	1	1	**3:1**		1			**1:0**
	LM 17-- 6					1	3		1	2		**1:0**									**3:2**		1			**1:0**
	LM 16				1	3	6	1	1	2		1	**2:1**		2	2			1	1	**3:1**		2	1		**2:1**
	LM 15						1			2		1	**0:1**	2	2	2	1		1		**3:2**			1		**0:1**
	Total MNI	1	8	1	3	6	12	2	3	7	3	3	8	**4:1**	8	8	5	3	2	3	**3:2**		8	2	3	**8:3**

A high number of fetal animal elements was found in some of the Solutrean levels in the Corral area and in the Lower Magdalenian levels of the Cabin, while in the other areas and levels fetal bones were not found (Figure 4.65). Fetal bones indicate that pregnant female carcasses were brought to the cave and butchered there, mainly during cold seasons.

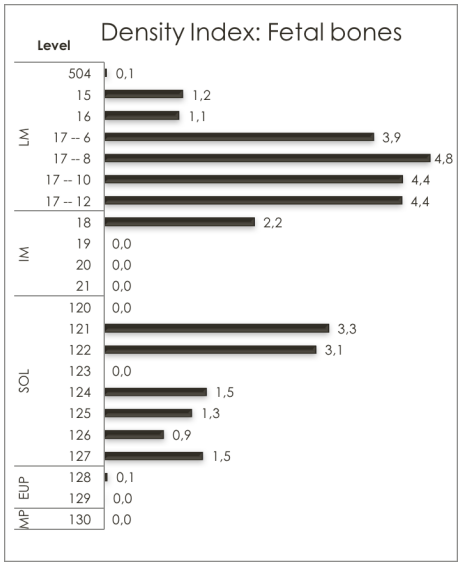


Figure 4.65: Fetal bones, the index encounter the number of specimen per 0.01m^3.

Age distribution of main game species is illustrated with a triangular plot of three age classes including the high abundance of young animals, including infantile, neonatal and fetal individuals. The composition of different ages varies among the studied units: Solutrean levels show the most equal distribution of ages, skewing is clearer among Magdalenian ones. Low MNIs skew age distribution patterns, containing often only one individual attributed to each age stage (see dot in the middle of the graph, Figure 4.66). The pattern for Spanish ibex differs from that of red deer as ibex are normally better represented by higher MNI. In comparison Levels 121, 124 and 125 have more often infantile and younger remains. The other Solutrean layers, Levels 122, 127 and 129 include more juvenile individuals. The Lower Magdalenian levels are dominated by adult individuals, for both, main prey species. Middle Magdalenian and some Upper Magdalenian levels, however, show again higher percentages in infantile individuals for red deer (MARÍN-ARROYO 2010). Whether the reason for this change are the result of human overhunting trends, variation in hunting season or other hunting strategies related diversification is difficult to determine.

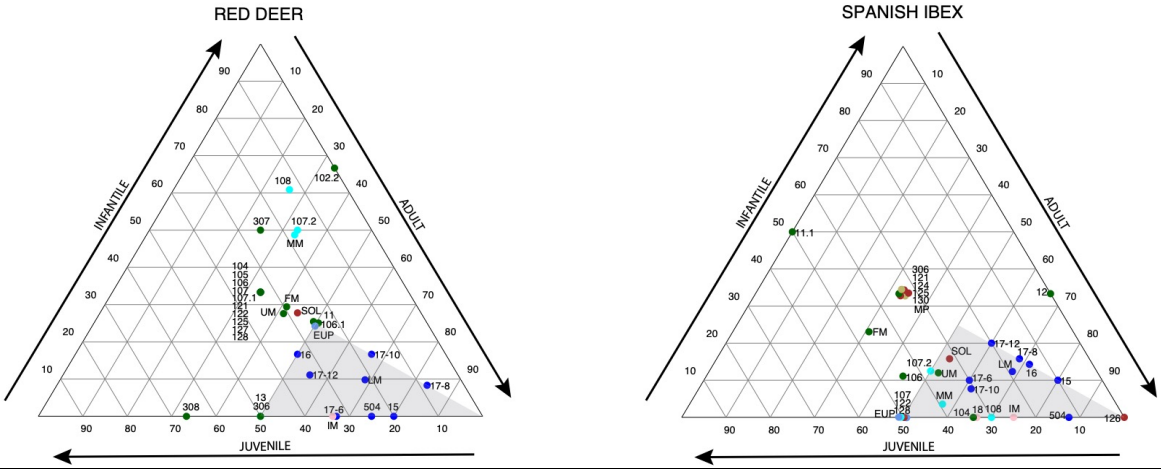


Figure 4.66: Age distribution of main prey species by levels. Grey shaded area=Prime dominated with juvenile and infantile less than 50%. Points: Middle Paleolithic- MP (yellow), Early Upper Paleolithic-EUP (grey), Solutrean-SOL (red), Initial Magdalenian-IM (pink), Lower Magdalenian-LM (blue), Middle Magdalenian-MM (cyan), Upper and Final Magdalenian-UM, FM (green). Published MM, UM, FM data from MARÍN-ARROYO 2010.

A summary of the frequency of young individuals found during analysis reveals an interesting chronological pattern (Figure 4.67). The %MNI of young individuals is much higher, by >50 % in the Late Middle Paleolithic, Early Upper Paleolithic and Solutrean periods than in the Magdalenian occupations. A change towards adult, prime age hunting seems to get more important during this latter period, which is the Early Magdalenian. Either hunting occurred mainly during herd aggregations in the mating season (fall rut) or human sought the best energetic return rates from prime age individuals which were deliberately targeted, or a combination of both (and other conditions) were met to produce this pattern. According to the prevailing interpretation of increased juvenile slaughter in the Magdalenian (FREEMAN 1973; STRAUS 1977; GONZÁLEZ-SAINZ 1989, 1992; GONZÁLEZ-SAINZ & GONZÁLEZ-URQUIJO 2004), such pattern occurred mainly during the later Magdalenian. When slaughtering of juveniles increase whose hunt are supposed to be less risky, but of lower energy return rate. The high percentage of young individuals in the pre-Magdalenian can be also the results of taking into account all faunal remains during study, including general bags, where smallest bones were also determined. These smaller bones are normally rarely studied in previous faunal analysis and in material from old excavations absent. Hunting of young animals is supposed to be 'easier' than of older, more experienced ones and supposingly increased when subsistence stress occurred and fallback foods being explored. The season of hunting is important since the degree of experience of a newborn in spring differs from the young that is almost one year old in winter. The lower importance of young animals during the Lower Magdalenian's hints towards economic strategies that used other fallback foods or not suffered dietary stress.

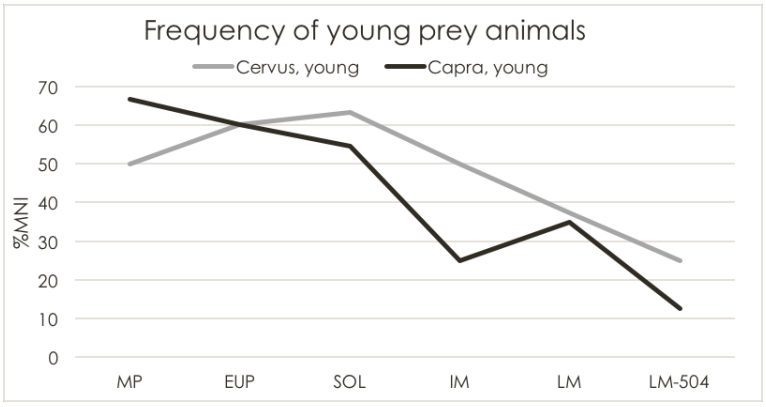


Figure 4.67: Frequency of young animals among the identified individuals by cultural periods.

An indicator for increased hunting pressure might be the often-observed pathologies in the Lower Magdalenian levels. Table 4.14 lists the pathological observations made in detail, which are only a few in the different studied levels. There was superficial infection of the periosteum (osteoperiostitis) on the long bones and just in a few cases osteomyelitis like structures that indicate periosteum elevation by pus (BAKER & BROTHWELL 1980). Sometimes were also infection of teeth identified.

Animal remains with pathological observations were mostly made in the Lower Magdalenian levels. The high percentage could be due to sample size or hunting pressure. A greater sample size allows us to observe more pathological variants relative to the total. The Lower Magdalenian might show a higher hunting frequency and show a greater sample size from the living population with which more animals with pathologies appear. On the other hand, during group chase or just normal hunts, animals might have been hit, fallen or even were hit by projectiles. The resulting injury and concentration of the infections on limb elements appear more often in prey animals that came from those (possible repeated) escape scenarios, if the same herd of animals were once again targeted. This hunting pressure might be visible through hunting fails on the same group of

animals repeatedly hunted in a limited area. Old and healed infections also indicate old individuals. In any case, it remains impossible to justify one or the other scenario beyond the observations that were made. Those animals carrying pathologies were probably weaker and an easier catch compared with healthy animals and could explain their higher frequency among prey animals.

Table 4.14: Pathological observations among Lower Magdalenian fauna.

Level	Observation	Animal and element affected
15	Spongy structure on bone (osteomyelitis)	Red deer: 1x metacarpus, 1x calcaneus
16	Spongy structure on bone (osteomyelitis)	Red deer: 1x humerus, 1x metacarpus Ind. size class: 1x long bone
17-8	Infection M1/M2	Ibex: 1x mandible
	Superficial infection of the periosteum	Red deer: 1x metatarsus Ind. large ungulate, 1x cervical vertebra
17-10	Deformation of tooth	Ibex: 1x Upper P4
	Superficial infection of the periosteum	Ibex: 1x maxilla outside, 1x metatarsus Red deer: 2x femur, 1x atlas articulating face Ind. size class: 3x long bone
	Spongy structure on bone (osteomyelitis)	Red deer: 1x femur Ind. size class: 1x long bone
	Healed impact damage?	Red deer: 1x metatarsus
17-12	Infection around dP2-3	Red deer: 1x mandible
	Infection of the periosteum	Ibex: 1x rib, interior surface Red deer: 2x maxilla, 1x rib, interior surface, 3x humerus shaft fragments, 1x metacarpus shaft, 1x metatarsus, shaft, 1x metapodial shaft, 1x frontal tibia shaft, 1x posterior ulna shaft, 1x long bone

4.2.4 Estimatation of obtained biomass

Biomass calculation represents a different kind of quantification of the distribution of the main prey species (Figure 4.68) compared with %NISP and MNI indices. According to the biomass (average values of available meat given by Freeman (1973: p. 22), modified by Marín-Arroyo and González-Morales (2009: p. 54)), red deer always seems to have had a higher dietary contribution for El Mirón habitants than ibex, except in levels 19-21 (albeit with very low NISP), 17-6 and 16. Only Level 108 (MARÍN-ARROYO 2010) seems to have had a very similar high biomass to Level 17 samples contribution from red deer, ibex and chamois, but in total was the biomass of Level 17 minimum about three times higher than from Level 108. Chamois was the third most represented prey ungulate that never had an important dietary role during the Lower Magdalenian, but its dietary portion was relative higher during other times of occupations.

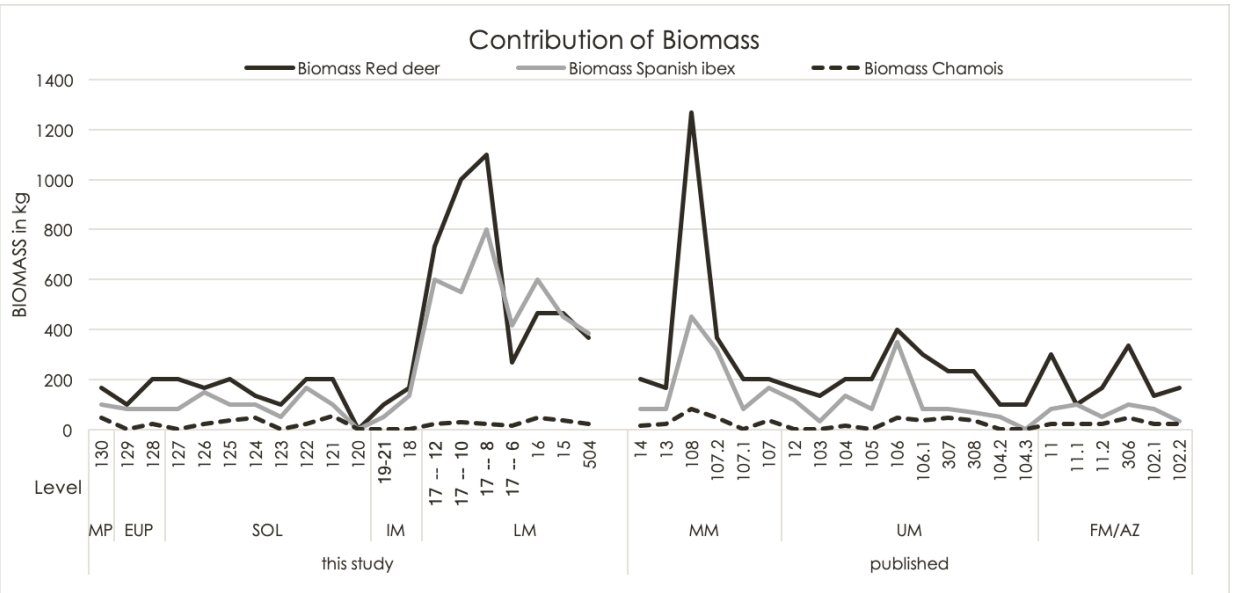


Figure 4.68: Biomass (in kg of edible meat) of main prey species from this study compared with previously published data (MM=Middle Magdalenian, UM=Upper Magdalenian, FM/AZ= Final Magdalenian/Azilian) from El Mirón (Marín-Arroyo 2010).

If the represented biomass is the amount of edible meat, it should be relative to the groups size during occupations. Further, the biomass calculation of the main prey species red deer, ibex and chamois were used to theoretically estimate how many people could have been supported by this meat supply; the calculation steps and parameters are explained in methods chapter.

According to some basic set parameters (MARÍN-ARROYO 2008), each kilogram of usable meat provides in average 1,125kcal, and 2,440.25kcal (after modified data from Kelly 1995) are estimated for each adult hunter-gatherer of daily needs. Based on the amount of meat, the dietary contribution can be calculated by the number of humans supported by this amount of prey (only the main prey species, red deer, ibex and chamois, are included). As an exercise, varying diets i.e. only meat based, a mixed diet with varying contributions from non-ungulate faunal sources (plants, fish, mollusks, etc.) with an intake of 20%, 50% and 80% of ungulate meat were obtained with the following results (Table 4.15). These are suggestions based on ethnographic and archeological data; i.e. a detailed dietary reconstruction for the Lower Magdalenian 'Red Lady' buried in El Mirón cave provide a direct correlation of faunal material and human diet. Based on dental calculus and stable isotope (C,N) analyses it is suggested that those Lower Magdalenian foragers had a mainly meat-based diet (80%) with a significant contribution of aquatic food (probably salmon, plus mollusk when living near the shore) and some plant food including seeds and boletus mushrooms (GARCÍA-GONZÁLEZ ET AL. 2015; POWER ET AL. 2015).

The roles of horse and large bovid (bison or auroch) in the diet are unclear. Anthropogenic modifications were recognized on very few bones of these larger ungulates in El Mirón cave. Single body parts seem to be scattered among the occupations and it is questionable that each element counts for a complete animal in terms of biomass, thus, their inclusion would falsely increase and possibly skew the food contribution estimations and thus were excluded.

Table 4.15: Amount of biomass and theoretical number of adults it was possible to supply for 7 days under varying diets for studied levels and published data from El Mirón.

					Adults possible to feed for one week (7days)			
Culture	**Level**	**Biomass (kg)**	**useable meat & fat (kg)**	**energy obtained (kcal)**	**only meat eating**	**mixed diet (80% meat)**	**mixed diet (50% meat)**	**mixed diet (20% meat)**
MP	130	312	120	135309	8	**10**	16	40
EUP	129	183	71	79657	5	**6**	9	23
	128	306	119	132950	8	**10**	16	39
SOL	127	283	110	123280	7	**9**	14	36
	126	339	131	147199	9	**11**	17	43
	125	338	131	146612	9	**11**	17	43
	124	278	107	120739	7	**9**	14	35
	123	150	58	65226	4	**5**	8	19
	122	389	150	168984	10	**12**	20	49
	121	353	136	153059	9	**11**	18	45
IM	19-21	150	58	65226	4	**5**	8	19
	18	300	116	130356	8	**10**	15	38
LM	17 -- 12	1356	524	588967	34	**43**	69	172
	17 -- 10	1580	613	686886	40	**50**	80	201
	17 -- 8	1923	744	835301	49	**61**	98	245
	17 -- 6	699	268	302915	18	**22**	35	89
	16	1112	428	482251	28	**35**	56	141
	15	954	368	414175	24	**30**	48	121
	504	773	298	335287	20	**25**	39	98
MM	14	298	116	129727	8	**9**	15	38
	13	273	106	118423	7	**9**	14	35
	108	1799	699	782368	46	**57**	92	229
	107.2	729	281	316182	19	**23**	37	93
	107.1	283	110	123280	7	**9**	14	36
	107	404	156	175430	10	**13**	21	51
UM	12	283	110	123141	7	**9**	14	36
	103	167	65	72580	4	**5**	8	21
	104	348	135	151330	9	**11**	18	44
	105	283	110	123280	7	**9**	14	36
	106	795	307	345183	20	**25**	40	101
	106.1	421	164	183020	11	**13**	21	54
	307	362	140	157146	9	**11**	18	46
	308	338	131	146751	9	**11**	17	43
	104.2	150	58	65226	4	**5**	8	19
	104.3	100	39	43623	3	**3**	5	13
FM/AZ	11	406	158	176573	10	**13**	21	52
	11.1	223	86	96585	6	**7**	11	28
	11.2	239	93	103993	6	**8**	12	30
	306	479	186	208028	12	**15**	24	61
	102.1	239	92	103853	6	**8**	12	30
	102.2	223	87	96777	6	**7**	11	28
AVERAGE:								
MP		312	120	135309	8	**10**	16	40
EUP		245	95	106303	6	**8**	12	31
SOL		304	118	132157	8	**10**	15	39
LOW MAGD		1200	463	520826	30	**38**	61	152
MID MAGD		631	245	274235	16	**20**	32	80
UP MAGD		325	126	141128	8	**10**	17	41
FINAL MAGD		301	117	130968	8	**10**	15	38

For comparative purposes in biomass estimations it is referred to a period of one week (7days), although it is difficult to know how long some of these occupations of the cave actually lasted and for sure these occupants were not planning their stays in weeks. Twice the number of people in half of the time or *vice versa* are also possible scenarios. For example, the biomass estimations and calculation of supported people infers that the occupations from the Late Middle Paleolithic to the Solutrean, generally could have supported

a group of six to twelve people having a 80% meat based diet for one week living in El Mirón cave (Table 4.15).

In a diachronic view, the beginning of the Lower Magdalenian occupations in the Vestibule front of El Mirón cave marked a change, which reflect either a drastically increase of people that could have been fed with the available meat hunted or longer stays at the site. Each of the four sublevels from Level 17, the main Lower Magdalenian occupation, could have supported over 22 up to 61 humans (on an 80% meat-based diet) for one week. There was a downward change in density with time among the Lower Magdalenian occupations of the Vestibule front excavation area, but the late Lower Magdalenian occupations, of Levels 15 and 16, still could have supplied hunter-gatherer groups of more than 30 persons. Later Upper Magdalenian occupations of the site show generally lower find density and reflect lesser site use. Only the Middle Magdalenian Level 108 located in the Vestibule rear seems to have contributed a greater amount of meat supply for over 57 people, which is still about a third of Level 17; a calculation based on the formula presented here and published MNI from Late Magdalenian levels (MARÍN-ARROYO 2010).

These estimation of groups sizes are too low to support foraging lifestyles and population dynamics as suggested from ethnography saying that hunter-gatherer bands comprise around 25 people (KELLY 1995; BINFORD 2001). Such group sizes are definitely confirmed by the new data for the Lower Magdalenian. However, group sizes seemed to be much smaller for Solutrean, Early Upper Paleolithic and Middle Paleolithic occupations, which were more the size of a core family (8-10 people). This can be reasonably explained by probably many missing data that may be hidden in other un-excavated occupation areas in the cave or loss of material due to their old age as a major caveat. El Mirón was excavated in a total amount of about 35m² of the Vestibules total area of at least circa 250m² making any interpretation at the site -- only the interpretation of a sample – same as any other archaeological interpretation.

This estimation, however, leads us to infer that the responsible agents have stayed just for a logistic trip of fewer people, or they stayed shorter, or they had a more diverse not-recorded less-meaty diet, or their main activity area was located somewhere else in the cave. However, Solutrean evidence indicate, also by other economic signals of site occupation and animal exploitation, rather short stays of probably smaller groups.

It should be also considered, nevertheless, many Paleolithic biomes have no analog to today and how patchy the environment was might have differed a lot (DAVIES ET AL. 2003). “Small world” social networks (BUCHANAN ET AL. 2019: p.1), i.e. Clovis lithic network, can maintain contact over long distances and such large geographic dispersed populations are connected via exchange of mates, information, traditions, and materials, as recognized long as nested social flexible units (KELLY 1995; GAMBLE 1999; BINFORD 2001). More mobile units that maintained larger networks in smaller family groups could have been economically more resilient, since smaller groups are more mobile and more residential moves per year make groups more fertile (SUROVELL 2000). Such mobility pattern displays social networks possible also via satellite groups or seasonal occupations provide core areas with viable connectedness (SCHMIDT & ZIMMERMANN 2019), this would imply to rethink current estimation of population sizes, that may be overestimated. Unfortunately, yet, we can’t tell, if the necessary connectedness was provided by such low population structures and assumed long-distance networks. Whether such was the successful strategy until the beginning Magdalenian remain open questions, but thereafter changes in mobility, population size and possible network structure clearly occurred.

To further clarify site occupation durations and the cave’s role within the settlement system of these forager groups, seasonality of death for game fauna was considered.

4.2.5 Hunting seasonality

The season of death for prey animals for each level were studied based on tooth eruption patterns, tooth wear and bone fusion stages for the two main prey species, red deer and ibex, although most seasonal indications were available from ibex. As summarized in Figure 4.69, a seasonal change between the occupations in El Mirón cave is seen. Killing occurred in the oldest Late Middle Paleolithic occupations of ibex in its first year in winter-spring, in Early Upper Paleolithic Levels 128 and 129, of ibex in spring- and late autumn, maybe related to seasonal migrations of animals.

Solutrean occupations vary from late autumn to spring in Level 126, from late autumn-winter in Level 125, spring in Level 124 and 122, again late autumn-spring in Level 121 and Levels 18-21; i.e., mainly cold season occupations. Solutrean occupations preferentially in the colder months of the year appear first counterintuitively, given the cave's montane location and glacial climate conditions. But the late autumn-early winter season coincides with the mating period when females and males gather together to form large temporary mixed sex herds (GRANADOS ET AL. 2001; ALADOS & ESCÓS 2012) and rut-distracted animals might pay less attention to impending predator attacks.

During winter-early spring were accumulated Initial Magdalenian occupation in the Vestibule front (but a larger sample from an Initial Magdalenian level in the Vestibule Rear will be available when the study of Levels 119-119.3 is completed by M. Carvalho).

A more complex seasonal pattern was observed for the Lower Magdalenian firstly represent longer, residential stays. Level 17-12 shows the highest number of elements useful for seasonal death estimations with a concentration of red deer kills in late summer-autumn and ibex deaths in winter-spring. In the later occupations of Level 17-10 and 17-8 killing of red deer occurred also in late summer-autumn but also in late spring and ibex in late autumn-early winter, increasing until spring in the latter occupations. In Level 17--6 ibex deaths were the last time concentrated in late autumn-winter and afterwards site occupation changed. Winter-spring stays might be not the only good seasons for taking shelter in El Mirón Cave, but it is also well placed for hunting this species, as ibex might have moved down to lower altitudes in winter due to snow cover and as such were more easily reachable than during summer months due to their feeding behavior in higher, unreachable pastures (MARTÍNEZ & MARTÍNEZ 2009; MOÇO ET AL. 2013).

From now on, occupations seem to be more dispersed throughout the year, likely more logistically, with Level 16 shows autumn as well as winter-spring ibex deaths and red deer were hunted in late spring and in summer. The youngest Level 15 ibex were hunted from late summer to autumn, as well as in hinds to winter and in spring deaths. Red deer hunting was attested for late summer and autumn to winter also in Level 15. It is interesting to observe that the last uppermost Lower Magdalenian Level 15 shows a shift in seasonal occupations towards late summer-autumn hunts more similar to later Magdalenian occupations at El Mirón (MARÍN-ARROYO 2010), indicating subsistence and mobility adaptation before other cultural changes are recognizable.

Red deer was preferentially hunted in late summer-autumn, for example in Levels 17-12, 17-10 and 17-8. These larger animals seemed to have been brought to the cave more sporadically and often temporary ahead compared to the ibex hunted during occupations of El Mirón cave from the late Middle Paleolithic to the Late Lower Magdalenian. Maybe they were alternatingly hunted when people were staying at El Mirón Cave. Seasonal information on red deer skeletal remains are scarce, which might be biased by a more selective transport of those larger body parts to the site. Especially, field butchering could have been more advanced, maybe when kills were made in the wider catchment area of the cave or even butchering were located just outside in the unexcavated entrance of the cave. Further information on the skeletal profile of game species might reveal more insights into animal exploitation strategies as discussed in the next paragraphs.

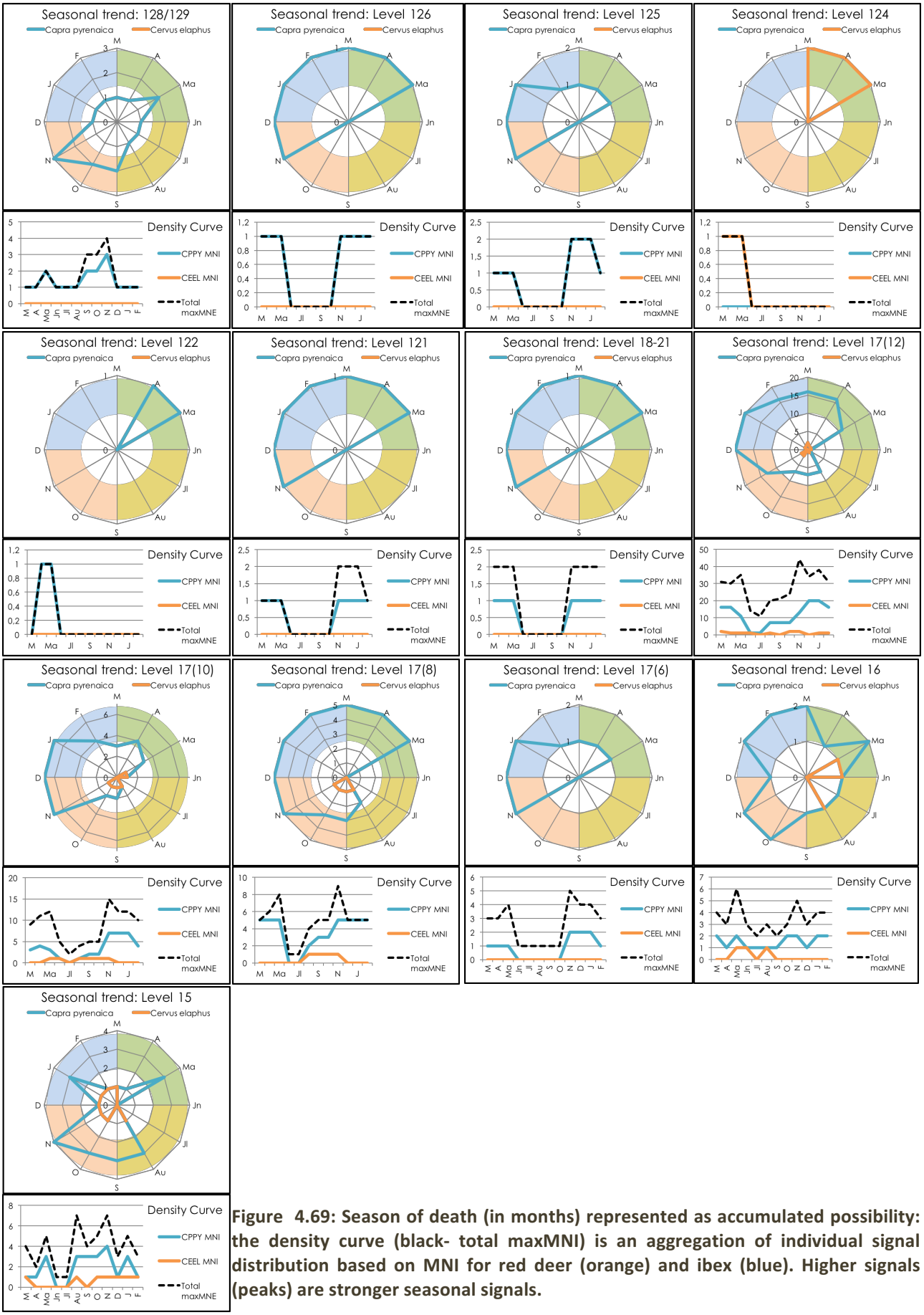


Figure 4.69: Season of death (in months) represented as accumulated possibility: the density curve (black- total maxMNI) is an aggregation of individual signal distribution based on MNI for red deer (orange) and ibex (blue). Higher signals (peaks) are stronger seasonal signals.

Information regarding season of death of animals are summed up in the following table (Table 4.16). Here were added the information about the three skulls of Level 17—10 with attached antler parts indicating males killed during autumn—winter (based on comments from L.G. Straus, July 2019).

Table 4.16: Season of death: x mark presence of seasonal indicators, numbers when MNI was available (from individuals that have not fulfilled their third year of life).

MNI	Early UP	Age in months		Season of death	spring	summer	autumn	winter
1	ibex	24-30m	subadult	summer-autumn		x	x	
1	ibex	16-18m	juvenile	autumn			x	
1	ibex	18-24m	juvenile	winter-spring	x			x
MNI	Solutrean							
1	ibex, 122	12-13m	juvenile	spring	x			
1	ibex, 121	18-24m	juvenile	winter-spring	x			x
1	red deer, 124	10-13m	infantile	spring	x			
1	ibex, 125	18-20m	juvenile	autumn-winter			x	x
1	ibex, 125	30-36m	subadult	autumn-spring	x		x	
1	ibex, 126	30-36m	subadult	autumn-spring	x		x	x
MNI	Lower Magdalenian Level 17—12							
12	ibex	30-36m	adult	winter-spring	12			12
9	ibex	18-24m	juvenile	winter-spring	9			9
2	ibex	6-12m	infantile	winter-spring	2			2
1	red deer	10m	infantile	spring	1			
1	ibex	24-27m	subadult	spring-summer	1	1		
1	red deer	27m	subadult	late summer		1		
1	red deer	15-18m	juvenile	late summer-autumn		1	1	
	ibex	27-30m	subadult	summer-autumn		6	6	
MNI	Lower Magdalenian 17—10							
4	ibex	18-20m	juvenile	late autumn-winter			4	4
3	ibex	30-36m	adult	winter-spring	3			3
1	ibex	11-13m	juvenile	spring-early summer	1	1		
1	red deer	1m	neonate	spring-early summer	1	1		
1	red deer	15-18m	juvenile	late summer-autumn		1	1	
3	red deer		adult	autumn-winter			3	3
1	ibex	27-30m	subadult	autumn			1	
1	ibex	4-9m	infantile	autumn-winter			1	1
MNI	Lower Magdalenian 17—8							
4	ibex	30m	adult	autumn			4	
1	ibex	18m	juvenile	autumn			1	
1	red deer	15-18m	juvenile	autumn			1	
2	ibex	6-12m	infantile	winter-spring	2			2
MNI	Lower Magdalenian 17—6							
1	ibex	18-20m	juvenile	autumn-winter			x	x
1	ibex	30-36m	adult	winter-spring	x			x
MNI	Lower Magdalenian 16							
1	ibex	30-36m	adult	winter-spring	x			x
1	ibex	27m	subadult	summer		x		
1	red deer	1m	neonate	summer		x		
1	red deer	27m	subadult	summer		x		
1	ibex	16-18m	juvenile	autumn			x	
1	ibex	9m	infantile	winter				x
MNI	Lower Magdalenian 15							
1	red deer	27m	subadult	summer		1		
3	ibex	27-30m	subadult	autumn			3	
1	red deer	5-10m	infantile	autumn-winter			1	1
2	ibex	32m	subadult	winter				2
1	ibex	6-12m	infantile	winter-spring	1			1
2	ibex	36m	subadult	spring	2			

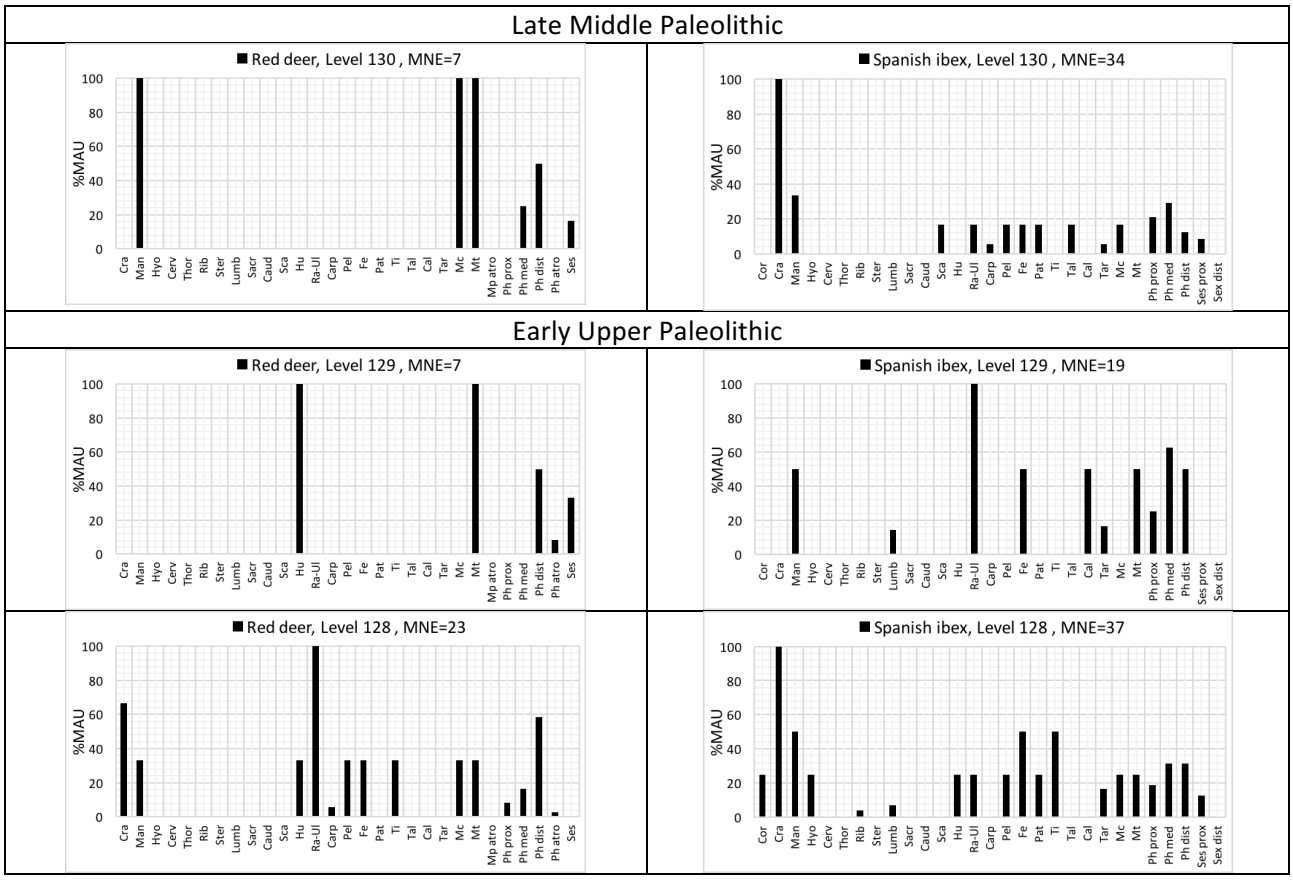
4.2.6 Animal transport and exploitation strategy

Skeletal profiles and bone fragmentation are investigated to decipher transport of animal carcasses, formation of the faunal assemblages and site function from a diachronic perspective.

Topographical settings and prey species density (beside season, human needs, group size, etc.) influences the way in which prey is transported to a site. According to the topographic index of El Mirón cave (~100m above the Calera river valley floor), which contains 9.1% of steep hills (slope over 30 degree) and 90.9% of the valley floor/ plain areas in its 1.2 hours (km²) catchment area range (MARÍN-ARROYO 2009), it might be assumed that hunting in the immediate surroundings of the site followed a selective transport behavior. Ibex might have had its living areas in the close surroundings of the montane, cliff-dominated cave, while and red deer presumably lived on the river valley floors and lower slopes of the Asón and its tributaries. Both habitats are visible and easily accessible from the (central) place of El Mirón cave (CANNON 2003). These settings led suggest a dual exploitation of red deer and ibex for economic reasons, with selective transport of body parts.

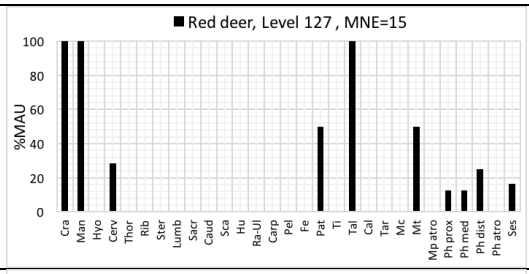
First, bivariate Skeletal Profile analysis were applied. For comparative analysis, the indices with which to investigate the character of accumulation or destructive processes during the formation of the faunal assemblages as well as an interpretational framework for the paleoeconomic behavior of the hunter-gatherers are presented in the following section. For statistical analysis only were selected those levels which had more than five total MNE represented. What follow are the results from analysis of the Minimum Anatomical Units (%MAU) and Body Part Representation Index (BPRI), a derived index from %MAU.

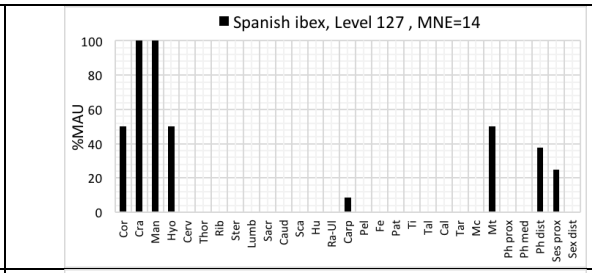
MINIMUM ANATOMICAL UNITS (%MAU). The results of %MAU for the main prey species red deer and Spanish ibex, as well as for the identified elements categorized in size classes give first insights into the skeletal profiles for El Mirón site and its diachronic development thereof. The data are summarized to show the body part representation by cultural periods. A graphical illustration of %MAU for red deer and ibex for every level studied in El Mirón cave is presented in detail, the skeletal element distribution in %MAU is the base for most of the statistical analysis that follow (Figure 4.70).

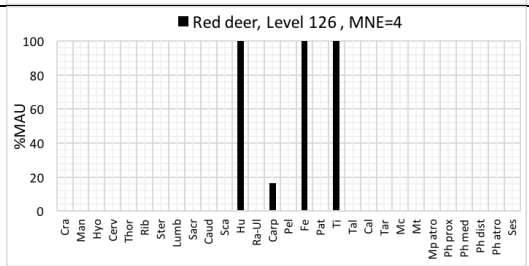


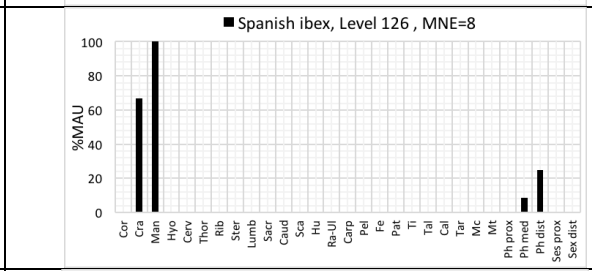
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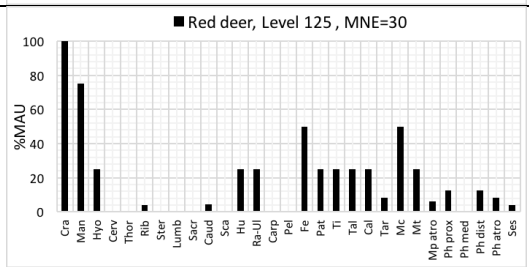
Solutrean

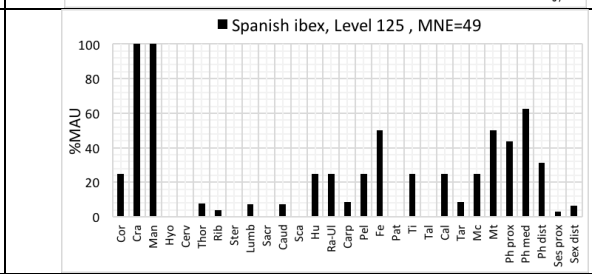


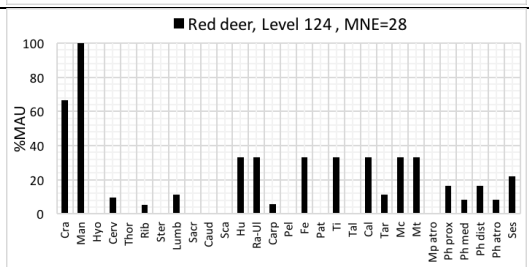


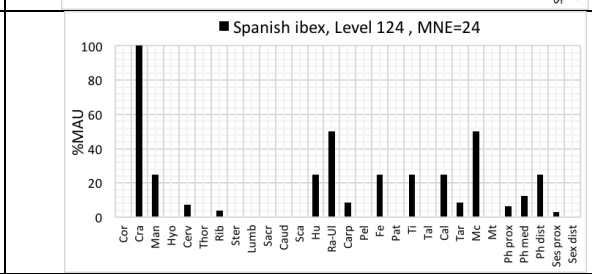


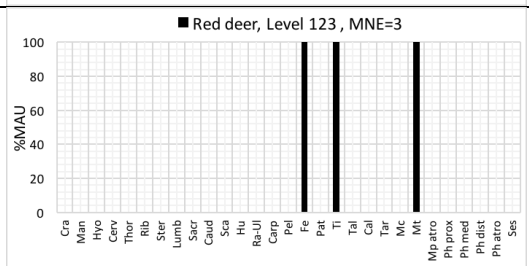


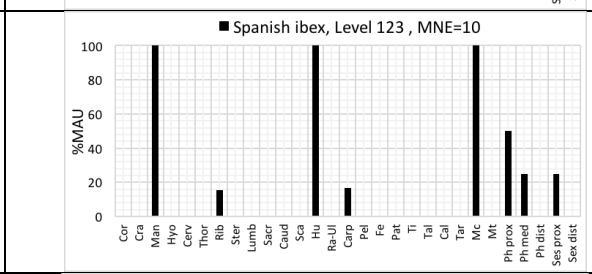


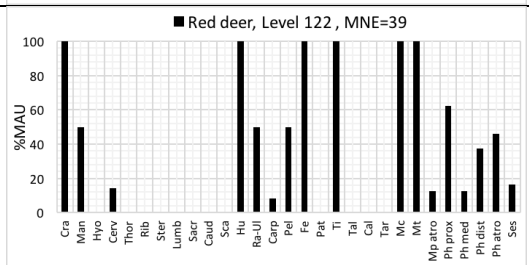


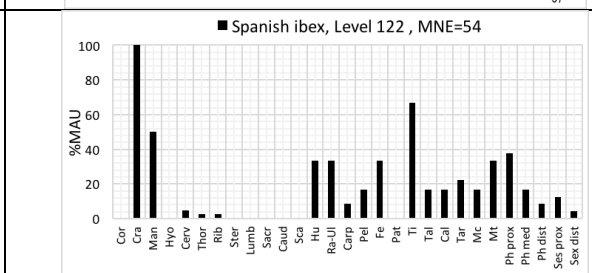


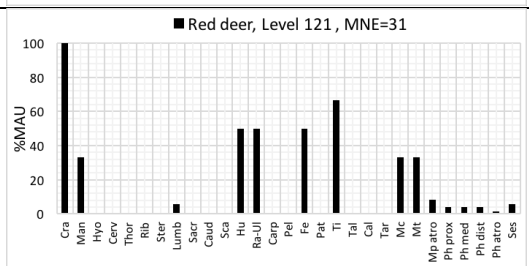


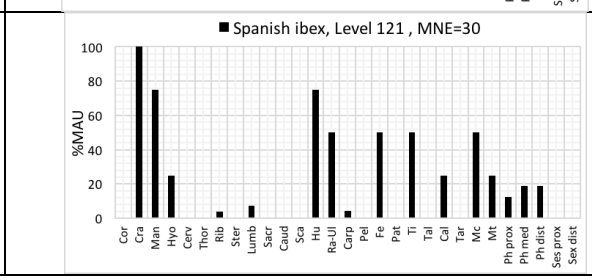






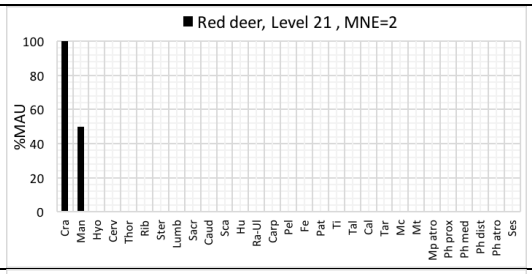


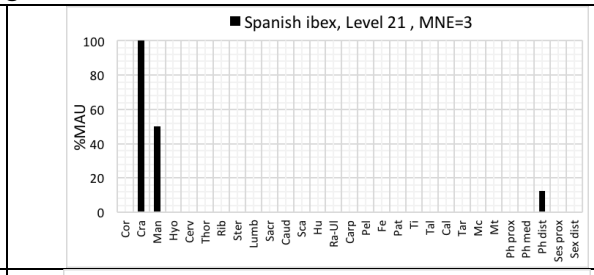


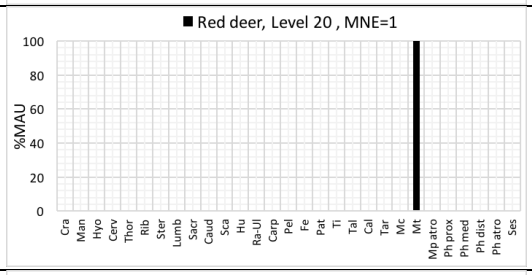


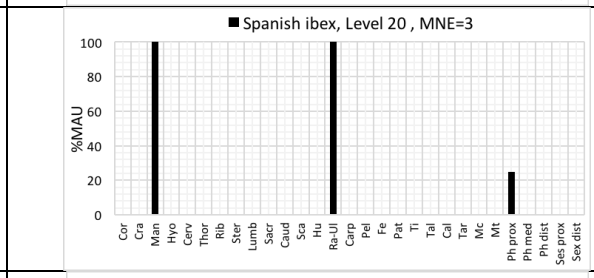
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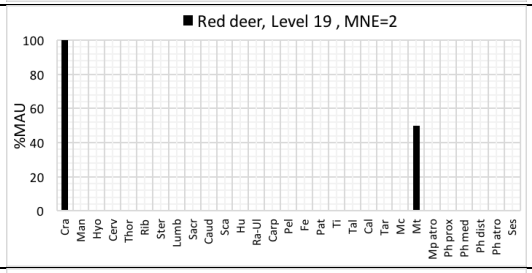
Initial Magdalenian

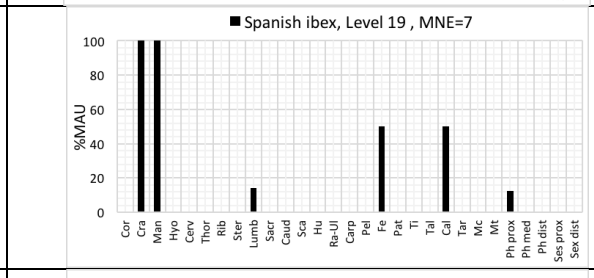


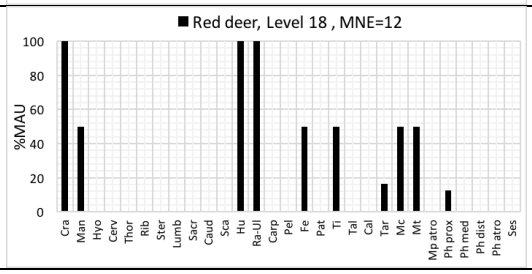


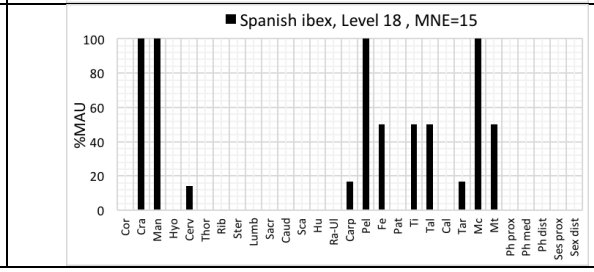




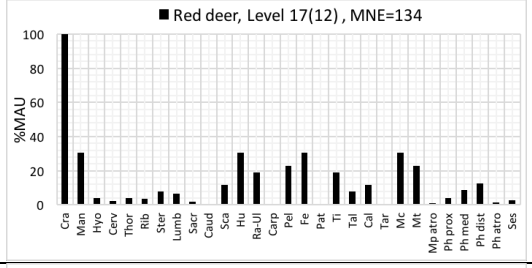


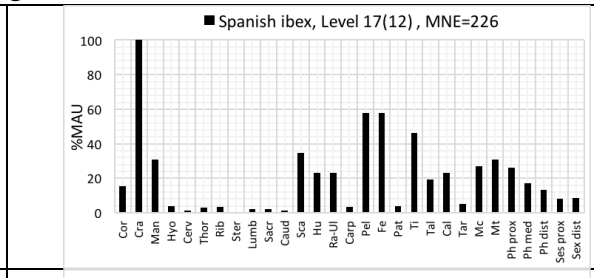


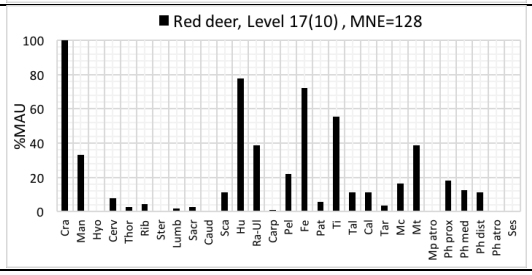


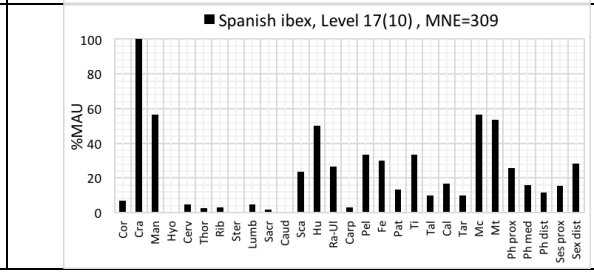


Lower Magdalenian









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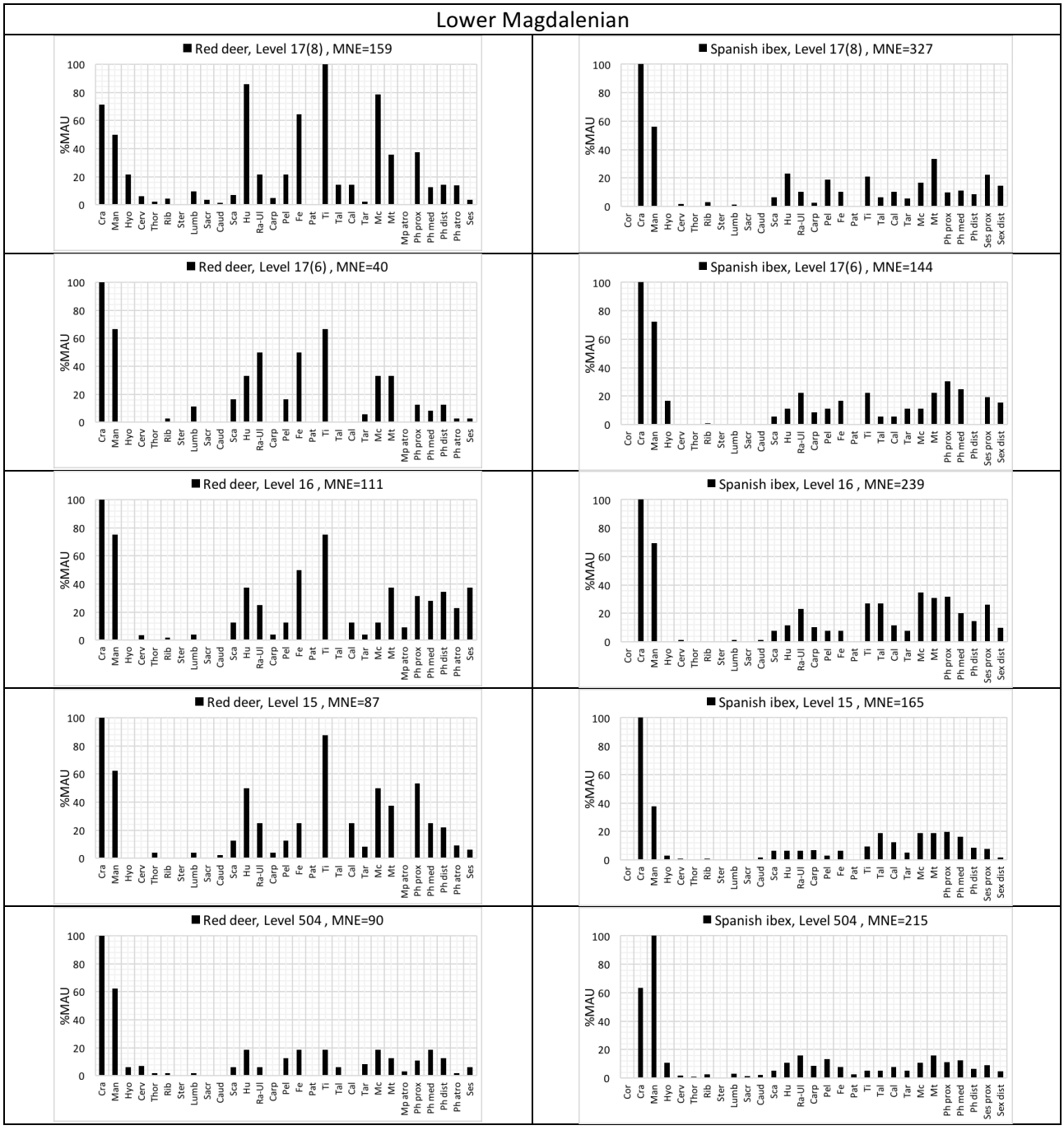


Figure 4.70: Frequency of Minimum Anatomical Units (%MAU) by species and levels for red deer and ibex.

The MNE is summarized for red deer and ibex to produce the following %MAU according to the cultural periods addressed (Figure 4.71).

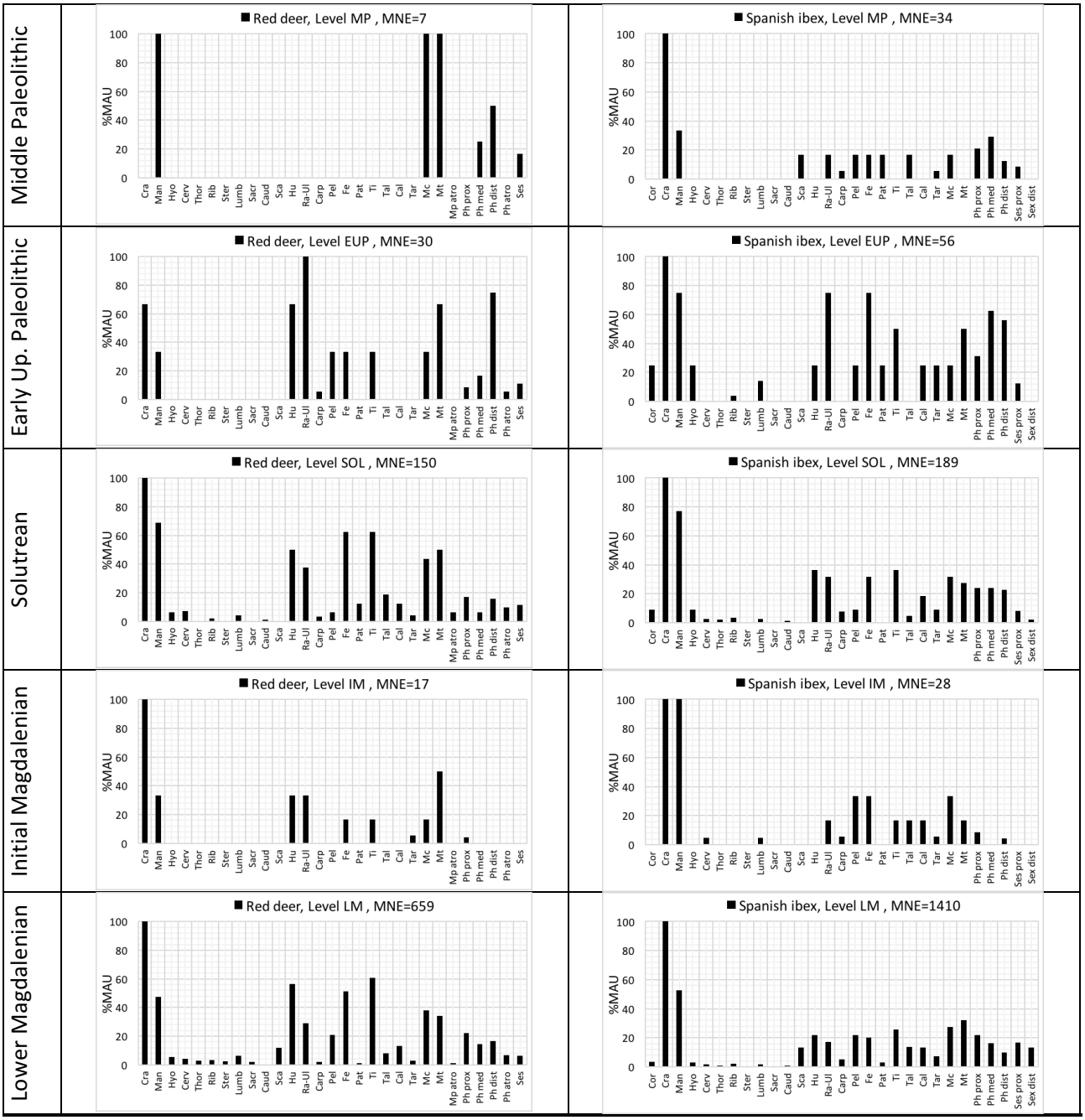
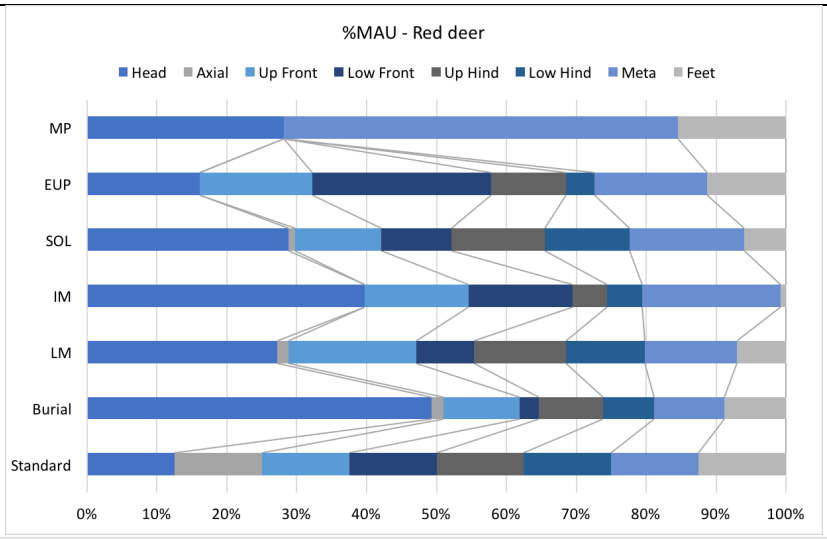
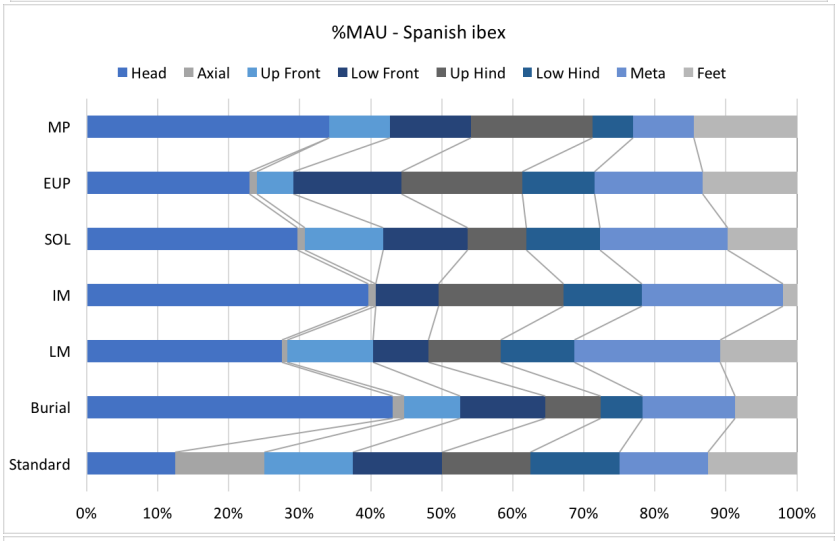


Figure 4.71: Summary of %MAU by cultural periods.

BODY PART REPRESENTATION INDEX (BPRI). Based on the Body Part Representation Index (Figure 4.72), Late Middle Paleolithic red deer remains in the El Mirón cave are exclusively represented by head, metapodial (lower leg) and foot body parts (dominated by the first two of the list). Head elements are constantly overrepresented in all the faunal assemblages under study. To estimate only maximum MNE (maxMNE), among head elements were chosen the highest MNE between upper/lower teeth and maxillary/mandibular bone. This procedure was used for calculation maxMNE, because dental finds are naturally overrepresentated due to their higher identification rate and lower destructive rate. Axial elements are constantly underrepresented, whether due to attrition, transport or other reasons needs to be clarified in consequent analysis. The upper front limb, shows quite constant representations throughout the Upper Paleolithic cultural periods, very similar to the upper hind limb and the standard. The %BPRI rate of lower front elements is higher in the EUP, lower in the Solutrean, higher in the Initial Magdalenian and lower in the

Lower Magdalenian and Burial levels compared to the standard. The lower hind elements show a reverse pattern for the Upper Paleolithic occupations of the site. Metapodial proportions seem to be quite similar among the study units with its lowest proportion in the burial layer. Feet element show a slight decrease until the IM levels and later increase in their proportions. Specifically, were included the distribution of body parts from bones that were grouped in size classes to see how their pattern complement the observed element representation in red deer and ibex. This means that elements that are difficult to identify taxonomically might be naturally underrepresented.





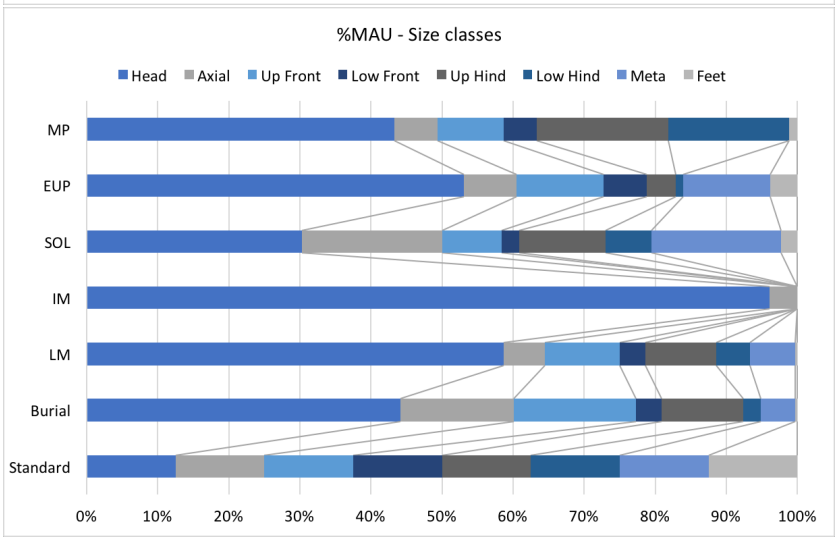


Figure 4.72: The Body Part Representation Index (BPRI) group %MAU by body parts for red deer, Spanish ibex and size classes by cultural periods. MP-Middle Paleolithic (130), EUP-Early Upper Paleolithic (128,129), SOL-Solutrean (Level 120-126), IM-Initial Magdalenian (18-21), LM-Lower Magdalenian (Level 15-17), Burial-Lower Magdalenian Level 504.

Tests of correlation between %MAU, MGUI and bone density were performed and the results are considered accordingly (correlation coefficient and p-values). The correlation test results show the strength and direction of the linear and/or monotonic relationship between two variables. According to the bivariate correlation of %MAU versus %MGUI and %MAU versus % bone density site function can be inferred (GRAYSON 1989; LYMAN 1992). The correlation coefficient range between -1 and +1, a Pearson r (or Spearman ρ [rho] for ranked data) located on the boundaries would indicate a perfect linear (or monotonic) correlation and a coefficient of r=0 indicate no linear (or monotonic) relationship between the variables. Positive test results show a positive relationship, while negative ones show a negative one.

The test results for the conducted correlation analysis of Meat, MGUI and bone density indices for El Mirón cave are summarized in Table 4.17 for red deer, Table 4.18 for ibex, bones in size classes in Table 4.19 and all identified elements in Table 4.20. Some levels have a number of MNE that is too low for performing these tests and were not taken into account during interpretation, for red deer these are Levels 19,20,21, 123, 126 and 129, for ibex Levels 20 and 21 and for size classes 18-21 for Meat, MGUI and Density analysis.

The results for red deer are described first, see Table 4.17 . The frequency of anatomical units (%MAU) in relation to meat values show a weak, negative correlation. A negative correlation means that skeletal elements with higher meat portions are generally less represented; these are femur, ribs, vertebrae, for example (BINFORD 2012). The correlation of %MAU to MGUI values seem to be very similar to the meat index. Most of the test results from bone density correlation with %MAU reveal positive, weak to strong relationships, which suggest that more elements of higher bone density were identified during analysis; these are mandible, scapulae, tibiae, metapodial, for example.

Table 4.17: Statistical correlation of red deer MNE with meat, MGUI and density index (bold= positive correlation; italics= significant p- values (<0.05), bold italics= highly significant p-values (<0.01))

Cervus elaphus	Meat index				MGUI				Density index			
Level	Pearson (r)	p	Spearman (rho)	p	Pearson (r)	p	Spearman (rho)	p	Pearson (r)	p	Spearman (rho)	p
130	-0.27	0.231	-0.36	0.105	-0.33	0.149	-0.48	*0.027*	**0.27**	0.251	**0.13**	0.585
128	-0.20	0.385	-0.33	0.143	-0.19	0.407	-0.39	0.078	**0.28**	0.226	**0.40**	0.077
127	-0.30	0.190	-0.48	0.029	-0.32	0.156	-0.53	*0.013*	-0.12	0.617	-0.33	0.155
125	-0.07	0.768	-0.19	0.398	-0.10	0.678	-0.21	0.370	**0.39**	0.087	**0.39**	0.088
124	-0.12	0.591	-0.29	0.207	-0.14	0.559	-0.33	0.144	**0.38**	0.099	**0.39**	0.090
122	-0.02	0.939	-0.23	0.325	**0.06**	0.808	-0.26	0.265	**0.54**	*0.014*	**0.53**	*0.016*
121	0.00	0.993	-0.17	0.457	**0.05**	0.823	-0.20	0.378	**0.61**	***0.004***	**0.65**	***0.002***
18	-0.05	0.838	-0.12	0.619	-0.02	0.930	-0.20	0.396	**0.58**	***0.007***	**0.71**	***0.001***
17(12)	-0.04	0.854	**0.01**	0.957	-0.12	0.619	-0.07	0.769	**0.65**	***0.002***	**0.59**	***0.006***
17(10)	**0.10**	0.653	-0.13	0.579	**0.17**	0.456	-0.11	0.624	**0.71**	***<0.001***	**0.79**	***<0.001***
17(8)	-0.02	0.935	-0.26	0.246	**0.09**	0.685	-0.19	0.417	**0.57**	***0.008***	**0.62**	***0.003***
17(6)	**0.02**	0.948	0.00	0.993	**0.03**	0.906	-0.09	0.692	**0.63**	***0.003***	**0.63**	***0.003***
16	-0.10	0.669	-0.29	0.200	-0.03	0.884	-0.24	0.289	**0.43**	0.057	**0.42**	0.068
15	-0.29	0.207	-0.40	0.069	-0.21	0.363	-0.36	0.109	**0.55**	*0.013*	**0.57**	***0.009***
504	-0.14	0.539	-0.19	0.404	-0.24	0.301	-0.27	0.243	**0.30**	0.205	**0.27**	0.244

Ibex results show a different pattern of distribution, see Table 4.18. The range of the meat index and MGUI test results are generally smaller; thus, the peaks of Kernel density are higher, indicating a more uniform distribution among the ibex elements compared to red deer. Some of the meat and MGUI values show a significant negative correlation with %MAU, Level 15 and 16, implying that meat-poor elements are abundantly present, these are cranial and mandible remains, for example. The correlation with bone density is also in ibex positive, but with a higher contribution of negative associations compared to the red deer observations. The major difference between these two species is that the correlation in ibex ranges from moderately negative to moderately positive, which is in total a weaker correlation than in red deer. The skeletal profile of ibex bones does not show a clear sorting and/or selective preservation due to bone density, therefore, a broad spectrum of ibex bones is present. This pattern possibly corresponds to complete ibex bodies being transported to the cave and they have not suffered strong biological or physiological destruction down to a level where skeletal elements are non-identifiable.

Table 4.18: Statistical correlation of Spanish ibex MNE with meat, MGUI and density index (bold= positive correlation; italics= significant p- values (<0.05), bold italics= highly significant p-values (<0.01)).

Capra pyrenaica	Meat index				MGUI				Density index			
Level	Pearson (r)	p	Spearman (rho)	p	Pearson (r)	p	Spearman (rho)	p	Pearson (r)	p	Spearman (rho)	p
130	-0.20	0.380	-0.32	0.159	-0.28	0.222	-0.41	0.063	-0.13	0.606	-0.09	0.725
129	-0.30	0.190	-0.40	0.074	-0.31	0.176	-0.42	0.060	-0.04	0.886	-0.09	0.724
128	-0.15	0.518	-0.18	0.429	-0.17	0.461	-0.28	0.218	-0.11	0.667	-0.18	0.466
127	-0.18	0.445	-0.30	0.191	-0.24	0.286	-0.37	0.099	0.06	0.810	0.20	0.434
126	-0.07	0.751	-0.30	0.190	-0.14	0.546	-0.41	0.068	-0.33	0.179	-0.40	0.104
125	-0.24	0.289	-0.41	0.064	-0.30	0.193	-0.50	0.022	-0.03	0.900	0.00	0.985
124	-0.32	0.157	-0.36	0.106	-0.35	0.123	-0.43	*0.050*	**0.21**	0.395	**0.17**	0.503
123	-0.19	0.418	-0.30	0.193	-0.23	0.323	-0.33	0.150	**0.18**	0.463	**0.20**	0.436
122	-0.28	0.224	-0.34	0.132	-0.25	0.274	-0.38	0.091	**0.32**	0.195	**0.42**	0.086
121	-0.23	0.316	-0.32	0.162	-0.23	0.308	-0.41	0.064	**0.14**	0.591	**0.13**	0.615
19	-0.01	0.969	-0.02	0.944	-0.05	0.839	-0.09	0.694	-0.06	0.802	-0.22	0.380
18	0.00	0.999	0.00	0.987	-0.01	0.979	-0.01	0.960	**0.21**	0.393	**0.40**	0.098
17(12)	-0.05	0.819	-0.09	0.705	-0.05	0.824	-0.13	0.567	-0.03	0.911	**0.07**	0.794
17(10)	-0.25	0.278	-0.24	0.302	-0.28	0.213	-0.33	0.141	**0.20**	0.422	**0.11**	0.666
17(8)	-0.20	0.396	-0.30	0.187	-0.24	0.299	-0.36	0.112	**0.23**	0.352	**0.16**	0.530
17(6)	-0.21	0.362	-0.32	0.154	-0.26	0.260	-0.39	0.083	**0.28**	0.252	**0.33**	0.175
16	-0.38	0.088	-0.69	***0.001***	-0.42	0.061	-0.73	***<0.001***	**0.45**	0.061	**0.44**	0.070
15	-0.33	0.149	-0.67	***0.001***	-0.38	0.093	-0.67	***0.001***	**0.41**	0.088	**0.41**	0.091
504	-0.24	0.303	-0.27	0.245	-0.15	0.516	-0.54	*0.012*	**0.32**	0.193	**0.29**	0.238

All identified elements were finally tested to overcome possible skewed correlations for the reason that some elements are more difficult to identify taxonomically, such are ribs and vertebras, which are potentially found in bones only identified anatomically in size classes and not taxonomically, see Table 4.19.

Table 4.19: Statistical correlation of bones in size classes based on NISP with MGUI and density index (bold= positive correlation; italics= significant p- values (<0.05), bold italics= highly significant p-values (<0.01))

Size classes	MGUI				Density index			
Level	Pearson (r)	p	Spearman (rho)	p	Pearson (r)	p	Spearman (rho)	p
130	**0.34**	0.187	**0.40**	0.113	**0.05**	0.848	**0.09**	0.746
129	-0.15	0.556	-0.24	0.361	**0.40**	0.124	**0.16**	0.548
128	-0.21	0.417	-0.24	0.354	-0.40	0.129	-0.12	0.646
127	**0.52**	*0.034*	**0.49**	0.048	-	-	-	-
126	**0.48**	0.051	**0.29**	0.259	**0.04**	0.897	-0.06	0.825
125	**0.84**	***<0.001***	**0.79**	***<0.001***	**0.16**	0.545	**0.17**	0.521
124	**0.54**	*0.026*	**0.38**	0.131	**0.23**	0.384	**0.39**	0.131
123	**0.46**	0.066	**0.39**	0.117	-0.05	0.865	-0.14	0.617
122	**0.29**	0.259	**0.36**	0.156	**0.26**	0.339	**0.43**	0.099
121	**0.53**	*0.028*	**0.47**	0.056	**0.43**	0.098	**0.34**	0.193
504	**0.67**	***0.003***	**0.68**	***0.003***	-0.14	0.612	-0.04	0.896
17--12	**0.67**	***0.003***	**0.73**	***0.001***	**0.26**	0.333	**0.27**	0.312
17--10	**0.44**	0.077	**0.67**	***0.003***	**0.47**	0.063	**0.23**	0.402
17--8	**0.13**	0.622	**0.16**	0.538	**0.32**	0.225	**0.21**	0.436
17--6	**0.27**	0.298	**0.26**	0.309	**0.39**	0.137	**0.25**	0.353
16	**0.10**	0.690	**0.15**	0.565	**0.52**	*0.040*	**0.33**	0.206
15	**0.11**	0.684	**0.15**	0.578	**0.22**	0.406	**0.34**	0.194

The summary of %MAU of all elements identified in correlation to MGUI shows a weak to moderate, positive correlation, see Table 4.20. The relationship to bone density shows a stronger and positive correlation. The weaker and negative correlation was observed in the oldest Late Middle–Early Upper Paleolithic levels 130-128 and Solutrean Level 127. The Spearman rho test result is increasingly monotonic the younger the assemblages get, which is the opposite of what would be expected by density mediated destruction through taphonomic processes across time. The main skeletal representation pattern, therefore, might not be explained by diagenetic processes, but rather by human activities.

In summary, when applying this method, the majority of statistical test results imply a high percentage of attritional effect, which means the loss of a great part of the spongy tissue and can be associated with scavenger or density- mediated destruction due to trampling, sediment compaction, weathering, chemical disintegration, etc. or intentional bone breakage.

The often-negative correlation of the meat index and MGUI is common also in other Paleolithic sites (BINFORD 1981, 1984, 1985; STINER 1991, 1994). A reverse utility curve infers the overrepresentation of low utility elements and on the contrary an underrepresentation of high utility elements. The latter elements include high quality and quantities of bone fats, which are also more frequently represented within the animal body compared to long bones, for example. However, reverse utility curves might be the product of density-mediated destruction of bones and introduces the problem of equifinality (LYMAN 1994; ROGERS 2000). The degree of attrition was inferred by the skeletal profile according to the density index as we have seen in the statistical analysis. These results, however, leave questions as to what would be the context of attritional modified faunal assemblages and are these visible in El Mirón cave?

Table 4.20: Statistical correlation of identified anatomical elements %MAU based on NISP with meat, MGUI and density index (bold= positive correlation; italics= significant p- values (<0.05), bold italics= highly significant p-values (<0.01))

All elements	MGUI				Density index			
Level	Pearson (r)	p	Spearman (rho)	p	Pearson (r)	p	Spearman (rho)	p
130	-0.15	0.572	-0.12	0.653	**0.29**	0.274	**0.26**	0.339
129	-0.18	0.491	-0.28	0.283	-0.07	0.799	**0.17**	0.524
128	**0.00**	0.990	**0.06**	0.814	**0.43**	0.094	**0.39**	0.132
127	**0.26**	0.316	-0.15	0.568	-0.18	0.498	-0.17	0.530
126	**0.51**	0.037	**0.36**	0.157	**0.26**	0.331	**0.40**	0.127
125	**0.59**	*0.013*	**0.45**	0.068	**0.43**	0.098	**0.55**	*0.028*
124	**0.35**	0.175	**0.21**	0.418	**0.54**	*0.030*	**0.67**	***0.004***
123	**0.47**	0.057	**0.39**	0.124	**0.50**	*0.046*	**0.51**	*0.044*
122	**0.28**	0.279	**0.23**	0.376	**0.64**	***0.008***	**0.73**	***0.001***
121	**0.43**	0.089	**0.45**	0.069	**0.59**	*0.017*	**0.64**	***0.007***
21-18	**0.19**	0.465	**0.27**	0.303	**0.58**	*0.018*	**0.66**	***0.005***
504	**0.35**	0.173	**0.17**	0.508	**0.62**	*0.010*	**0.79**	***<0.001***
17--12	**0.46**	0.065	**0.59**	0.013	**0.60**	*0.014*	**0.62**	*0.011*
17--10	**0.39**	0.121	**0.33**	0.190	**0.60**	*0.014*	**0.69**	***0.003***
17--8	**0.28**	0.269	**0.16**	0.552	**0.63**	***0.009***	**0.71**	***0.002***
17--6	-0.03	0.909	**0.07**	0.777	**0.63**	***0.009***	**0.72**	***0.002***
16	-0.03	0.907	-0.02	0.936	**0.64**	***0.008***	**0.66**	***0.005***
15	-0.16	0.543	-0.12	0.655	**0.61**	*0.012*	**0.73**	***0.001***

Three possible scenarios could have led to the observed results, which will be discussed briefly in what follows: Scenario 1) The meat-rich skeletal elements were left on the kill-site and not brought to El Mirón, Scenario 2) the elements that are rich in meat were selectively destroyed by biological or diagenetic processes or Scenario 3) humans destroyed bones intentionally.

Scenario 1) According to the optimal foraging model it is unlikely that the meat on the bones of hunted prey animals was not excessively used during the Paleolithic. It is likely that especially meat-rich parts as present on the axial skeleton were preferentially transported to the base camp for processing due to their higher butchering costs (O'CONNELL ET AL. 1990; MONAHAN 1998; MADRIGAL & HOLT 2002; MARÍN-ARROYO 2009). Especially ibex seemed to be transported as complete carcasses to El Mirón cave. A selective transport means that certain body parts gets left behind on the kill site. These include skeletal elements, which have either a low utility value or low processing costs as are long bones and ribs where stripping of meat is done easily (CANNON 2003). Other examples of these are the humerus or tibia, which are elements that are actually well represented in El Mirón cave. According to this assumption the results would refer to El Mirón as a kill site rather than a base camp. Nearby kills would then be prepared inside El Mirón to be transported somewhere else. While it is true that especially ibex would probably have been possible hunted in the close surroundings of the site, this scenario is more unlikely for red deer, which presumably lived and were hunted in the over 100m valley floor below the site or even further away (Valle de Ruesga—middle Asón valley).

Scenario 2) A positive correlation of %MAU with bone density was observed among the faunal assemblages in El Mirón cave, implying that the more of the better surviving elements due to bone density are present. Elements of high bone density are different between red deer and ibex, which is indicated by a weak correlation between both bone density indices. Red deer bones show a higher positive correlation with bone

density than do ibex bones. Accordingly, a density mediated attrition on bone survivorship due to trampling, sediment compaction, chemical dissolution, etc. (BINFORD & BERTRAM 1977; LYMAN 1984, 1994; KLEIN 1989; LAM ET AL. 1998, 1999; LAM & PEARSON 2005; MARÍN-ARROYO & OCIO 2018) or carnivore scavenging (Marean & Spencer 1991; Domínguez-Rodrigo 1999) that primarily affected skeletal elements of low bone densities, would have altered the two main species differently. Natural species-specific bone destructions are only possible when bones would have accumulated separately in the cave deposits, a case which was not observed in El Mirón; bones of both species were always found mixed.

If there is a high representation of long bone shafts versus ends, the key might lie in the origin of accumulation of the assemblages and it need to be excluded that carnivores were the main accumulation agents (MAREAN & SPENCER 1991). In El Mirón cave, a major contribution by scavengers can be excluded due to the lack of massive carnivore activity as discussed in the previous taphonomy chapter.

Further, need to be considered that the effect of attrition would apply to all faunal remains addressed here, meaning the effects should be visible in both main prey species equally, which was not attested by the statistical analysis.

Finally, the greater portion of the faunal units under study seem to be biased by density-mediated destruction. This does not correlate with the observations that were made during excavations (of well-preserved faunal remains) and the here previous presented taphonomic analysis, which indicate wide-ranging good bone surface preservation. The taphonomic analysis done on the single bone specimens reveal that major destructive taphonomic processes can be ruled out (i.e., the bones are well preserved and in good conditions) and further human activities are inferred which might include human selective processing of bones such are rendering within-bone nutrients by the comminution of cancellous bone parts (LYMAN 1994; CHURCH & LYMAN 2003; JANZEN ET AL. 2014).

Scenario 3) Human activities destroyed bones intentionally for further processing such as grease rendering, which in consequence has affected the skeletal profile observed. According to these activities other task-related features of within-bone nutrient processing activities should be present; for example, varied impact marks on bones (MORIN & SOULIER 2017), high fragmentation of the cancellous bone parts (compare Outram 2001; Janzen et al. 2014) and hearths associated with fire cracked rocks (NAKAZAWA ET AL. 2009). The abundance of fire cracked rocks can be potentially associated with grease rendering, but also with delimited (or 'well-defined') hearths or other heating related activities (STINER ET AL. 2005; MANNE ET AL. 2006). The Lower Magdalenian levels studied in El Mirón cave containing occupations where fire cracked rocks and several hearths appeared (NAKAZAWA ET AL. 2009; STRAUS & GONZÁLEZ-MORALES 2018). Intense, frequent human occupation no doubt also caused also intensive trampling and bone breakage.

As an interim conclusion about the obtained results, Scenario 1 can be rejected due to the lack of supportive reasons to leave meat rich parts behind. The attritional effects observed does not reflect natural attrition and Scenario 2 might be rejected, too. The consequent analysis will test the correlation of the fauna from the different levels against the marrow and grease index to explore this last Scenario 3 further. A combined method, thus, is applied to further untangle this phenomenon.

4.2.7 Exploitation of within-bone nutrients

The following is tested, if the skeletal profile resamples within-bone nutrient processing by comparing the skeletal representation with marrow and grease yield in skeletal elements. The Spearman's coefficient of correlation towards anatomical identified elements, based on ranked NISP data and correlation was used.

The Spearman test results for skeletal profiles addressing marrow exploitation show at first that a low number in elements lead generally to weak correlations, thus, levels 130, 127 and 123 for red deer and 129, 127 and 123 for ibex were excluded for consideration in exploitation pattern development in El Mirón cave.

Red deer fragmentation ratios of NISP/MNE actually show cases of positive and significant correlations to the Marrow Index, which indicate the higher the marrow content in the bone the higher fragmented it is (Table 4.21). This relationship is highly significant in Levels 124, 504, 17-8, 17-6, 16 and 15 for red deer. Spanish ibex bones only show significant relationships between the fragmentation ration and Marrow index in the two Levels 504 and 16. In contrast to red deer, the ibex data shows some examples of negative correlations, the low samples sizes may be an issue and have biased the tests. A negative correlation with the Marrow Index was also observed among the elements of all Ungulates identified which also had a comparable smaller number of elements represented for analysis. Levels 17-12 and 17-8 showed a significant, positive correlation of the two indices indicating marrow processing activities.

In summary, there is a tendency towards an exploitation of bone marrow identifiable among the studies units in El Mirón cave. It might be possible that other, additional process/ activities are masking the phenomenon of bone marrow exploitation. The extensive practice of marrow extraction was considered as being evident in El Mirón cave due to the high fragmentation rate of long bone elements and frequent occurrence of impact marks on bones that suggest an efficient bone-opening technique practice during the varied occupational phases (also compare taphonomy chapter).

Table 4.21: Statistical correlation of NISP/MNE with Marrow Index, * = data sets excluded for analysis due to low numbers. (bold= positive correlation; italics= significant p- values (<0.05), bold italics= highly significant p-values (<0.01))

Marrow Index	*Cervus elaphus*			*Capra pyrenaica*			*All Ungulates*		
Level	n	Spearman (rho)	p	n	Spearman (rho)	p	n	Spearman (rho)	p
130	6*			11	**0,29**	0,387	19	**0,18**	0,461
129				8*			11	-0,36	0,278
128	13	**0,57**	*0,041*	15	**0,17**	0,551	16	**0,12**	0,656
127	7*			6*			12	-0,20	0,530
126							15	-0,29	0,294
125	13	**0,15**	0,622	17	**0,35**	0,169	20	**0,33**	0,154
124	15	**0,66**	***0,007***	14	**0,37**	0,192	18	**0,33**	0,180
123	3*			6*			11	**0,20**	0,560
122	14	**0,39**	0,172	18	**0,43**	0,078	19	**0,44**	0,058
121	11	**0,57**	0,065	15	**0,30**	0,285	18	**0,42**	0,083
504	18	**0,79**	***<0,001***	20	**0,54**	*0,014*	20	**0,28**	0,232
21-18				15	**0,19**	0,487	15	**0,40**	0,140
17(12)	21	**0,51**	**0,017**	21	**0,08**	0,732	20	**0,53**	*0,017*
17(10)	20	**0,44**	0,054	21	-0,20	0,384	20	**0,42**	0,068
17(8)	20	**0,62**	***0,003***	20	**0,08**	0,749	19	**0,56**	*0,013*
17(6)	15	**0,80**	***<0,001***	16	-0,01	0,964	19	**0,40**	0,086
16	18	**0,60**	***0,008***	19	**0,47**	*0,041*	19	**0,34**	0,157
15	17	**0,70**	***0,002***	18	**0,42**	0,080	19	**0,42**	0,076

The Spearman test results for skeletal profiles addressing grease exploitation show also that a low number of elements lead to general weak correlations, thus, levels 130, 127 and 123 for red deer and 129, 127 and 123 for ibex were excluded for consideration in exploitation pattern development in El Mirón cave (Table 4.22).

A highly significant and positive correlation between the fragmentation ration and grease index was observed for red deer remains for the Levels 124, 504, 17-8, 17-6, 16, and 15. Also highly significant correlate Levels 504 and 16 for ibex. This pattern is also true for all ungulate bones in Levels 17-12 and 17-8. The other levels show positive correlations with the grease index, which generally suggest that skeletal elements with higher grease content are more heavily fragmented in the El Mirón site throughout time.

Table 4.22: Statistical correlation of NISP/MNE with Grease index, * = data sets with low numbers for analysis. (bold= positive correlation; italics= significant p- values (<0.05), bold italics= highly significant p-values (<0.01))

Grease Index	*Cervus elaphus*			*Capra pyrenaica*			*All Ungulates*		
Level	n	Spearman (rho)	p	n	Spearman (rho)	p	n	Spearman (rho)	p
130	5*			10	-0,08	0,834	17	-0,10	0,700
129				8*			10	-0,71	0,021
128	12	**0,48**	0,094	13	-0,20	0,516	14	-0,02	0,935
127	7*			4*			10	-0,61	0,062
126							13	-0,53	0,061
125	12	**0,27**	0,371	15	**0,09**	0,749	18	**0,02**	0,923
124	15	**0,37**	0,175	13	**0,01**	0,973	16	**0,02**	0,928
123	3*			6*			10	-0,23	0,519
122	13	**0,71**	***0,007***	17	**0,15**	0,570	17	**0,16**	0,546
121	10	**0,51**	0,134	14	**0,36**	0,206	16	**0,19**	0,492
504	17	**0,63**	***0,007***	19	**0,22**	0,364	18	0,00	0,997
21-18				14	**0,44**	0,116	13	**0,35**	0,243
17(12)	20	**0,25**	0,289	19	-0,05	0,845	18	**0,22**	0,379
17(10)	19	**0,11**	0,648	19	-0,09	0,704	18	**0,65**	***0,003***
17(8)	19	**0,16**	0,511	19	**0,02**	0,922	17	**0,44**	0,074
17(6)	14	**0,46**	0,098	15	**0,24**	0,393	17	**0,17**	0,507
16	17	**0,30**	0,237	18	**0,59**	**0,010**	17	**0,26**	0,310
15	16	**0,45**	0,078	17	**0,50**	**0,040**	17	**0,35**	0,173

In summary, red deer shows the fragmentation ratio with the strongest and positive correlation to the Marrow Index among the analyzed data, which is in ibex more moderately. The third correlation of ranked NISP from all ungulates shows negative correlation in the older levels under study, which generally contained scarce evidence of human activities. While cracking bone cavities for marrow extraction was described before as a feature of human accumulations in Paleolithic sites, the negative correlation of ranked NISP and the Marrow index seems to separate the levels accordingly to their origin of accumulation. Levels showing a negative correlation had a lower impact of human activities. Ranked NISP and Marrow Index correlates well in Late Paleolithic human dominated accumulations.

The grease index correlates with the ranked fragmentation ratio NISP/MNE moderately well in red deer remains and generally weak in ibex, but with a much larger scattering of the data. The ranked NISP data show again a two-part distribution. The strong negative correlations are Levels 130 (Late Middle Paleolithic), 129-128 (Early Upper Paleolithic), 127-126 (Solutrean) and 123 (Solutrean), again the older levels. The other Solutrean Levels 125, 124, 122 and 121 basically show no correlation with the grease index, which might indicate that the technique of grease rendering was not applied yet intensive during these periods of time at El Mirón cave. Interestingly, with the Initial Magdalenian (albeit very small samples) an increase in positive correlation between ranked NISP and Grease index, which means that elements rich in bone grease tend to be more often present in fragments than ones containing low quantities of bone fats (JANZEN ET AL. 2014), is observed.

In general, red deer remains show a stronger correlation towards the indices than ibex. This is a pattern that might be explained by the circumstances that ibex was more likely transported to the site as whole carcasses due to either its smaller size and/or proximity of its steep, rocky hunting grounds to the cave. Both scenarios infer lower transport costs for this species. The larger size red deer, on the other hand, presumably was more selectively transported up to the steep slope surrounded El Mirón cave due to its body size. This selection behavior, thus, implies economically influenced decision-making towards an optimal subsistence strategy that was carried out by the hunter-gatherers based at this place.

For the further interpretation, the micro-bone fraction from El Mirón levels with published experimental study (MORIN & SOULIER 2017) about marrow and grease rendering activities will be compared. From El Mirón data was plotted the tally for each category by cultural levels for diachronic analysis, where it was compared with reference data of marrow (Ref- MCE) and grease processing (Ref- BGRE) according to %NR from the publication.

The results from the published experimental study (MORIN & SOULIER 2017) show (Figure 4.73) that grease-rendered bones (Ref- BGRE) from the experiment contribute to the smallest size class of bones (1-2cm) in comparison to only marrow processing (Ref-MCE). All of the size distributions of %NR for El Mirón levels exceed the grease-rendering values in the smallest size class. Middle Paleolithic and Early Upper Paleolithic size distributions seem to be similar, with a high amount of small bone fragments. Attention needs to be drawn to the circumstance that these levels include relatively many small animals such as leporids and birds, which contribute automatically to small specimen sizes so that and these results might be skewed. Despite the fact that Solutrean and the Lower Magdalenian occupation periods show higher %NR in the smaller categories, the cultural remains seem to resample the described pattern of only marrow extraction for the former and applied grease-rendering technique for the latter cultural period. In El Mirón the degree of observed bone fragmentation is very severe in comparison to what is presented in the BGRE experiment. The authors explained that the BGRE include more bigger fragments as they are more likely to be identified and can be used as criteria for their blind test experiment; for this reason, they stopped comminution of epiphyseal fragments when the fragments formed a flat “cake”, generally after 5-8 blows (MORIN & SOULIER 2017: p. 99). Church and Lyman (2003) were able to show that during the first hour of boiling, smaller specimens render more grease than larger ones, despite the fact that it is possible to obtain the same total grease amount from bones of up to 5cm in size. Thus, the tradeoffs in bone grease extraction consist in weighing the costs of collecting fuel and water against the costs of increasing bone comminution (JANZEN ET AL. 2014); the changing availability of these resources or saving energy costs may affect tradeoffs over time and space.

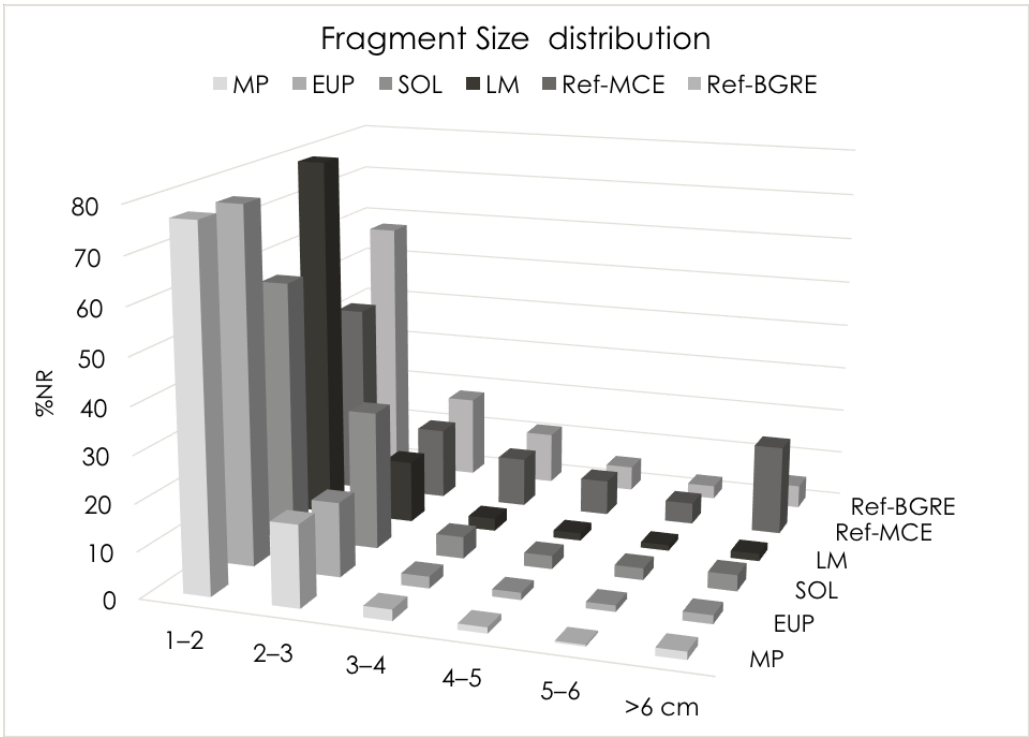


Figure 4.73: Fragment size distribution of cultural levels in comparison with BGRE and MCE reference data (after MORIN & SOULIER 2017). El Mirón levels: MP-Middle Paleolithic, EUP-Early Upper Paleolithic, SOL-Solutrean, LM-Lower Magdalenian.

For food cooking water is necessary. Water could have been collected in the nearby rivers or might have been available in the cave itself, as active dripping from the cave ceiling is evidenced nowadays. Water dripping might always have been present within this limestone cave as indicated through different wet patches seen during excavations, while their locations may have changed throughout time. The existence of intensive manganese coating processes in the Vestibule rear (MARÍN-ARROYO ET AL. 2008), which percolation is only possible by the presence of water, suggest that water was present over long periods of time present in this area of the cave. Especially the areas close to the cave wall might have been dripping zones. For the Lower Magdalenian occupations, the smaller bone fragments in El Mirón cave indicate a higher amount of energy spend on bone crushing, possibly to reduce the use of fuel or water for cooking during the grease rendering processes. Whether post-glacial conditions might have provided abundant melt-water is questionable, since some Lower Magdalenian environments have been described as having been relatively dry (STRAUS & GONZÁLEZ-MORALES 2012), but a trend of warming summers suggest glacier melting processes that relive water within a generally dry environment (SERRANO ET AL. 2015). The Lower Magdalenian levels in the rear Vestibule squares close to the cave wall are located in a generally wet area and were described as having a possible stone wall (STRAUS & GONZÁLEZ-MORALES 2018), maybe related to cooking activities or collecting water in the cave? A detailed taphonomic and chemical analysis of the bones in the Vestibule area would help to better understand the whole cooking phenomenon for the Lower Magdalenian.

The question of fuel availability (necessary for such cooking activities) is hard to decipher for the glacial maxima and immediate post-glacial period. The El Mirón palynological and micromammal sequence of records from the cave suggest that cool and arid conditions in an open environment existed during the Solutrean (~LGM) occupations, with the lowest number of woodland species (STRAUS & GONZÁLEZ-MORALES 2009; STRAUS ET AL. 2011; ANTOLÍN ET AL. 2013; STEVENS ET AL. 2014). Marine and lacustrine cores suggest, however, that the LGM have been more humid in the region (MORENO ET AL. 2012), and post-LGM Lower Magdalenian times being colder and drier than the LGM itself (STEVENS ET AL. 2014). A (final) deforestation or forest reduction seem to have occurred mainly during the Lower Magdalenian. This implies limited availability of wood as fuel, although localized stands of pine and juniper did exist in the area. The frequent use of bone as fuel is, however, not indicated by the taphonomic analysis. It needs to be kept in mind, however, especially

when grease rendering is addressed, both activities would target the same resource in the bone, the fat, either for burning or nutritional extraction. Thus, according to energy efficiency, more man power might have been used to smash bones smaller and to save fuel for grease-rendering processes. For the final interpretations, it seems very likely that bone grease-rendering activities are at least partly responsible for the high amount of small and micro-bones within the Lower Magdalenian fauna.

4.2.8 Bayesian modeling for disentangling faunal skeletal profiles

The next method applied with which to decipher the element representation in El Mirón cave is the relatively new probabilistic method of Bayesian Modeling (BM method) for disentangling faunal skeletal profiles (MARÍN-ARROYO & OCIO 2018). Parameter α represents skeletal transport and parameter β represents attrition for main prey species red deer and ibex.

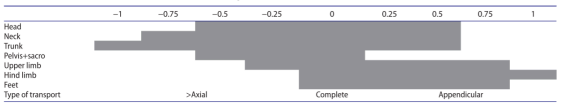
For the Late Middle Paleolithic and other levels, the BM method was not applied as NISP values were very small (<50). The oldest data obtained by such method comes from Level 128 from Spanish ibex skeletal profile Results are shown in Figure 4.74. For the Early Upper Paleolithic profile α median is located close to null, with a slightly right drift, which infer complete body transports with little selection on appendicular elements, possible the result of carnivore activity according to the taphonomy. A stronger selection of appendicular elements is implied during the Solutrean occupations with its highest expression in Level 121 with α values of 0.56 and 0.35, for red deer and ibex, respectively. For the initial occupation phase of the Lower Magdalenian infers the BM method the possibility of transport of complete bodies for ibex and red deer, which change during its course to a greater selection of appendicular body elements of the latter (with α medians ranging from 0.17 to 0.27) up until Level 16 and Level 15 showing a slight decrease.

The results for ibex show a slightly different pattern with Levels 17-12 to 17-8 indicating all close to null values in α median and, thus, they infer a transport of complete ibex bodies to the cave. Here again, the values increase until Level 16 up to $\alpha = 0.16$ with a slight decrease in Level 15. Level 504 show the lowest median of α values recognized for both species with -0.02 for red deer and -0.25 for ibex. These results indicate the most axial focused transport for this deposit, where ibex shows a stronger axial presence than red deer and the latter fall into the distribution of complete body transport.

The Early Upper Paleolithic level show a quite elevated β median in Level 128, which indicate high attrition for this unit likely again by carnivores, where values ranging from 5.29 to 6.54, for ibex and red deer, respectively. For a general comparison where the lowest values, thus, the highest survival of the elements reached with median values of ~3, which correspond to a 15% survival rate. The Solutrean levels for red deer infers again a high loss of bone elements by attrition, but these results are followed by quite low values in Level 124. Levels 122 and 121 together show higher, but quite similar values. In Level 125 contrary to what was observed for red deer, show Spanish ibex elements quite good probabilities for survival, and the median in Level 124 is the lowest one. The uppermost Solutrean levels, on the other hands, have higher β medians of 4.75 and 5.36 again.

Interpreting the Bayesian Model results:

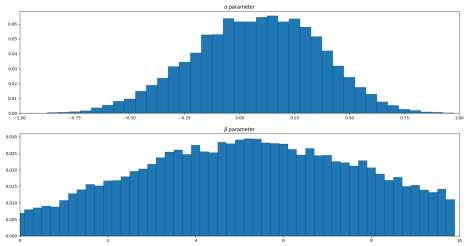
α parameter



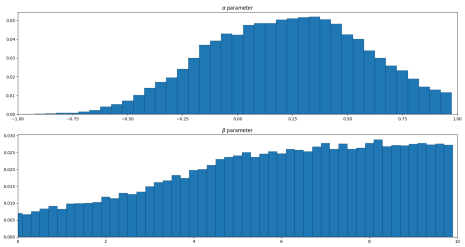
β parameter

β	0	1	2	3	4
Survival (%)	100	50	26	15	8

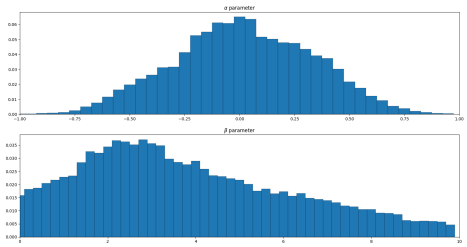
Capra pyrenaica, Level 128
Median: α=0.11; β=5.29



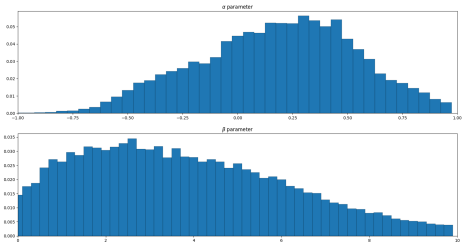
Cervus elaphus, Level 125
Median: α=0.26; β=6.3



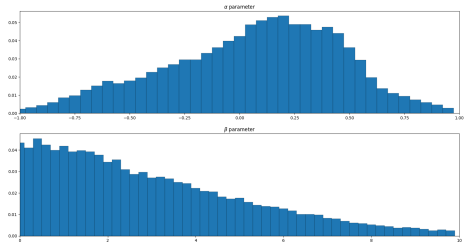
Capra pyrenaica, Level 125
Median: α=0.04; β=3.5



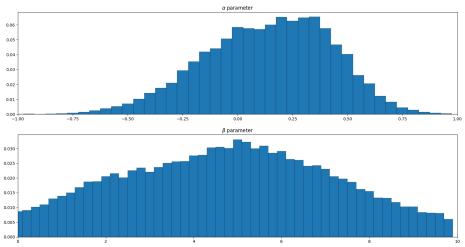
Cervus elaphus, Level 124
Median: α=0.23; β=3.6



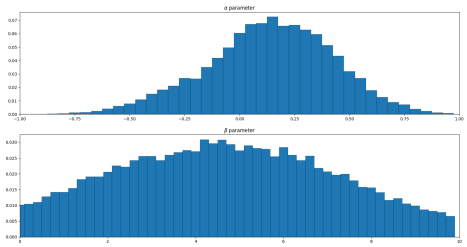
Capra pyrenaica, Level 124
Median: α=0.13; β=2.53



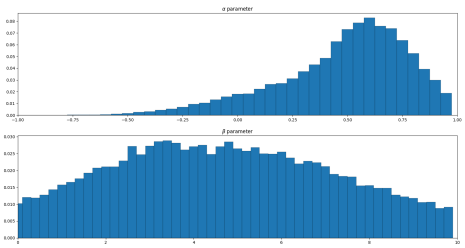
Cervus elaphus, Level 122
Median: α=0.18; β=4.92



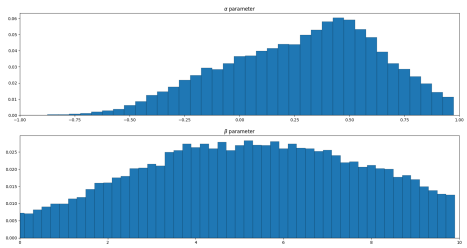
Capra pyrenaica, Level 122
Median: α=0.17; β=4.75



Cervus elaphus, Level 121
Median: α=0.56; β=4.7

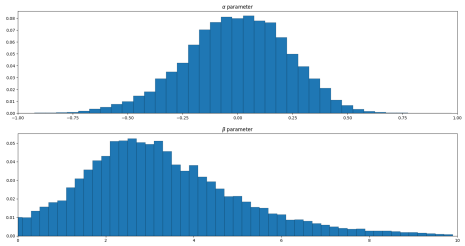


Capra pyrenaica, Level 121
Median: α=0.35; β=5.36

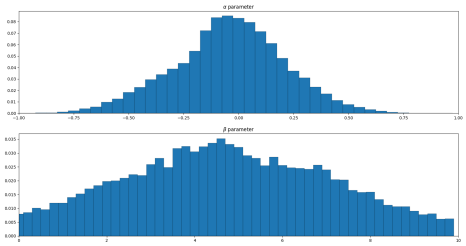


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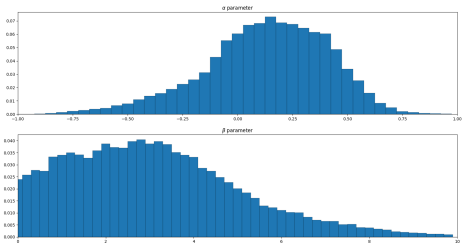
Cervus elaphus, Level 17-12
Median: α=0.03; β=3.14



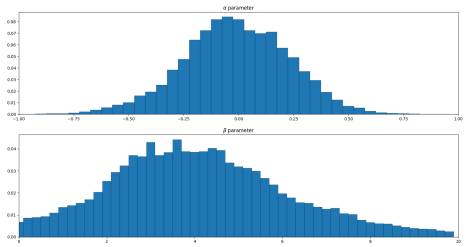
Capra pyrenaica, Level 17-12
Median: α=-0.01; β=4.78



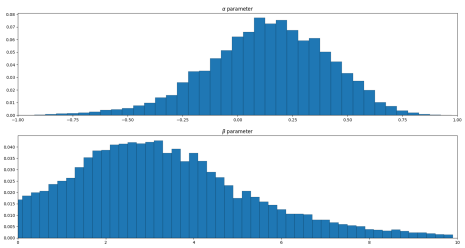
Cervus elaphus, Level 17-10
Median: α=0.18; β=2.98



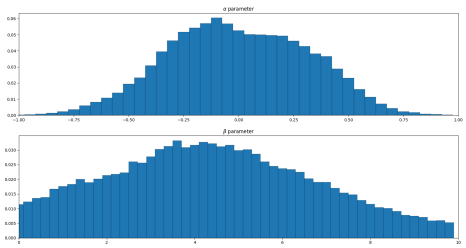
Capra pyrenaica, Level 17-10
Median: α=0.01; β=4.07



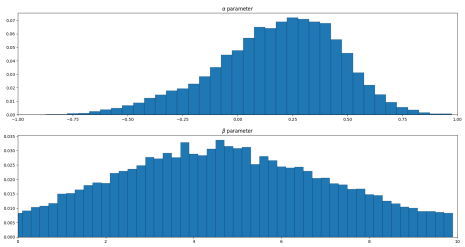
Cervus elaphus, Level 17-8
Median: α=0.17; β=3.19



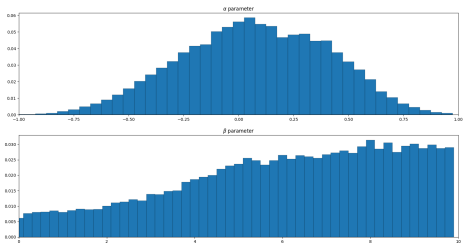
Capra pyrenaica, Level 17-8
Median: α=0.01; β=4.41



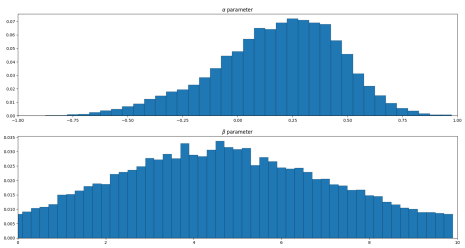
Cervus elaphus, Level 17-6
Median: α=0.23; β=4.72



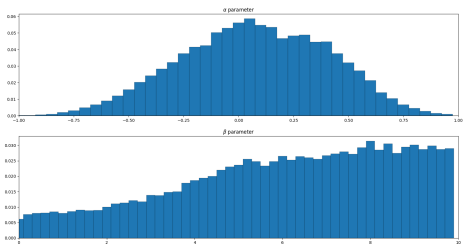
Capra pyrenaica, Level 17-6
Median: α=0.1; β=5.78



Cervus elaphus, Level 17-6
Median: α=0.23; β=4.72



Capra pyrenaica, Level 17-6
Median: α=0.1; β=5.78



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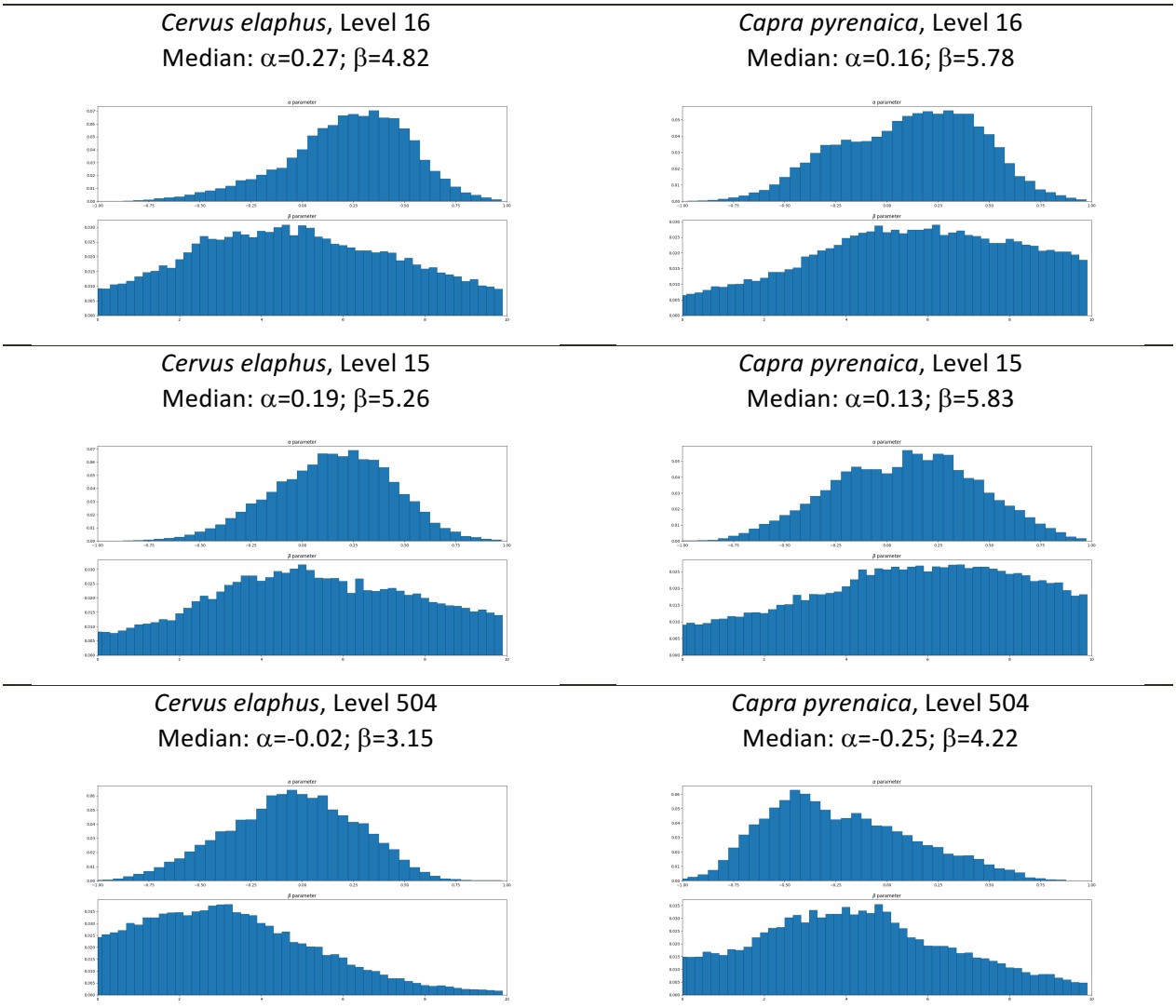


Figure 4.74: Bayesian model of skeletal profiles: Alpha parameter= skeletal transport, Beta parameter = attrition for main prey species in levels with NISP >50.

Attrition is similar in main Lower Magdalenian occupations (Levels 17-12 to 17-8) and the burial from Level 504, with values generally higher (indicating stronger attrition) in ibex. For both species, the degree of attrition arises in Level 17-6, Level 16 and also Level 15. This indicates that during the late Lower Magdalenian preservation conditions changed towards worst post-depositional conditions.

When comparing the inter-species Bayesian Model method value distribution by Pearson and Spearman rank correlation among the levels, α medians correlate significantly throughout the levels (n=13, Pearson(r)=0.879, p=<0.001, Spearman(rho)=0.817, p=0.001), by which similar degree of transport applied to both species in each level are inferred. In reference to the attritional effect, β values on both main game species do not correlate significantly (n=13; Pearson(r)=0.297, p=0.324, Spearman(rho)=0.291, p=0.334).

In relationship to other results obtained by the correlation of %MAU to MGUI, bone density, the Bayesian Model method allowed to deal with more complex questions as such include to evaluate the transport decision and posterior attrition (compare also MARÍN-ARROYO & OCIO 2018), which priori was done in independent steps when evaluating the correlation of %MAU to MGUI and bone density. But it remains unsolved, if the different degree of attrition between the two main game species is of human or other origin.

The different skeletal elements represented by level was combined to obtain a general trend for each cultural period and to verify broader trends (Figure 4.75). During the Early Upper Paleolithic, red deer and ibex were transported in similarly-complete conditions to the cave in the context of a limited human role, where ibex only has a slightly higher appendicular contribution. In turn, a stronger degree of attrition for red deer compared to ibex according to the β parameter is inferred. A more selective transport of the appendicular skeleton is observed in Solutrean occupations, which is remarkable higher in red deer than in ibex. The degree of attrition seems low compared to the other cultural periods, thus, a better survival rate of the elements is supposed. The Lower Magdalenian results imply a selective transport in red deer towards the appendicular skeleton, but complete body transport of ibex to the cave. For this unit, in comparison to the Solutrean occupations, the degree of attrition is slightly increased in both main prey species, maybe for reasons of dense occupations, bone smashing and/or trampling.

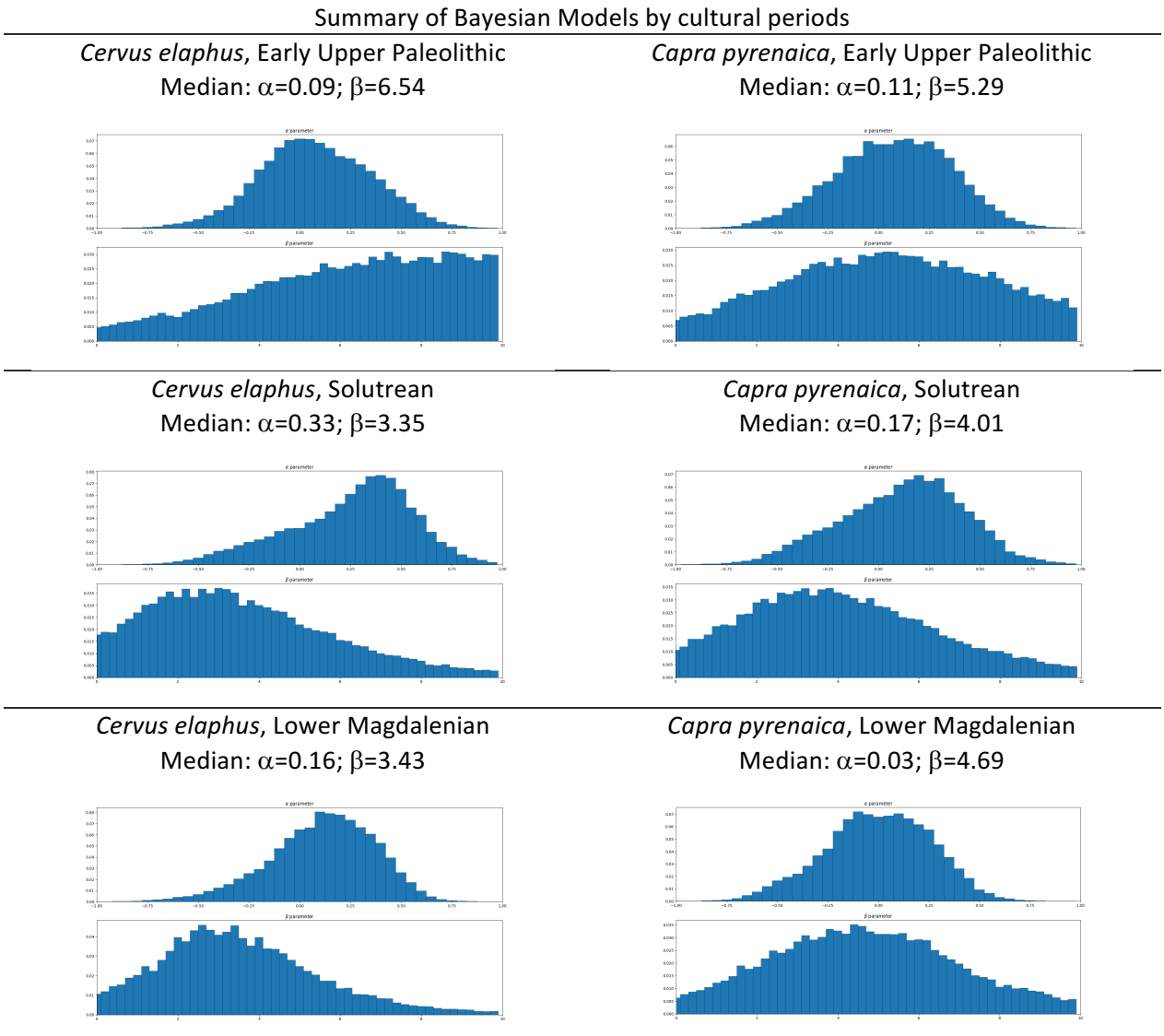


Figure 4.75: Bayesian model of skeletal profiles: Alpha parameter= skeletal transport, Beta parameter = attrition for main prey species and summary by cultural periods.

One final concern about the skeletal profile, will be discussed here: What is the role of the smaller bones, such as carpal, tarsal, sesamoids and atrophic phalanges, which are well preserved in El Mirón cave and normally referred to as riders in archaeological contexts (BINFORD 1981, 2012). These skeletal elements were frequently found among the faunal remains, but they have a basically no utility. The methodical considering of micro-bone fraction from general bags in El Mirón cave is exclusively responsible for the high percentage of this elements among the faunal remains, while they are normally not considered as being large enough for individual recording during excavation. On the other hand, these small items seem to be often completely preserved, especially in Paleolithic sites where other bones frequently intentional cracked. It is one important point that the completeness of these elements enables osteometric comparison on many more individuals than it is usually possible on Paleolithic archaeological long bones, revealing an advantage of these elements. Especially tarsal and carpal bones are highly entangled with the bones tendons and tissues, these are circumstances that not let them enter an archaeological site on their own. These elements don't have a high meat value and neither would they have been exploited for within-bone nutrients. In relative terms, these characteristics making these small bones an important reference for element counts, biometric studies as well as for nutritional, taphonomic and economic studies according to selective transport. Thus, the present analysis has shown the importance of such often underestimated elements, but hopefully considered accordingly in future works. The manifold components of economic strategies that had been carried out at El Mirón add hermeneutically with previously obtained taphonomic results as concised below.

4.2.9 Conclusions on hunting behavior and site function at El Mirón

On a site level, the project presented here complements the archaeozoological studies carried out by J.Altuna for the Holocene levels and by A.B.Marín-Arroyo for the Pleistocene/Holocene transition and the end of the Tardiglacial of the Mirón Cave (MARÍN-ARROYO 2010; STRAUS & GONZÁLEZ-MORALES 2012). Especially the rich Lower Magdalenian occupations ensure a thorough interpretation of human economic strategies seldom seen for Paleolithic sites.

Regarding the questions proposed at the beginning of this chapter are outlined the presented archeozoological results revealing human behavior.

Which is, and how can be explained the frequency of species in the archaeological units/levels? With an improved faunal quantification method that included all faunal remains from presorted general bags and individual finds, 14 different species among the macro-mammal remains, including eight ungulates and five different carnivores, were identified and few human remains. The dominance of ungulates and the limited representation of carnivores suggest that the latter played only a minor role in activities that took place in this cave. Such a low activity profile of carnivores, as accumulation agents, also aligns with the results in the previous taphonomy chapter. In El Mirón Cave, large carnivores might have entered the cave at any time when humans were not in residence; however, small carnivores, presumably mainly foxes, seem to have used the cave more frequently. The dominant, but still of low frequency, non-human agents identified at the site are birds of prey, mainly used the cave for breeding, as confirmed by eggshells remains. However, vulture activities are confined to certain skeletal elements, especially grease-rich parts, and not accumulate extended parts of the body, making the taphonomic modification pattern of digested bones distinguishable from human-made contexts.

Humans seem to have been the major selector of macro-mammal species that entered at El Mirón Cave throughout time. Occasionally horse and bovid remains are present, but whether and to what degree they have played a role as a food resource during the occupation of this cave stays unclear. These very large species either have not lived in the cave surroundings or due to their large biomass were presumably always heavily selectively transported, focusing on the soft tissues that not include bony parts. A human hunting

preference laid in the two species: red deer and ibex might have had several reasons as they potentially dominated the local topography (MARÍN-ARROYO 2009). Further cultural or social constraints or economic reasons could be specific exploitation strategies of either solely or combined resource components such as hides, meat, marrow, grease, tendons, bones as a raw material source, or as fuel.

Skeletal profile analysis is the strategy used that further disentangle the formation history of the studied material; particularly, to determine if the faunal assemblages reflect transport behavior or attrition whose head elements are over- and axial elements are underrepresented. Results showed that the skeletal distribution is mainly the results of human transport decision making and exploitation techniques, with less contribution of carnivore activities or attrition. Carnivores were never a significant accumulation agent at El Mirón cave, but more dominant at the older levels (Late Middle Paleolithic and Early Upper Paleolithic). The skeletal profile reflects the food procurement of meat-rich parts as well as bone marrow of main prey species equally. Ibex was transported mostly entirely to the cave, red deer more selectivity. If so, grease-rendering techniques that produced large quantities of bone refuse of comminuted skeletal parts are not anatomical or taxonomical identifiable and reflect sustainable resource maintenance. Especially in the Lower Magdalenian layers, where excellent faunal preservation, the under-representation of grease-rich elements (i.e., long bone epiphyses), and indications of cooking through stone boiling techniques in El Mirón Cave (NAKAZAWA 2007; NAKAZAWA ET AL. 2009) exclude overall attrition as reasoning.

Does the degree of utility of animal resources vary through time? During the earlier occupations of the cave, animals were transported complete for essential meat and marrow exploitation. The Solutrean and Lower Magdalenian occupations differ somewhat economically. A skeletal pattern that progressively develops towards a more selective transport, the increasing importance of grease rendering activities attest changing economic strategies.

What kind of change is observable within the paleoeconomic behavior pattern? The clear resource intensification pattern came from meat and marrow use (overall a phenomenon typical for Paleolithic sites) to intensive grease exploitation. The function of the site within the local settlement system of occupying hunter-gatherer groups might be fundamental for its use. Late Middle Paleolithic and Early Upper Paleolithic people more similarly used the cave for short, ephemeral periods. Early Solutrean occupants used El Mirón as a hunting camp in an early phase, maybe with short residential stays and later mostly for hunting purposes; in a sense, as L.G. Straus long has proposed. The Lower Magdalenian occupation has more of the whole skeletal representations, with low attrition in the early phase that implies more extended residential stays to change later towards an intensified exploitation of resources, including bone grease rendering. The cave, then, show all characteristic of being a proper base camp in presumably a more extensive resource management system, which is later replaced by a more scheduled seasonal use.

To conclude, the detailed analysis of El Mirón faunal materials allowed to stress the importance of red deer and ibex species for this montane site, and how humans adapted their exploitation strategies. The further regional paleoeconomic development from the Late Middle Paleolithic to the Magdalenian analyzed the role of the site in the further regional context, how humans serve resource demands of changing population densities, and social networks.

4.3 Spatial use and discard patterns

A multidisciplinary approach was integrated into this dissertation to investigate zooarchaeological and taphonomic implications of faunal remains in the spatial aspect. Intra- and inter-level analyses compare the new taphonomic evidence obtained from the faunal assemblage with other archaeological finds, to interpret their spatial relationships. The proposed intra-site analysis of archaeological remains enables to visualize the activities human carried out, define the site function and reveal its role in the subsistence system of Paleolithic hunter-gatherers. This research line also entails a better understanding of the sequence of discard patterns and post-depositional processes at the site.

4.3.1 Faunal spatial scattering related to human activities

The Lower Cantabrian Magdalenian occupations have one overarching aspect in common, which is the density of occupation, very rich in organic materials, hearth remnants, artefacts, etc., as found in Altamira, El Castillo, El Juyo, Rascaño, Santimamiñe (UTRILLA-MIRANDA 1981; CABRERA-VALDÉS 1984; LÓPEZ QUINTANA 2011; STRAUS 2013; STRAUS ET AL. 2016; FONTES ET AL. 2016), and El Mirón cave ('Cabin' or Outer Vestibule levels 15, 16 and 17, 'Trench' or Mid-Vestibule Level 312, 'Corral' or Vestibule Rear levels 109-116 and levels 504-505; Figure 4.76) (GONZALEZ-ECHEGARAY & FREEMAN 1992; STRAUS 1992; GONZÁLEZ-MORALES & STRAUS 2014a). For these distinctive archaeological deposits, it is assumed that the history of occupation reveals varied aspects of Upper Paleolithic lifeways, while their extraordinarily thick, dense artefact, manuport and bone accumulations make it difficult to differentiate individual living floors during excavation. In consequence, they are usually treated as complete units and referred to as a palimpsest, albeit they provide considerable, yet difficult to untangle and decipher, evidence of specific human activities.



Figure 4.76: Example of the dense Lower Magdalenian human occupation levels in El Mirón Cave, rich in organic artifacts. Left: typical dense surface of Level 17, Square I3, Spit 60; right: find context of spearthrower found in Level 17. (Photographs courtesy of L.G. Straus-left, and M.R. González Morales right)

Therefore, here it was proposed to use intra-site spatial analyses for the purpose of identifying Lower Magdalenian hunter-gatherer activities in El Mirón cave based on faunal remains from a palimpsest accumulation. Here, bone-micro-fragments, commonly <3cm in size and not individually plotted, but collected by sub-squares during excavation or from water screening for each spit were included to identify

Paleolithic living floors (BAILEY 2007; MALINSKY-BULLER ET AL. 2011; GEILING ET AL. 2016). Fauna were analyzed applying the McKellar's Principle, which states that small refuse items are commonly discarded in the same area in which they were produced, rather than disposed of somewhere else. By this principle, larger items are more prone to transport, while small *in situ* refuse, tends to penetrate into the sediment through trampling (MCKELLAR 1983; SCHIFFER 1983). Small bone fraction are therefore better suitable markers of activity zones or living floors (MALINSKY-BULLER ET AL. 2011). Additionally, they can represent primary refuse as they are less likely to be displaced during surface cleaning (BINFORD 1978; SCHIFFER 1996). Bone micro-fragments are markers of activity zones and living floors in relatively stable archaeological levels, as they represent mostly residual primary refuse, such are small refuse items such as manufacturing debris of antler, bone or stone found in association with finished tools can be helpful in identifying activity zones (O'CONNELL ET AL. 1991; NAKAZAWA 2007; MARÍN-ARROYO 2009; FONTES ET AL. 2015; GEILING & MARÍN-ARROYO 2015; ULLAH ET AL. 2015).

Combined analytical studies of zooarchaeological methods and spatial distribution analysis using Geographical Information Systems (GIS) has enabled to achieve these goals. The methodology proposed also allow to identify locations of specific past human activities. A specific approach for such detailed analysis and the integrity of such methods is outlined first, in an example of the special case of human activities involved in rituals of human burial activities.

4.3.2 Refining intra-site taphonomic and spatial analysis

Geographical Information System (GIS) software are commonly applied to analyze the intra-site spatial distribution of archaeological finds in order to reconstruct complex ancient activities (BAXTER ET AL. 1997; MARÍN-ARROYO 2009; HENRY 2012; ORON & GOREN-INBAR 2014). What is here presented, is the application of GIS to Paleolithic burials in Upper Paleolithic contexts, which is a novelty (HENRY-GAMBIER ET AL. 2013).

Here, it is asserted that reconstructions of activity zones within campsites for diachronic behavior studies are more precise and complete when they incorporate small bone fractions as indicators of primary refuse areas. For refining the methodological approach of the taphonomy of faunal remains, density analyses are applied to create plots of spatial distributions to investigate dense archaeological layers and enable the interpretation of activity zones. The identification of activity zones such as the hearth areas, bone processing areas and dumping zones were obtained and condensed into systematic plots. The interpretation of Paleolithic burials can comprise-- among other factors the distribution of human bones, the spatial relation of possible grave goods, grave-covering stones, or its location within the site and modification of existing sedimentary deposits (PETTITT 2011).

The meticulous recovering of all preserved data from archaeological sites and the analysis to a taphonomic-spatial level are the two main aspects which are focused here, since they have poorly addressed in the past. Here, a double approach has been achieved because 1) by reconstructing the effect of all taphonomic factors that modified the preserved faunal remains is possible to trace the accumulation context and post-depositional processes. The location of these (trans-) formation processes, their sequence, and intensity, for example bone cracking activities, trampling, hearth locations, etc. is essential to decipher shifts in site use and 2) when an adequate analysis of the bone micro-fragments (recovered in the fine-mesh sieving or water screening of excavated sediments) are typically intensively collected during archaeological excavations is performed, the obtained information is outstanding to understand diagenetic and site formation processes.

Broadly speaking, this double approach accomplishes a high-resolution spatiotemporal analysis of prehistoric macro-mammal remains, from a taphonomic perspective, which includes several objectives. These are:

- In the light of site formation processes, it is aimed to evaluate: 1) the role played by carnivores and 2) specific human activities that reflect on-site human subsistence strategies, their sequence and location. Considering off-site and on-site human actions, it is established to integrate a *chaîne opératoire* approach from which human behavior implications can be derived.
- Refining the methodological basis of using GIS and statistical methods for archaeological spatial analysis, while focusing on the taphonomy of faunal remains.
- Developing a protocol for deciphering archaeological palimpsest that include not only the analysis of large and identifiable faunal elements but also bone-micro fragment. The protocol is useful to improve the understanding of the archeo-stratigraphy and the spatial relation of faunal to other archaeological remains.

Consequently, three thematic sub-sections of the spatial studies are presented. The materials and methods applied for spatial analysis are implemented in Chapter 3. This designed approach is published in different international journals as part of this PhD project. The thematic sub-sections are:

- How deciphering an archaeological palimpsest by the inclusion of bone micro-fragments (see also GEILING ET AL. 2018).
- Human spatial use revealed by taphonomic modifications: (see also GEILING ET AL. 2016).
- The spatial-taphonomy of the Lower Magdalenian human burial where osteological remains are meticulously associated with other archaeological find categories (see also GEILING AND MARÍN-ARROYO 2015).

Zooarchaeological and taphonomic studies inferred the existence of good preservation conditions within the Lower Magdalenian levels at El Mirón. With those faunal remains in focus, following are described case studies of how spatial analysis can improve current interpretations of the Paleolithic world and archeological contexts.

4.3.3 Deciphering dense faunal deposits

Within the following paragraphs are presented a density analysis of faunal remains via density indices calculations, density profile plots, density distribution maps with which human activity areas were localized and compared diachronically. The combined faunal collection from Levels 15, 16 and the sub-samples 17-6, 17-8, 17-10, and 17-12 (a total of c. 50%) of Level 17 includes 186,649 bone micro-fragments, with 13,665 burnt bones and 2,948 bone flakes. All these bone micro-fragments together are useful to understand the general state of preservation and the composition of the archeozoological assemblage, making their study suitable as a preliminary assessment method during faunal analysis.

Three density indices are stressed for the initial spatial analysis: Density Index (DI), Weight density Index (WDI) and Fragments Size Index (FSI). They were calculated from the counts and weights and are summarized for the taphonomic categories of burnt bones and bone flakes via boxplots (Figure 4.77) as an example for this kind of taphonomic analysis. The category of burnt bones displays a relatively high DI mean in Level 17 (highest in sample 17-10) and decreases with the transition to the Levels 16. The DI mean of bone flakes is quite similar, although, it already significantly drops earlier, within Level 17. A comparable pattern is observed in the WDI for burnt bones and bone flakes, where sub-sample 17-6 from Level 17 always is more similar to Level 16 sub-samples. The FSI values show no significant pattern or cluster of higher or lower values through time indicating their variability seems to be better expressed by horizontal spatial statistics, which will be applied in a consequent step.

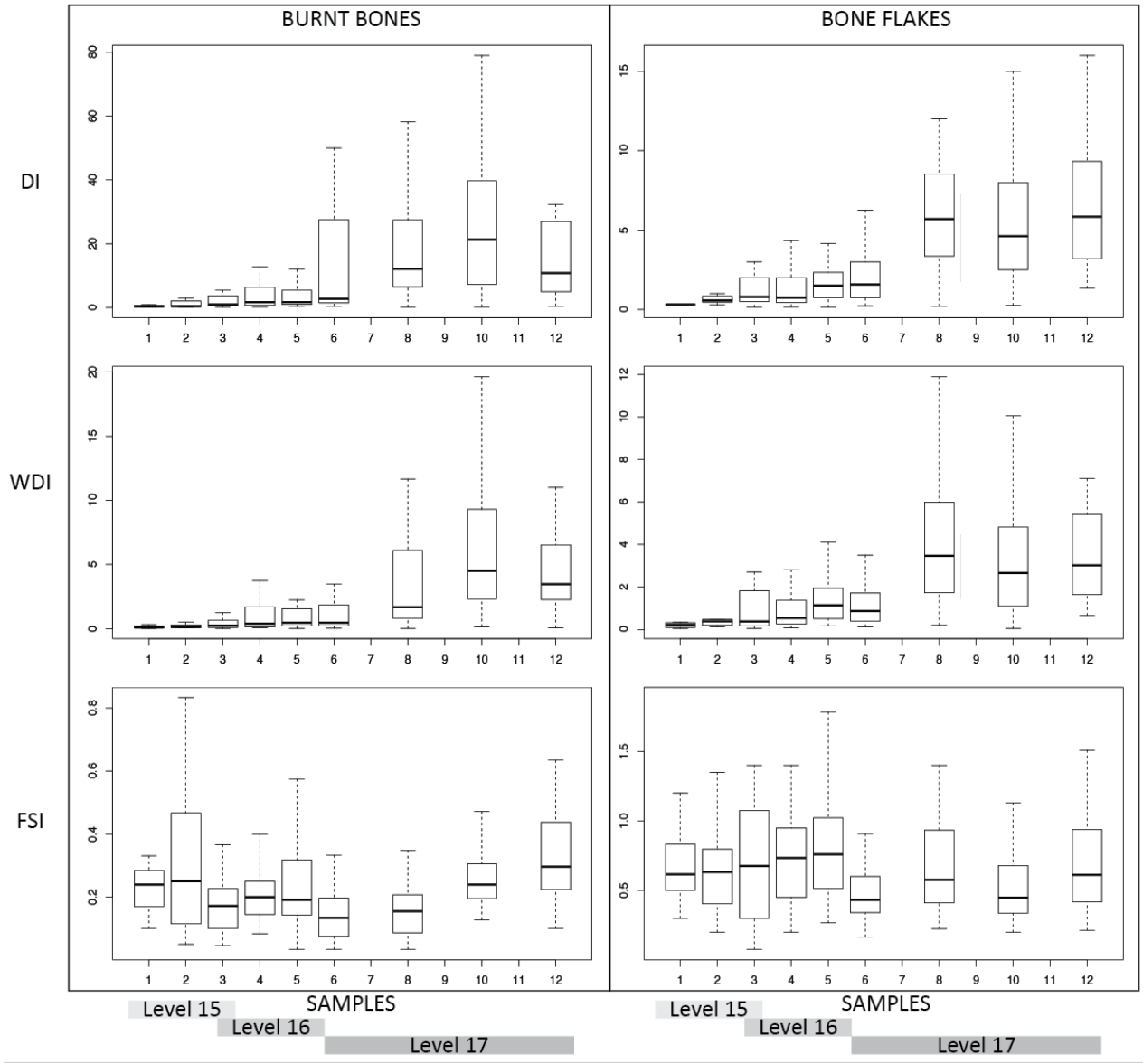


Figure 4.77: Boxplot distributions for index values DI, WDI and FSI of burnt bones and bone flakes from general bags by sub-samples under study (outliers excluded). (published in Geiling et al. 2017, Figure 4)

Within the spatial distribution study, spatial distribution results are presented by profile plots (for Levels 15, 16 and 17) and distribution maps (for Level 17) showing the density analysis for the different taphonomic categories using the DI, WDI, FSI indices. The late Lower Magdalenian occupation Levels 15 and 16 are excluded from horizontal analysis here as their detailed study is published in previous analysis (GEILING ET AL. 2016), but described within the second step of analysis later in this chapter. To exemplify how to decipher an archaeological palimpsest with the method, distribution maps focusing on the following criteria are presented: (1) the 'palimpsest problem' of Level 17 and (2) the proposed human-made accumulations of burnt bones and bone flakes.

Density profile plots. The results of vertical variability in density of all bone micro-fragments is illustrated with Voronoi maps showing vertically lower study sub-samples. they have a greater faunal remains density compared to the upper ones, meaning that generally density decreases with time (Figure 4.78; compare Appendix F). It is remarkable that a cluster of higher DI values is observable along the northern border of the excavation area, which might have two causes: (1) more bones were deposited closer to the center of the

Vestibule forming a midden-like bone accumulation (as is the case, for example, in some of the Lower Magdalenian layers of El Juyo Cave near Santander) or (2) bones are more crushed in this area due to intentional cracking or processing, or unintentional trampling (which might be more frequent in areas away from the cave wall, i.e., in the H-J/4 row of squares than in the H-J/2 row adjacent to the wall).

WDI show higher values in the center of the excavation area. The sub-squares along the southern cave wall show clusters of both low DI and WDI values, indicating that the centers of activity were located at some distance from the cave wall. The higher FSI values concentrate mainly in the upper sub-samples of Level 15 and 16, indicating bone fragments of larger sizes within these levels. Higher bone fragmentation was found along the northern border of the excavation area, where FSI values are generally smaller.

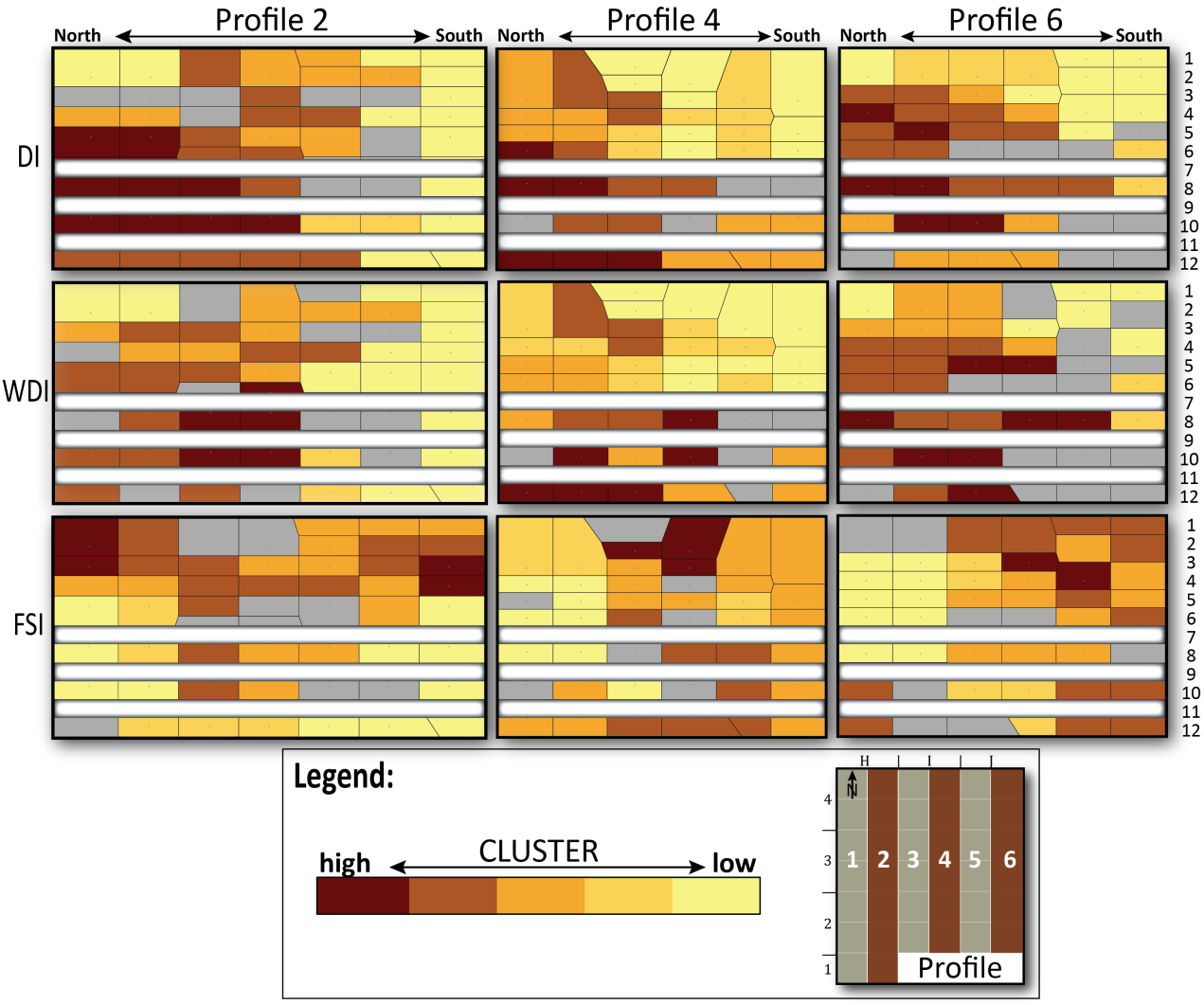


Figure 4.78: Profile plots show density distributions created with the ArcGIS Voronoi map tool using index values DI, WDI and FSI of all bones from general bags. Here is shown and compared profile 2, 4 and 6. (published in GEILING ET AL. 2017, Figure 5)

Density distribution maps. The distribution of all bone micro-fragments indicates by significant p-values and the Moran's Index that they are clustered, despite the FSI in Level 17 samples 17-8 and 17-12 (Table 1.1). Burnt bones are clustered in all studied samples, but WDI and FSI in sample 17-6 and FSI in 17-10 exhibit no significant p-values for spatial statistics. Several p-values for bone flakes lie outside the 5% of probability

range and these distribution patterns could possibly be explained by random chance; the insignificant values are the DI values for sample 17-12, the WDI values for sample 17-8 and the FSI values for sample 17-6, 17-8 and 17-10.

Table 4.23: The results of the autocorrelation for distribution maps are shown for each sub-sample 6, 8, 10, 12 from Level 17 and the indices DI, WDI and FSI. (published in GEILING ET AL. 2017, Table 1)

	All bones			Burnt bones			Bone flakes		
	Sample	Moran's Index	p-value	Sample	Moran's Index	p-value	Sample	Moran's Index	p-value
DI	6	0,59	>0,001	6	0,35	0,001	6	0,43	0,001
	8	0,30	0,002	8	0,23	>0,001	8	0,68	>0,001
	10	0,19	0,022	10	0,22	0,016	10	0,22	0,028
	12	0,27	0,007	12	0,30	>0,001	12	0,12	0,256
WDI	6	0,53	>0,001	6	0,13	0,197	6	0,28	0,025
	8	0,20	0,029	8	0,23	0,001	8	0,15	0,106
	10	0,29	0,002	10	0,34	0,001	10	0,27	0,010
	12	0,50	>0,001	12	0,42	>0,001	12	0,30	0,013
FSI	6	0,20	0,052	6	0,11	0,265	6	0,04	0,493
	8	0,05	0,448	8	0,33	0,003	8	0,12	0,171
	10	0,18	0,051	10	0,03	0,535	10	-0,10	0,529
	12	0,18	0,107	12	0,25	0,020	12	0,26	0,040

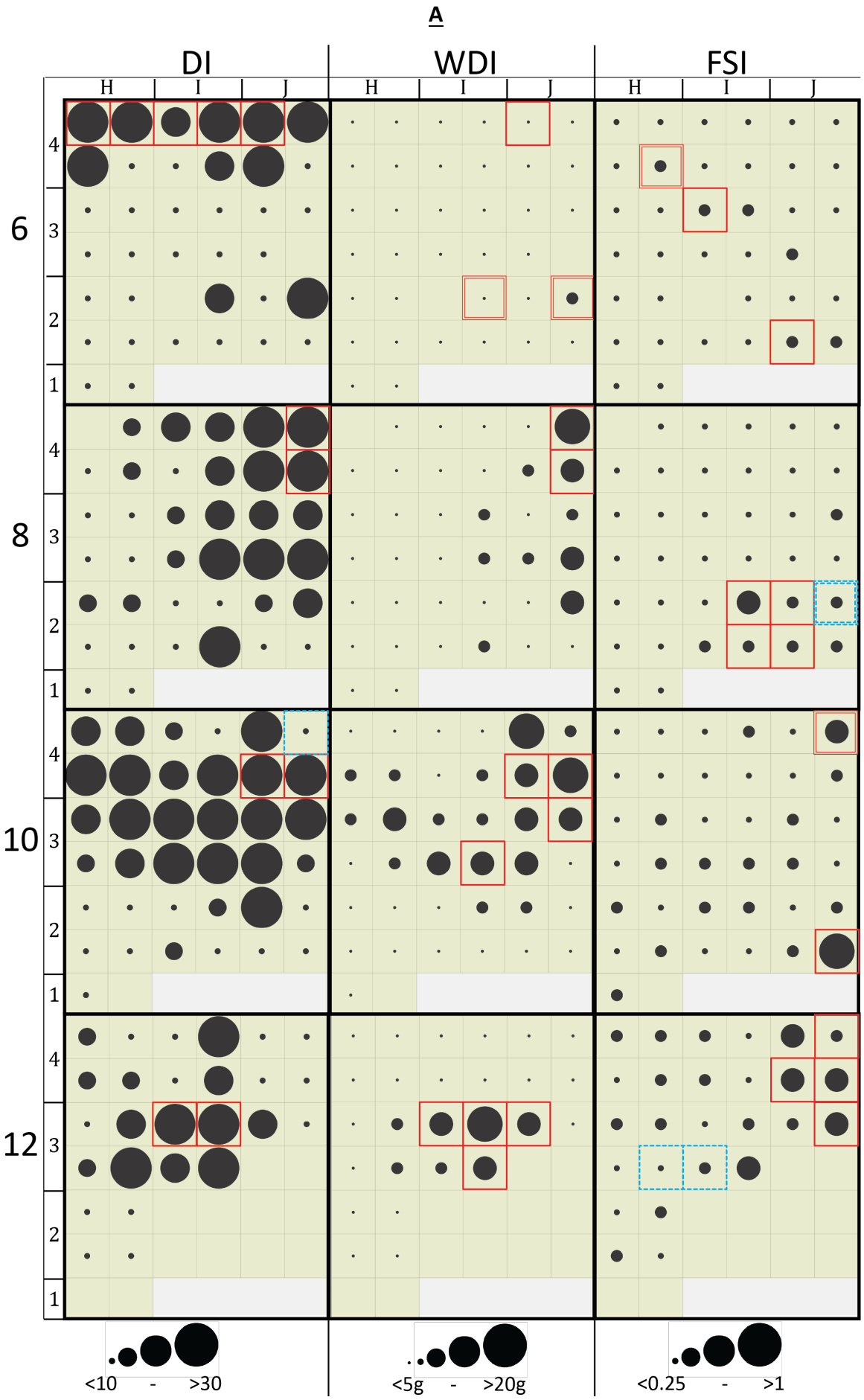
By analyzing the distribution of burnt bone fragments, questions of hearth location and hearth-related activities will address (compare Figure 1.4-A and Appendix **F**). Every result will be summarized by sub-sample in the following paragraph.

The first distribution map of sample 17-12 shows an overlap of DI and WDI cluster with high values in the same area, relatively in the middle of the excavation area. Higher concentrations in burnt bones have been found in the H3, I3 and I4; high FSI values indicate larger fragments in the north-eastern part of the Corral excavation area.

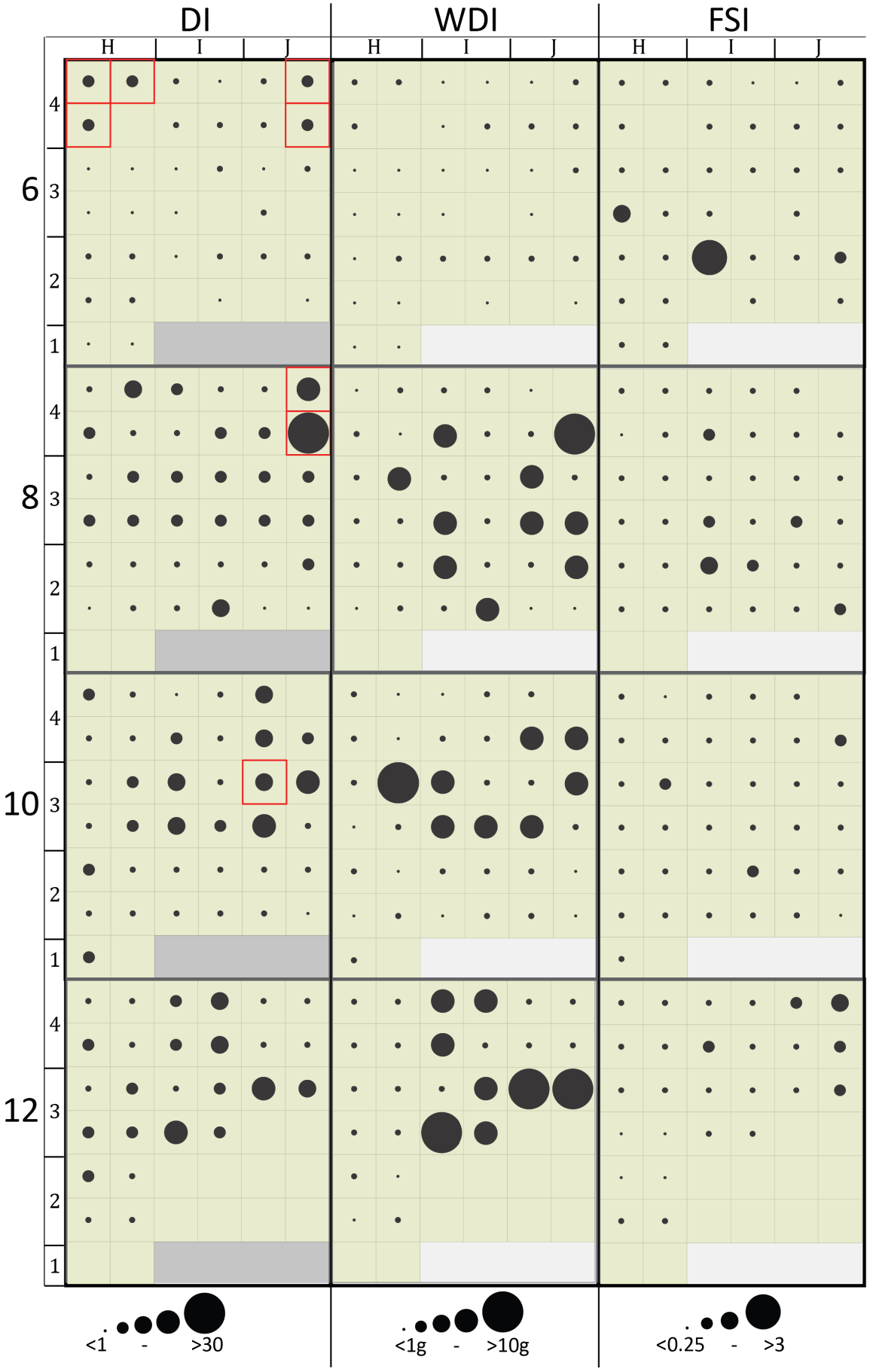
The next sample (17-10) displays generally higher DI values in most parts of the excavation section, while WDI values follow a semi-circular distribution south and east of square H4. FSI values are dispersed, with two non-significantly clustered, high-density concentrations in the north-eastern and south-eastern corners of the excavation area.

Concentrations of burnt bones shift to the eastern border of the excavation area within the next sample (17-8), while high clusters of DI and WDI are located in square J4. A cluster of larger fragments is identified close to the southern cave wall. The middle part of the excavation contains somewhat higher DI values, but comparably low WDI and FSI values indicating small fragments in higher quantities.

The last, uppermost sample (17-6) in Level 17 shows a concentration of high DI values of burnt bones along the northern excavation border, with generally low WDI values. Some higher FSI values seem to be aligned in a diagonal zone, ranging from around square H3 to J2, but WDI and FSI values are not significantly clustered.


A
DI
WDI
FSI
H
I
J
6
8
10
12
1
2
3
4
<10 - >30
<5g - >20g
<0.25 - >1

B



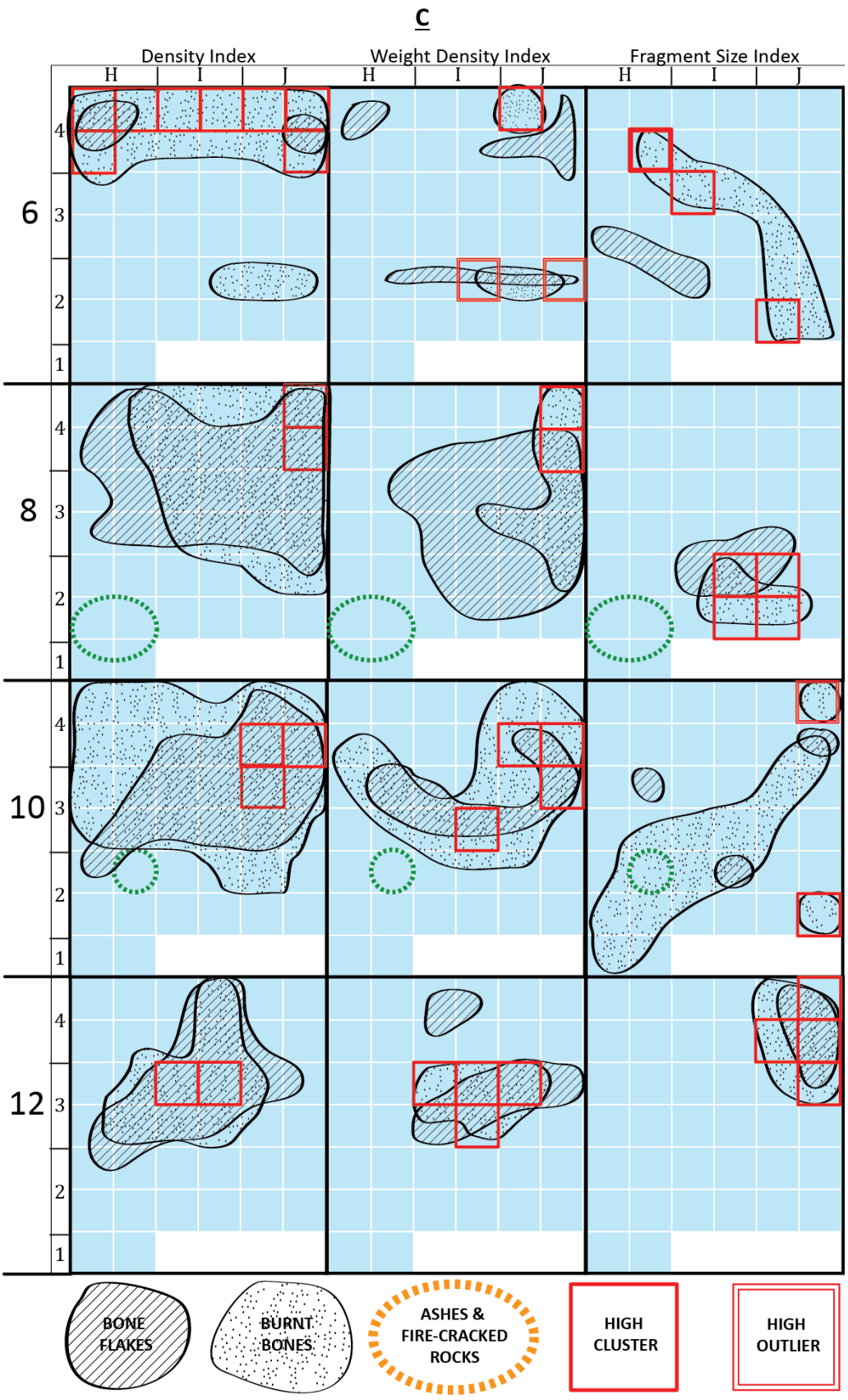


Figure 4.79: Distribution maps showing density index values DI, WDI and FSI of burnt bones (A) and bone flakes (B) for Level 17 samples 17-6, 17-8, 17-10 and 17-12. Symbols: Black dot sizes are relative to their index value with highest values representing larger bubbles. Each index follows its own scale. Thick squares = cluster, thin double outlined squares = outliers, red = high, blue dotted = low. (published in Geiling et al. 2017, Figure 6). (C) Synthesis of bone cracking and burning activity areas.

For analysis, only obvious bone flakes were encountered for each spit to establish the distribution of bone flakes, which result from bone- cracking activities (compare Figure 4.79-B and Appendix **F**). The first distribution map from the lowest sample (17-12) shows somewhat higher concentrations of DI and WDI values for bone flakes in squares I3 and J3, but DI values show no significantly clustered pattern. Larger fragments seem to be located in the north-eastern corner.

In sample 17-10, there is a high cluster of DI values located in J3 and J4, but values seem to be more dispersed. H3-B shows a comparable high value in WDI of bone flakes.

The overlying sample 17-8 shows an overlap of high DI and WDI values in J4 and some bigger pieces close to the southern cave wall.

The uppermost study sample (17-6) in Level 17 displays higher DI and WDI values along the northern excavation border, while FSI values are randomly distributed. Some bigger bone flakes are found in the southwest of the excavation section.

The identification of activity areas. The archaeological remains indicate that a broad spectrum of activities was performed within the Outer Vestibule at El Mirón cave. The spatial analysis performed here, add the localization of activity areas for burning, meat-, marrow-and grease-processing, and next to those activities, part of the area was also used as a discard zone. Figure 4.79-C shows a synthesis of those distributions and patterns of high index values are outlined.

These results will be summarized from the bone micro-fragment density analysis from bottom to top as it follows (compare Figure 1.5): The oldest occupation in this analysis is sample 17-12 from the base of Level 17, where the excavation uncovered remains of diverse activities, which concentrate in the middle area of the trench. Activities in this sample appear very spatially limited or localized and one shed antler base was dropped outside the activity area.

With the next sample (17-10), activities shifted into a semi-circular arrangement with lower densities of anthropogenically modified faunal materials in the middle, which are similar to a hearth centered-model (BINFORD 1978). Though, this pattern is different from the proposed model in terms of its organization as in the center of the area there might have been a working/cooking place instead, including bone grease rendering using the stone boiling technique as suggested by other archaeological finds at the site (NAKAZAWA ET AL. 2009). Shed antler cores and antler with attached skull were discarded at the edge of the activity area.

The next higher sample (17-8) shows a concentration of bone-cracking activities and burnt bones in the north-eastern corner of the excavation area, again with a possible discard zone including larger fragments along the southern cave wall. It is in this marginal zone where previous analysis of fire-cracked stones by Nakazawa et al. (2009) suggested the existence of another hearth location. Another large area extending from the middle to the northern border, in the zone of most activity, is characterized by high fragmentation rates that might indicate trampling action. The center of fauna- related activities might have shifted 'outside' of the excavation area to the north-east, i.e. toward the center of the Inner Vestibule.

The uppermost sample (17-6) in Level 17 yields its highest concentration of DI values along the northern excavation border and the larger fragments that are aligned diagonally within the area might indicate a discard zone.

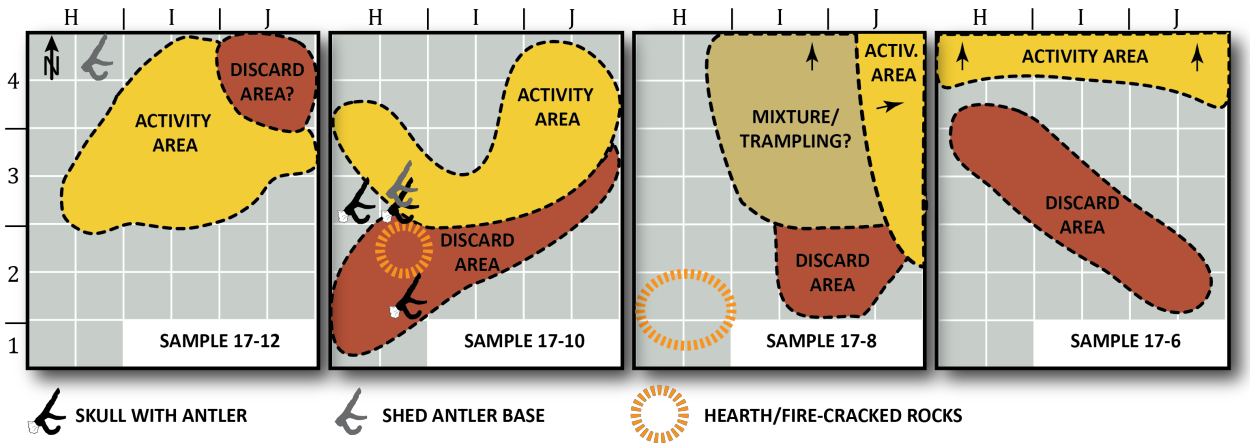


Figure 4.80: The reconstruction of activity areas is based on the data obtained from density analysis and the locations of high degrees of clustering, here focusing on burnt bones and bone flakes from the sub-samples 6, 8, 10, and 12. Areas are subdivided into possible activity or discard areas and trampling zones. Dotted circles mark suggested hearth locations from previous studies of fire-cracked rocks (NAKAZAWA ET AL. 2009). Published in GEILING ET AL. 2017, Figure 7.

In summary, it was seen that a former, quite localized activity area (maybe delimited through tent walls) may have changed into the segregated use of space (a more open structure) similar to what would be a hearth centered- model based on anthropogenically modified bones. This central area was not identified as a hearth during excavations, but might represent a cooking place, as small burnt bone fragments and bone flakes are grouped here and hot stone cooking is suggested for Level 17, since abundant fire-cracked rocks have been identified (NAKAZAWA 2007). With continuous occupation of this location, the center of carcass-related activities seems to shift to the north-eastern border of the excavation area, further inside the cave, leaving evidence of a possible trampling zone (maybe again artificial tent limits), indicated by a high number of smaller fragments in the middle of the area. The uppermost sample 17-6 of Level 17 shows a high concentration of activities at the northern border; it is probable that they represent the last traces of Level 17 activities, while spatial distributions seem similar to those of Level 16 materials in terms of density. These results might indicate another shift of activities and site use towards the center of the Vestibule, north of the excavation area.

Methodologically, one of the most important steps for density analysis is to provide a comparable dataset through the definition of indices that standardizes find density and refers to the same amounts of sediments excavated. The DI-density index based on the number of specimens represented in each taphonomic group seems to be a very appropriate value with which to identify spatial clusters. The WDI values seem to be equally useful for accessing density variability data and to reveal spatial patterns. In cases of low-density occupations, the FSI seems to be a stronger value, although, it is more of a supplementary index used in combination with the two above-described ones for reconstructing spatial patterning. The here developed method is a rather easy one when only using weight and WDI calculation for density analysis, especially by saving time that would be needed to count the bone micro-fragments. But it has to be taken into account that the WDI index is stronger when combined with the FSI, whose calculation is in turn based on both counts and weights. DI on its own seems to be also a strong value to show different patterns, but it depends on the degree of fragmentation on the bone assemblage and might be skewed by it. Finally, the DI is not recommended to use the DI on its own when extensive bone cracking activities might be present in the layers, because high frequencies can result from either intensive bone cracking, trampling, etc. or actual high densities of finds.

Voronoi Maps have been found to yield easy-to read visual output with ArcGIS software, even if they are 'exploratory' tools. The statistically significant output given by the spatial statistic tools using Moran's method is shown as suitable for the questions posed here, as the method locates clusters of both high and low values and, thus, the targeted objectives of the study are met.

The results of this study highlight the value of bone micro-fragments in faunal studies, which are normally less than 3cm in size. But if these micro-fragments are not considered in macrofaunal analyses, valuable information is undoubtedly lost. When including the analysis of general bags which contain those bone micro-fragments, usually more identifiable items are found, especially the smaller skeletal elements, as well as tiny pieces of worked bones. Both, large and small items, contribute to our understanding of past subsistence behavior. Therefore, this study shows that skeletal representation changes drastically and the interpretation on the faunal assemblages differs when micro-fragment data are included. Most of the bone micro-fragments are able to contribute neither to taxonomical nor anatomical identifications rates, but other categories such are bone flake densities can be compared to bones with impact marks for detecting bone-cracking work areas, for example (GEILING ET AL. 2016). It is in the nature of burnt bones to be heavily fragmented and thus small (SHIPMAN ET AL. 1984; COSTAMAGNO ET AL. 1999, 2005, 2009; THÉRY-PARISOT ET AL. 2005), making them relatively rare among individually recorded remains, a circumstance that can lead to an incomplete faunal record if small fragments are not considered adequately. The degree of fragmentation of small, intentionally broken bones might proceed even further with intensive human occupations and thus trampling activity (MILLER ET AL. 2010). These bone micro-fragments could be the ultimate end-products of a long *chaîne opératoire* of animal carcass exploitation (THÉRY-PARISOT ET AL. 2005) that might include all the activities of hunting, dismembering, defleshing, marrow bone cracking, cooking, burning and, finally, trampling. After all, bone micro-fragments originated from larger bone pieces and thus from complete anatomical elements of animals that were hunted and transported by past hunter-gatherers.

This case study focused on micro-fragments as a resource of additional information for deciphering archaeological palimpsests. With the analysis of palimpsest deposits, we can access information on various levels (BINFORD 1981; BAILEY & GALANIDOU 2009). The here presented results show that archaeologist can understand human behavior better when combining both, whole time-averaged palimpsests and the dissection thereof into finer (albeit more or less arbitrary) sub-units that come closer to single-event timespans.

Observations on the massive palimpsests that existed in many Lower Magdalenian settlements in northern Spain provide researchers with information of long-term trends. These kinds of deposits especially characterize that specific period in the Cantabrian Region, but we poorly understand what caused them to emerge or eventually to decline. Furthermore, we have no idea as to how these occupations were related to other variables or causal factors such as environment, demography, social relationships, etc. We should remark that these long-term trend interpretations often originated from the nature of excavation practices. Old excavated materials frequently leave researchers with no choice but to lump archaeological information from many different living floors together, because finds had not been anywhere close to meaningfully subdivided during excavation (spectacularly the case, for example with Obermaier's ≥2 m-thick Lower Magdalenian horizon in El Castillo), as compared to modern excavations done by spits of only one to a few cm in thickness, with meticulously recorded depths, single-piece plotting and fine-mesh screening (STRAUS 2008). Palimpsests are the most usual records and will remain time-averaged deposits that researchers need to untangle if/when they are willing to try to understand the processes that led to their formation and abandonment.

Here I present a protocol with which to access more detailed information of the accumulations context in archaeological palimpsests. It is explained how to decipher a palimpsest by creating sub-samples of defined

sizes for comparing them which at least comes closes to approaching single events. Find density variability seems to be one suitable method with which to track shifts within palimpsests, especially when concentrations of bone micro-fragments sorted into taphonomic categories can be used to test for variability in space and time.

With the present results, it was possible to show that density of diverse find categories varied through time and space as exhibited by the test of the global and local Moran's Index for profile plots and distribution maps. The results of local cluster and outlier analyses identified different clusters off both, high and low density within the profiles, as well as in the distribution maps. The initial assumption and observation that the many individual Lower Magdalenian occupations together represent such a palimpsest, where further segregations of events are not possible to distinguish, is reconsidered. A good direction was taken before, when the subdivision of these levels was performed for density analysis of lithic finds (FONTES ET AL. 2018), but not using standardized units and not taken into account the varied sediment thickness of each sample unit made this density analysis fuzzy and not comparable to other finds. The additional-new results of the present analysis show, contrarily to the previously suggested central hearth position in Level 17 indicated by charcoal flakes and fire-cracked rocks (NAKAZAWA ET AL. 2009), that the central role was taken presumably from the cooking activity itself, but not from the hearth. The hearth is the feature involved in the cooking process. Bone cracking and small superficial hearths that contain fire-cracked rocks seem to be located around and near that center of activity, comparable to what was observed in a study of a prehistoric Indian village (KARR ET AL. 2015) and illustrations therein (Figure 1.6-B).

For El Mirón cave can be summarized that, when included, taphonomical categorized bone micro-fragments can provided additional chronological information that did not exist before this detailed study of the occupational history. The excavators (L.G. Straus & M.R. González-Morales) have always referred to the dense Lower Magdalenian occupations as being difficult or impossible to subdivide further. It was shown that the here presented kind of analysis might be an easily replicable, efficient method for deciphering palimpsest deposits in El Mirón cave, which could be tested for other Paleolithic sites. Reading the collected information produced by the use of this method, in turn, reveal important insights into past hunter-gatherer lifestyle changes.

4.3.4 Faunal distribution reveals the segregated use of space

The next case study uses the faunal remains from Level 15 and 16 for a more detailed, activity-specific spatial analysis exemplified by bone-cracking and burning activities. The targeted faunal materials taxonomical determinations also revealed that most of the identified taxa could be attributed to *Cervus elaphus* and *Capra pyrenaica*. The succeeding spatial distribution analysis of individual items is concentrated on these two species, while taphonomic studies revealed the anthropogenic character of accumulation (as demonstrated before in Chapter 4.1).

The general spatial distribution of the whole set of recorded as individual faunal remains shows dense archaeological accumulations in two main areas: one across squares H2, H3 and H4 and another one in square J3 (Figure 1.6-A). The spatial distribution of the two main game species (Figure 1.6-B), *Cervus elaphus* and *Capra pyrenaica*, show similar concentration across the Cabin area. The close clusters of 50%- and 95%-density borders indicate a rapid increase in point intensities in the same areas of higher general densities. The spatial cluster of high-density areas for each species overlap by more than 50%. The similarity in find provenance indicates that there is no species-specific area for processing or dumping faunal material; in other words, the bones of both species were processed and discarded in the same areas across the site.

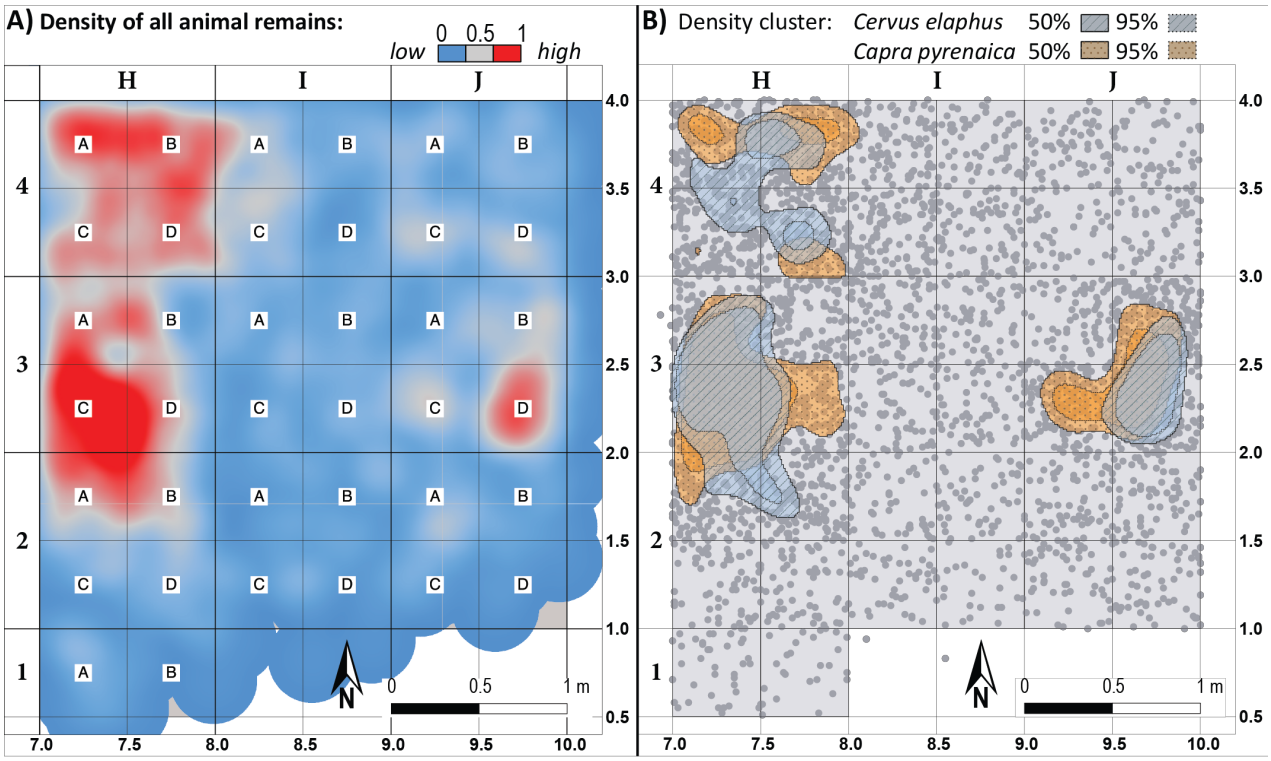


Figure 4.81: The spatial distribution pattern of faunal remains shows: A) generally high densities corresponding to hotspots in meter- squares H3, H4 and J3; B) that the spatial distribution clusters of high densities of the two main game species, *Cervus elaphus* and *Capra pyrenaica*, largely overlap and indicate similar processing or discarding activities (Grey points mark individual faunal finds).

Burnt bones (commonly <2cm) are generally smaller than unburned residues (STINER ET AL. 1995; COSTAMAGNO ET AL. 2005) and might remain in place according to the McKellar's Principle; and they may help to localize hearths, especially if structural hearth elements missing (ALPERSON-AFIL ET AL. 2009; GOREN-INBAR & ALPERSON-AFIL 2010). Most of the burnt bones found at El Mirón Lower Magdalenian layers are fully carbonized, which corresponds to the "Color Code 3" from Stiner et al. (1995: p. 226) and were correlated to hearth features within these levels. Burnt bone concentrations within the three sublevels analyzed cluster differently, while showing some degree of spatial overlap. High concentrations of burned bones are found: in the lower Sample 5 in subsquares J4-D, J3-B,D; in the middle Sample 4 in subsquare I4-B and subsquares J4-B,C,D; and finally in the upper Samples 1-3 in I4-B,C and J4-D (Figure 1.7).

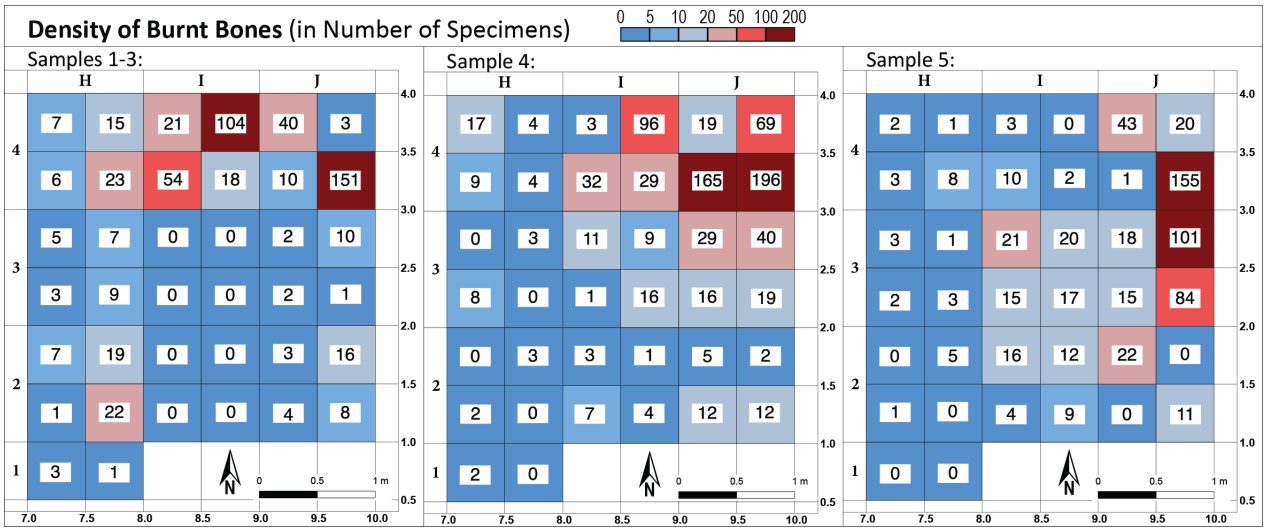


Figure 4.82: The small refuse burnt bone distribution varies between Samples1-3, 4 and 5. Amounts of burnt bone remains constant in the northeastern edge of the excavation areas (square J4), which may be associated with a hearth.

The spatial distribution of individually plotted larger bones, with impact marks and small bone chips/ flakes, show different concentration (marked in red; Figure 1.8) indicating varied density areas.

- In the lower Sample 5, bones with impact marks concentrate in subsquare J3-D, while more loosely dispersed throughout the remaining excavated squares.
- In Sample 4, bones with impacts cluster within squares J3 and H4, as well as subsquare H3-C.
- In Sample 1-3, bones with impact marks were found in squares H3 and H4 as well as in the southeastern edge of the excavation area (square J2).

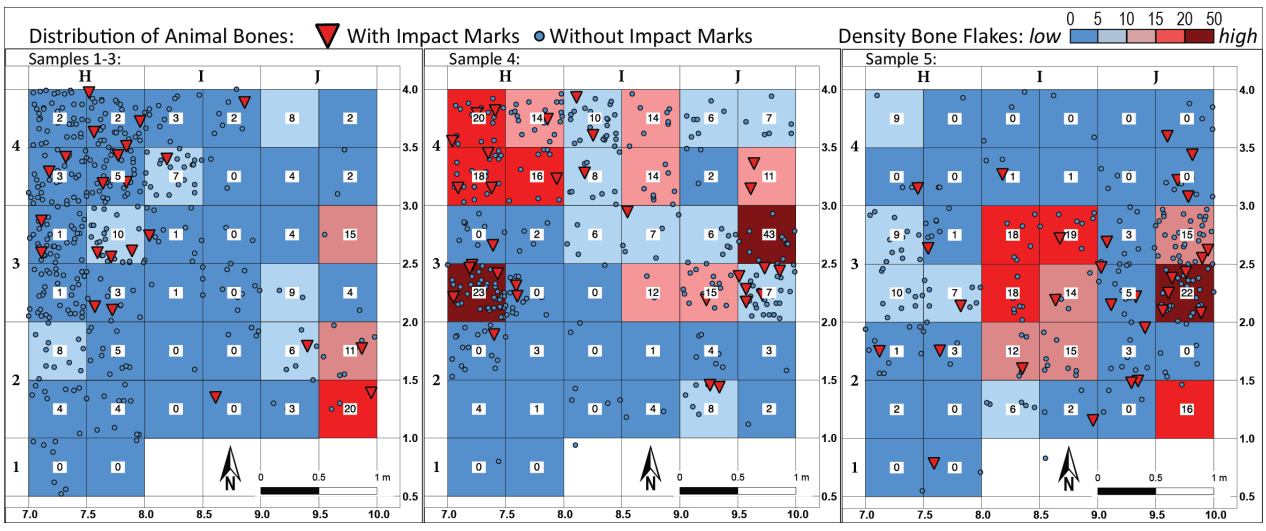


Figure 4.83: Impact marks on bones and bone flakes/chips are combined to achieve the spatial distribution of bone working areas dedicated likely to marrow extracting or grease rendering activities. Individual faunal remains with impact marks are plotted individually. Based on the quantity of bone flakes the subsquares were color-coded according to low and high densities, from blue to red, respectively.

Bone flakes and chips from general bags show a different spatial pattering. In Sample 5, these find categories clustered within sub-squares J3-D, J2-D and square I3. The superimposed Sample 4 shows high amounts of bone chips in sub-squares J3-B, H4-A, -C, -D and H3-C, while within Sample 1-3 chips concentrate in sub-square J2-D. Within the sub-levels analyzed the bone flake concentrations and bones with impact-marks coincide in some areas. In Sample 5 and Sample 4 these categories overlap in square J3; within Sample 4, additional overlap was identified in squares H3 and H4. In Sample 1-3, no overlap was detected.

The following results were obtained during the intra-site spatial analysis of bone cracking and burning activities:

The analyses of general point patterns using Kernel density and creation of heatmaps show cluster of individual finds. The faunal distributions in Levels 15 and 16 inside the Cabin area are not homogeneous (Figure 4.83), according to 'first-order' characteristics (BEVAN ET AL. 2013). The excavation area represents a spatial heterogeneity, probably because the southern excavation border is the cave wall. Due to accumulation principles, items do cluster along vertical borders (HARRIS 1989). This might be the reason for accumulation clusters along the southern squares, but does not explain varied point intensities in other areas. Low point intensities next to hot spots are visible along the western and eastern excavation borders. They were presumably created due to 'edge effects' of point distribution while using kernel density analysis (ORTON 2004). In any event, these patterns do not affect the question addressed here concerning general bone distribution by ungulate species.

With the help of the results, it is explored whether the two most hunted animal species, red deer and ibex, overlapped in their spatial distribution patterns (Figure 4.81). Their almost complete coincidence implies that both species (with similar anatomies but moderately different average sizes) were butchered, exploited and discarded in the same way and therefore, suggests a uniformity of accumulation processes. The results have revealed that non-cultural formation/destruction processes were very limited relative to cultural ones, leading to confidence in the following discussion about activity areas within Levels 15 and 16 of the El Mirón Vestibule Front ('Cabin') excavation area, with the obvious caveat that this 9.5m² area represents a very small portion of at least 250m² habitable surface of the Vestibule.

It was possible to distinguish activity zones within the late Lower Magdalenian palimpsest horizon in El Mirón cave (Figure 1.9-A), in particular hearth, working and dumping areas can be seen. The spatial data of the faunal remains permits archaeologists to identify activity areas, comparable to ethnographic examples of disposal modes in bone assemblages (BINFORD 1978; BARTRAM ET AL. 1991).

The distribution of small burnt bones concentrates around square J4. The spatial patterning of burned remains may indicate the location of a hearth in the northeast of the excavation area. In addition to the burnt material, ashy dark, organic rich sediments were excavated in this square as described in the excavation notes (GONZÁLEZ-MORALES & STRAUS Unpub.). Some of the bones were possibly used to fuel the fires at the site. Spongy, cancellous bones are better fuel, while dense long bone shaft fragments are unsuitable as fuel, given that they do not burn reliably (THÉRY-PARISOT 2002; VILLA ET AL. 2004; COSTAMAGNO ET AL. 2005; THÉRY-PARISOT ET AL. 2005; BOSCH ET AL. 2012). Whether the burnt bone fragments at El Mirón Level 15 and 16 were simply disposed into the fires or served as a secondary fuel source (wood was relatively scarce during Oldest Dryas in this region) remains open for discussion, but seems less likely when grease-rendering was practiced at the same time.

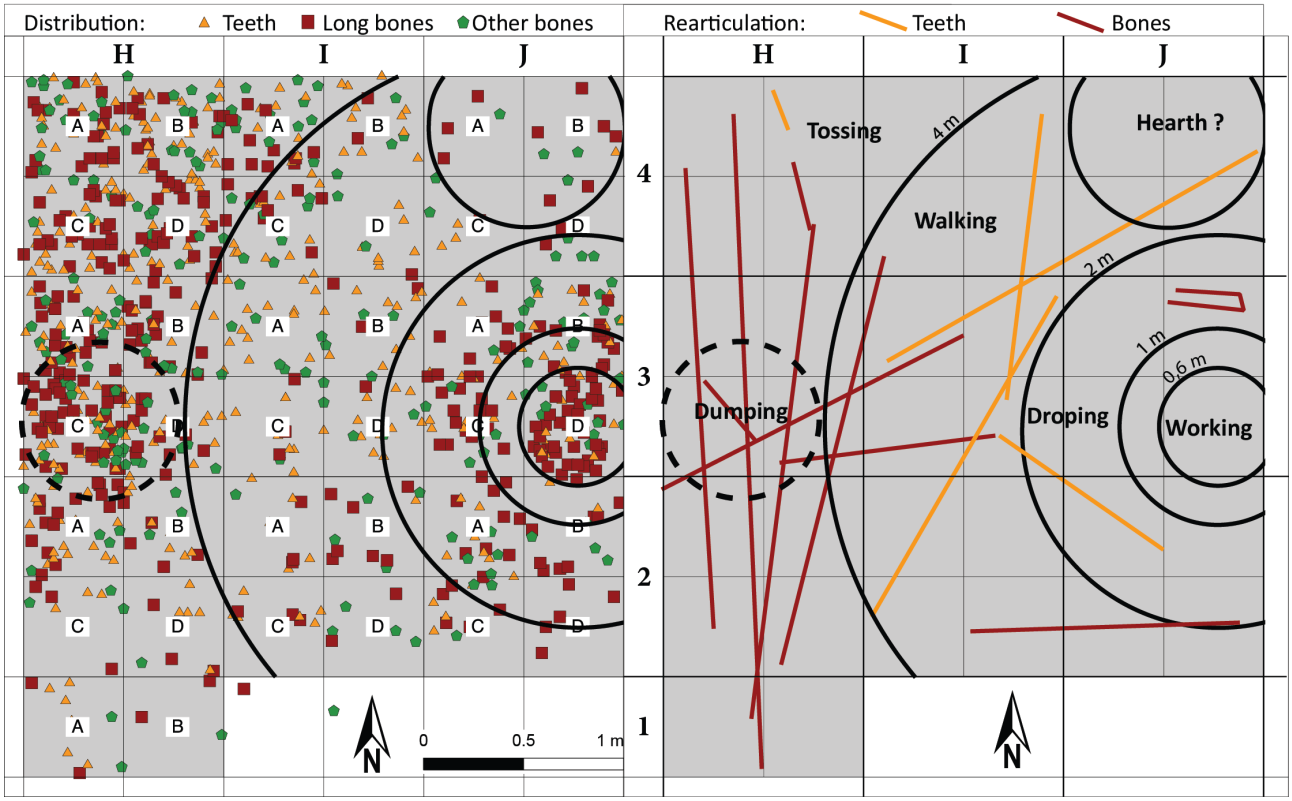


Figure 4.84: Spatial organization of the bone types identified at El Mirón floors: long bones fragments are clustered in two areas opposed to areas where smaller bones (short or irregular) and teeth are found. The spatial interpretation of activity zones inside the late Lower Magdalenian camp in Levels 15/16 at El Mirón cave is related to bone working, dropping, walking, tossing and dumping zones. A hearth was presumably located around square J4, while a bone processing area around square J3 appears to have played a central role in the organization of reconstructed bone processing activities.

Intentional bone cracking activity areas have been identified in square J3, in both Sample 5 and Sample 4. Bones were deliberately fragmented, probably in the course of marrow extraction and preparation for grease rendering activities (JANZEN ET AL. 2014). Three criteria are often recalled for the identification of bone grease rendering at prehistoric sites: stone anvils to break bones prior to cooking, fire-cracked rocks indicative of stone boiling and highly fragmented spongy bones (BINFORD 1978; STINER ET AL. 2005). Stone-boiling technology has been found in the El Mirón Lower Magdalenian deposits, which indicates cooking activities in the same area and time period (NAKAZAWA ET AL. 2009). Despite the fact that the quarzitic sandstone cobbles were probably used as percussion stone or anvils before being heated, no other specific stone anvils for the purpose of bone cracking were identified (STRAUS & GONZÁLEZ-MORALES 2007, 2012a). A drop zone (around 1 m in radius), located on the peripheries of the working zone in square J3 was determined, based on larger bone leftovers with impact marks. The working area was possibly a central locus of bone processing activity close to the fireplace and the drop- zone, possibly similar to what is reconstructed at a prehistoric Indian village grease-rendering station (KARR ET AL. 2015).

Along the surroundings of the bone-processing zone, within a two-meter radius, the high density of long bone items decreases and mostly teeth and other bone types such as short or irregular bones are represented. The area may be interpreted as a walking area as it contains fewer long bone fragments (squares I2, I3 and I4) and a working zone. Further away (at more than a two-meter radius) from the working zone, a dense accumulation of faunal material with anthropogenic modifications is interpreted as a toss zone (squares H2, H3 and H4).

In sub-square H3-A across Sample 4 another small cluster of small bone refuse fragments, burnt bones and bones with impact marks was found. Given the overall thickness (1-2 cm; one spit) and dense accumulation, this area could be interpreted as a dumping zone (O'CONNELL ET AL. 1991; SCHIFFER 1996). Ethnographical comparisons have shown that hearths and adjacent areas were cleaned only when primary refuse densities reached unpleasant levels. After removing the larger pieces, only the smaller fragments remain in place (SCHIFFER 1996). Cleaning processes might be necessary during long or frequently repeated occupations, as is implied for the Lower Magdalenian El Mirón residential hub campsite.

The *distribution of activity zones* within the LM layers of El Mirón is supported by refitting of the faunal material. The number of bone refits increase within the toss or drop zones, while teeth are commonly rearticulated within the walking zone. Additionally, narrowing down excavation spits to check for bone refits might help the identification of activity areas within such thick archaeological cave deposits. I am aware that present bone refits are the only way with which to prove the existence of living floors in Lower Magdalenian layers of El Mirón, since the associated lithic artefact assemblages have not yet been studied from this perspective.

4.3.5 Special activities of a human burial

The last case study used a slightly different approach towards spatial analysis. I analyze a sequence of events to detail the formation of a specific site structure; the human burial of the 'Red Lady' from Lower Magdalenian context (STRAUS et al. 2015a).

Four main analytical steps have been designed for studying the Paleolithic human burial purpose and the results are presented in this order:

1) Explore the human burial location inside the cave,

2) Define the natural and artificial area chosen by humans in which to deposit the human body and which site structures were found at that context

3) Establish the human skeletal representation and the spatial distribution of taphonomic modifications to the bones and

4) Determine the relationship of human bones with other finds in the immediate area of the burial.

1) Human Burial Location within the Vestibule. The burial deposition is contemporary to the main human occupations of El Mirón, which are the Lower Magdalenian deposits of Level 17 in the Outer Vestibule; in the Vestibule rear they are represented by Levels 116-110 and in the SE rear corner (burial area) by Levels 505-504. The main living area is rich in lithics (comprising indications of massive, *in situ* bladelet production), several osseous artifacts (antler sagaies, mostly undecorated) and macrofaunal remains (with intensive cut marks, bone breakage for marrow extraction and thermal alteration evidence), which is mirrored only with less intensity by the Lower Magdalenian burial layers (FONTES ET AL. 2015; MARÍN-ARROYO & GEILING 2015).

The human burial was deliberately placed between an engraved and red ochre-stained, ~1x1x2m limestone block in the back of the Vestibule and the eastern and southern cave walls, in an area of approximately 3.75m², (Figure 4.85). Humans engraved the western face of the block after it had fallen from the roof around 16.5ka uncal BP (GONZÁLEZ-MORALES & STRAUS 2014b, 2015, Fig.8). The block next to the burial was painted with a mixture of red ochre and micro-fragments of bones (SEVA ROMÁN ET AL. 2019).

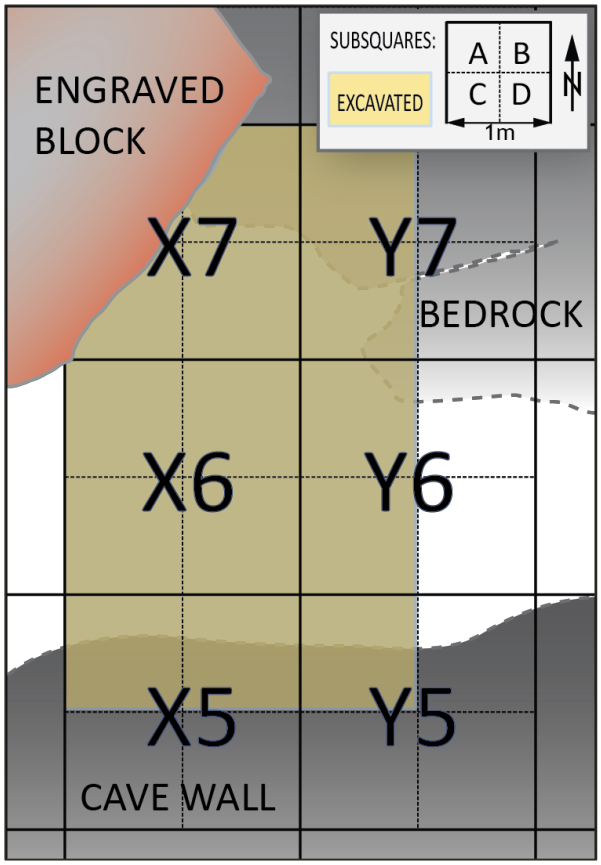


Figure 4.85: Detail of the excavations in the burial area. The engraved block is located in the northwest corner of the area painted with red ochre; the shallow uprising bedrock ledge is in the east and the steeper cave wall in the south of the burial pit. (Plan by JM. Geiling; see also Geiling and Marín-Arroyo 2015, Figure 3).

2) Preparation of the burial pit. All individual finds recorded in sub-squares B and D from squares X5, X6 and X7 of levels 503, 504, 505 and 506 were combined to recreate a stratigraphic density profile (Figure 1.12). The via GIS tools created profile view make it possible to see that these levels followed the characteristic pattern at the southern burial area, which is a 'bathtub'-like distribution governed by the cave morphology with a shallow uprising cave wall in squares X5/6. In square X7, however, this level sloped down, while cutting partially into Level 505, creating a burial pit. The pit reached down to the shallow, uprising cave wall (a bedrock ledge in northern X-Y7). In the southern part of the burial area, the cave wall drops vertically at the middle of the square X7, providing greater depth to the burial.

The sediment coloration in Level 504 is characterized by red ochre with specular hematite. The underlying Level 505 is clearly distinguished from Level 504 by darker sediment coloration, rich in charcoal and ash, but with no red ochre, and the presence of hand-sized *éboulis* overlying level 505 in X6.

In the northern parts of the burial area, post-depositional distortions of the sediments are visible, especially in X7. Overlying Level 503 is undisturbed, evenly distributed through the excavated burial area and entirely covering Level 504.

The spatial study show that the main human bone concentration was inside the burial pit borders (Figure 4.86).

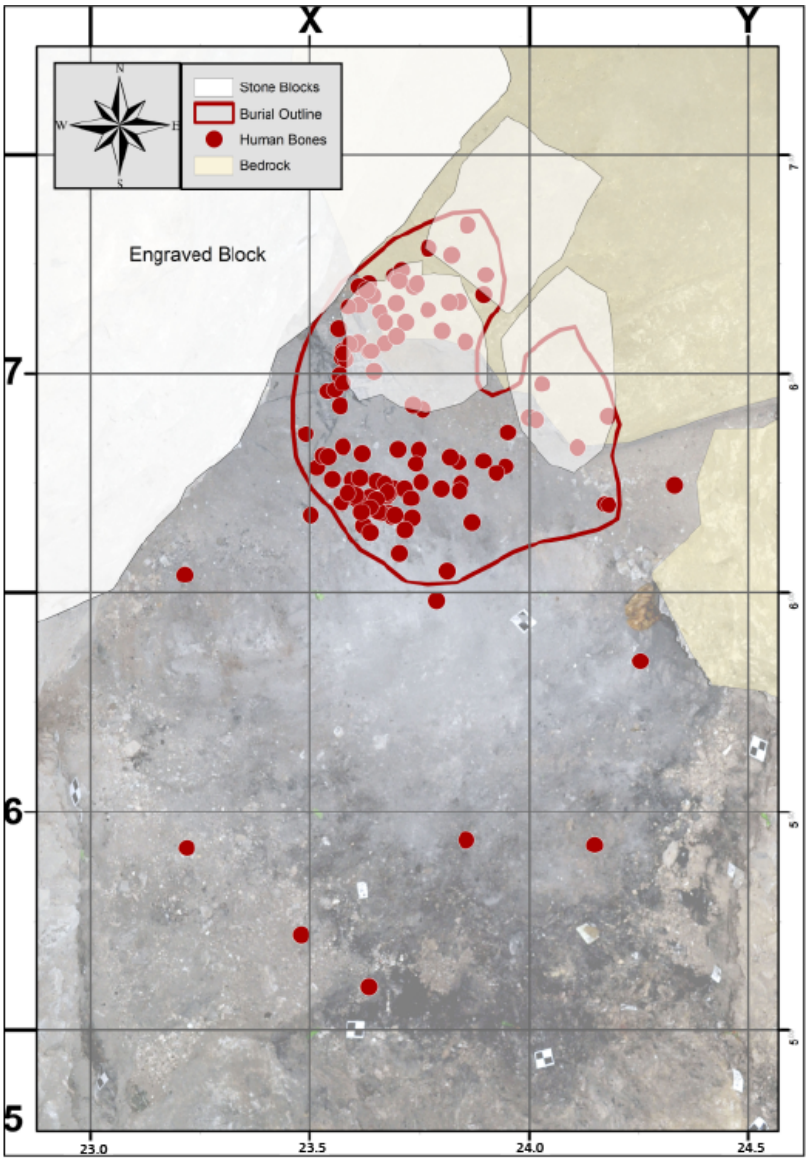


Figure 4.86: The positions of the main rocks in the burial area are shown in relation to the distribution of the human bones. Photographs were geo-referenced and used to reconstruct the outline of the burial, as well as associated features: the engraved block, limestone blocks placed atop human remains, bedrock and cave wall. Background photo: end of the excavations 2013. (Photos by M.R. González-Morales, geo-referencing and vector graphics by J.M. Geiling) (GEILING AND MARÍN-ARROYO 2015, Figure 4).

From a taphonomic perspective, during the preparation of the burial pit, Level 504 was already formed and probably still in formation. Some faunal finds in level 504 were still uncovered or partially covered (superficial deposit), while in Level 505 they were already buried according to the coloration of the bones (Figure 1.12). A color code classification was used to group bones having a typical light bone color (Type 0), internal manganese stains (Type 2), a uniformly light brown (Type 2) and dark brown (Type 3) tone or completely blackened bones (Type 4) (MARÍN-ARROYO ET AL. 2008: pp. 803–4). Thus, the darker the external bone color, the more intense was the manganese coating, and the longer the bones were exposed to these processes. In the burial area, 85% of the animal bones were lighter than Type 2/3 and only 15% showed a darker coloration (MARÍN-ARROYO & GEILING 2015). This implies that those 85% were uncovered or recently covered while the 15% were completely buried at the time the burial pit was dug. The back-filled sediments in the burial pit, especially Level 504 in square X7, were in part a mixture of sediments and finds from Levels 504 and 505. Once the burial pit was made, people deposited the woman's body. During the decomposition process, human bones as well as the animal remains underwent slight manganese coating processes, which stained them with fairly light colorations of Types 1 and 2 (MARÍN-ARROYO 2015).

Some of the excavated finds from the burial were covered with red ochre and dotted with sparking crystals, which was identified during geochemical analysis as specular hematite (SEVA-ROMÁN ET AL. 2015) from a

source c. 25 to the north on Monte Buciero at the present shore (SEVA-ROMÁN ET AL. 2019). Specifically, 44% of the human bones and 18% of animal bones appeared partially covered with red ochre (MARÍN-ARROYO & GEILING 2015), which was atop the mineral dendrites of manganese also found on them (MARÍN-ARROYO 2015). The human mandible and tibia were the bones most covered with thick ochre patches suggesting direct and intentional (re-) staining using this mineral. These two elements were located together in X7-D. Also, other skeletal remains, such as hand and feet bones, showed ochre coating but less intensively.

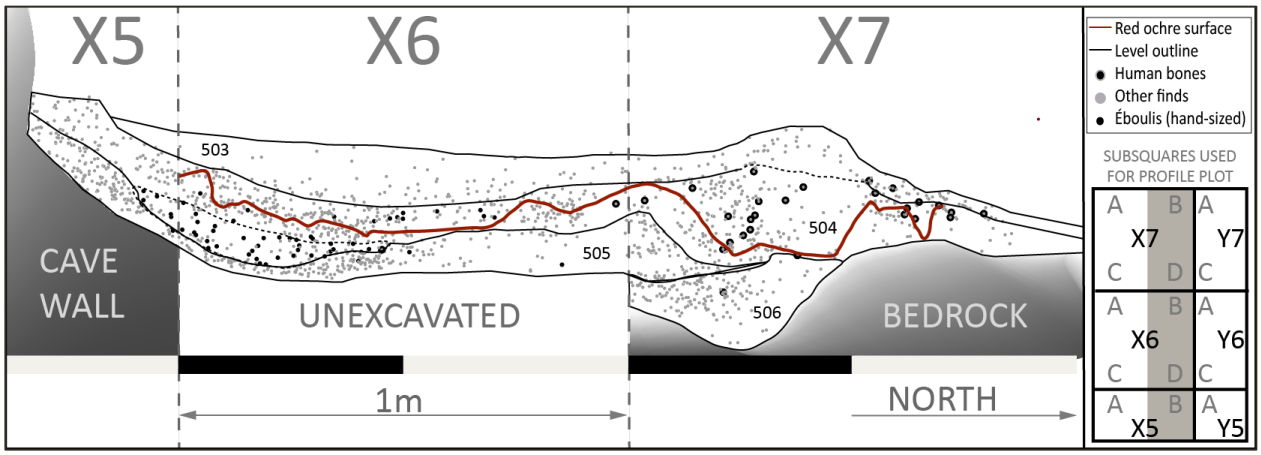


Figure 4.87: The 2D distributions were used to display the stratigraphic sequence as a North-South-profile between sub-squares X-B/D-5/6/7. The dimensions of Levels 503, 504, 505 and 506 are projected through individual measurements and separated by the level borders (black lines). The profile line of the red ochre surface is shown inside level 504 (red line). The outline of the burial pit could be reconstructed based on the sediment change between Levels 504 and 505 visible in Square X7 identified from photographs made during excavations. (Profile reconstructed by J.M. Geiling; published under Geiling and Marín-Arroyo 2015, Figure 5; leaning on section drawing by L.G. Straus and R.L. Stauber).

The ochre powder was not uniformly distributed throughout the whole area. During excavations, loose red ochre and specular hematite were found distributed in the southern part of the burial area (X5/6 and Y5/6) and denser, spatially more continuous and thicker in vertical distribution in the northern part adjacent to the engraved block. GIS software as used to recreate the surface of red ochre and stained finds with the results of a 'thin', discontinuous (patchy) layer in a concave form in the south and a thicker layer in the northern part (Figure 1.13).

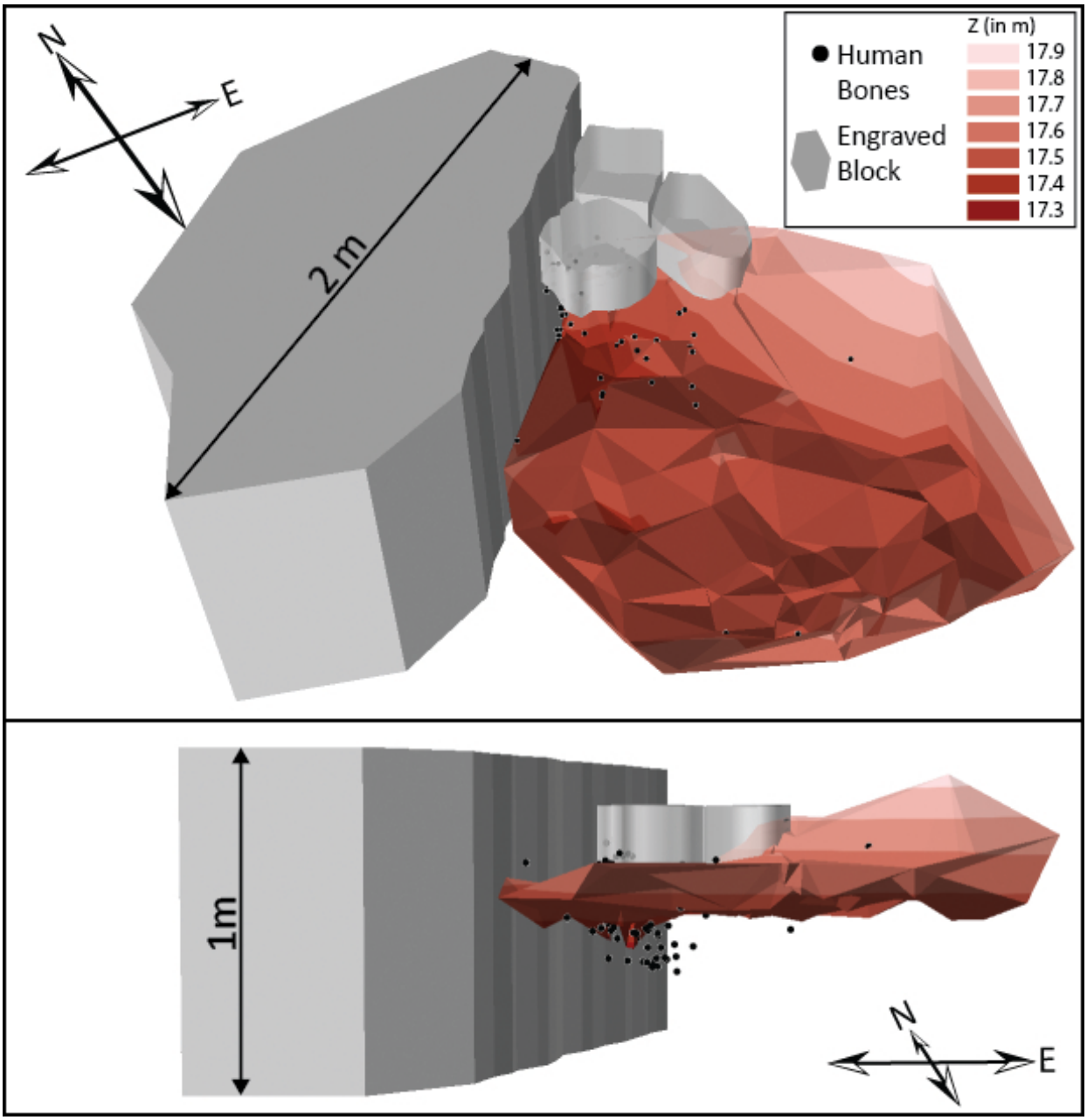


Figure 4.88: The 3D-polygon- surface creation used the Triangulated Irregular Network (TIN) tool to visualize the distribution of ochre remains. Reconstructed is a surface based on red ochre finds (red ochre-stained human and animal bones, as well as samples of red ochre pieces) in context with the engraved block, the smaller portable rocks and the distribution of human remains. The red ochre surface does not reach as deep as certain actual vertical positions of human remains. (3D-polygon- surfaces created by JM Geiling) (Geiling and Marín-Arroyo 2015, Figure 6).

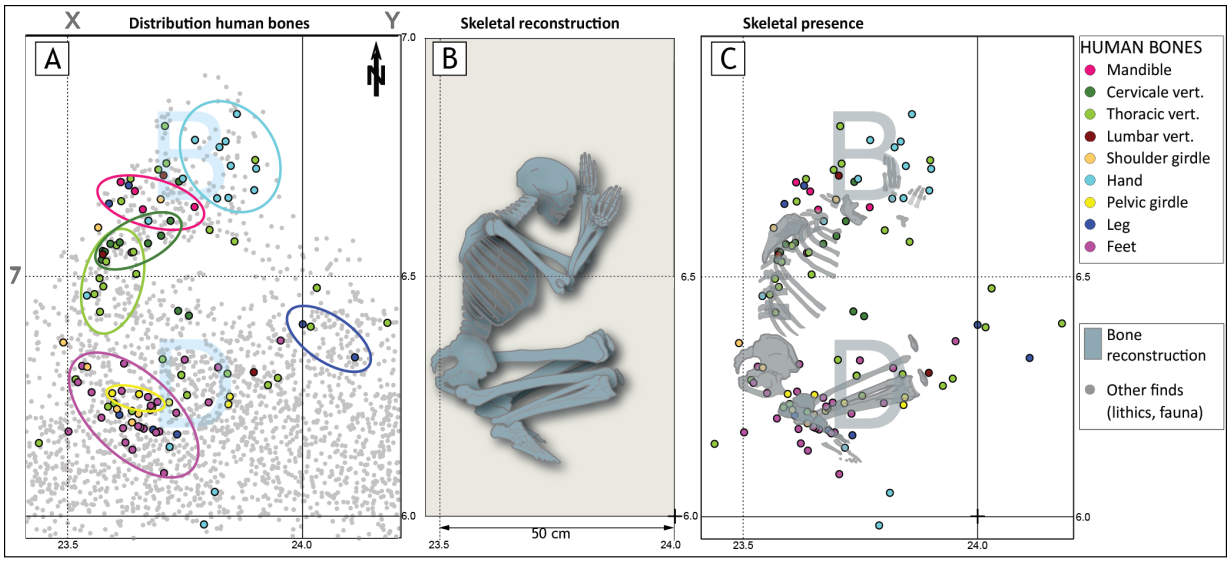
Red ochre was uncovered on the eastern side of the engraved block and underneath two medium- sized stone blocks, a smaller one and a slab were found in square X7 in 2010 (GONZÁLEZ-MORALES & STRAUS 2015, Fig. 11). The dimensions of the two bigger blocks and the slab are 40x35x18, 31x25x21 and 40x24x8 cm respectively (compare counterclockwise the blocks shown in Figure 4.86). The here reconstructed locations of the limestone rocks and human remains reveal that they were placed directly atop the burial, in the north end of sub-square X7- B (STRAUS et al. 2015a, Fig.4).

3) Human body position within the grave and post-depositional movements. Based on the spatial distribution of the human bones, the position of the woman's body was reconstructed. The size of the grave pit is estimated to have been as large as about two sub-squares (around 0.5 m²). During the analysis, the human body was divided in nine anatomical parts (Table 1.2). Human bones were found distributed among four squares (X6, X7, Y6 and Y7), but they were heavily concentrated in sub-squares B and D of X7 (Figure 4.86).

Table 4.24: The table shows the relationship between the depths of human bones and their scattering in the burial area. The area in square meters is calculated based on only the human remains with individual #XYZ-values and their spatial distribution outline of the human elements shown in Figure 1.15.

Human Body Parts	Number of XYZ-values	MAX Z	MIN Z	DIFFERENCE Z values	AVERAGE Z values	Area m²
Mandible (mandible, lower teeth)	6	17.721	17.633	0.088	17.685	0.03
Cervical vertebrae	12	17.517	17.432	0.085	17.484	0.04
Thorax (thoracic vertebrae, ribs, sternum)	36	17.803	17.433	0.370	17.610	0.74
Lumbar vertebrae	3	17.666	17.464	0.202	17.532	0.04
Shoulder girdle (shoulder, clavicle)	7	17.674	17.387	0.287	17.496	0.06
Hand (carpals, metacarpals, phalanges)	18	17.713	17.436	0.277	17.570	0.83
Pelvic girdle (pelvic bone, sacrum, coccyx)	7	17.503	17.423	0.080	17.456	0.01
Leg (tibia, fibula)	7	17.639	17.486	0.153	17.578	0.15
Foot (talus, calcaneus, metatarsals, phalanges)	26	17.642	17.317	0.325	17.413	0.33

In order to ascertain how the different body parts were concentrated or dispersed within the burial, bones of each body part were circled (Figure 1.14-A). Based on the circled body parts, the position of the woman's corpse was reconstructed (Figure 1.14-B). The bone distribution indicates that the human body was in a highly flexed position, placed on the left side with the head towards the north and the back against the engraved block (Figure 1.14-B). The torso was lying on the bedrock ledge and the lower body was above the bedrock fissure to the south (sub-square X7-D; Figure 4.86). Most of the long bones including the humeri, radii/ulnae, femora and the left tibia are missing from this deposit (Figure 1.14-C). The cranium is also absent, although an isolated upper incisor was found (CARRETERO ET AL. 2015). The over-representation of small and fragile skeletal elements such as distal phalanges, sesamoids, carpals, tarsals, vertebrae and ribs, among others, are not consistent with a secondary burial pattern, where an abundance of larger bones logically would be represented.



D)



Figure 4.89: The human body position was reconstructed using a vector graphic overlying the XY-distribution of human bones. The analysis was completed in three steps: A) Through individual coordinates, the distribution of the human remains was plotted in square X7 and clustered body parts were circled; B) Based on the actual bone position and body part cluster was reconstructed the human body position: highly flexed lying on the left side; C) representation of human bones in the sub-squares B and D in square X7. D) Practical body position reconstruction by J.M. Geiling. (GEILING AND MARÍN-ARROYO 2015, Figure 7; photography courtesy of M.R. González-Morales)

In terms of reconstructed vertical position and horizontal dispersal per square meter (Figure 1.15), the hand bones and the mandible had the relative highest positions in the deposit, while the foot bones had the lowest positions. The leg bones were moderately disturbed; while the fibula fragments remained more or less in their original body position, the right tibia was displaced from the supposed body position by around 50 cm

to the north, next to the mandible. If the corpse had been originally placed in a highly flexed position, an anthropogenic extraction of the cranium and long bones would not have entirely mixed up the sediments containing other skeletal elements. In summary, the results of the distribution study indicate that the mandible, cervical vertebrae and pelvic girdle bones showed the smallest vertical and horizontal movements within the original burial. However, body parts such as the hands, feet and thoracic bones were the most displaced elements within the burial (Table 4.24).

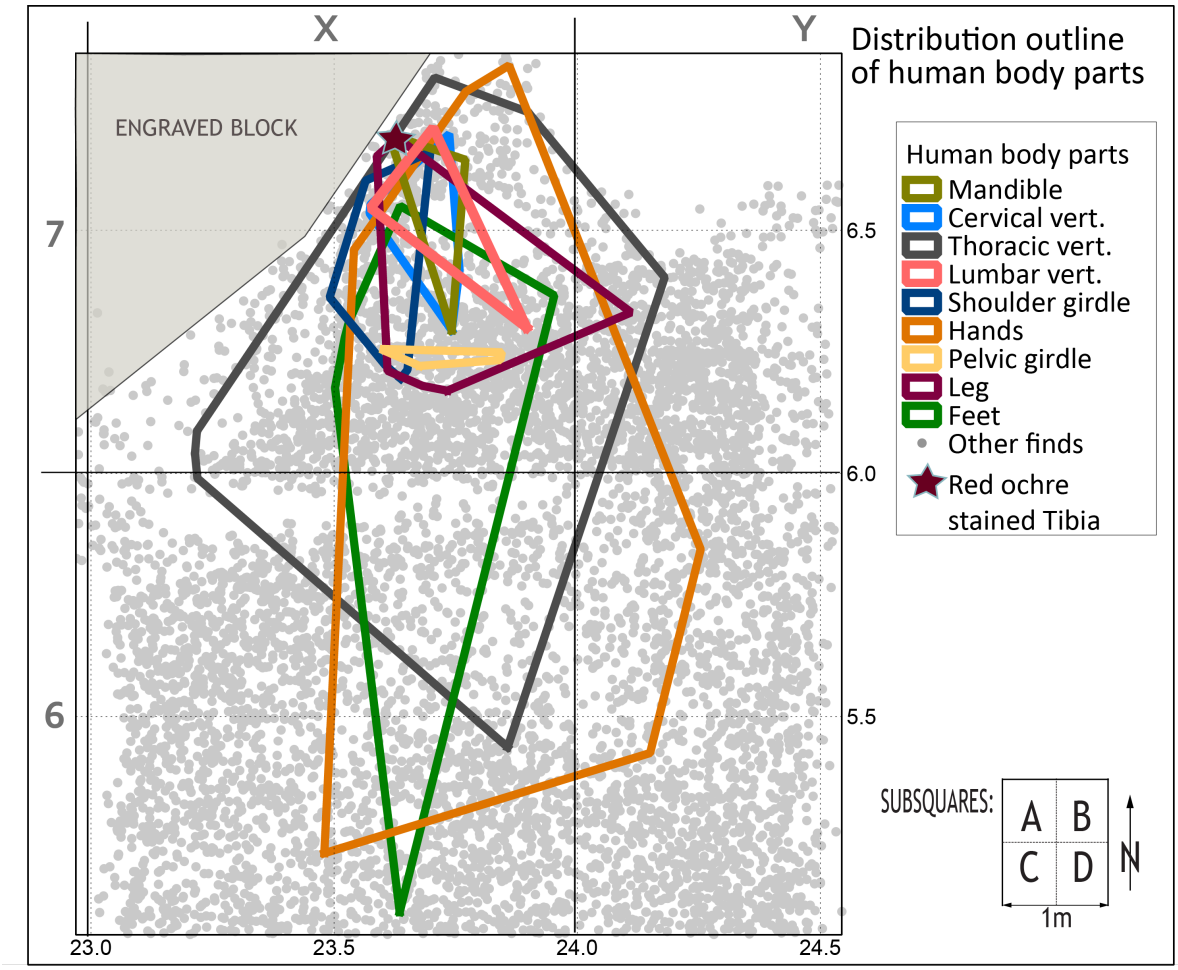


Figure 4.90: Illustrated are the outlines of the distribution of human body parts by using the spatial data of each human bone. The bones with maximal horizontal expansions marking the outline of each body part distribution. The extension of the outlines was measured and compared to their height variation. Highlighted is the red ochre stained tibia in the northern part of the burial area. (Extension outlines illustrated and measured by JM Geiling) (GEILING AND MARÍN-ARROYO 2015, Figure 8).

The highly flexed body position lying on the left side within this swallow burial pit reconstructed reveals that settling of the sediment while the body decomposed and the fact that the protecting stones covered only the upper torso, might have exposed and eased access to the human leg bones (Figure 4.86). The interruption of the original burial by biological agents is suggested according to the following observations. The initial disruption of the burial context was possible from a wolf according to the dimensions of the furrowing marks found only on both metaphyses on the right tibia (STRAUS, GONZÁLEZ-MORALES, & CARRETERO 2011; MARÍN-ARROYO 2015). While the spatial distribution shows that the human patellae and the majority of the foot

bones remained more or less in the proposed primary burial position (Figure 4.89), the tibia was found near the original location of the human mandible. First, this implies that the carnivore removed the tibia from the burial after soft tissue decomposition and element disarticulation. Secondly, the tibia was completely stained with ochre and some specular hematite, which covered both the previously formed manganese coating and the carnivore marks, therefore, it is apparent that the tibia was intentionally (re-) stained with ochre after the carnivore gnawing episode, and was then redeposited in the burial area, by humans (MARÍN-ARROYO 2015).

4) Relationship of human bones with other finds within the burial fill. With the aim of reconstructing the burial context and considering the possibility of grave goods in Level 504, spatial density analysis of the finds (animal bones and teeth, lithics and red ochre pieces) found in the area were plotted to define possible relationships with human bones.

The density plot of all finds displays two distinguishable areas of concentration (Figure 1.16-1). First, a northern distribution along the southeastern edge of the engraved block (squares X6-A, X7-BD, Y7-C) and a second one in the southern part of the burial area are visible, both seem to follow physical boundaries. These borders represent vertical limitations of the artifact distribution. In contrast, the eastern cave wall is configured as a shallow uprising slope, and here the archaeological levels naturally follow suit, rising and thinning out toward the east. The existence of niches in addition to the slightly sloping Level 505, complicated the differentiation of the levels along the southern cave wall. The high number of lithic artifacts and faunal remains in squares X5 and Y5 might partially be attributed to some mixture between Levels 504 and 505, because red ochre staining as differentiating criteria was not at all as continuous in this area as in X7 and Y7 and X6 and Y6.

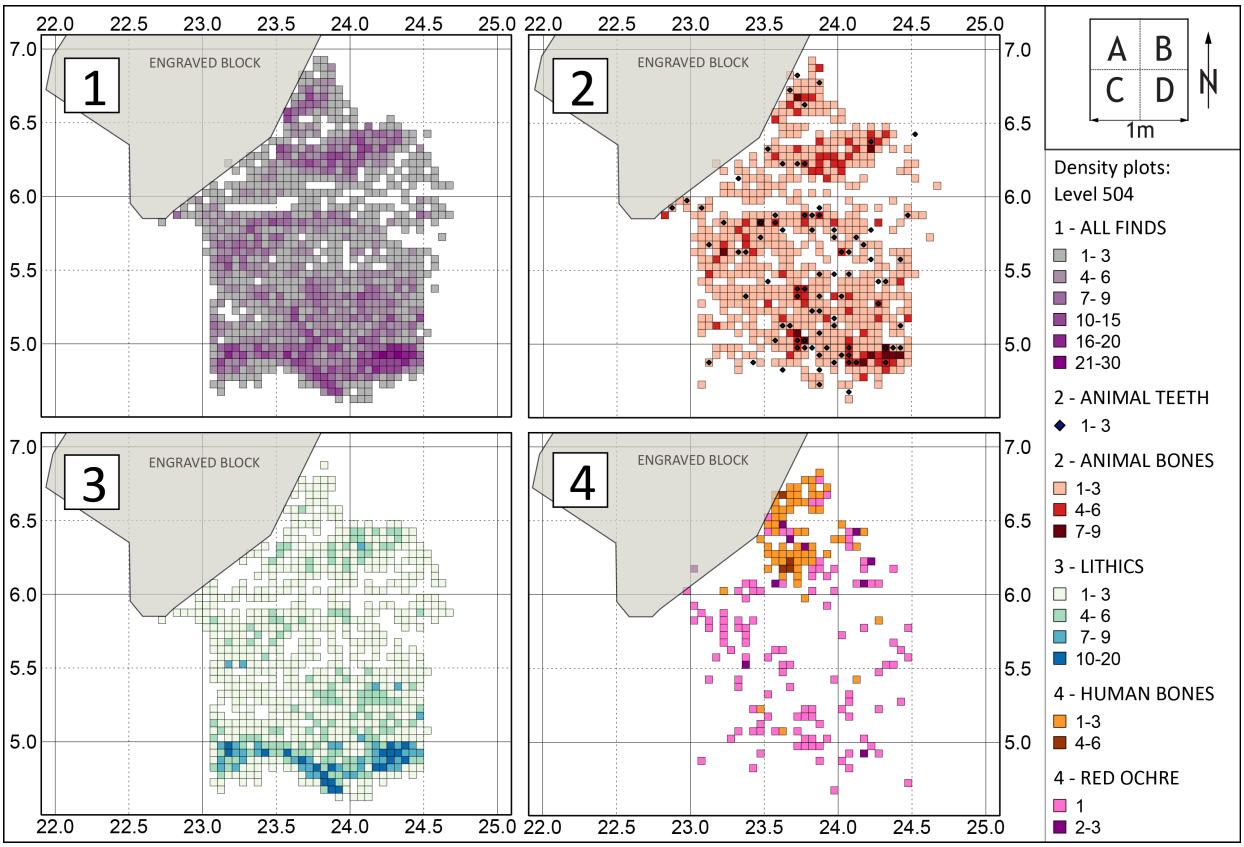


Figure 4.91: The density plots of individual records using artifact frequencies within a generated mesh grid overlay from Level 504 representing the context of the human bone finds. Each density plots express the

number of finds per overlaid, projected sample grid with a mesh size of 25 cm2. The following plots show distinctive archaeological categories: (1) All finds are plotted together to show the general find distribution. (2) The dispersed animal teeth and bones. (3) The density of lithics counted the number of stone artifacts per each projected sample. (4) The distribution of human bones and red ochre samples. (Density plots by JM Geiling) (GEILING AND MARÍN-ARROYO 2015, Figure 9).

Erosion of the stratigraphic western section between square X7 and X6 between 2011 and 2013 is responsible for the gap in data points in this thin slice of the burial area. The animal teeth and bones represented (Figure 4.77-2) follow the general distribution of the other finds, with a concentration of animal cranial bones and mandibles (including the teeth) along the southern cave wall. Similar to the animal bones distribution, there is a remarkably low density of lithics in the middle of the whole burial area (Figure 4.91-3). However, some outstanding finds have been recovered in this zone. These are a large quartz crystal (X7, sub-square D, Nr. 1550), a perforated ibex incisor, two perforated shells, five bone needle fragments and undecorated antler sagaies (FONTES ET AL. 2015; GUTIÉRREZ-ZUGASTI & CUENCA-SOLANA 2015). Despite the appearance of those artifacts, it is not possible to confirm their relationship to the burial activity, and, in consequence, these finds may not necessarily be interpreted as grave goods. The zooarchaeological results indicate that macromammal remains were probably leftovers from consumption and the area was used in part as a garbage dump during some Lower Magdalenian occupations (MARÍN-ARROYO & GEILING 2015). Finally, the human bones are mainly concentrated in only two sub-squares X7-B and X7-D, in the northern part of the burial area (Figure 4.91-4), showing a semicircular distribution patch open to the East. The distinguished human bone distribution pattern confirms the intentional deposition of a complete, flexed human body on its left side as reconstructed above, and that no other artifacts show the same dispersal limitation, something that also helps to discount the possibility of grave goods inside this burial.

Some relevant context has to be considered before discussion, which is detailed next. During the Magdalenian, dated between ca. 17-11.5ka uncal BP., - i.e., 20.4-13.6ka cal BP (STRAUS & GONZÁLEZ-MORALES 2012a), with a 6.800 year-duration and a geographical distribution eventually stretching from southwestern to north-central Europe, only a few primary human burials are known (notably in France). Some of these reflect a deliberate selection of body parts (BELLO ET AL. 2011; ORSCHIEDT 2013). Within European Magdalenian contexts secondary burials are more regularly found (particularly in France, Germany, Poland and the United Kingdom) and only 23 of the Late Upper Paleolithic burials are considered to be primary interments (PETTITT 2011; ORSCHIEDT 2013; RIEL-SALVATORE & GRAVEL-MIGUEL 2013). Until recently, not many *Homo sapiens* remains have been found and no clear burials have been identified in the Iberian Peninsula before the Mesolithic (ARIAS CABAL & ALVAREZ-FERNANDEZ 2004; AURA-TORTOSA 2010). Outstanding are findings made 1911 by Hugo Obermaier (1924) in El Castillo cave, three valleys west of El Mirón in central Cantabria. Two human frontal bones were found in a kind of secondary interment context in the very thick Initial and Lower Magdalenian Beta-horizon of the cave. Another burial practice is implied by a few late Magdalenian humans remains from a child, a juvenile and an adolescent accompanied with perforated shells found in Galería de Cisterna, Portugal (TRINKAUS ET AL. 2011).

It was therefore outstanding the discovery of a possible ritualized burial of an adult female in a Lower Magdalenian context at El Mirón Cave (STRAUS, GONZÁLEZ-MORALES, & CARRETERO 2011). This burial was first published as being a secondary interment based on no readily apparent anatomical relationships or articulations among the bones seen during excavation and an exceptional amount of red ochre staining of the bones. The burial contained a single adult female with a body height about 1.59 m and 60 kg weight (STRAUS, GONZÁLEZ-MORALES, & CARRETERO 2011: pp. 1161–2; CARRETERO ET AL. 2015). The aim of this case study was to analyze the context and the remains found in the Paleolithic human burial in El Mirón cave and to identify its origin, thus providing a high resolution of human spatial activities.

The presented analysis allows following discussion of results. In contrast to the initial interpretation of the El Mirón Lower Magdalenian burial as a secondary one (STRAUS, GONZÁLEZ-MORALES, & CARRETERO 2011), the spatial distribution analysis has been essential in understanding the formation of the burial area, the reconstruction of the original body position in a primary burial and the sub-sequent *in situ* distortion of the interment.

The close location of the burial behind the large, engraved and ochre-stained limestone block in the Vestibule Rear might have been deliberately selected, as the decorations may have had special meaning to or were made from these hunter-gatherers (GONZÁLEZ-MORALES & STRAUS 2015). The partially hidden area selected for the burial, although close to the living place according to very thick cultural layers located to the west of the engraved block, was clearly separated from it. In this sense, the area could be identified as a carefully selected place for a Paleolithic interment.

The vertical and horizontal spatial analyses of the contents of the sedimentary deposit have been helpful in identifying the dimensions of the partially artificial space created for the purpose of containing a human corpse, and the post-depositional movements that later occurred. The analysis has shown that the sediment was partially mixed in the northern part of the area, where the human remains were originally deposited. The main dispersal of human bones is inside the burial pit borders.

While the sediments in square X7 show evidence of the excavation of a burial pit into the underlying level, the different manganese coating of human and animal bones represent a mixture of both levels (504 and 505). This mixture is also supported by the radiocarbon dates obtained from these levels: one, on the human fibula (15 460±40 uncal. BP, MAMS-14585) and another on an ungulate bone (15 740±40 uncal. BP, UGAMS-7217) from Level 504 and on an animal bone in Level 505 (15 670±40 uncal. BP, UGAMS-15183) gave a slightly younger central date (STRAUS, GONZÁLEZ-MORALES, & CARRETERO 2011; STRAUS ET AL. 2015b, Tbl. 1). Sediment in the southern burial area stayed in stratigraphic order with evidence of animal bone refits (MARÍN-ARROYO & GEILING 2015), which strengthens the idea of their *in situ* situation. All levels followed the concave contour of the bedrock, with fewer finds in the middle in this area.

Three-dimensional plotting of bones with specific taphonomic modifications in combination with the dispersal of all the human body parts has been valuable to understand post-depositional movements within the burial.

It was possible to set the limits of an artificial red ochre surface, based on the position of red ochre mineral pieces and stained human and animal bones. This indicates a burial-associated floor for red ochre processing, where red ochre powder was dispersed over the burial area or prepared to cover the human remains. The ochre did not reach the lowest and less disturbed areas where human bones were placed, According the spatial reconstruction were especially the feet not effected, thus, there is no a clear evidence to prove that ochre was dispersed during the initial interment. The different depths shown by the 3D-model of the red ochre surface in square X7 potentially reflects the reworking of sediments, as would happen during the destruction of the primary burial. Nonetheless, the thick and patchy ochre staining on the tibia, mandible and other bones suggest a direct pigment application onto bare bones after the flesh decomposition process and carnivore gnawing (MARÍN-ARROYO 2015). The tibia was placed back into the grave, close to the mandible, where the highest concentration of ochre was found. It is supposed that humans extracted the rest of long bones and cranium from the burial, while this disrupted place and remaining human bones were ritualized covered with ochre and specular hematite.

The overall human body part representation (missing the cranium and most long bones) is not due to carnivore disturbance, bone density or diagenetic processes. Most of the human remains are well preserved.

Small and fragile bones are significantly overrepresented as has been specified during the anthropological and taphonomic studies of the human remains (CARRETERO ET AL. 2015; MARÍN-ARROYO 2015).

The spatial analyses have revealed a distortion of the primary body position, as some anatomical elements were horizontally and vertically displaced more than others. This is potentially related to the carnivore activity, as well as to posterior human extraction of long bones and cranium, possibly for redeposition at another undiscovered location, perhaps to make a secondary burial with these skeletal elements somewhere else. Human groups might have initialized these secondary burial practices to restore proper funeral treatment.

The other objects found in the burial area showed no clear relationship to the buried woman (GUTIÉRREZ-ZUGASTI & CUENCA-SOLANA 2015). The recovered artifacts are consistent with general Lower Magdalenian 'garbage', rather than necessarily being special grave goods.

The complex activities carried out in the El Mirón burial makes it an exceptional phenomenon, not only for the Lower Cantabrian Magdalenian, but also for the Iberian Upper Paleolithic in general, so poor in human burials–with the notable exception of the Lagar Velho Gravettian one in central Portugal (DUARTE ET AL. 1999). There are few stereotypical burial norms during the Magdalenian. In general, primary interments are identified based on almost complete anatomically articulated body representations associated to one funeral event, incorporating burial pit preparation, cairn covering or grave goods (for example: (VANHAEREN & D'ERRICO 2005). While criteria to distinguish secondary burials are a deliberate selection of isolated human remains, evidence of corpse disarticulation, reuse of the burial space to rebury various bodies and even circulation of body parts (PETTITT 2011; ORSCHIEDT 2013; RIEL-SALVATORE & GRAVEL-MIGUEL 2013). The present study was able to demonstrate characteristics of both categories, including both primary and secondary burial practices. This is the first time that an anthropically disturbed primary burial in a Paleolithic context has been described.

The spatial distribution analyses applied in this study to assess the funerary context have to date been only infrequently used in the study of Upper Paleolithic human burials. Previous analyses of other contemporaneous burial contexts have been mainly based on anthropological and geological methods, where descriptive skeletal representation, reconstruction of the human body position and stratigraphic location of the burial within the site are usually presented (e.g., SVOBODA 2008; ARIAS CABAL ET AL. 2009; SANDGATHE ET AL. 2011; DOBROVOLSKAYA ET AL. 2012; RENDU ET AL. 2014). Comparative analyses giving descriptive tables with information on human burial practices are mostly restricted to presence/absence and are organized by cultural periods and by modern countries (HARROLD 1980; PETTITT 2011; ORSCHIEDT 2013; RIEL-SALVATORE & GRAVEL-MIGUEL 2013). Thus, these analyses investigate archaeological categories, such as grave goods, cairn coverings, existence of burial pits, body positions and ritual activities such as red ochre use, for interpreting human mortuary practices during the Paleolithic. However, analyses of Upper Paleolithic burials using 3D-find recording and taphonomy in combinations with multidisciplinary data are still infrequent. This gap arose mostly due to early disinterment prior to the use of modern excavation techniques. Thus, most of those burials and finds of human remains lack spatial records. One of the few exceptions is the Gravettian human burial of Abri Pataud, as it includes intra-site spatial analyses of the burial location in relation with the bone position, vertical and horizontal dispersion and covering blocks and taphonomy of human bones (HENRY-GAMBIER ET AL. 2013). And the Lagar Velho infant burial is also well published (DUARTE ET AL. 1999; ZILHÃO & TRINKAUS 2002).

The spatial distribution analysis of the human burial found in El Mirón Cave, contributes new ways with which to conduct this kind of Paleolithic research. First, the comparison between the horizontal and vertical dispersal of archaeological finds has proved to be a powerful tool with which to evaluate the complexity of a 19.000-year-old human burial. Second, by analyzing their spatial interrelationships a new analytical means

for to studying human burial activities was presented. The reconstruction of events for the human burial in El Mirón cave is exceptional and, in combination with the petrographic, anthropological and taphonomical studies, it has been possible to demonstrate how the burial pit was made, filled and reworked. The sequence of burial activities has shown the original position of the human body, how the original burial was disturbed first by a carnivore and later by humans (likely also involving creation of a secondary burial or depositions of individual bones elsewhere either in the cave or outside) and finally how the remaining human bones were left covered again until they were discovered beginning in 2001.

4.3.6 Conclusion on human paleo-space-use at El Mirón

Nowadays, the use of technological instruments of detailed spatial recording of archaeological finds in Paleolithic sites is a standard procedure to reconstruct the original position of each elements which is done helping to understand site formation, function and allow the possibility of human behavior reconstructions (VAQUERO & PASTÓ 2001; MARÍN-ARROYO 2004; ALPERSON-AFIL ET AL. 2009; MALINSKY-BULLER ET AL. 2011; GUAN ET AL. 2011; PARKINGTON 2013; ORON & GOREN-INBAR 2014). A long-standing trend in archaeology has been to use, collect and describe the most diagnostic finds that contain implications on cultural association that allow an association of the finds in their chrono-cultural context and direct interpretation. Hence, archaeologist have come to master the cultural contextualization of the finds, the researchers can now focus more on the details that humans left behind with which behavior reconstruction can be drawn in much more facets using spatial analysis.

The approach, incorporating spatial analysis on the taphonomy of faunal remains was integrated in this dissertation work to investigate what kind of understanding on human behavior we can improve when considering the small fraction of archaeological find categories, the spatial distribution of them and the taphonomic history of the deposit. The details of human activities, which in consequence of their accumulative reconstruction, can be used to extrapolate specific data on past realities are of interest here. While different research lines exist to serve these aims, here are dominantly employed zooarchaeological, taphonomic and computational methods on dense bone accumulations in the Vestibule Front of the site featuring subsistence activities.

Spatial distribution analyses were realized to simplify complex data, enabling to recognize spatial patterns among archaeological find categories that have not been detected until this point. Particularly, good bone preservation indicates little post-depositional disturbance. Even very porous, spongy, tiny bones of young animals remained. During excavations no significant sediment movements, pressure-fracturing, or water flows in the form of channels, or burrows were observed in the levels analyzed in this study. There are no evident phenomena which would have suggested a disturbance of the original archaeological layers (GONZÁLEZ-MORALES & STRAUS Unpub.; STRAUS & GONZÁLEZ-MORALES 2012b). These results demonstrate the existence of an intrinsically intact archaeological stratigraphy of the Lower Magdalenian strata that are very suitable for investigating the spatial distribution pattern of finds, from which evidence of activity areas can be inferred. Additionally, cultural formation processes can be used to enhance interpretations of human behavior. Due to the problems that usually archeologists face when attempting the analysis of very thick cave deposits (the 'palimpsest problem'), spatial distribution analysis can simplify the data, enabling one to recognize spatial patterns among archaeological find categories that are not visible with the naked eye. Consequently, the following conclusions of this chapter, the insights into the activity areas of Lower Magdalenian layers in El Mirón cave, will be discussed, based on spatial distribution analysis of faunal remains.

Three case studies have been demonstrated how significantly spatial analysis can help to understand past human behavior. Following conclusion have been obtained for spatial analysis performed during this study:

The results of the presented studies highlight the value of bone micro-fragments in faunal studies, which are normally less than 3cm in size and sometimes weigh less than 1g, especially under the aspect of deciphering archaeological palimpsests.

Taphonomic and zooarchaeological results are extremely valuable and researchers are prone to lose additional information if the study of bone micro-fragments, normally originating from extant collection, is not dealt with accordingly. Bone micro-fragments represent parts of the *chaîne opératoire* of animal carcass exploitation, thus improving our human behavior analysis through the reconstruction of discrete activities (HIETALA & LARSON 1984), the segregated use of space and shifting site use. Both, large and small archaeological items, contribute to our understanding of human activities and subsistence behavior. Therefore, this study shows that skeletal representation changes drastically and the interpretation on the faunal assemblages differs when all bones are included. Especially small bone micro-fragments can display one of the ultimate end-products of a *chaîne opératoire* of animal carcass exploitation (O'CONNELL ET AL. 1991; THÉRY-PARISOT ET AL. 2005; ULLAH ET AL. 2015) that might include all the activities of hunting, dismembering, defleshing, marrow bone cracking, cooking, burning, food procurement, sharing, storage, and, finally, trampling.

The dissection of palimpsest deposits into finer (albeit more or less arbitrary) sub-units that come closer to single-event timespans helps us to understand human behavior. With this method, it was possible to show that vertical and horizontal find distributions within this palimpsest were not the results of random chance, but their density variability could be referenced to different human activities. Especially in the Cantabrian Region, where many key Lower Magdalenian deposits are characterized as palimpsests of human occupation, for example, occupational horizon in the Outer Vestibule area at El Mirón cave or pictured as undisturbed, still *in situ* living surfaces in the case of La Garma cave in central coastal Cantabria (ARIAS-CABAL & ONTAÑÓN-PEREDO 2014). When included, taphonomical categorized bone micro-fragments can provided new, additional chronological information of the occupational history.

Activity zones can be distinguished within the sub-levels of the palimpsest horizon in El Mirón cave; in particular hearth, working and dumping areas are observed (BINFORD 2012). The different zones are supported by refitting remains indicating that the reconstructed spaces were maintained or reused. Further activity areas identified at El Mirón can be attributed to a grease-rendering working zone for bone processing advanced with a drop zone, a walking zone, a dumping area and a toss zone near hearths (BINFORD 1978; STINER ET AL. 2005; JANZEN ET AL. 2014). The bone-processing zone had a central role in the spatial organization of this area of the site. This specific activity produces a large quantity of bone debris, which, in turn, is visible in the high-density Lower Magdalenian layers found across Cantabrian Spain and makes it archaeologically tangible. Whether these thick deposits are the results of cultural-specific activities (such as intensive grease-rendering), settlement strategies or exceptional population density of the Lower Magdalenian remains to be seen. If an intensive grease exploitation was for nutrition or hide impregnation or other reason will be the subject to be refined in future research.

Further human behavioral details, however, have been, obtained during analysis of the El Mirón burial. The analysis of the Lower Magdalenian burial Level 504 confirms that it also contained remnants from a living space, but in much lower densities and with more of a discard zone character compared to the Outer Vestibule occupations of Level 17 (GEILING & MARÍN-ARROYO 2015; MARÍN-ARROYO & GEILING 2015). The human burial in El Mirón cave seems to have been placed in an area with special meaning for Lower Magdalenian human groups. The interment was made behind a large block, which was perhaps engraved and definitely ochre-stained in relation to the burial, in a place within the large Vestibule, but separated from the main living area.

The spatial analyses carried out using GIS software have shown details of the preparation of the area used to bury the human body. The results have also demonstrated a partial mixture of sediments between Levels 504 and 505, the covering of the area with ochre and specular hematite in relation with the treatment of the corpse, the vertical and horizontal movements of several anatomical body parts due to limited carnivore activity and the likely anthropogenic extraction of the long bones and cranium to made a secondary burial somewhere else either in another (unexcavated) part of the cave or outside. Spatial distribution analyses produced new results for the various finds recovered in the burial area. This fact has contributed to identify when and how the burial pit was made, what post-depositional events affected the primary burial and how human bones were spatially related to lithic and faunal remains in the surrounding sediments. The results of the spatial analyses, in combination with the taphonomic analyses of the human and animal bones, have shed new light on archaeological remains and the significant role of post-depositional phenomena on the final interpretation of this unique burial context.

The high resolution spatio-temporal analysis of prehistoric palimpsests from a zooarchaeological and taphonomic perspective availed new aspects of the burial in El Mirón cave. In contrast to the initial interpretation of the El Mirón Lower Magdalenian burial as a secondary one (STRAUS, GONZÁLEZ-MORALES, & CARRETERO 2011), the spatial distribution analysis has been essential in understanding the formation of the burial area, the reconstruction of the original body position in a primary burial and the subsequent in situ distortion of the internment. The complex activities carried out in the 'Red Lady' burial makes it an exceptional phenomenon, not only for El Mirón itself. The case study displays an outstanding example for deciphering human activities during the Paleolithic with special attention on taphonomic modifications here related to the treatment of death and the place of the dead in the living world. As such, this study allows accessing details on characteristic human behavior from some thousand years ago.

Altogether is inferred a segregation of space use during the Lower Magdalenian occupations in El Mirón cave with a large or even main food processing area in the Outer Vestibule, fairly exact located where the cabin excavation area was set up.

It can be summarized that the formulation of a method that dissects palimpsests into smaller units, which in consequence enables us to investigate site formation processes, changes in small-scale subsistence strategies, intra-site human behavior, and population dynamics. These accomplishments are key contributions of this dissertation project, which will be refined and expanded in future work.

4.4 Environment, annual climate seasonality and vegetation

4.4.1 Human-environmental interactions

As this dissertation aims to test whether climate events and changes in hunting behavior, subsistence practices, and settlement patterns coincided, where the environment provide the context of human actions as an essential factor. The environment is important since it determines the supply of economic requirements for a specific locality (HOLLING 1959, 2001). For hunter-gatherer lifeways, criteria of such local environments-- the supply of food, water, and raw material-- determine the function of a site in the settlement system (UTRILLA 1994; BINFORD 2001, 2012; PHOCA-COSMETATOU 2004; BICHO ET AL. 2006; BURKE 2006; BACHELLEIRE ET AL. 2009). The subsistence sand settlement system, however, varies depending on the contemporary social system. As culture is largely adaptive, it is essential to identify the dynamics that act behind cultural changes. The main locus of cultural adaptation is or resulting in the subsistence system, specifically related to economic behavior (KELLY 1995). Possible factors driving those changes are in discussion; they might be of environmental, social, or demographic origin (GONZÁLEZ-SAINZ 1989; STRAUS 1992; BRADTMÖLLER ET AL. 2012). The present analysis focuses on elucidating detailed paleo-environmental conditions to determine whether specific environmental changes influenced human behavior, regarding the aspects that for others relevant social or demographic aspects of causation such detail remains difficult to achieve.

Annual climate seasonality is an important variable in paleo-environmental reconstructions. Intensity of seasonal temperature changes and precipitation regimes are major factors of ecosystems structure regulating vegetation communities (VINCENS ET AL. 2007; GOOD & CAYLOR 2011; GARCIA ET AL. 2014). As such, annual seasonality, when strong enough to be recognized, also influences herbivore behavior as dependent on plant food availability. In consequence, seasonality also affects the activities of living human communities with a mobile hunter-gatherer lifeway, as it might have been so in the past (ANTHONY 1990; KELLY 1992; LIEBERMAN ET AL. 1993; HÄRKE 2004; HAKENBECK 2008; VAN DOMMELEN 2014). When Prehistorians want to discuss human settlement and subsistence dynamics, annual climate seasonality is a key topic to be considered. There are several examples of human behavior analysis that used stable isotope studies to investigate seasonal climate fluctuation and settlement/subsistence systems (e.g., FONTANA 2000; BALASSE ET AL. 2003; AARIS-SØRENSEN ET AL. 2007; BRITTON ET AL. 2009; BLAISE & BALASSE 2011; TORNERO ET AL. 2013). Subsistence-driven mobility patterns seem to be established often on the water and food- resource distributions in the landscape, which in most cases fluctuate seasonally, thus moving base camps avoids the problem of resource depletion around any individual site (BINFORD 1980; KELLY 1983; PARKINGTON 2001; VENKATARAMAN ET AL. 2017). Heavy seasonal resource exploitation can restrict how habitable a local environment is and for how long; annual seasonal fluctuation of biomass, for example, is then really a part of any site's characteristics. Seasonality is also of interest in site characterization, because the seasonal fluctuations in temperature and humidity also change the environmental carrying capacity in the area around a specific site; a factor which refer to the term "micro-environment" in what follows.

Defining the micro-environment around a Paleolithic site of interest might include questions such as: how much this area was affected by fluctuations of temperatures, humidity and consequently available plant and animal biomass. All these different factors together characterize the local habitat conditions that humans exploited specifically at the time when they occupied the site.

Today, ungulates can provide more information than simply whether they were part of the human diet. By measuring the isotopic values on their skeleton, the conditions at the time they lived can be inferred, and specifically, when humans hunted them. So, there is a direct relationship among the ungulates, the paleo-environment, and the humans. In consequence, this work seeks to infer seasonal environmental conditions when humans hunted and lived at El Mirón Cave. Different approaches reconstruct the Upper Paleolithic

micro-environment, they are analysis of stable isotope and phytoliths in dental calculus compared to previously known environmental data.

For explored for seasonal fluctuations in local environments, the stable isotope values of oxygen and carbon in was measured in enamel structural carbonate, and phosphate of the horse, red deer and ibex teeth. Intra-tooth $\delta^{18}O$ and $\delta^{13}C$ stable isotope analysis provides an established method to study, amongst others, seasonal temperature and humidity variation, local mean environmental conditions, tooth formation duration, birth season and most recently social animal group identification (FRICKE ET AL. 1998; BALASSE 2002; READE ET AL. 2015; JULIEN ET AL. 2015). Additional strontium analysis detailed whether the presence or absence of seasonal fluctuation originate in seasonal migratory behavior of prey species (BENTLEY 2006; BRITTON ET AL. 2009). Carbon and nitrogen isotopic analysis on ibex collagen is awaiting, and results are preliminarily.

Phytoliths, the silicate bodies of plant tissue, have been also analyzed from herbivore dental calculus to compare the evidence on the types of consumed vegetation with stable isotope results and other proxies already partially available such as pollen. Both samples are possible to take from the same tooth. During cleaning of the tooth surface for stable isotope analysis dental calculus deposits are collected, i.e., during the same sample preparation procedure. Determine the dietary components in form of phytoliths in herbivore tooth enamel aims to decipher equifinality signals in isotope results. Phytolith remains from consumed plants encrust within the growing matrix, during formation of dental calculus or tartar. The mineralized biofilm of dental plaque composes calcium phosphate mineral salts and remnants of formerly viable micro-organisms (LIEVERSE 1999; BLONDIAUX & CHARLIER 2008; RADINI ET AL. 2017). These plant particles accumulate during an animal's life, potentially representing parts of their diet (MIDDLETON & ROVNER 1994; FOX ET AL. 1996; HENRY & PIPERNO 2008; HARDY ET AL. 2009, 2018; LEONARD ET AL. 2015; NORSTRÖM ET AL. 2019).

Previous environmental data available (micro- and macro-fauna, sedimentology, etc.) are collected and compared with the obtained results. Such information is useful by combining multiple lines of evidence for improving interpretations. In northern Iberia, several studies reconstruct mostly overall climate changes for the whole region rather than on a local level to gauge the possible overall impact of climate variation on animal and human populations. Such a regional approach makes it rather difficult to understand micro-habitats and the local environments where humans lived. Therefore, it is necessary for reconstructing micro-environments to consider the available climatic/environmental proxies and to integrate them into a combined interpretation. In El Mirón, for example, with sedimentological studies (STRAUS ET AL. 2001; FARRAND 2012), macrofauna (ALTUNA ET AL. 2004; MARÍN-ARROYO 2010; ALTUNA & MARIEZKURRENA 2012; MARÍN-ARROYO & GEILING 2015; MARÍN-ARROYO ET AL. 2018a; DEMARCHI ET AL. 2019), micro-mammal studies (CUENCA-BESCÓS ET AL. 2009, 2010b; BAÑULS-CARDONA ET AL. 2014), pollen (IRIARTE-CHIAPUSSO ET AL. 2015), and many climatic proxies available are integrated to the results obtained from the new approaches applied here (O/C in stable isotopes in ungulate teeth and phytoliths trapped in the dental calculus of animals hunted by humans). This procedure aims to provide a more detailed environmental sequence.

4.4.2 Reconstructing micro-environmental conditions and animal ethology

To elucidate the local environmental conditions at a site such is El Mirón, a limited timeframe of study is most practically, here concentrating on human occupations during the Lower Magdalenian. The Lower Magdalenian period is additionally outstanding for two more reasons: first, this period has abundant archaeological material preserved allowing a broad analysis for a specific period. With the help of the data from this period—so richly represented both in El Mirón and in Cantabrian Spain— will be better understood whether (and how) climatic conditions may have influenced the emergence and disappearance of the Lower Magdalenian cultural phenomenon in the Cantabrian region. Second, it is suggested by the extant record that the Lower Magdalenian occurred under still fairly severe climatic conditions (Oldest Dryas), allowing one

to reconstruct an extreme of harsh living conditions within the northern Iberian refugium of the Last Glacial (MIS-2), while populations flourished. A detailed micro-environmental history and the local evidence about other environmental data improves the overall interpretations of climatic conditions for such a period. By main concerns addressing a better characterization of Lower Magdalenian environmental conditions (animal habitat, climate seasonality, or water availability) and accumulation context of such, the following hypotheses are proposed corresponding to the aimed objectives:

A) If diagenetic alterations are low, the archaeological material is well suited for isotope studies.
B) If patchy environments existed along the Cantabrian region, then we expect animal habitat reconstructions indicate the existence of such micro-environments.
C) If the ungulates experienced remarkable seasonal climate fluctuations, then fluctuating oxygen values should be detectable in the in incremental tooth enamel samples of those animals.
D) The stronger seasonal climate changes, the stronger were adaptation towards seasonal behavior (i.e. seasonal movements) shown by those animals.
E) The more similar seasonal climate fluctuation and amplitude isotope signals of different animals, the likelier is hunting took place within a temporal and spatial limited scope. Or more explicitly: If hunted animals came from the same herd, then related seasonal isotope patterns should be observed.
F) If animals were practicing seasonal migrations, then constrained birth seasons might be present.
G) The larger seasonal migrations of animals were along different rock-underground, the stronger the strontium variation in incremental tooth samples could be.
H) Interpretation of equifinality in animal isotope results will improve when combined with phytoliths from dental calculus addressing additional dietary components, then solely interpreted.

The list of samples of the items contains Table 4.25, where the incremental carbon and oxygen analysis in bioapatite from tooth enamel was performed to study annual variation in inhabited environments.

Table 4.25: Samples for stable isotope analysis.

Code	Species	Element	Level-Square	Number	Spit
ISO-CP-up_1	Capra pyrenaica	lower M3 right	16-I2	396	28
ISO-CP-up_2			16-H3	872	59
ISO-Cp-up_3			15-H4	1061	51
ISO-CP-mid_1			17-H4	1792	60
ISO-CP-mid_2			17-J2	957	23
ISO-CP-mid_3			17-H3	1648	67
ISO-EQ-low_1	Equus ferus	upper P left	17-I3	5535	66
ISO-EQ-low_2	Equus ferus	upper M2L	17-J3	4681	47
ISO-CE-low_3	Cervus elaphus	lower M3 right	17-I4	5083	72
ISO-CE-low_4		lower M2			
ISO-CE-low_5	Cervus elaphus	lower M3 right	17-H3	3510	74
ISO-CP-low_6	Capra pyrenaica	lower M3 left	17-H3	5278	80
ISO-CP-low_7		lower M2 left			
ISO-CP-low_8	Capra pyrenaica	lower M3 right	17-I4	3427	66

To better understand dietary intake of those animals under study, the results integrate dental calculus analysis of red deer, ibex, large bovid and horse teeth into environmental reconstructions from stable isotope of El Mirón Lower Magdalenian levels done on tooth enamel. Table 4.26 list the samples for phytolith analysis on herbivore dental calculus.

Table 4.26: Samples for dental calculus analysis.

Code	Species	Element	Level	Square	Number	Spit
PHY-01	Capra pyrenaica	Lower M3, right	15	J4	1404	60
PHY-02			16	H3	872	59
PHY-03			17	H3	1648	67
PHY-04			17	H2	1500	50
PHY-05			17	I4	3893	68
PHY-06			17	H3	5278	80
PHY-07	Equus ferus	Molar	17	H4	1253	54
PHY-08	Bos/Bison	Premolar	17	H2	1362	49
PHY-09	Cervus elaphus	Molar	17	I4	5702	73
PHY-10	Capra pyrenaica	Lower M3, right	17	J2	262	17
PHY-11			17	I4	1532	54
PHY-12			17	J4	1538	61
PHY-13			17	H3	1291	64
PHY-14			17	H3	1745	68
PHY-15			17	I3	1668	51
PHY-16		Lower M3, left	17	H3	1997	69
PHY-17		Lower M3, right	17	J4	3898	68
PHY-18	Equus ferus	Molar	17	H3	1542	66
PHY-19	Capra pyrenaica	Lower M3, right	17	H4	1061	51
PHY-20			17	I3	1031	47
PHY-21			17	J2	957	23
PHY-22			17	H4	1792	60
PHY-23			17	I4	2032	59

Following paragraphs discuss the results for multi-isotope and phytolith analysis according to the hypothesis and a concluding seasonality model. When considering discussions and reviews on the interpretation of stable isotope analysis (KOHN & CERLING 2002; HEDGES ET AL. 2004; BENTLEY 2006; ROBERTS ET AL. 2018; PEDERZANI & BRITTON 2019), it is clear that several factors can influence the isotopic signal recorded in animal tissue, whose origins are often difficult to disentangle as explained in the methods chapter. Relevant factors, such as temperature, humidity, altitude, diet, drinking behavior, etc., all can influence isotopic composition in bone/tooth. For each hypothesis, result and relevant factors will be discussed in detail.

4.4.3 Multi-isotope results on ungulate teeth enamel

This section combines the results of the stable isotopic composition of oxygen and carbon from structural carbonate, strontium from calcium and oxygen results from phosphate in enamel bioapatite. In Appendix H table, the individual stable isotope values are presented. These results imply diagenetic alterations, habitats occupied by animals, and evidence of seasonality of deaths.

In general, the multi-isotope analysis done on tooth enamel, on the structural carbonate fraction of the bioapatite revealed good carbonate content. Table 4.27 summarizes the carbon and oxygen results. The highest carbon values measured on structural carbonate of ibex enamel are -10.63‰ and the lowest values are -11.96‰. The highest oxygen values measured on structural carbonate of ibex enamel are -2.62‰ and the lowest values are -6.05‰. Only in one case, a Spanish ibex lower right M3, I4-3427 (ISO-CP-low_8) compared with a Spanish ibex lower M3, right, H4-1792 (ISO-CP-mid_1), the latter had slightly higher mean values, with greater standard deviations of carbon and oxygen values.

Table 4.27: $\delta^{13}C$ and $\delta^{18}O_{PO4}$, $\delta^{18}O_{CO3,}$ $^{87}Sr/^{86}Sr$ values on structural carbonate and phosphate of two ibex tooth enamel from Level 17.

		$\delta^{18}O_{PO4}$‰VSMOW	$\delta^{13}O_{CO3}$‰VPBD	$\delta^{13}O_{CO3}$‰VPBD	$^{87}Sr/^{86}Sr$
I4-3427	min	17.0	-11.7	-5.4	0.708248
(ISO-CP-	max	19.0	-11.3	-4.0	0.708428
low_8)	mean	18.0	-11.5	-4.7	0.708334
	SD	0.6	0.1	0.5	0.000090
	amplitude	2.0	0.5	1.5	0.000180
	N samples	13	13	13	3
H4-1792	min	16.4	-12.0	-6.1	0.708370
(ISO-CP-	max	19.9	-10.6	-2.6	0.708404
mid_1)	mean	18.2	-11.4	-4.0	0.708387
	SD	1.2	0.4	1.1	0.000024
	amplitude	3.5	1.3	3.4	0.000034
	N samples	15	15	15	2

Silver phosphate precipitates from tooth enamel were measured in triplets (the average of three aliquots from the same sample) to improve precision and accuracy of measurements during analysis. In Appendix H Table, results of all $\delta^{18}O_{PO4}$ aliquot measurements are detailed. Table 4.28 summarizes the results of mean-phosphate values:

Table 4.28: $\delta^{18}O_{PO4}$ mean of analyzed triplet silver phosphate precipitate.

Species	**Code**	**$\delta^{18}O_{PO4}$‰VSMOW**				**Amplitude**	**Samples**	**Square-find number**
		min	max	mean	sd	max-min	n	
Horse	**ISO-EQ-low_1**	16.43	18.15	17.13	0.4	1.7	19	I3-5535
	ISO-EQ-low_2	16.61	17.70	17.23	0.3	1.1	19	J3-4681
Red deer	**ISO-CE-low_3**	16.01	17.02	16.61	0.4	1.0	8	I4-5083M3
	ISO-CE_low_4	15.97	17.57	16.70	0.6	1.6	9	I4-5083M2
	ISO-CE-low_5	16.59	18.59	17.50	0.7	2.0	9	H3-3510
Ibex	**ISO-CP-low_6**	15.85	18.16	17.05	0.8	2.3	16	H3-5278M3
	ISO-CP-low_7	16.23	18.24	17.32	0.8	2.0	11	H3-5278M2
	ISO-CP-low_8	17.00	19.00	18.01	0.6	2.0	13	I4-3427
	ISO-CP-mid_1	16.38	19.93	18.24	1.2	3.6	16	H4-1792
	ISO-CP-mid_2	15.78	18.89	17.34	1.0	3.1	17	J2-957
	ISO-CP-mid_3	17.41	18.69	18.27	0.4	1.3	14	H3-1648
	ISO-CP-up_1	16.74	19.46	18.12	0.9	2.7	14	I2-396
	ISO-CP-up_2	15.27	17.99	16.80	0.8	2.7	14	H3-872
	ISO-CP-up_3	16.37	19.46	17.94	1.0	3.1	15	H4-1061
All horse				17.18	0.39	1.72	38	
All red deer				16.95	0.71	2.62	26	
All ibex				17.67	1.00	4.66	130	
Total							194	

In bioapatite phosphate in enamel, the average of all triplet mean-phosphate values measured on horse are 17.18‰±0.39, red deer 16.95‰±0.71 and ibex 17.67‰±1.00. The strontium isotope results from horse teeth for sample I3-5535 are $^{87}Sr/^{86}Sr$ = 0.709062±31.89, $^{87}Sr/^{86}Sr$ = 0.709253±33.74, and $^{87}Sr/^{86}Sr$ =

0.709247±30.93, and for sample J3-4681 are $^{87}Sr/^{86}Sr$ = 0.709254±110.21, $^{87}Sr/^{86}Sr$ = 0.709167±100.43, and $^{87}Sr/^{86}Sr$ = 0.709260±33.82.

To explore broader isotopic signal trends, samples from each chrono-stratigraphic group were taken for isotope studies as explained in the Chapter 3 of Material and Methods. Samples coming from the Lower Magdalenian levels; from the stratigraphically lower (ISO-low_1-8 ~ lower part of Level 17), middle (ISO-mid_1-3 ~ middle part of Level 17) and upper (ISO-up_1-3 ~ Levels 16 and 15) unit (see Table 4.28) were compared statistically.

Phosphate oxygen isotope ratio variation, mean and density distribution were first examined to obtain an initial overiew of data distribution. According to the group factor species, data were tested for normality and the normal distribution of data is accepted accroding to the Shapiro-Wilk test results (horse: W = 0.97331, p-value = 0.4881; red deer: W = 0.95171, p-value = 0.2542; ibex: W = 0.99052, p-value = 0.5216). However, oxygen isotope ratio variation and density distribution vary between species, as illustrated in Figure 4.92. The data is tested subsequently by the group factor time among only ibex oxygen isotopic ratio variation. Multiple comparison is performed by one-way ANOVA to test the hypothesis, if the means of the different groups are the same based on the factor time. The one-way ANOVA test results show no statistically significant differences between chronologically different ibex oxygen isotopic ratio means as determined by one-way ANOVA ($F(2,127) = 2.727$, $p = 0.0692$). These overview results of mean signal differences between contemporary species indicate different perception of the environment for horse, red deer and ibex due to factors that need to be determined in what follows, which can be the existence of behavioral alterations, for example.

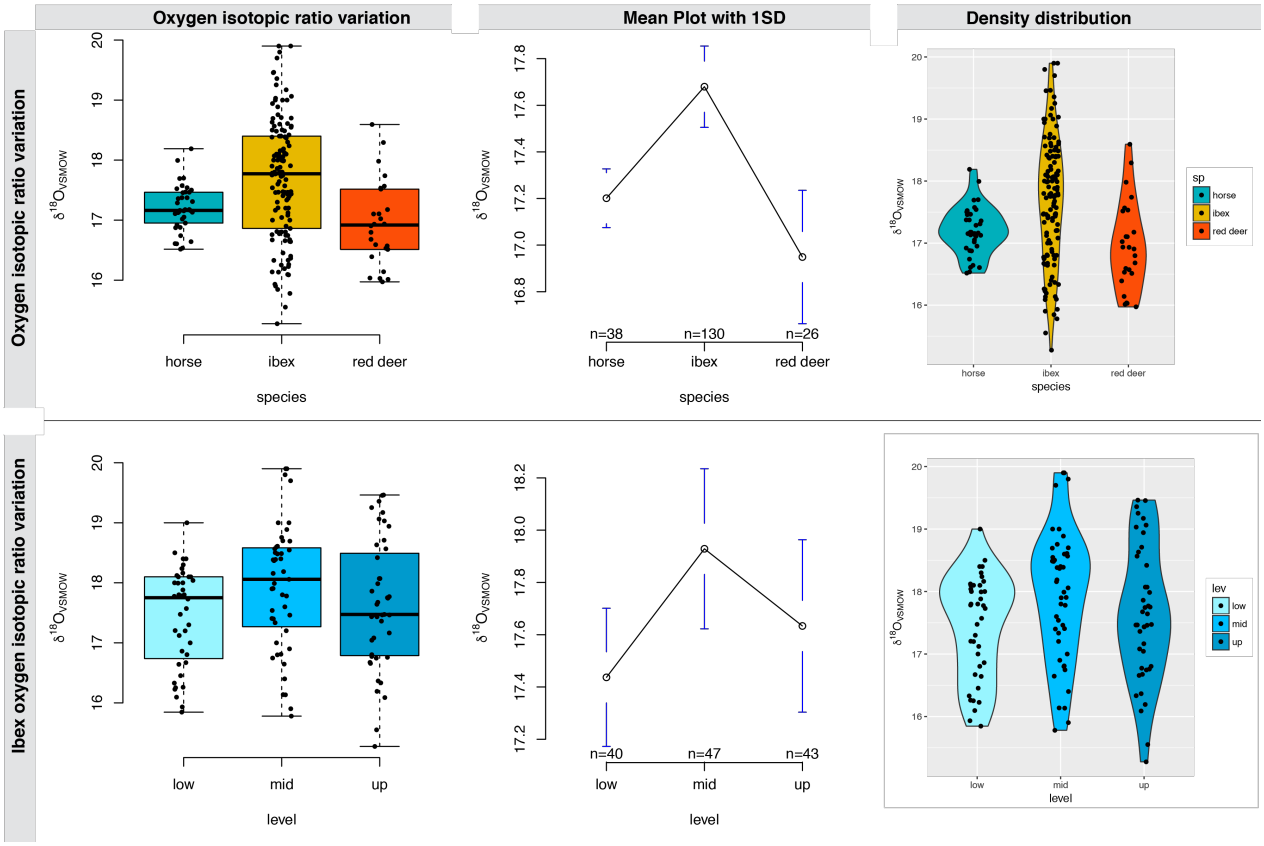
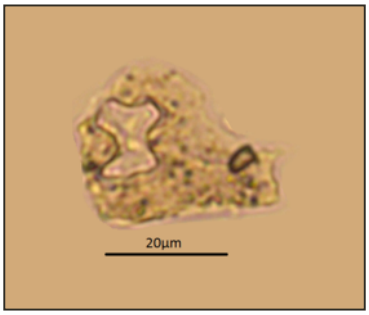


Figure 4.92: Phosphate oxygen isotope ratio variation, mean and density distribution by factor species (horse, red deer, and Spanish ibex) as well as by factor time for only ibex (low, mid, and up).

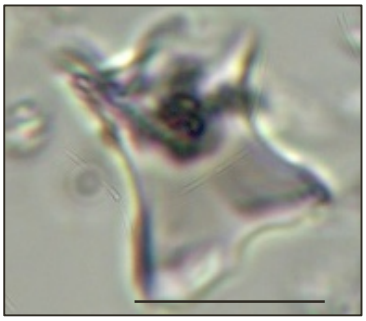
4.4.4 Phytolith results from herbivore dental calculus

Analysis of dental calculus were performed to refine the interpretation of the stable isotope studies. Analysis of dental calculus was performed on herbivore teeth and samples were prepared as described in the methods chapters. Phytolith sample digestion, phytolith extraction and identification under the microscope has been kindly realized by a specialist in this field of analysis (Dr. L.M. Hilbert who made the phytolith sample preparation and identification at the University of Exeter, England).

Dental calculus samples were analyzed from the teeth of one red deer, one large bovid, two horses and 19 Spanish ibex teeth from the Lower Magdalenian levels in the El Mirón Cabin area. All samples analyzed presented rare phytoliths, not only low in frequency but also in poor taphonomic condition, but some characteristic morphotypes were identified (Figure 4.93).



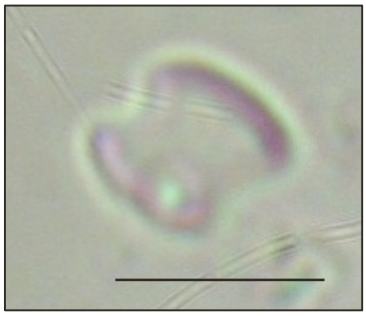
(A) Cross-shape phytolith from the leaf of Poaceae.



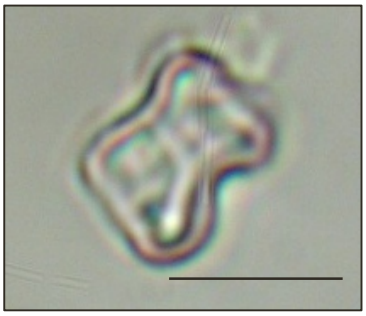
(**B**) Poaceae leaf rondel (phy-12)



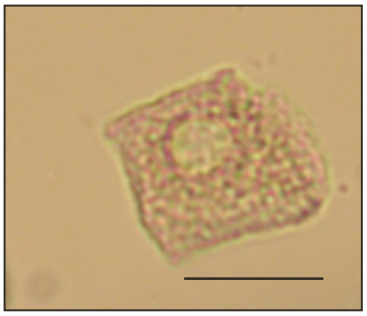
(**C**) Poaceae leaf bulliform (phy-12)



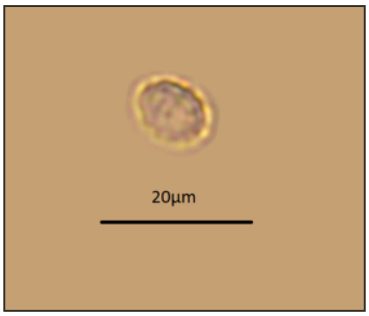
(**D**) Chloridoideae leaf short-saddle (phy-12)



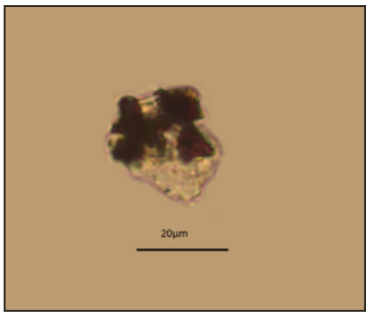
(**E**) Panicoideae leaf billobate (phy-12)



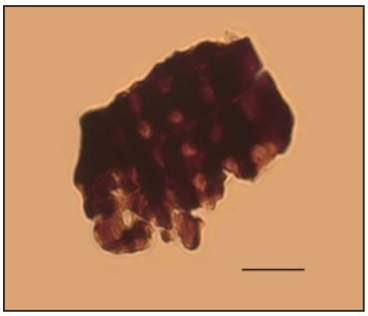
(F) Cyperaceae leaf achene body (phy-18).



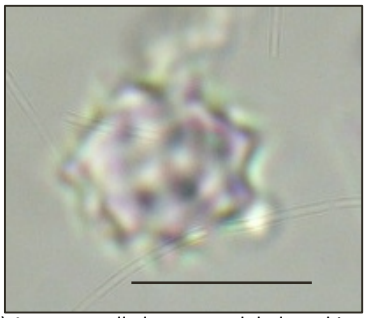
(G) conical to hat-shaped body produced in all parts of Arecaceae.



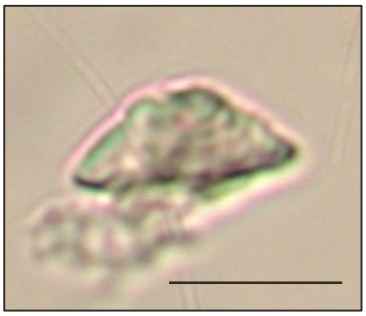
(H) opaque perforated body from the seed and inflorescence of Asteracae.



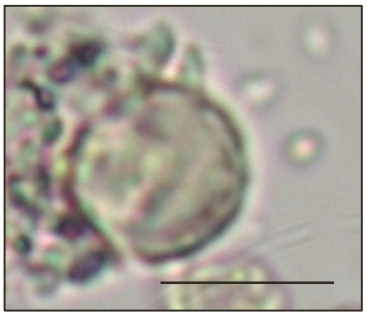
(J) opaque perforated platelet -body from the seed and inflorescence of Asteracae (PHY-5).



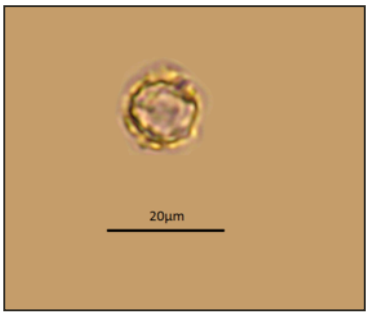
(**K**) Arecaceae all plant parts globular echinate (phy-10)



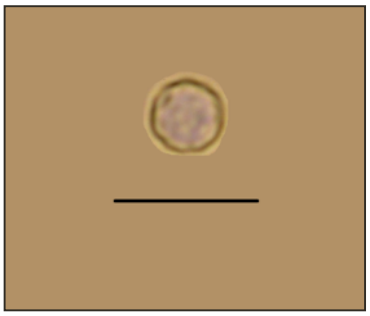
(L) Arecaceae all parts of plant conical to hat-shaped body (phy-12)



(M) Arboreal from all parts globular granulate (phy-22)

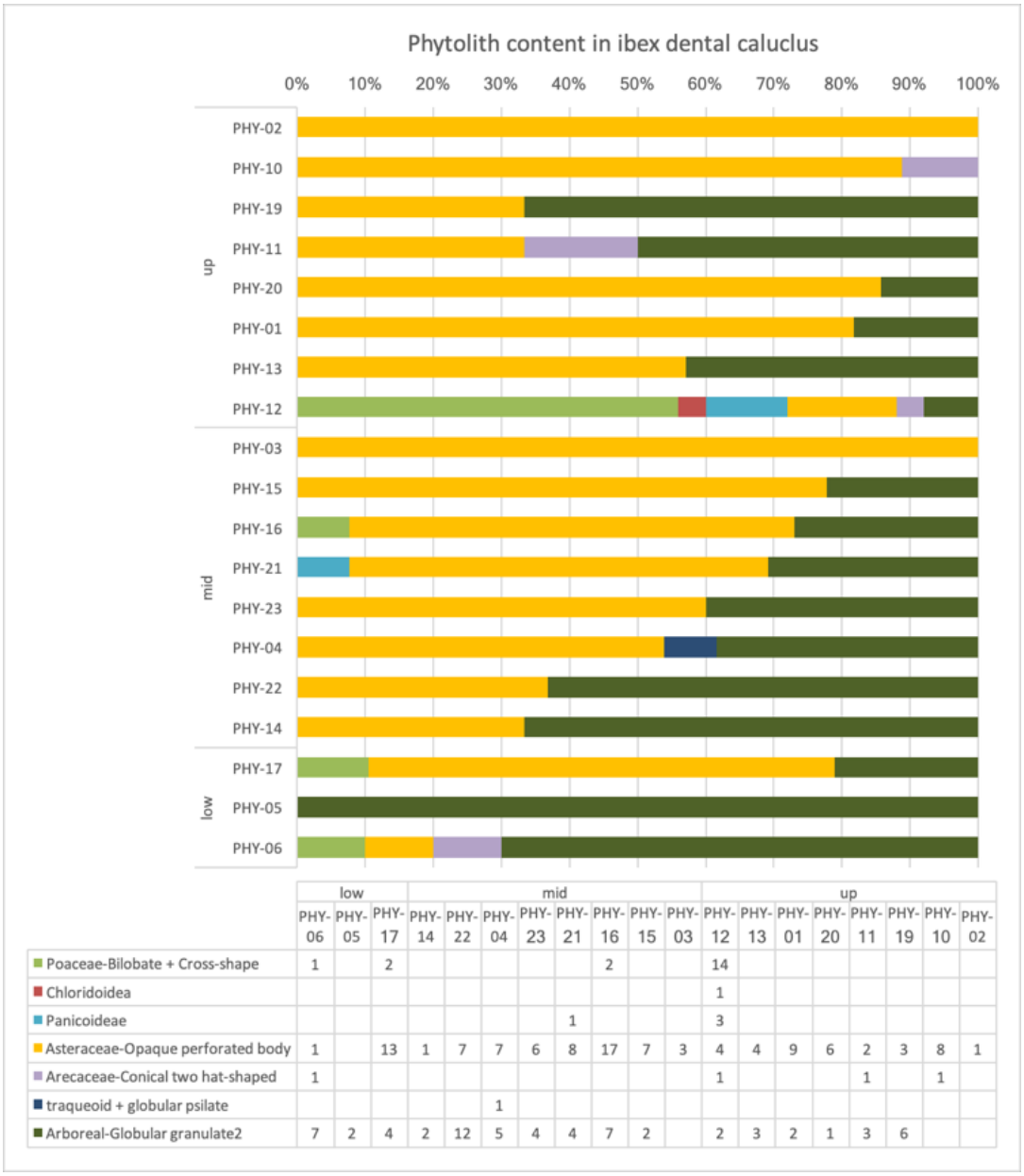


(N) Globular granulate from the wood of trees.



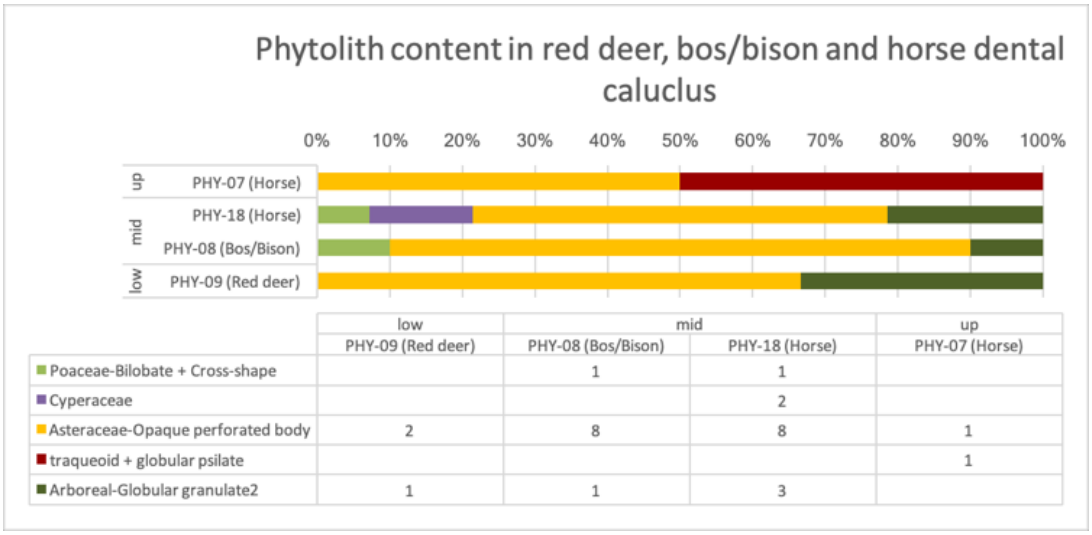
(O) Globular psilate non-diagnostic morphotype.

Figure 4.93: Microphotograph of phytolith and their taxonomic and anatomical associations from sampled teeth. Scales =20 µm. (Phytolith identification and photographs by L.M. Hilbert)



A

	low			mid								up							
	PHY-06	PHY-05	PHY-17	PHY-14	PHY-22	PHY-04	PHY-23	PHY-21	PHY-16	PHY-15	PHY-03	PHY-12	PHY-13	PHY-01	PHY-20	PHY-11	PHY-19	PHY-10	PHY-02
Poaceae-Bilobate + Cross-shape	1		2						2			14							
Chloridoidea												1							
Panicoideae								1				3							
Asteraceae-Opaque perforated body	1		13	1	7	7	6	8	17	7	3	4	4	9	6	2	3	8	1
Arecaceae-Conical two hat-shaped	1											1				1		1	
traqueoid + globular psilate						1													
Arboreal-Globular granulate2	7	2	4	2	12	5	4	4	7	2		2	3	2	1	3	6		



B

	low	mid		up
	PHY-09 (Red deer)	PHY-08 (Bos/Bison)	PHY-18 (Horse)	PHY-07 (Horse)
Poaceae-Bilobate + Cross-shape		1	1	
Cyperaceae			2	
Asteraceae-Opaque perforated body	2	8	8	1
traqueoid + globular psilate				1
Arboreal-Globular granulate2	1	1	3	

Figure 4.94: Phytolith content in herbivore dental calculus from lower (low), middle (mid) and upper (up) part of Level 17 of El Mirón. (A) Spanish ibex, (B) other herbivores.

Opaque perforated bodies from *Asteraceae* (flowering plants) were the most common morphotype identified, with the exception of PHY-05, this phytolith was present in all samples. The second most common type were arboreal (from trees) globular granulate. Samples PHY-12 and PHY-16 were the ones with the highest amount of phytolith diversity. Sample PHY-18 was the only one that had Cyperaceae (sedges, often growing on wet grounds) morphotypes, which was the dental calculus sample from the horse. Red deer had an insufficient number of phytolith for further interpretation, but among which were identified Asteraceae and arboreal ones. Also dominated by Asteraceae, the dental calculus from the large bovid [I.E., aurochs or bison] included also arboreal and Poaceae phytoliths. The amount of phytolith in each sample are summarized below, the graphs show percentage and each quantity is shown on the bottom (Figure 4.94).

4.4.5 Discussion of results

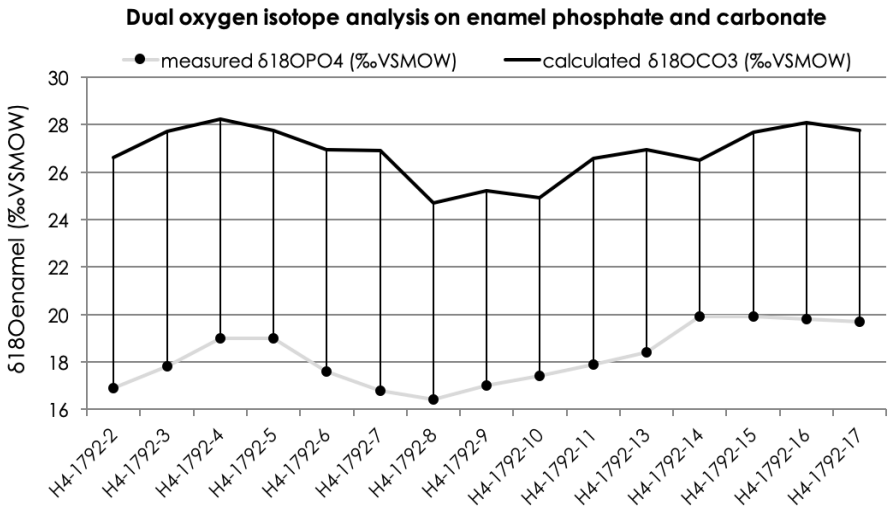
A. Diagenetic alterations of bioapatite

Before further discussion and interpretation on results, the presence and degree of diagenetic alterations of teeth needed to be tested. The diagenetic test was applied on two teeth of assumed different diagenetic states, based on only visual categorization of preservation (which is often the standard procedure for the selection of tooth for isotopic analysis). Sample H4-1792 (ibex lower M3) seemed diagenetically unaltered, while I4-3427 (ibex lower M3) appeared diagenetically altered as seen by the naked eye (compare photographs in Figure 4.95), by discoloration and by cracks.

The results were compared by the difference between measured $\delta^{18}O_{PO4}$ (‰VSMOV) and calculated $\delta^{18}O_{CO3}$ (‰VSMOV). The latter was calculated from the measured $\delta^{18}O_{CO3}$ (‰V-VPBD) after the conversion equation after Coplen 1988: $\delta^{18}O_{PO4}$ (‰VSMOV) = 1.03092[$\delta^{18}O_{CO3}$ (‰V-VPBD)] + 30.92. The result show a mean and standard difference for H4-1792 of 8.6‰±0.96 (Figure 4.95, A) and for I4-3427 of 8.1‰±0.50 (Figure 4.95, B). These values are within the range of what would be expected within diagenetically unaltered specimens, when compared with the modern mammal remains. The mean, relative constant fractionation factor between phosphate and structural carbonate is described in modern mammals by a difference of 9.1‰, suggesting discarding samples with offsets of <7‰ and >11‰ (BRYANT ET AL. 1996; MARTIN ET AL. 2008; PELLEGRINI ET AL. 2011; CHENERY ET AL. 2012; DOMINGO ET AL. 2015). Only two enamel samples, H4-1792-14 with 6.6‰ and I4-3427-3 with 6.7‰, have a lower difference than 7‰, thus potentially being contaminated samples.

H4-1792 (ISO-CP-mid_1)





I4-3427 (ISO-CP-low_8)



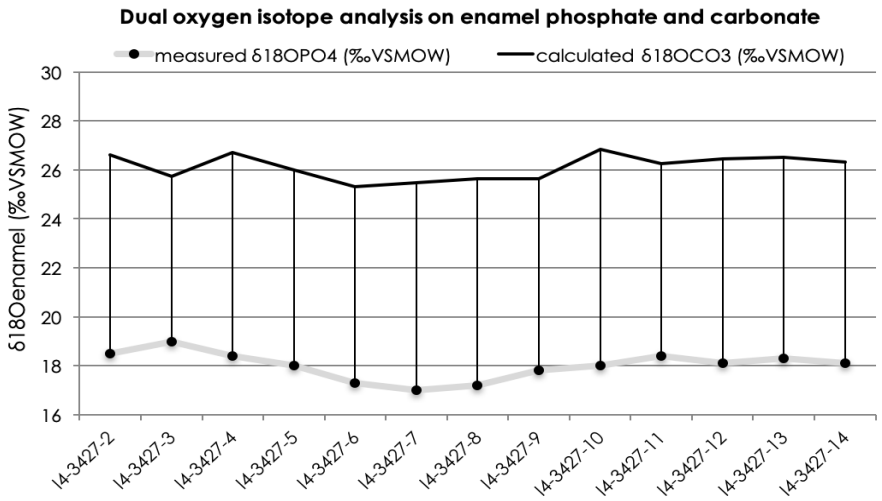


Figure 4.95: Diagenetic alterations test of isotopic results for difference of phosphate and carbonate. ‰VSMOW values were measured from phosphate group and calculated from carbonate group from ‰VPDB values. Intra-tooth sampling on ibex lower M3 from middle of Level 17 A) H4-1792(ISO-mid_1) and the lower part of Level 17 B) I4-3427(ISO-low_8).

The initial standard deviation in the H4-1792 is twice as high as in the I4-3427. Although, when subdivided, the first samples (H4-1792-2 to H4-1792-7) have an average of 9.51‰±0.51 and the following ones 7.99‰±0.63 (H4-1792-8 to H4-1792-17). This subdivision illustrate that a similar low standard deviation exists in one tooth, but with a different higher and a lower mean in the former single samples compared with the latter, respectively. The change of difference mean might be to the change in sampling technique applied after this first seven samples (Figure 4.96-A), where further samples were cut more rectangular into the enamel (Figure 4.96-B). Samples of a greater depth (Sampling B) might contain, additionally to the outer enamel, more of the middle and inner enamel layers, compared with more superficially taken samples (Sampling A), which fully mineralized at different times and might give more averaged values (ZAZZO ET AL. 2012; BLUMENTHAL ET AL. 2014; BENDREY ET AL. 2015). In consequence, mean values of the two teeth obtained with the same sampling technique contain similar oxygen values.

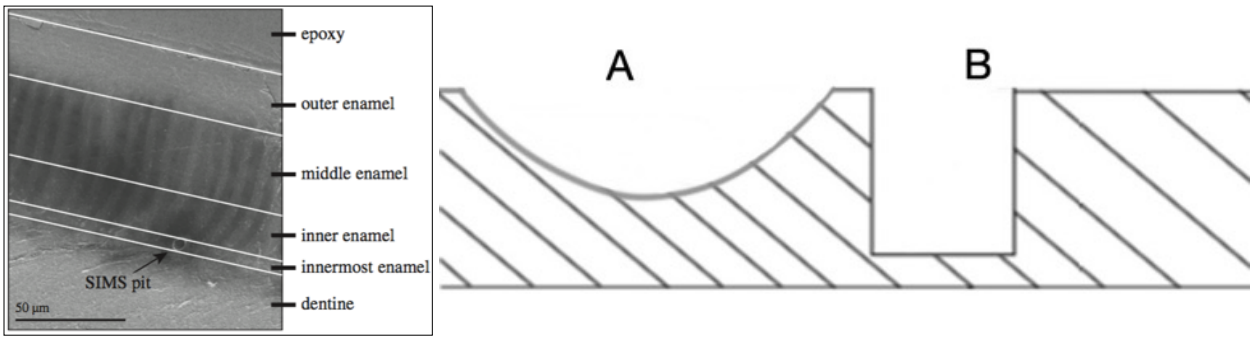


Figure 4.96: Left: Microscopic view of enamel layers in a tooth where outer, middle, inner and innermost enamel layers are visible (from Blumenthal et al. 2014). Right: example of enamel sampling techniques, (A) shallow and wider or (B) deeper and rectangular indicating the possible different amounts of enamel layers contributing to the sample.

Also, the relationship of $\delta^{18}O_{PO4}$ and $\delta^{18}O_{CO3}$ can be used to detect diagenetic alteration as they precipitate in equilibrium with the body water. The distance to the equilibrium line of $\delta^{18}O_{PO4}$ and $\delta^{18}O_{CO3}$ is correlated to growing bioapatite alterations. The results obtained show two groups (Figure 4.97). Isotopic signals lying to the left or right of the equilibrium line are assumed to indicate values that are diagenetically modified, due to the interaction with meteoric water, $\delta^{18}O$ enriched water (through evaporation) or depleted water (meltwater or high altitudinal rain) (IACUMIN ET AL. 1996). Diagenetic alterations are generally lower in tooth enamel than in bone, due to their larger crystal structure, but also lower in the phosphate compared with the structural carbonate component of the bioapatite. The large reservoir of oxygen is the phosphate and the oxygen bond stronger to the phosphate than the carbonate, making diagenetic alterations less likely (CHENERY ET AL. 2012). In consequence, the carbonate-oxygen is more liable to pervasive diagenesis and recrystallization of enamel results in a transition from biogenic hydroxylapatite to carbonate fluorapatite, a process that homogenizes the trend in $\delta^{18}O$ signals (BRYANT ET AL. 1996).

Results obtained when comparing the different sampling methods A and B, shallower and deeper drilling into the tooth enamel, respectively, are the following. Results from sampling A lie mainly to the right and those from sampling B to the left of the equilibrium line. Both show, however, overall minimal alterations which are within the normal range. These minimal alterations, although, seemed to shift $\delta^{18}O_{CO3}$ results slightly. A shift to the right side i.e., towards lower oxygen values could be obtained when carbonate had exchanged oxygen with $\delta^{18}O$-depleted waters. On the opposite, a shift to the left side towards higher oxygen values could be obtained when carbonate had contacts with $\delta^{18}O$-enriched waters. Having these two shifts represented, within the same tooth, needs further explanation.

One possible reason could be that cracks along the enamel allow enriched or depleted waters to react with the structural carbonate and affect these values. This case cannot be excluded as actually a superficial crack exist along the anterior part of the buccal tooth crown of H4-1792 (mid_1), although, it would be expected a shift of $\delta^{18}O_{CO3}$ values in one direction or the other and not in either way. Another explanation could be that the water in which the tooth might have soaked (in the Cabin area, but unlikely as sediments did not standing waters in the area) changed from depleted to enriched, or *vice versa*. In this case, the different enamel layers (out, middle, inner) might be affected temporarily in a different way due to varied porosity.

A second explanation could be that the tooth was soaked in depleted water (from high altitudinal rains or meltwater), which later evaporated (enriched). In this scenario, however, the existence of larger amounts of

surface water would be expected, which is not supported by other finds in this specific layer, since the Cabin area is the part of the cave where dry sediments dominate (FARRAND 2012).

A third scenario would be that human activities changed these values. Food cooking and boiling activity may have changed the isotopic composition. For example, when cooking the tooth inside the mandible (actually rich in bone marrow), the outer part of the enamel would be most affected. The outer enamel carbonate could then be depleted through cooking activity, as cooked meat normally shows depleted oxygen values (DAUX ET AL. 2008; ROYER ET AL. 2017). To elucidate the latter scenario more research is needed, especially in the context of the Lower Magdalenian levels in El Mirón cave, where cooking stones (NAKAZAWA ET AL. 2009) were found in the same layers as the analyzed ibex teeth. Indeed, fire-cracked rocks, charcoal and hearths are very abundant especially in these levels.

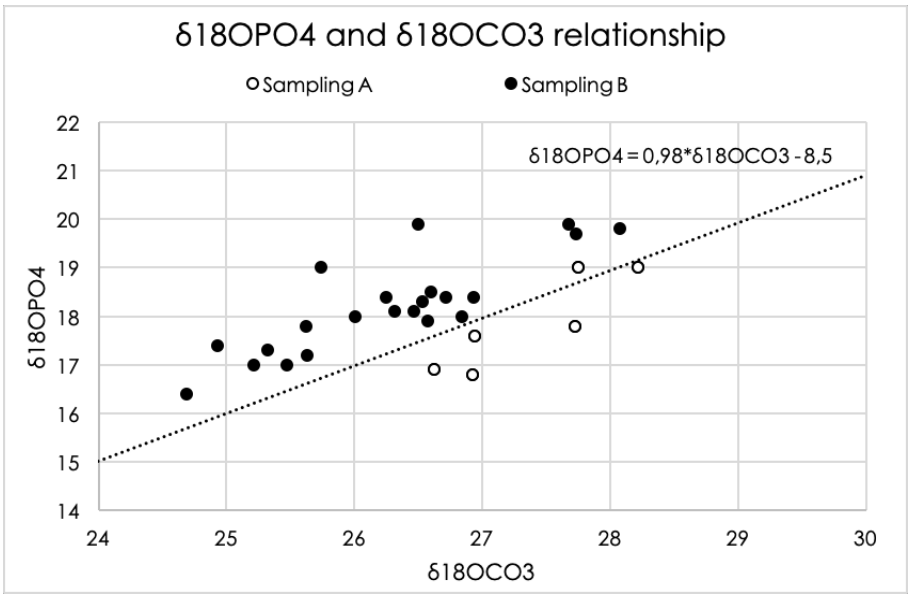


Figure 4.97: Correlation of $\delta^{18}O_{PO4}$ and $\delta^{18}O_{CO3}$ in ibex sample H4-1792 show limited diagenetic alterations in reference to the best fit relationship (IACUMIN ET AL. 1996). Differences in sampling technique, however, are reflected.

The obtained fractionation factor observed between $\delta^{18}O_{PO4}$ and $\delta^{18}O_{CO3}$, nevertheless, it might be typical for Spanish ibex bodies, as the fractionation factor depends on body temperature, however more investigations are needed here.

Despite these observations, the carbonate-phosphate difference seemed to fall within the expected limits of unaltered enamel, further analysis and interpretations were done on the phosphate group within the bioapatite of tooth enamel. The results from the structural carbonate do not suggest vast post-depositional diagenetic alteration of the $\delta^{18}O_{CO3}$ and the oxygen values obtained from the carbonate can be further interpreted. This interpretation is coherent with previous observations from the Lower Magdalenian in the Cabin area of El Mirón Cave, which show minimal diagenetic alterations and find contexts that have been referred to as being well-preserved (GEILING ET AL. 2016; STRAUS ET AL. 2018).

B. Habitat reconstruction from isotopic results

In absence of major diagenetic changes, basic habitat reconstructions can be made based on the assumption that results from carbon and oxygen analysis on structural carbonate of teeth reflect mean values of isotopic compositions of inhabited dwelling areas in the Cantabrian region. In El Mirón Lower Magdalenian levels ibex

teeth (N=2) averaged carbon values were -11.5‰±0.1 and -11.4‰±0.4 and averaged oxygen values were 26.1‰±0.5 and 27.1‰±1.5.

There are only a few datasets of tooth enamel carbonate analysis available in the region for comparison of the same moments from La Paloma cave (Asturias, Spain), with the caveat that the site has a lowland plain, non-montane location very different to El Mirón. The La Paloma stable isotope report covers the Lower, Middle and Upper Magdalenian, which is the period most closely related to the ones under study from El Mirón, from which a habitat reconstruction of the present results might be inferred in comparison. Figure 4.98 compares stable isotope carbon and oxygen ranges of ibex for El Mirón with published isotopic signals from La Paloma (DOMINGO ET AL. 2015).

In El Mirón Lower Magdalenian levels, averaged carbon values of the same samples from El Mirón have slightly lower carbon values (N=2;-11.5‰±0.1 and -11.4‰±0.4) compared with La Paloma (N=7;-10.3‰±0.5) (DOMINGO ET AL. 2015). The La Paloma carbon results were interpreted by the authors (DOMINGO ET AL. 2015) as coming from Spanish ibex that were hunted in a woodland to woodland mesic-C3 grassland. The ibex from La Paloma lay within the range of highest mean carbon values of horse/red deer and lowest mean carbon values of Bos/Bison, suggesting separated dietary niches or habitats.

In El Mirón Lower Magdalenian levels, the averaged oxygen values (26.1‰±0.5 and 27.1‰±1.5) of ibex (N=2) are similar compared with La Paloma ibex (N=7) oxygen values (26.3‰±0.6) (DOMINGO ET AL. 2015), which would be suggested when they are contemporary. According to habitat, ibex can be nicely separated from horse and red deer values according to higher oxygen values in La Paloma. In El Mirón, the slightly younger sample H4-1792 (17-8) has a higher mean as well as a higher standard deviation in oxygen values, which in consequence might indicate that this individual had occupied a different habitat than the others. It shows a wider habitat variation, which possibly is related to migratory mobility of the animal. From an eco-ethological point of view (and for future research), it would be interesting to see whether these differences are due to sexual based behavioral- dimorphism as males are expected to carry out larger annual movements (ACEVEDO & CASSINELLO 2009).

The $\delta^{18}O_{enamel}$ results from El Mirón correspond to published values for Eurasian Pleistocene ungulates (BOCHERENS ET AL. 1995; ECKER ET AL. 2013; RIVALS ET AL. 2015). According to the lower $\delta^{13}C$ enamel values, El Mirón ibex would have dwelled in a slightly more wooded or more humid habitat or have had more browsing-dominated diets than ibex in La Paloma cave during the Lower Magdalenian. This is inferred from the knowledge that depletion of carbon values can occur due to soil respiration and low-light photosynthesis in forested areas where plants produce more negative values due to less water evaporation also known as the canopy effect (VAN DER MERWE & MEDINA 1991; DRUCKER ET AL. 2008) and more leaf-based diets produce lower $\delta^{13}C$ values in mixed feeders (CERLING ET AL. 1999). The slightly higher $\delta^{18}O_{enamel}$ values of the one individual from El Mirón then infer that this individual was living at either different altitude, distinctive canopy, varied aridity zones, or under general distinctive, non-contemporary climatic conditions of a warmer-more humid climate. Increased browsing activity could have also evaluated $\delta^{18}O_{enamel}$ values (KOHN 1996).

The relationship of carbon values in species could also represent that Bos/Bison were living in different micro-environments than horse and red deer, and ibex practices wider diets as other species consuming C3 plants growing in a mixed environment or moved regularly between different habitats (CERLING & HARRIS 1999; BOCHERENS 2003; DRUCKER ET AL. 2008). The ibex environmental adaptability was recently demonstrated in analysis at La Riera Cave (JONES ET AL. 2020).

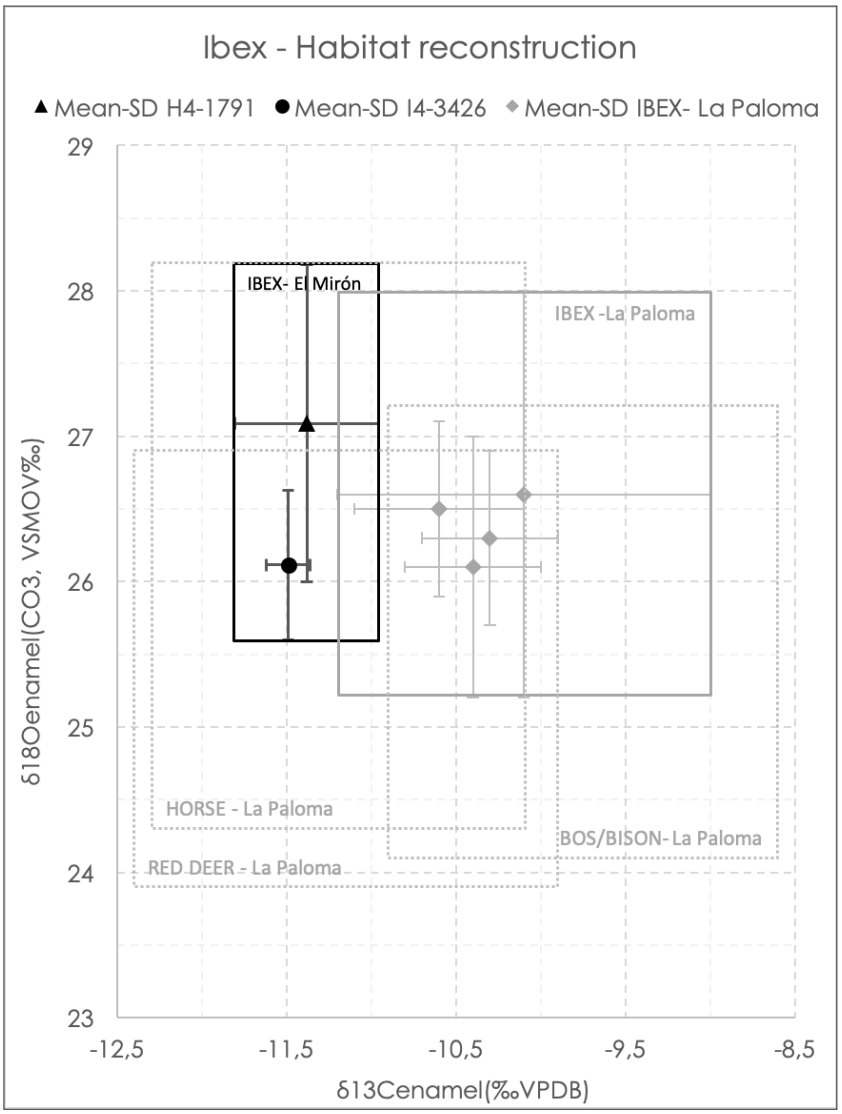


Figure 4.98: Spanish ibex (triangle=H4-1792, circle=I4-3427) habitat reconstruction based on carbon and oxygen from El Mirón in comparison to La Paloma (squares=ibex) isotopic results (in light grey: data extracted from DOMINGO ET AL. 2015).

It is also known that untreated fossil materials are slightly depleted in $\delta^{18}O$ and enriched in $\delta^{13}C$ compared to fully pretreated fossil enamel (ROWLAND 2006), which could apply here as material was studied untreated. Although, the tooth enamel samples studied here show shifted values compared to La Paloma, they show a shift into the opposite direction than untreated materials, inferring that the original differences could have been even stronger, if this effect applies.

The general habitat interpretation is supported by the unpublished carbon and nitrogen results of stable isotope analysis on ibex bone collagen undertaken by Dr. J. Jones (personal communication, June 2019) at El Mirón, while samples from Levels 15, 16 and 17 representing mainly the end of the Lower Magdalenian occupations at the cave. $\delta^{13}C_{collagen}$ and $^{15}N_{collagen}$ and results indicate that these ibexes were living in dry and cold environments of low soil activity, conforming environmental deteriorations occurred or continued during the course of the Lower Magdalenian. Published results from El Mirón for comparison from red deer bone collagen analysis of carbon and nitrogen are for Late Middle Paleolithic Corral Level 130 at -20.0‰$\delta^{13}C$ and 4.0‰$\delta^{15}N$ (N=2) (MARÍN-ARROYO ET AL. 2018a). There average is for Solutrean Corral Levels 121-127 at -20.3‰$\delta^{13}C$ and 2.4‰$\delta^{15}N$ (N=13), for Lower Magdalenian Cabin Levels 15 to 17 at -20.2‰$\delta^{13}C$ and 2.9‰$\delta^{15}N$ (N=18), for Middle Magdalenian Cabin Levels 13 and 14 at -20.2‰$\delta^{13}C$ and 2.8‰$\delta^{15}N$ (N=7), for Upper/Final Magdalenian Cabin Levels 11 and 12 at -20.3‰$\delta^{13}C$ and 3.1‰$\delta^{15}N$ (N=11), and for Mesolithic Cabin Level 10.1 (STEVENS ET AL. 2014) at -20.5‰$\delta^{13}C$ and 4.5‰$\delta^{15}N$ (N=1). These results indicate that red deer were

consuming C3 plant in an open landscape and soil activity was reduced during Solutrean and Magdalenian occupations under glacial conditions. However, higher nitrogen values measured on red deer and ibex from more lowland and coastal locations, at La Paloma and La Riera for example (DOMINGO ET AL. 2015; JONES ET AL. 2020), remark the mosaic structure of the Cantabrian landscape during that time.

Although this analysis is truly a tiny sample and not justify much generalization, it is a starting point especially towards reconstructing the local, perhaps very different environments of (El Mirón) catchment areas around specific sites that may have influenced which subsistence strategies and land use pattern was applied. More analysis is needed and future work in stable isotope analysis (especially the future publications from Dr.J. Jones & Dr.A.B. Marín-Arroyo) will be great value for better understanding the patchiness of environments in the Cantabrian region.

C. Inter-species oxygen variability in enamel phosphate.

Before analyzing in detail intra-individual oxygen results obtained from El Mirón cave, it is worth mentioning the few published data from the Cantabrian region on tooth enamel origin. These include ones that were done in La Paloma Cave (DOMINGO ET AL. 2015) and were used for reconstructing a baseline of oxygen signals in this particular region, since oxygen measured on the enamel phosphate fraction is rare in Paleolithic samples. New results were also published from studies on horse teeth from the Middle to Upper Paleolithic transition at El Castillo and Covalejos caves (JONES ET AL. 2019).

Almost all oxygen value variability of the El Mirón and La Paloma samples seem to fall within similar ranges, while the Upper Magdalenian dataset shows slightly lower $\delta^{18}O$ values at La Paloma (Figure 4.99). A phenomenon that is probably indicating broader climatic regime changes such was the reactivation of the Meridional Overturning Circulation (MOC) around 14.5ka when a warm-humid climatic regime was established in the northern Iberian Peninsula (DENTON ET AL. 2006; DOMINGO ET AL. 2015). The before near-shutdown of the MOC during the "Mystery Interval" from 17.5ka to 14.5ka (DENTON ET AL. 2006: p.14) caused severe colder and drier climate conditions.

While exhibiting a much smaller standard variation, horse mean oxygen values from El Mirón cave (mean=17.2±0.4‰) match the general distribution of horse oxygen values obtained from the Lower and Middle Magdalenian levels of La Paloma (mean ~17.4±1.2‰).

At Paloma cave, all red deer mean oxygen values seem to cluster narrowly (mean=17.5±0.8‰), but El Mirón samples show lower mean values (mean=16.9±0.6‰). Animals from both archaeological sites seem to have similar $\delta^{18}O$ variations, despite the specimen of undetermined origin from Paloma cave.

Among the large bovids, *Bos primigenius/Bison priscus*, mean oxygen isotopic values decrease steadily with time from the Lower to the Upper Magdalenian in La Paloma. Chamois shows high intra-individual variability (mean=17.6±1.6‰), which might be explained behaviorally by this animal's altitudinal movements in the montane zone, which contrasts with the larger bovid values from La Paloma, that exhibit small variations. Ibex oxygen isotopic results from El Mirón (mean=17.7±0.8‰) differ remarkably with what has been reported from La Paloma during the Lower and Middle Magdalenian (mean=19.1±0.5‰). The Upper Magdalenian $\delta^{18}O$ values (mean=17.8±0.5‰) from La Paloma, although, are located within similar ranges to El Mirón Lower Magdalenian ones, but show less variability. There are different explanations:

One explanation could be that El Mirón ibex could obtained water by drinking rather than through dietary intake of enriched plant waters as it happens in those ibex from La Paloma, but caprines are normally non-obligate drinkers.

An opposite suggestion would be that rapid climatic changes manifested two different climates (a drier and a more humid one) for ibex during a relatively well-defined short cultural period (Lower Magdalenian El Mirón Level 17: 15.7 to 15.4ka uncal BP and La Paloma Level 8: 14.6ka uncal BP).

Another possible explanation would be that ibex at El Mirón experienced a more humid environment (that produced more depleted $\delta^{18}O$ values) at the time when ibex in the surrounding of La Paloma ibex lived in a drier environment, maybe due to inhabiting varied micro-environments of more closed valley floor locations *versus* more open landscapes. Since La Paloma (~29.5km) and El Mirón (~32.9km) had similar distances to the -120m-LGM-shore, the reason for different micro-environments might have been variation in the location of precipitation as suggested in recent climate reconstruction for Iberia (LUDWIG ET AL. 2018; Fig.6). Maybe it was generally drier in Asturias. Humidity, in the surroundings of El Mirón, then might be comparable to that of the La Paloma ibex during Upper Magdalenian (DOMINGO ET AL. 2015), as seen in isotope changes towards the transition to Holocene climates. Within a dry and cold environment, water availability could be locally different; for example, meltwater from the mountains would be seasonally abundant in periglacial zones.

For improving such habitat reconstructions during the periods when humans occupied the sites, further stable isotope analyses on ibex tooth and bones from more sites, as well as in the other animals present in the site would be useful for refining the interpretation proposed here.

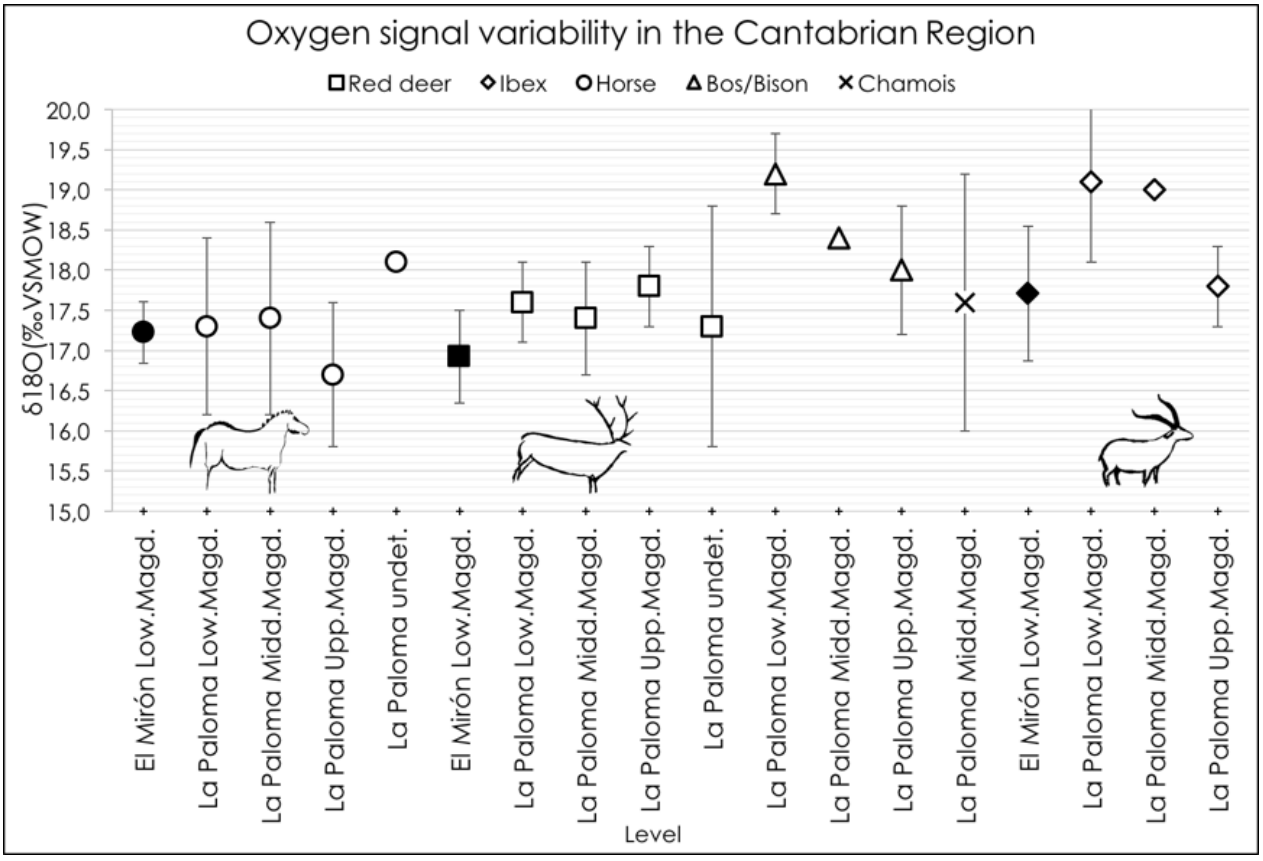


Figure 4.99: Comparison of $\delta^{18}O$ mean values with errors obtained on carbonate teeth enamel from ibex, horse and red deer at El Mirón cave (filled symbols) and La Paloma (open symbols) (DOMINGO ET AL. 2015).

Inter-individual oxygen variation of obligate drinkers was compared. Whether the Cantabrian region provides strong-enough seasonal conditions as are required to be registered in tooth bioapatite has been tested in this work. Strong seasonality exhibits characteristic seasonal fluctuations in the isotopic composition of

drinking water or plant water that is recorded during tooth mineralization (PASSEY & CERLING 2002, 2004; KOHN 2004). The isotopic composition can be obtained by incremental sequential samples of enamel with results being expressed as $\delta^{18}O$ enamel (‰VSMOW) reflecting precipitation, alongside food, air and physiology (KOHN ET AL. 1998; KOHN & CERLING 2002). The oxygen signal in the tooth enamel is delayed and dampened compared to the original oxygen signal through turnover time in the body and the process of enamel mineralization (PASSEY & CERLING 2002; KOHN 2004).

Results of El Mirón horse oxygen values include slightly different maxima (ISO-EQ-low_1=18.2‰, ISO-EQ-low_2=17.7‰) and minima (ISO-EQ-low_1=16.5‰, ISO-EQ-low_2=16.6‰) and comprise a difference of curve amplitude (=variation; ISO-EQ-low_1= 1.67‰ and ISO-EQ-low_2=1.09‰). The minima of both teeth are located at similar levels, while the maximum of sample ISO-EQ-low_1 is higher than of ISO-EQ-low_2 (Figure 4.100). Sample ISO-EQ-low_1 is a M2 and the beginning of the oxygen values sequence might be shifted by the lactation period perhaps overlapping with the first month of the mineralization of M2 (HOPPE ET AL. 2004).

Less oxygen signal variation is expressed in the horse enamel of El Mirón compared with La Paloma cave, which might reflect individual behavioral or other reasons. While the general environment and larger seasonal changes should be similar during the Lower Magdalenian period, the environmental oxygen signal might have been dampened in this species, meaning the signal strength is lowered. In different species, isotopic signals are dampened depending on mineralization rates, metabolism, specific diet or physiology (KOHN ET AL. 1996; FRICKE ET AL. 1998; BALASSE 2002; PASSEY & CERLING 2002; HOPPE ET AL. 2004; ZAZZO ET AL. 2005) and seasonal mobility (BRITTON ET AL. 2009).

Different explanations for the present observations in El Mirón are possible:

Animals could have used distinct sources of drinking water such as larger waterbodies. While such mixing of drinking waters can also occur in large river systems, the modern drainage systems along the Cantabrian coast are rather 'short' and fed by abundant rainfall and waters run torrentially. Then if low altitude lakelands in the coastal plain could represent seasonally unvarying pools of water for horses to drink is questioned. A large water body such a lake, where seasonal waters are mixed, is unlikely to be the cause of low variability as there is no lake located in the proximity of the site (or anywhere in the entire region), there are no known lakes in the coastal area or in today-submerged lands. It is also possible that there was generally not much water running down the rivers, and very slow drainage mixed seasonal signals.

Animals could have been migratory. Some animals exhibit seasonal mobility that avoids full seasonal exposure, for example to snow in winter (BRITTON ET AL. 2009). Possible migration routes (for animals as well as for humans) in the Cantabrian region, given the local topography that forms natural barriers, would have been either along the coastal west-east corridor or several north-south connections from the sea to the mountains (and up to the Castillian plateau) along the river valleys to relatively low passes. Analysis of seasonal strontium variation is useful to determine if seasonal migration was exhibited from Pleistocene horses in the Cantabrian region. Such analysis was performed for these horse teeth and results are discussed below.

Imbibed waters do not reflect precipitation. Local maxima of high $\delta^{18}O$ recorded within the oxygen curve of the second molar correspond to positions locations in the tooth (according to mm from Enamel-Root-Junction=ERJ) that reflects winter values (BENDREY ET AL. 2015). It is common to expect that horse oxygen values would correspond to water consumed from local rivers, lakes or ponds (LONGINELLI 1984; LUZ ET AL. 1984; KOCH 1998; KOHN & CERLING 2002). In the Cantabrian region, these waters might not only represent oxygen values of annual precipitation (thus representing seasonal variation in rainfall), but might have included meltwater contributions of depleted oxygen values during summer times, especially in the period

after the LGM. This inversion of the $\delta^{18}O$ signal can be retrieved by imbibing glacial melt-water during summer seasons (GAT ET AL. 2001: p. 63). The origin of the stable isotope sample results from a period known as the "Mystery interval" (MORENO ET AL. 2012: p. 148), spanning the Lower and Middle Magdalenian, after the Last Glacial Maximum, which was characterized as the most arid and coldest period of the Late Glacial in northern Iberia. Aridity implies reduced rainfall intensity. Depleted melt-water might have been admixed into and contributed to groundwater and available drinking water sources (UNNIKRISHNA ET AL. 2002; MCGUIRE & MCDONNELL 2008) and, thus, being the origin of lower $\delta^{18}O$ mean values for horses. Glacial stability at the headwaters might have given rise to less alternating fluvial $\delta^{18}O$ values. The 'Mystery Interval' was a period of extensive winter sea-ice and warming summer conditions that fueled the slow retreat of mid-latitude mountain glaciers such as the one on Castro Valnera not far from El Mirón (DENTON ET AL. 2006). Further analysis on strontium variation in horse teeth, as well as more oxygen analysis would help to enlighten these issues.

Inter-individual oxygen variation of non-obligate drinkers was compared. Herbivore bioapatite varies in relation to their water physiology. Red deer, as a non-obligate drinker and as a mixed feeder, is a presumed consumer of $\delta^{18}O$ enriched plant food and displays enriched oxygen enamel values. Plants are usually isotopically enriched in $\delta^{18}O$ values compared to meteoric freshwater, because plant water evaporation (LUZ ET AL. 1990; AYLIFFE ET AL. 1992) and their isotopic composition follow general surface water trends and seasonal humidity effects (KOHN ET AL. 1998).

However, the results in El Mirón of mean oxygen signals in red deer (mean=16.9±0.6‰) are lower than in horse during the Lower Magdalenian. Although oxygen values follow seemingly perfect parts of sinusoidal curves, red deer show greater variability in oxygen values than what was observed in horse tooth enamel (Figure 4.101). Slightly depleted oxygen values might have been caused by red deer dwelling in either higher altitude, micro-environments of closed valley floors or in locations even further inland (MCGUIRE & MCDONNELL 2008). However, whether these effects are large enough to produce such larger shifts in the isotopic record is still questioned. Different reasons might have triggered these results.

Valley floors might had more (semi)-wooded areas along the river banks, possible small arboreal refugia, as reflected in micro-mammal analysis (CUENCA-BESCÓS ET AL. 2009), or restricted access to plants located in the riparian zone, compared to the coastal or montane area. Within these river valleys, more humid conditions might be present as they are more protected areas under generally harsh climatic conditions that allowed tree growth and provided potential leafy fodder for ungulates (BALASSE ET AL. 2012).

As the general climate seem to have been exceptionally dry during this period (MORENO ET AL. 2010), plant growth might have depended on groundwater or water originating from meltwater drainages along the mountainsides during summers (DENTON ET AL. 2006). These periglacial ecotones might be areas drained with melting waters and plants growing on melting water or groundwater would obtain general lower oxygen values than when based on meteoric water. Ingested plants, then, could theoretically display more depleted values than expected, although these plants originally had increased $\delta^{18}O$ signals through evaporation and may obtained some meteoric water seasonally. However, this effect might be also altered by higher plant enrichment in grasses than tree leaves, for example, and value shifts might be generally low.

Another explanation would be that red deer were hunted during different periods of generally colder or humid conditions or that different hunting locations had their own iso-zones according to local micro-environments, for example, beyond the watershed-line (MCGUIRE & MCDONNELL 2008) of the Cantabrian Cordillera located not very far to the south of El Mirón Cave on the *meseta* of Burgos.

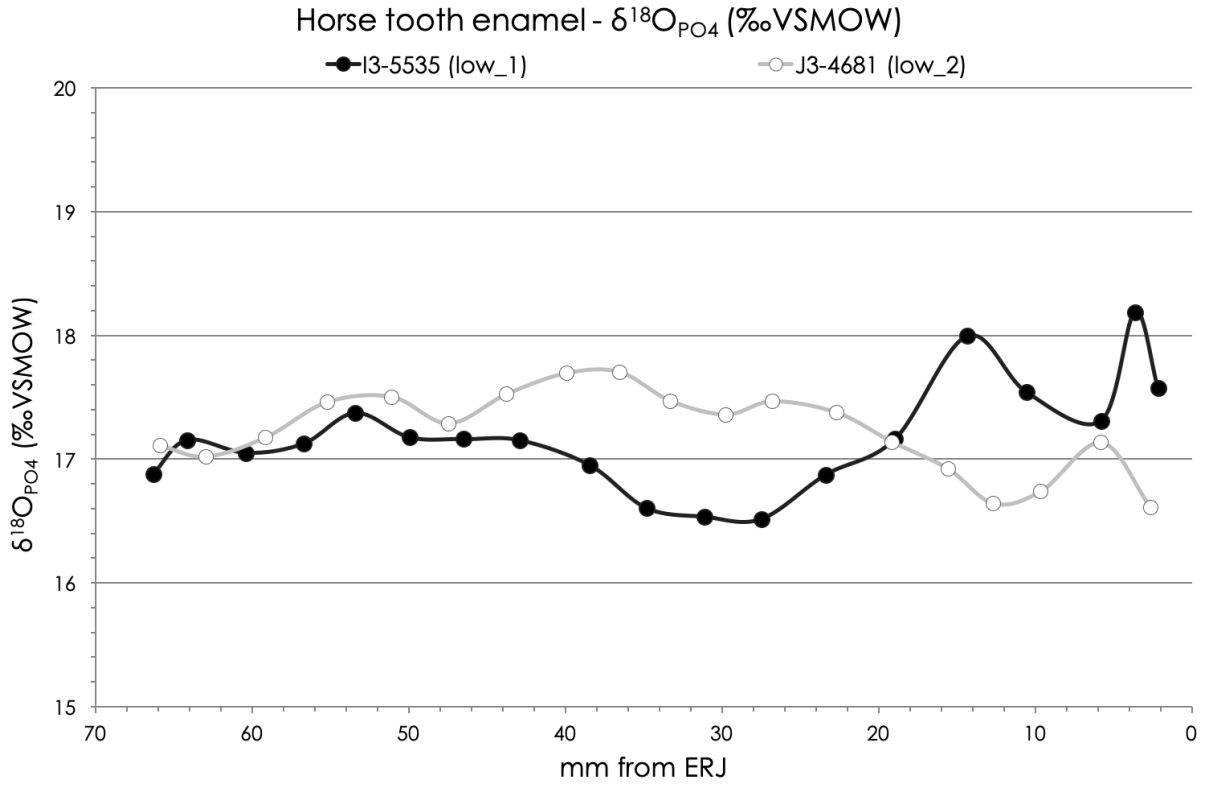


Figure 4.100: Horse intra-tooth variation of $\delta^{18}O$ values from Lower Magdalenian level 17 in El Mirón cave. Data are plotted against the relative position against the ERJ (Enamel Root Junction), which represents time.

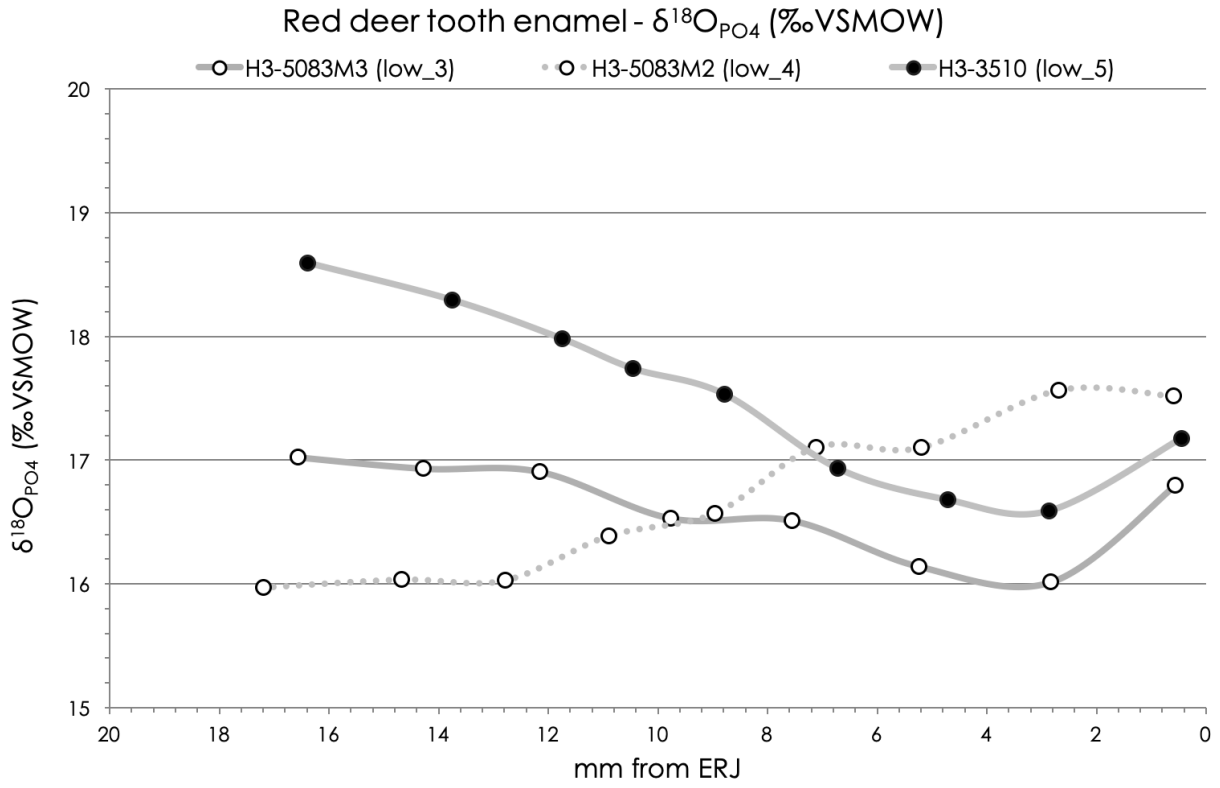


Figure 4.101: Intra-tooth variation in $\delta^{18}O$ for red deer tooth enamel from Lower Magdalenian Level 17 of El Mirón cave. Data are plotted against the relative position against the Enamel-Root-Junction (ERJ), which represents time.

Most of the sampled ibex teeth show a sinusoidal curve pattern on the oxygen values (Figure 4.102) as expected when seasonal fluctuations are strong enough to be recorded during tooth mineralization (PASSEY & CERLING 2002, 2004; KOHN 2004). The curve of $\delta^{18}O$ records of tooth enamel would reflect seasonality, with two high peaks and one trough in between, from over more than a year of time of initial enamel mineralization in lower M3 teeth. In ibex teeth, peak values of lower M3 would correspond to the third and fourth summer of the animal's life, and the first peak in lower M2 would stand for the second summer of the animal's life (BALASSE ET AL. 2012).

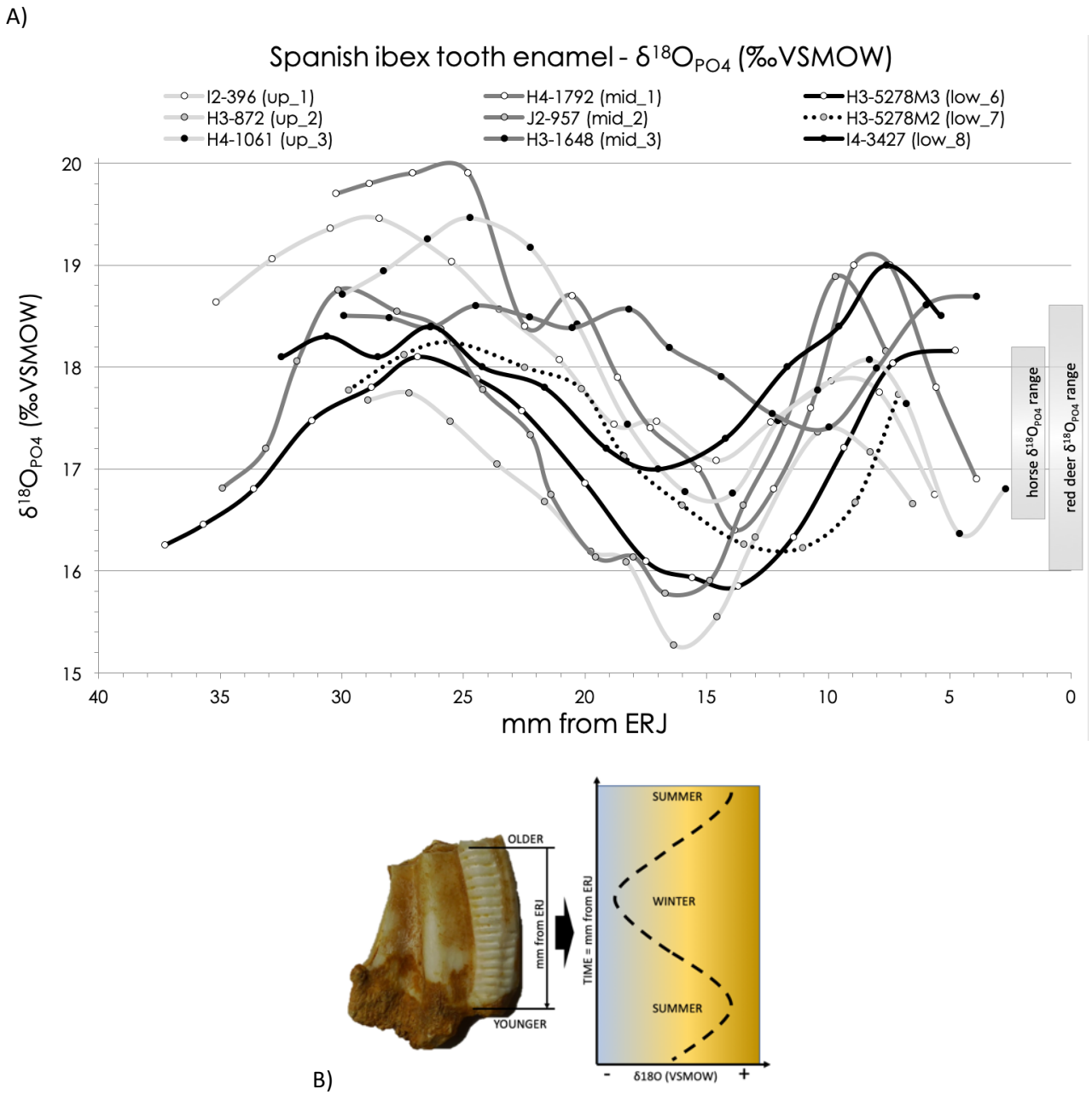


Figure 4.102: Intra-tooth variation in $\delta^{18}O$ for Spanish ibex tooth enamel from Lower Magdalenian Level 17 (lower and middle samples), 16 and 15 (upper samples) of El Mirón cave. Data are plotted against the relative position against the ERJ, which represents time. Oxygen curve: A) Lower Magdalenian ibex from El Mirón; B) expected sinusoidal oxygen variation curve.

In lower M3, the lowest $\delta^{18}O$ values, corresponding to the ibex's third winter of life, were tracked at a distance from the enamel-root-junction varying at mean of 14.06±1.96mm (trough; varied between 9.97 and 17mm); the highest $\delta^{18}O$ values, reflecting summer times, were recorded at a mean distance from the enamel-root-junction at 7.4±2.05mm (peak1; varied between 3.88 and 9.86mm) and 26.54±1.75mm (peak2; varied between 24.5 and 28.92mm). The period, equivalent to the length of M3 crown formed over a year, averaged 19.14mm; in M2 it measures ~18.3mm. Most of the variability in distances between events might be explained by tooth size and tooth formation speed.

El Mirón ibex mean oxygen values (mean=17.7±0.8‰) are higher than ones for horse (mean=17.2±0.4‰) and red deer (mean=16.9±0.6‰), but much lower than what is seen in La Paloma cave (mean=19.1±1‰) (DOMINGO ET AL. 2015). Ibex have higher intra-individual variability compared with horse and red deer, a fact which might not represent only seasonal variation in water, but perhaps changes in other habits of the animals that 'super-impose' on the seasonal signal (KOHN ET AL. 1998), such are dietary changes, behavior (altitudinal movements), or body physiology (although differences between females and males might be small and not recordable). While incremental oxygen values show sinusoidal variation, carbon values vary slightly (I4-3427-low_8) or increase slowly (H4-1792-mid_1), but do not co-vary with seasonal signals.

In the context of the above- discussed variability of oxygen values due to imbibing of meltwaters, ibex would be altered less by this phenomenon as being non-obligate drinkers. But, other reasons could have influenced the isotopic signal. The altitudinal effect (MCGUIRE & MCDONNELL 2008; MALAINEY 2011), however, might be stronger in ibex compared with horse or red deer due to altitudinal mobility (TORNERO ET AL. 2018).

Leaf water might be more relevant. It is generally enriched in $\delta^{18}O$ relative to meteoric water due to the evapotranspiration processes (WANG ET AL. 2008). Instead, these patterned oxygen values of peaks and troughs represent apparently summer (maxima $\delta^{18}O$ values of enriched meteoric water caused by higher temperatures and more aridity) and winter signals (minimum $\delta^{18}O$ values of meteoric water caused by lower temperatures and more humidity), respectively, when assuming seasonal variation in the oxygen isotopic composition of plants waters (BARBOUR 2007). However, several studies reported that in arid environments generally a larger variation in leaf water in plants exists (LEVIN ET AL. 2006; WANG ET AL. 2008; CERNUSAK ET AL. 2016), smaller wiggles along the oxygen curve might origin in dietary shifts in response to seasonal vegetation cover, moving between feeding grounds or other feeding opportunities (ALDEZABAL & GARIN 2000; MOÇO ET AL. 2013). The combined oxygen and carbon isotopic inter-individual curve of two ibex specimens might show these alternating intakes of plant food (Figure 4.103) that produce very slight fluctuations. Isotope variation would mostly originate in dietary superimposition of values. However, the animal (I4-3427-low_8) from the lower sample with less seasonal oxygen variation that implies less altitudinal migrations, shows repeated fluctuations in carbon values as it would have multiple switched between feeding grounds of different plant types.

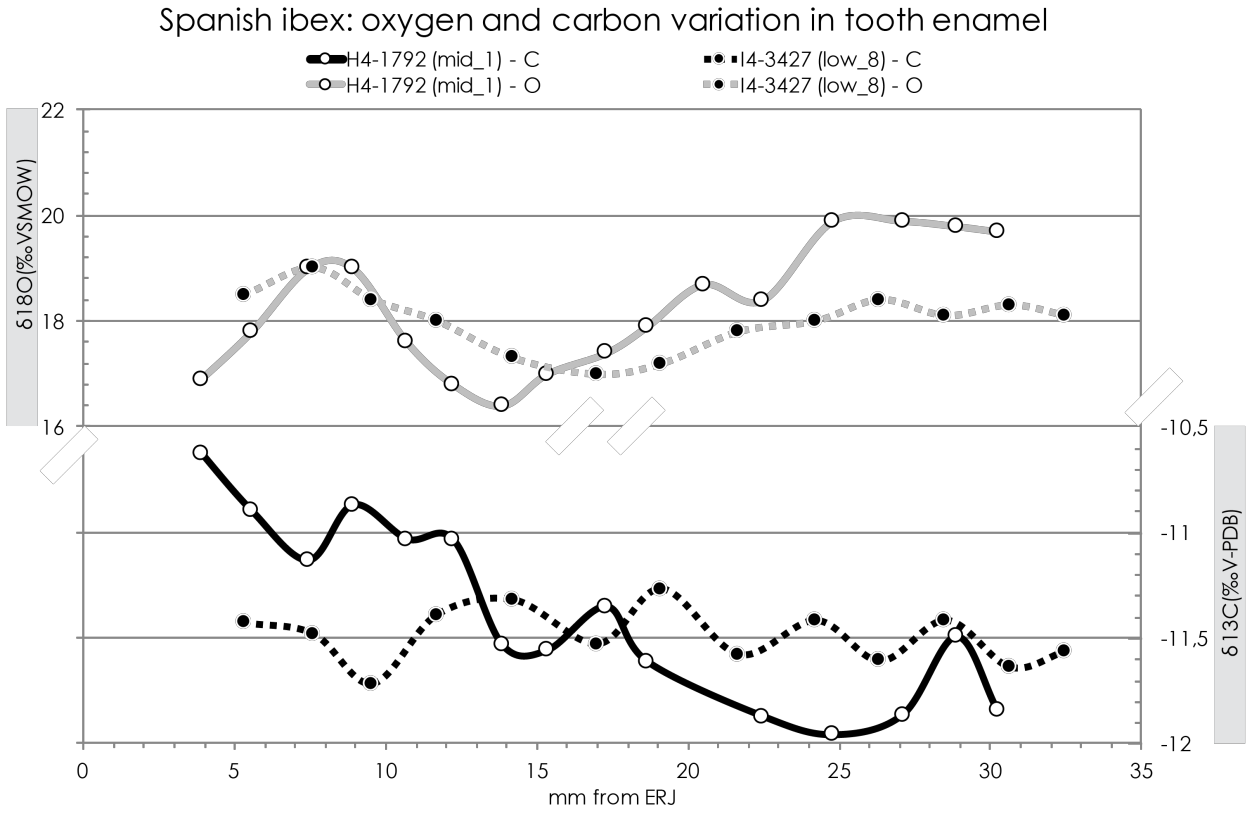


Figure 4.103: Combined curve of oxygen and carbon values from teeth carbonate of two ibex individuals from the middle and lower part of the Lower Magdalenian Level 17.

D. Seasonality influences animal behavior: migration and birth season

According to the observations made, it can be hypothesized, if strong seasonal variations exist in the given environment and ibex were occupying the upper limits of vegetation zones, then ibex would likely practice seasonal vertical mobility in search of food that is seasonally restricted (FISHER & VALENTINE 2013; MAKAREWICZ & PEDERZANI 2017). They might have spent the winter in lowlands and the summer in the higher mountains.

As a further analytical step for investigation, from oxygen isotope variability between the maxima and minima oxygen values, only extremes of the curve, such as peaks and troughs, are considered, respectively (Figure 4.104). Each individual curve was then reduced to the three points corresponding to sinusoidal curve peak2, trough, and peak1 as shown in Figure 4.102.

The lowest $\delta^{18}O$ values, were tracked at the trough varying at mean of 16.44±0.75‰. The highest $\delta^{18}O$ values, perhaps reflecting summer times, were recorded at 18.38±0.61‰ (peak1) and 18.83±0.7‰ (peak2). Those small variances may indicate that no major climatic changes seem to be recorded along the isotopic oxygen values among the individuals accumulated within this archaeological layer and observed differences may be explained behaviorally, anatomically or by gender. Variability of maxima and minima among the individuals is limited, only on a small scale, accordingly.

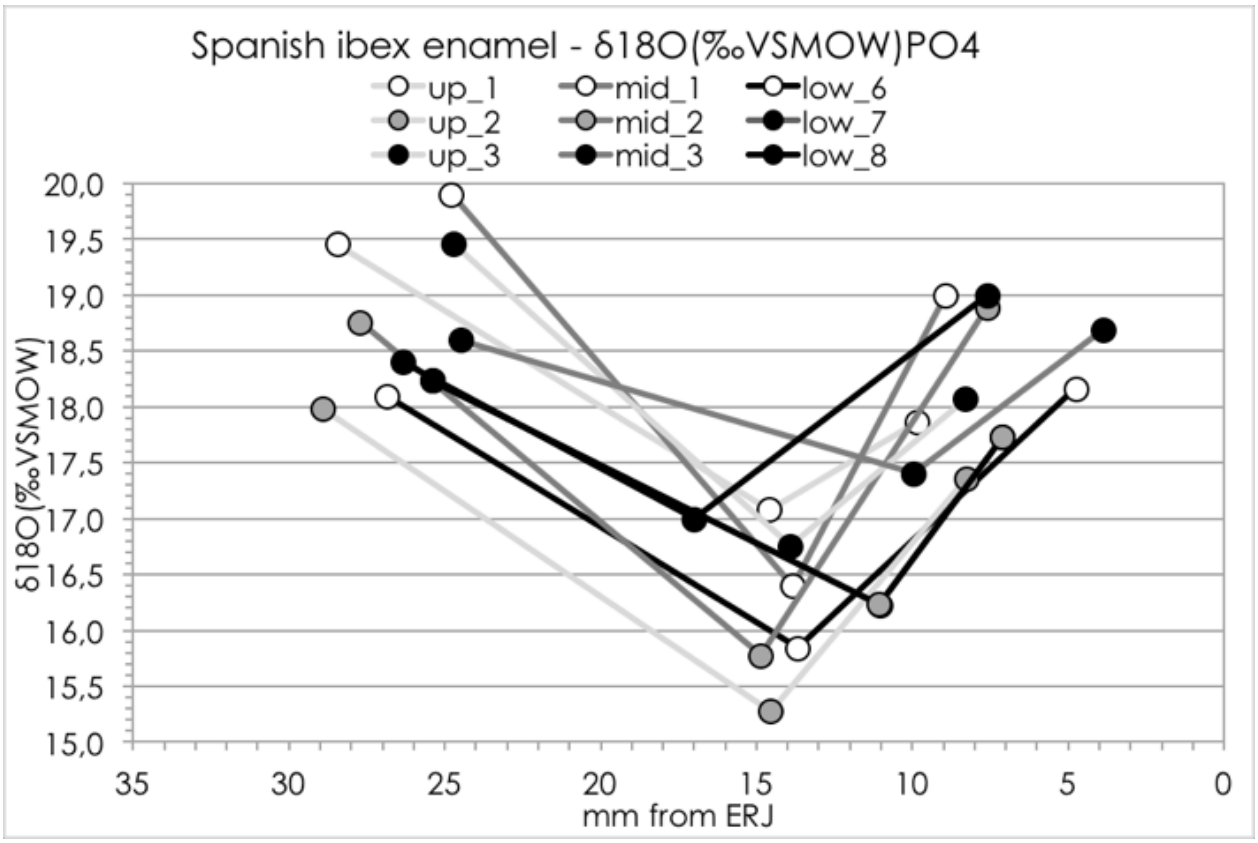


Figure 4.104: Oxygen sinusoidal curves reduced to extreme values of maxima and minima representing seasonality changes from summer/winter/summer points on ibex as obtained from curves shown in figure 1.9.

Then it is further assumed, if mobility (for example, vertical mobility when animals moving in between pastures of different altitudes or long-distance mobility when animals migrate to avoid seasonal extremes) is applied over wide ranges, then a constrained season of births should be present to favor newborn survival. An alignment of oxygen curves with low inter-individual variability would imply limited variation according to the birth season (BALASSE ET AL. 2003).

When comparing patterns of ibex oxygen curve, a strong similarity of the isotopic signal and similar location of maxima and minima values in distance to the ERJ are visible. These kinds of constrained birth times may indicate the application of vertical mobility among ibex. Each M3 tooth contains two peaks and one trough (compare Figure 4.105). The birth seasonality curves from Lower Magdalenian ibex have a similar pattern to some modern teeth and not to others. They are similar to one of the modern sheep data "Ovis 1216 M3" of an animal born in February according to a study of birth timing (BLAISE & BALASSE 2011), which corresponds to a birth season quite early within the year for ibex. The other modern sheeps "Ovis 0522 M3" and "Ovis 9726 M3" that not match this pattern were born in September as a reflection of unnatural birth season and domestication of animals. Although the shorter distance between events imply slower growing rates in tooth enamel of Spanish ibex compared with modern sheep, the observed oxygen pattern at El Mirón indicates the birth season would seem to be similar to what would be expected (April to June) for wild ibex according to modern reference data (GRANADOS ET AL. 2001). In migratory animals, such as most wild bovids, birth-timing is restricted so that the calving period is kept limited as possible until calves are strong enough to continue migrations under protection of the whole herd.

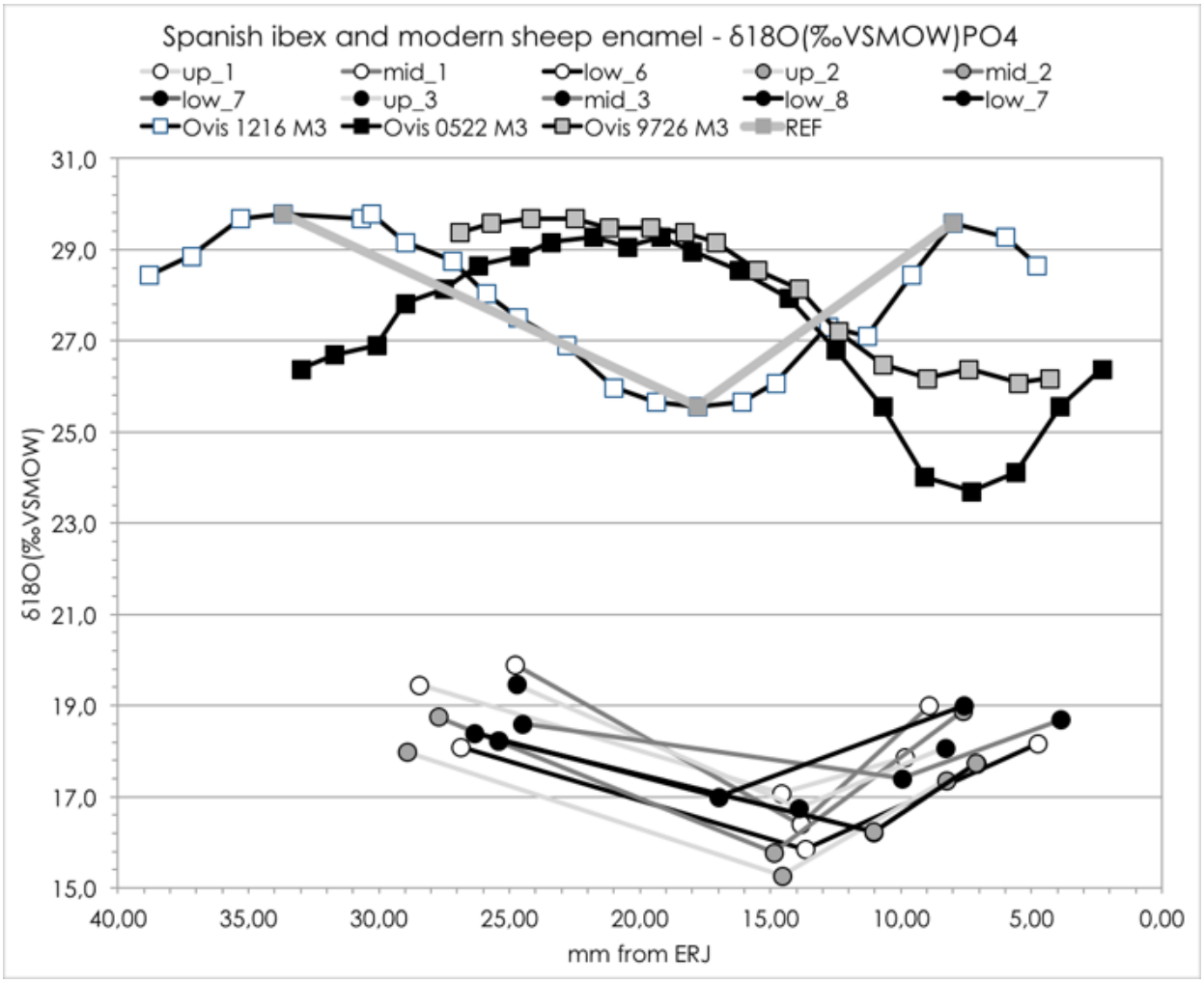


Figure 4.105: Oxygen curve: three points corresponding to sinusoidal curve peak2, trough, and peak1 from figure 1.8. compared with modern sheep sinusoidal curves. Circles - archaeological samples; squares - modern samples.

E. Hunting herds

It might be assumed that when animals show very similar isotopic records, then they might have been hunted in the same environment at the same time (JULIEN ET AL. 2015).

Results at the El Mirón show an inter-individual variability in peak1 values of 1.64‰, in a trough of 2.13‰ and in peak2 of 1.91‰. These results might infer that Spanish ibex inter-individual behavior varies the most during the winter season, which could have two reasons.

Either behaviorally, where it is specifically due to species behavior and ecology of different members of an animal group or when they are non-contemporaneous and with slight climate shifts in winter being observed.

The results obtained from El Mirón also do not exceed widely reported values of a single modern sheep group. For example, a modern sheep herd (with the same birth time, same location, same food, same water, etc.) also show slight inter-individual variability in oxygen values (BALASSE ET AL. 2012). Within this group, seasonally optimum inter-individual variability in oxygen values has been as high as 2.5‰ (summer-peak) and 1.6‰ (winter-trough). It is also known that a higher inter-individual variability in oxygen isotopic values exists in M3 compared with M2, according to the modern reference group of sheep (BLAISE & BALASSE 2011). While similar curve patterns could demonstrate contemporaneity among of individuals, larger differences between oxygen values do not infer the opposite. Inter-individual variability within the same group (herd) of

individuals may exist, even when they have experienced the same isotopic history during enamel mineralization. The similarity in seasonal signals observed among ibex, however, indicate very limited scope of time and space from which the animal origin. It is likely that humans revisited same hunting grounds of herds main territory.

To further explore these results, use can be made of the peak values of the oxygen variability curve by focusing analysis on a full- year cycle. For this we can excluding data which extend beyond one amplitude of a summer-autumn-winter-spring sequence for horse and ibex. For red deer, the focus is on the summer-to-winter signal, as these teeth do not record a full year-cycle to compare the curve characteristics. Results of each one-year amplitude, mean, minimum and maximum, maximum-minimum-difference and amplitude length are summarized in Table 4.29. In simple, this means there are winter and summer variances extracted and compared.

Table 4.29: Summary statistics of one-year summer-winter signals. Grey shaded area= ibex mean($\delta^{18}O$) lower than 17.5. mean, difference and length are retrieved from maxima and minima of a one- year cycle.

Species	Code	Square-nr	3rd year winter	4th year summer	3rd/4th year- amplitude		
			min	max	mean	difference	length mm
Horse	ISO-EQ-low_1	I3-5535	16.52	18.19	17.35	1.7	38.82
	ISO-EQ-low_2	J3-4681	16.61	17.70	17.15	1.1	50.27
Red deer	ISO-CE-low_3	I4-5083M3	16.01	17.02	16.52	1.0	13.74
	ISO-CE-low_4	I4-5083M2	15.97	17.57	16.77	1.6	14.07
	ISO-CE-low_5	H3-3510	16.59	18.59	17.59	2.0	13.53
Ibex	ISO-CP-low_6	H3-5278M3	15.85	18.10	16.97	2.3	19.56
	ISO-CP-low_7	H3-5278M2	16.23	18.24	17.23	2.0	18.30
	ISO-CP-low_8	I4-3427	17.00	18.40	17.70	1.4	20.92
	ISO-CP-mid_1	H4-1792	16.38	19.93	18.16	3.6	15.87
	ISO-CP-mid_2	J2-957	15.78	18.76	17.27	3.0	20.12
	ISO-CP-mid_3	H3-1648	17.41	18.60	18.00	1.2	18.39
	ISO-CP-up_1	I2-396	17.08	19.46	18.27	2.4	18.59
	ISO-CP-up_2	H3-872	15.27	17.99	16.63	2.7	20.65
	ISO-CP-up_3	H4-1061	16.76	19.46	18.11	2.7	16.43

Student's t test results show individual teeth not connected by the same letter are significantly different (Table 4.30). In ibex tooth, principally two distinctive groups of more related data are visible, these ones contain a $\delta^{18}O$ mean value of either lower or higher than 17.5‰. The group of ibex with mean($\delta^{18}O$) lower than 17.5 (grey shaded area in table above) contain samples from each of the three studied units.

Table 4.30: Relationship between samples based on $\delta^{18}O$ mean values (Student's t test) of one-year-cycle. Grey shaded area= ibex mean $\delta^{18}O$ isotope ratio <17.5.

Species	Sample						Mean
Ibex	ISO-CP-mid_3	A					18.18
Ibex	ISO-CP-up_1	A					18.05
Ibex	ISO-CP-up_3	A	B				17.93
Ibex	ISO-CP-low_8	A	B				17.92
Ibex	ISO-CP-mid_1	A	B				17.91
Red deer	ISO-CE-low_5	A	B	C			17.54
Horse	ISO-EQ-low_2		B	C	D		17.31
Ibex	ISO-CP-mid_2			C	D	E	17.27
Ibex	ISO-CP-low_7			C	D	E	17.19
Ibex	ISO-CP-low_6			C	D	E	16.99
Horse	ISO-EQ-low_1			C	D	E	16.97
Red deer	ISO-CE-low_4			C	D	E	16.79
Ibex	ISO-CP-up_2				D	E	16.78
Red deer	ISO-CE-low_3					E	16.58

Although there are seasonal related sinusoidal oxygen variations visible in all ibex teeth, there are marked differences in the amplitude of isotopic change. Some of these exhibit comparably higher $\delta^{18}O$ maximum, lower $\delta^{18}O$ minimum and varying amplitude length. Each distribution of oxygen isotope results from ibex tooth enamel is shown in (Figure 4.106) for a one-year cycle.

The highest $\delta^{18}O$ maxima (ISO-CP-mid_1=19.9‰, ISO-CP-up_1=19.46‰, ISO-CP-up_3=19.46‰) and lowest $\delta^{18}O$ maxima (ISO-CP-low_6=18.1‰, ISO-CP-low_7=18.24‰, ISO-CP-up_2=17.99‰) exhibit teeth from the lowest and the upper samples studied. The highest $\delta^{18}O$ minima (ISO-CP-low_8=17‰, ISO-CP-mid_3=17.41‰, ISO-CP-up_1=17.08‰) and lowest $\delta^{18}O$ minima (ISO-CP-low_6=15.85‰, ISO-CP-mid_2=15.78‰, ISO-CP-up_2=15.27‰) exhibit teeth from all different samples studied. Thus, by inter-individual variability cannot be distinguish archaeological units exhibiting generally higher or lower values. It is recognizable, however, a shift in isotopic mean values, which will be investigated further for the Lower Magdalenian sequence of El Mirón cave.

When considering amplitude length, the results can be subdivided in three groups:

- A) larger than 19mm (ISO-CP-low_8, ISO-CP-low_6, ISO-CP-mid_2, ISO-CP-up_2),
- B) ~19-18mm (ISO-CP-low_7, ISO-CP-mid_3, ISO-CP-up_1) and
- C) smaller than 17mm (ISO-CP-mid_1, ISO-CP-up_3) of the length of the tooth.

Variables change correlate neither by time nor by study units. They scatter throughout the sequence, where one may question, if other parameters generate this pattern. For example:

Different growing rates between females and males might be a possible influential factor that contributed to these results, when comparing those lower M3 amplitude ranges. Females complete their bone development two years before males do (SERRANO ET AL. 2006). When females are growing faster, a record of shorter amplitudes compared with males would be inferred. Thus, amplitude length would be expected to vary

according to sex. As well as a sex effect, a size effect also exists with larger animals have slightly different profiles, which then becomes a sex difference in sexual dimorphic species.

It is also known that behavioral differences exist between females and males; it is hypothesized that they vary in their habitat location and use according to differing activity budgets (ACEVEDO & CASSINELLO 2009), while the ecological context of the local conditions seems to trigger this behavior. Females might inhabit more protected areas (living in larger matriarchal herds with other females and offspring) and do not move as far up into mountain ranges as males do (GRANADOS ET AL. 2001). Recorded variation in amplitude $\delta^{18}O$ variances might be originated within this behavior, but larger data sets would be necessary to explore this issue in the future further.

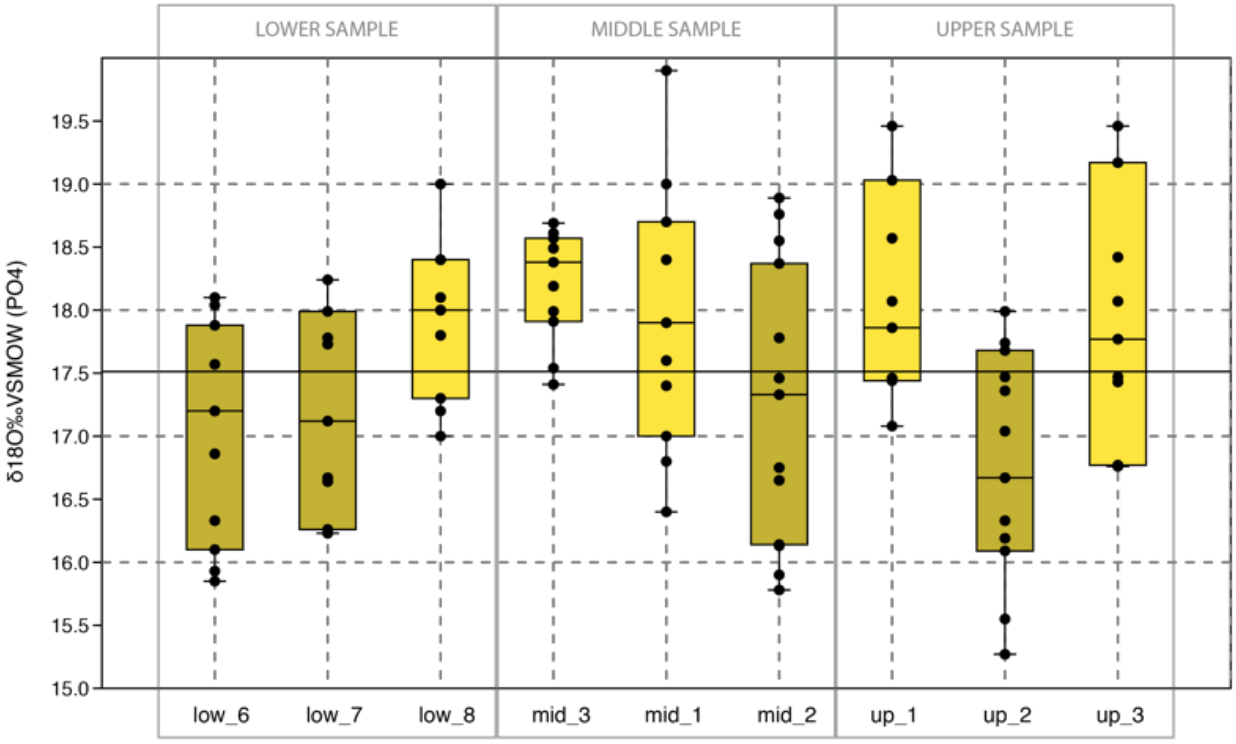


Figure 4.106: Oxygen variability for one-year-cycle records in ibex tooth enamel, including maximum, mean, minimum and variances from lower, middle and upper samples from the Lower Magdalenian Cabin area, El Mirón. Grey shaded= Individuals with mean $\delta^{18}O$ isotope ratio <17.5.

F. Oxygen-strontium relationship and migratory behavior

If migratory behavior might have had influenced isotopic results is another hypothesis to test and to decipher isotope variation in ungulate tooth enamel. It is known from poor environments that animals are 'forced' into by humans through husbandry or to apply migratory behavior themselves to optimize resource exploitation (BRITTON ET AL. 2009, 2011; TORNERO ET AL. 2018), the latter might have been present in post-LGM harsher glacial conditions in Europe. To access extent and directionality of mobility, oxygen and strontium isotopes can be tested for co-variation (EVANS ET AL. 2007; WIDGA ET AL. 2010; PEDERZANI & BRITTON 2019). Strontium isotopic signature were analyzed in ibex teeth as the abundant local prey species and in horse teeth as one of the rare species in El Mirón Cave. The rare presence of horse among the hunted species has led researchers to propose that it must not have been commonly found locally.

The measured strontium results in samples show in ibex a mean $^{87}Sr/^{86}Sr$ ratio of 0.708354‰ and in horse a mean $^{87}Sr/^{86}Sr$ ratio of 0.709207‰, showing higher values in horse than in ibex. Values of strontium in all individuals vary, but within small ranges (Figure 4.107).

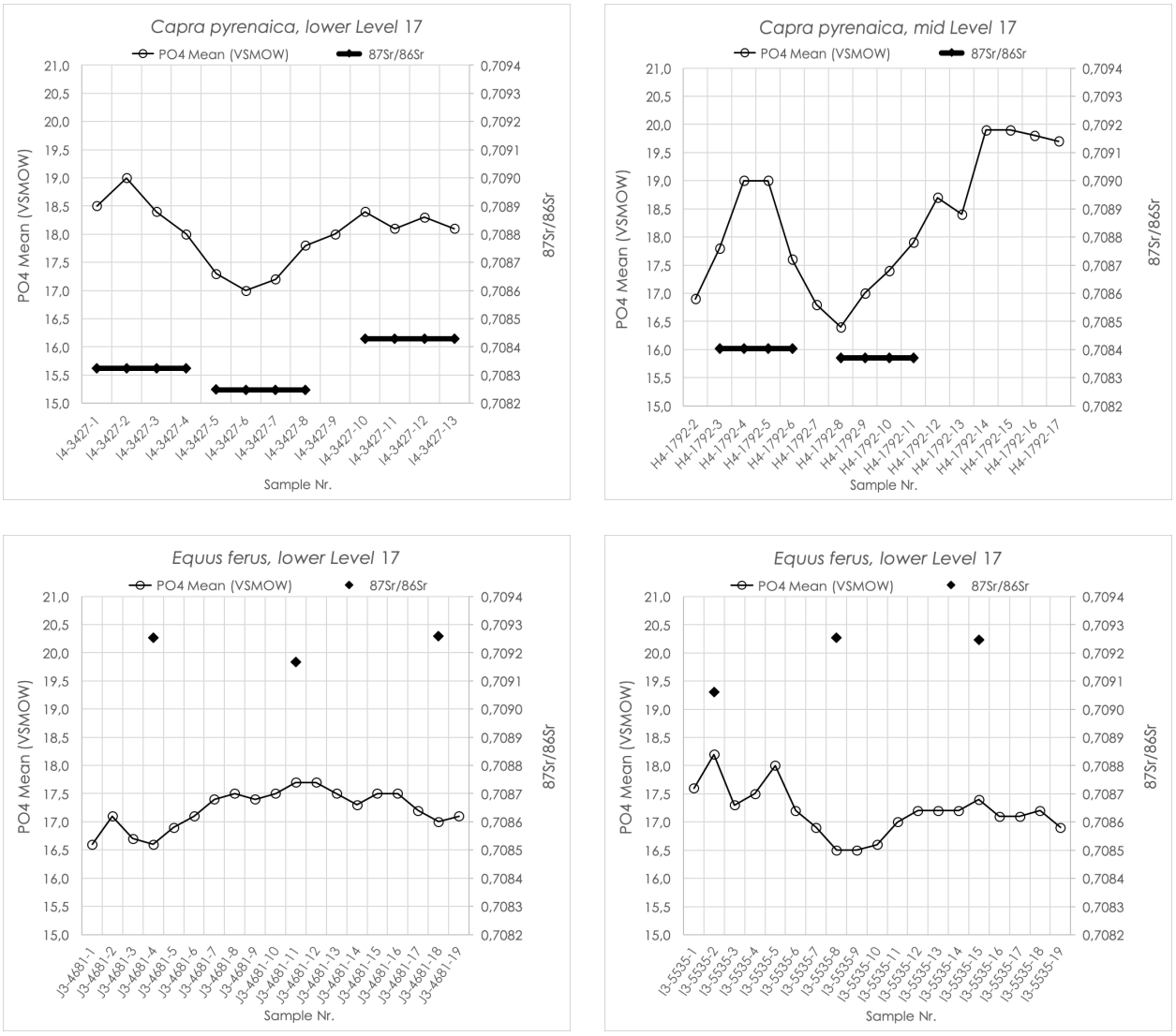


Figure 4.107: Variation of intra-tooth oxygen and strontium results on ibex and horse tooth enamel from Lower Magdalenian Level 17.

Those individuals have only carried out minor (seasonal) migrations between habitats as variation in strontium isotopic composition is low and reflect the bedrock composition of habitat. The obtained strontium results lie within the range of carbonaceous sediments, these include limestone, chalk, dolomite (compared to a country-wide map of bioavailable strontium for France by (WILLMES ET AL. 2018)), while currently no local strontium-bedrock assignment is available. The Asón river valley lies within bedrock of Aptian-Albian (Lower Cretaceous) limestone (IRIARTE ET AL. 2012). Different old limestone regimens might have varied strontium isotopic signatures as their formation varied due to the sea ocean water strontium content; through bedrock weathering, local strontium ratios are incorporated into plants and by consumption into the terrestrial organisms growing tissues (BENTLEY 2006; MALAINEY 2011). Thus, the ibex individuals might have moved around, but within small ranges, not leaving the limestone dominated area of the surroundings of El Mirón

cave site located within the Cantabrian Cordillera. Slight variation in the strontium signal, referred to movements within small ranges, were maybe altitudinal tendentiously following the oxygen shifts of sequential signals in the tooth samples, because strontium and oxygen isotopic composition seems to co-vary. Vertical migratory behavior in ibex could explain to some kind a modification of the seasonal signal that super-impose on the original one. This means that seasonal oxygen variation got superimposed by altitudinal seasonal variation. However, these results indicate seasonal moves of ibex rather than year-round random moves.

Horse strontium results are different to ibex by three observations: (i) the horse show neither apparent seasonal variation of oxygen nor strontium results, (ii) oxygen and strontium values do not co-vary, and (iii) most of the horse values fall into a similar range much higher than ibex. i) The present results could express that horses used narrow territories or resources from a patch with similar local geology, because annual rounds and higher mobility between patches would produce a more extensive intra-tooth variation of strontium values. Similarly shows oxygen variations no clear seasonal signal, possibly indicating horse experienced during lifetime only mild seasonal variation, this could be possible if horses were dwelling in near-coastal habitats of oceanic influence. ii) Strontium and oxygen variation are not related to each other, particularly excluding seasonal movements of horses. Besides oxygen variation in horse seems to be altered by drinking water not reflecting precipitation in light of particular dry environments and probable availability of meltwater supplies, strontium variation is relatively low. Besides the similarity in strontium values, the few samples of lower values might correspond to random excursions, maybe along valley floors or coastal areas. iii) A relevant additional result is that the here obtained strontium isotope analysis shows that ibex and horse have very different values, pointing to diffffernt feeding grounds. The main prey species ibex was hunted locally to El Mirón on nearby carbonate sedimentary rocks. However, seldom hunted horses show different elevated signatures probably from dwelling areas on mixed sedimentary rocks. Such bedrocks are proximate mainly found west from the Asón river valley as opposed to the Asón river valley itself and most of the Basque country with the bedrock of supposed lower values in bioavailability strontium. Whether few horses wandered along the Asón valley or horse remains were brought to the cave as travel food is difficult to determine, but the result supports the idea that horses were not commonly dwelling in nearby El Mirón surroundings. However, the major caveat remains that the range of bioavailable strontium is unknown for today's submerged coastal areas, as well as detailed strontium maps are yet not available for the Cantabrian Region.

Since interpretation of stable isotopes gives often different possible results due to equifinality of final values and the relative character of results, it was assumed that when dental calculus analysis was performed in addition to the stable isotope studies the result could refine the successive interpretation. This is what was also tested next. The following paragraph described how stable isotope analysis on tooth enamel can be improved by combination with phytolith analysis in dental calculus.

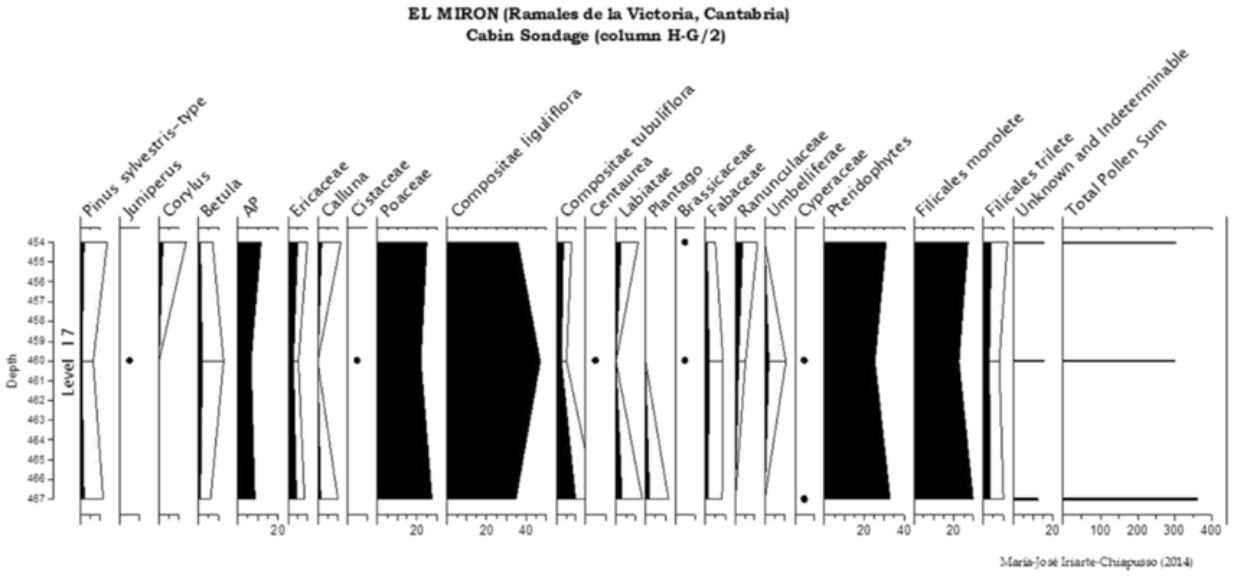
G. Phytolith analysis from herbivore dental calculus

The consistency with which these varied morphotypes of phytoliths were identified in the dental calculus of herbivores, leads us to believe that parts of these plants might have composed a portion of their diet. Consumed plant includes, in varying quantities, mainly flowering plant and tree parts supplemented by grasses and sedges. Spanish ibex is recognized as an intermediate browser - grazer and a herbivore that adapts its diets depending on the available vegetation cover (MOÇO ET AL. 2013). These results have different implications for Paleolithic environment and ecoethology reconstructions:

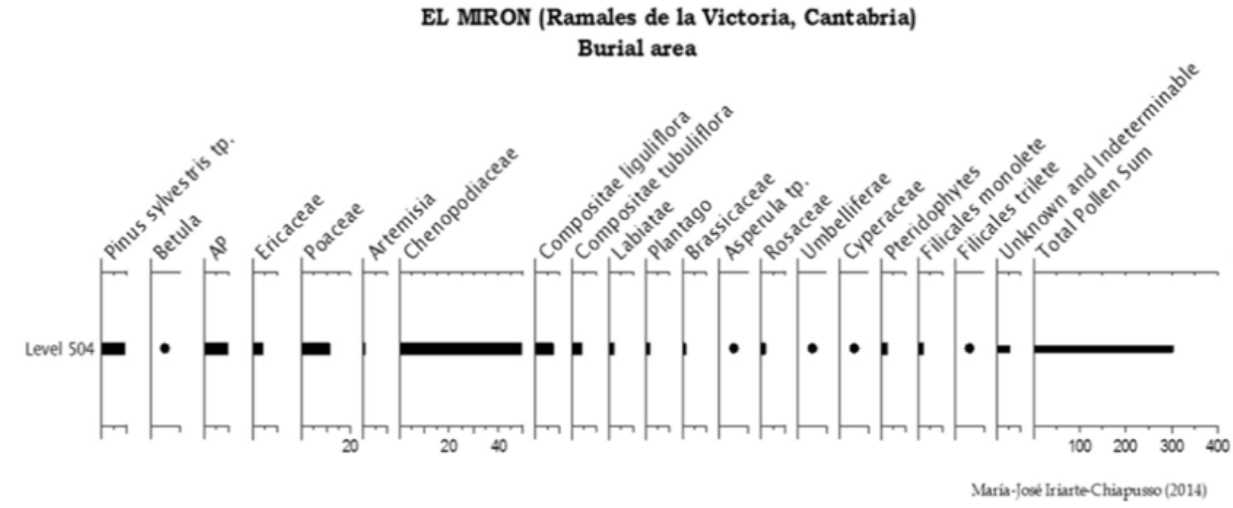
Herbivore dietary intake. The plant components identified in the dental calculus represent herbivore dietary choices of plants coming from a landscape that containing flowering plants, grasses and trees. This is supported by the fact that the variety of dental calculus plant components is similar to the plant remains

found in the surrounding sediments from the Lower Magdalenian levels of El Mirón (Figure 4.108). The sediments from Level 17 and the Burial Level 504 were analyzed earlier by Dr. M.J. Iriarte-Chiapusso (IRIARTE-CHIAPUSSO ET AL. 2015) and indicated that samples were dominated by flowering plants (Asteraceae/C.liguliflora) accompanied by grasses (Poaceae) and arboreal pollen. The sediments contained, however, more ferns (Pteridophytes and Filicales monolete) than what has been found in the dental calculus of herbivores studied here. The absence of ferns in the dental calculus show that although these plants existed in the local environment, they were not eaten by the sampled herbivores, as they might not have been typical fodder plants. This also supports that plant remains identified in the dental calculus truly reflect plant dietary intakes by the herbivores.

Herbivores occupied different niches. Sedges (Cyperaceae) have been occasionally identified in the pollen samples of the sediments (IRIARTE-CHIAPUSSO ET AL. 2015), and in the dental calculus only on horse teeth. Both samples are from the middle of the stratigraphy of Level 17. This makes sense, as horses have hypsodont teeth enabling to consume a variety of grasses compared with the other herbivores.



A



B

Figure 4.108: Pollen remains in sediments of Levels 504(A) and 17(B), cabin area El Mirón; diagrams from (Iriarte-Chiapusso et al. 2015).

Environmental change. Although there exist multiple pathways for inclusion of materials into ancient dental calculus, especially for humans (RADINI ET AL. 2017), the findings of this study clearly show that the dietary combination of plants containing such phytoliths that are preserved in dental calculus samples of herbivores change through time. The grasses phytoliths increased, while arboreal phytoliths decreased in the latter occupational periods compared to the earlier ones of the Lower Magdalenian. This pattern might indicate general dietary changes during a period of deforestation of the landscape, which is coherent to the observations made earlier by Iriarte-Chiapusso (2015) implying a change in the vegetation cover in Level 17. For the beginning of the Late Glacial, an intensive cold stadial period with climatic pulses infers the pollen from sediment deposits of El Mirón. A landscape with very little arboreal cover (dominated by scattered pines, if these pollens were even local) and few deciduous trees characterized this period. The most similar environmental records to those of Level 504 and the upper part of Level 17 (the most recent pollen sample) were detected in contemporary human occupations in cave deposits in La Riera (Level 19), El Rascaño (4) and Erralla (V) (IRIARTE-CHIAPUSSO ET AL. 2015).

4.4.6 Conclusion on Micro-environmental reconstructions

This study provides a unique line of analysis for understanding local environmental conditions, prey species ecology and Upper Paleolithic hunter-gatherer behavior for the Cantabrian region, as specified on several levels.

On an intra-individual level. Despite having analyzed the carbonate and the phosphate, without applying any pretreatment of the enamel samples, which could potentially alter results (PEDERZANI ET AL. 2020), the $\delta^{18}O$ offset of the obtained results are located within the expected range of diagenetically unaltered tooth enamel, evidenced on a biogeochemical level. When addressing Paleolithic issues thus, where material is potentially more taphonomically altered, it is suggested to examine rather the oxygen isotopic signatures from the phosphate than from carbonates to avoid analyzing oxygen from substituted secondary carbonate. However, here we analyzed the oxygen and carbon from the enamel carbonate obtained following novel results:

Carbon and oxygen from ungulate teeth enamel suggest differences in the dwelling habitat for ibex accumulated in El Mirón cave (Cantabria), with a signal indicating more humid/colder environmental conditions than similarly aged Spanish ibex from the La Paloma Cave site (Asturias), located 200km west of El Mirón.

Indeed, the individual within-tooth oxygen variation attested the presence of seasonality. These isotopic fluctuations, however, were low in horse, moderate in red deer and highest in Spanish ibex (Figure 4.109), suggesting at least, in the latter species behavioral superimposition of $\delta^{18}O$ records, for example by altitudinal movements.

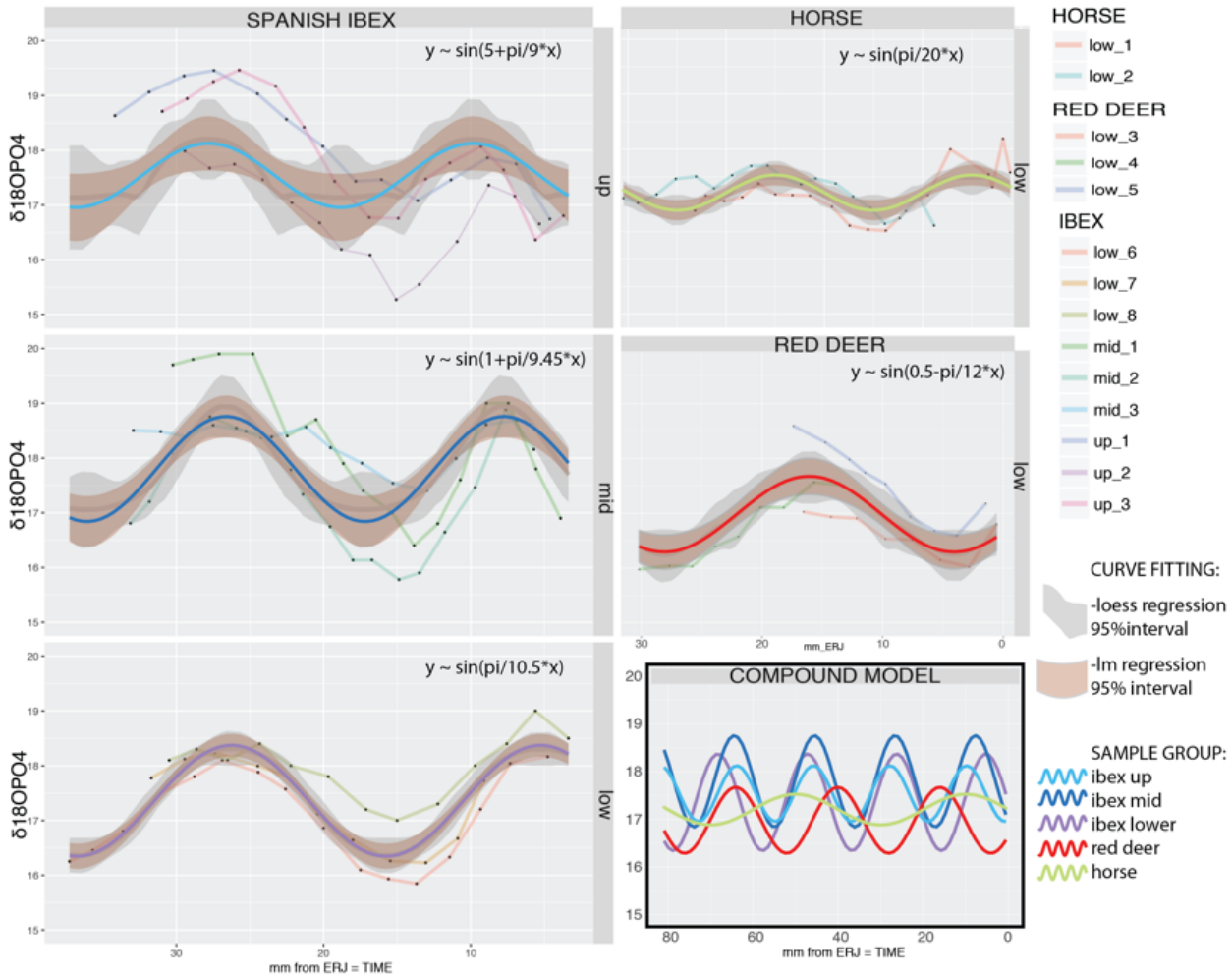


Figure 4.109: Loess regression were used to retrieve lineal model (lm) equations from sample groups for ibex, horse, and red deer using lower, middle, and upper samples from the Lower Magdalenian, Cabin area, El Mirón. One compound model (lower, right corner) finally is superimposed on the other sinusoidal models.

On an inter-individual level, varied animal behavioral implications occurred. According to the seasonal oxygen variations, different eco-ethology (i.e., animal behavior) for ungulates might have demonstrated, always with the caveats of limited sampled studied.

The oxygen isotope variation in horses indicate they practiced a high mobility or dwelled in areas of less seasonal fluctuations, and such is the coastal zone of the Cantabrian Region. Imbibing meltwaters introduced in rivers or ponds might have altered the environmental signal from those horse teeth, because extreme environmental aridity with limited rainfall in the region characterizes the Lower Magdalenian period. For horses, as obligate drinkers, the most challenging task might have been to obtain drinking water. This circumstance might have triggered their behavior and local distribution in the region, probably tightly bound to river waters (i.e., they had to live along the valley floor of the rivers and estuaries). They were the only species showing phytoliths of sedges, i.e., plants that are often growing on wet grounds, probably in riparian or coastal zones. Strontium analysis improved this interpretation, with horses showing a higher strontium isotope ratio than near El Mirón hunted ibex. The distinctive strontium isotope ratio from horse indicates a non-local, maybe near-coastal, or westward from the Asón valley on mixed bedrocks dwelling grounds, which explain why El Mirón inhabitants rarely hunted horses.

The moderate seasonal fluctuations found in red deer oxygen values might show the most local signal, less altered through behavior, indicating a general low-range-migrant practice.

On the contrary, the strong seasonality seen in Spanish ibex teeth might suggest that ibex displayed seasonal behavioral variances. If ibex practiced seasonal vertical mobility along the mountain slopes for adopting habitat and dietary practices according to cyclic abundance/absence of preferred food plants, then they show resilient behavior confronting harsh environments by adapting to seasonal changes. This so-marked seasonality signal was due to altered local environs and fluctuations in food availability, as observed during the same period in La Riera about 150km west of El Mirón (JONES ET AL. 2020). The observed constrain of thee birth season in ibex might be reasonable with the background on high mobility by understanding that the more births occurring in a few days, the quicker all newborns are strong enough to join moving with the herd. All of these analyzed ibex teeth show high similarity among each other. As such, those animals from different stratigraphic positions in the Lower Magdalenian deposits of El Mirón (inducing radiocarbon estimation errors, it last around 750 years) were living in similar environments, in the same region. They were not hunted during the same events, but some might represent animals that had lived in the same social band. A close relationship of hunting events, would support the idea of more intensive or longer duration of occupation of the cave, rather than short or unrelated visits or overall unstable environmental conditions. This shows that during the Lower Magdalenian no major climate changes have been observed and relatively stable climatic conditions (cold and dry) are inferred to have existed during the period of accumulation, but seasonal temperature fluctuations were strong enough to be registered and to influence animal behavior.

On an inter-species level. The newly retrieved results on stable isotopes add additional information on previous environmental data published, which infer different environmental conditions that represent varied isoscapes (which are landscape or foodweb specific isotopic signals, they can exist next to each other and are distinctive) within the Cantabrian region during the Late Glacial period, specifically during the Lower Magdalenian. The topographic subdivision of the Cantabrian region into coastal zone, interior valley floors and mountain ranges as such also indicates the existence of many micro-environments, reflecting three different isoscapes: the then-somewhat-wider coastal zone which might have had more stable climate with less seasonal variation, but open to the oceanic regime, the valley floors enclosing the riparian zone of more protected areas, maybe fed by meltwaters, and the mountain zone which experienced harsher winter seasons. During the early Lower Magdalenian, extended aridity characterized the Cantabrian montane region where humid meadows might have existed along the valley floors. These were likely areas of red deer habitat much of the year and of ibex in the cold (snowiest) season. Ibex sought feeding opportunities at higher altitudes during summer times. The initial hypothesis that horses, as obligate drinkers reflect the most genuine signal of the environment by imbibing meteoric waters, was rejected, because of the possible insufficient presence of meteoric waters due to overall environmental aridity, likely admixing of meltwaters into waterbodies used for drinking, and probable migratory behavior. Ibex represent a signal with high variability, superimposed by behavior. It seems that red deer represents intermediate-enriched $\delta^{18}O$ (VSMOW) values of plant water influenced by browsing activity, but as such closely related to paleo-environmental conditions. Dwelling in riparian zones might have influences the stable isotope composition within these animals, although only to a limited extent. The riparian zones are the terrestrial biome that might have dominated the Cantabrian valley landscapes, representing the relatively narrow strip of land adjacent to steep hillsides. Hydrophilic plants therein might contain carbonate values similar to those of the surroundings areas, but slightly depleted oxygen values of lower evaporation.

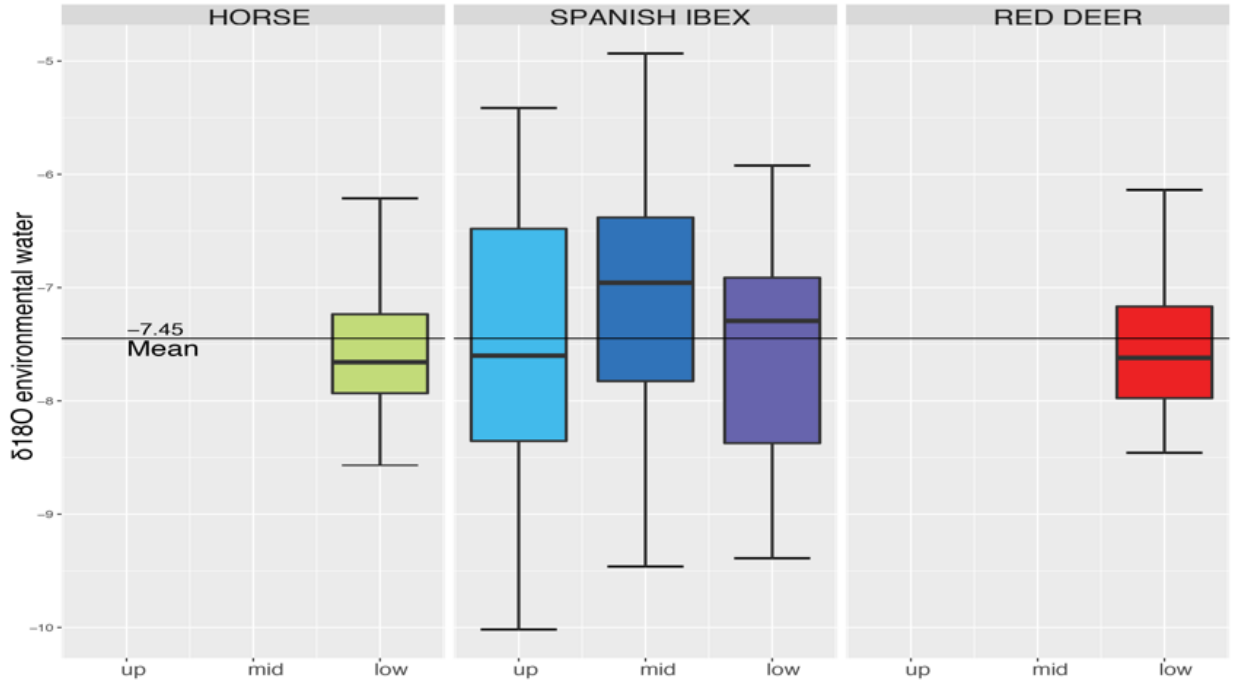


Figure 4.110: Variation of reconstructed $\delta^{18}O$(VSMOW) of imbibed environmental waters shown by sample groups of lower, middle and upper samples from the Lower Magdalenian, Cabin area, El Mirón. Mean value is shown for all values from horse, ibex and red deer.

When recalculating the oxygen signal of imbibed environmental waters (ANGELA & LONGINELLI 1990; DELGADO HUERTAS ET AL. 1995; DOMINGO ET AL. 2012) by those herbivores (Figure 4.110), they showed very similar values for horse ($\delta^{18}O$ (VSMOW) mean= -7.61±0.5‰) and red deer ($\delta^{18}O$ (VSMOW) mean=-7.59±0.6‰). However, ibex reflect slightly different mean and standard deviation values of imbibed water ($\delta^{18}O$ (VSMOW) mean= -7.37±1.1‰), presumable due to altitudinal mobility and dietary adaptations. While ibex most likely inhabited higher altitudes (colder) of the interior mountain zone, horse and red deer might also reflect more temperate micro-environments of coastal influence and lower altitude. Compared with the great variance of decadal modern-day references, for example for Santander ($\delta^{18}O$ (VSMOW) mean = -4.97±1.51 ‰ or León ($\delta^{18}O$ (VSMOW) mean = -7.79±2.38‰), it is remarkable that retrieved archaeological values represent a coherent environmental signal of colder, but more stable conditions than Santander nowadays, for example; although the smaller sample size of archaeological materials should be taken into account. Interestingly there was reconstructed for the Magdalenian of La Paloma Cave a value $\delta^{18}O$ (VSMOW) of −6.7±0.2‰ (DOMINGO ET AL. 2012), which is higher (less cold) than what was observed in El Mirón cave. Those differences may be due to non-contemporaneous accumulation or the existence of distinctive regional micro-environments in the Nalón compared to the Asón river valley, where the former experienced milder coastal or lowland climates.

While the authors of recent stable isotope analyses dealing with the plausibility of existence of the mosaic of isozones in time and space in the Cantabrian region, all support the idea of the relative importance of 'micro-environments' (JONES ET AL. 2018, 2019). However, how micro-environments are distributed in time and space is still debated. Broader implications on the role of micro-environments might be inferred throughout the present analysis.

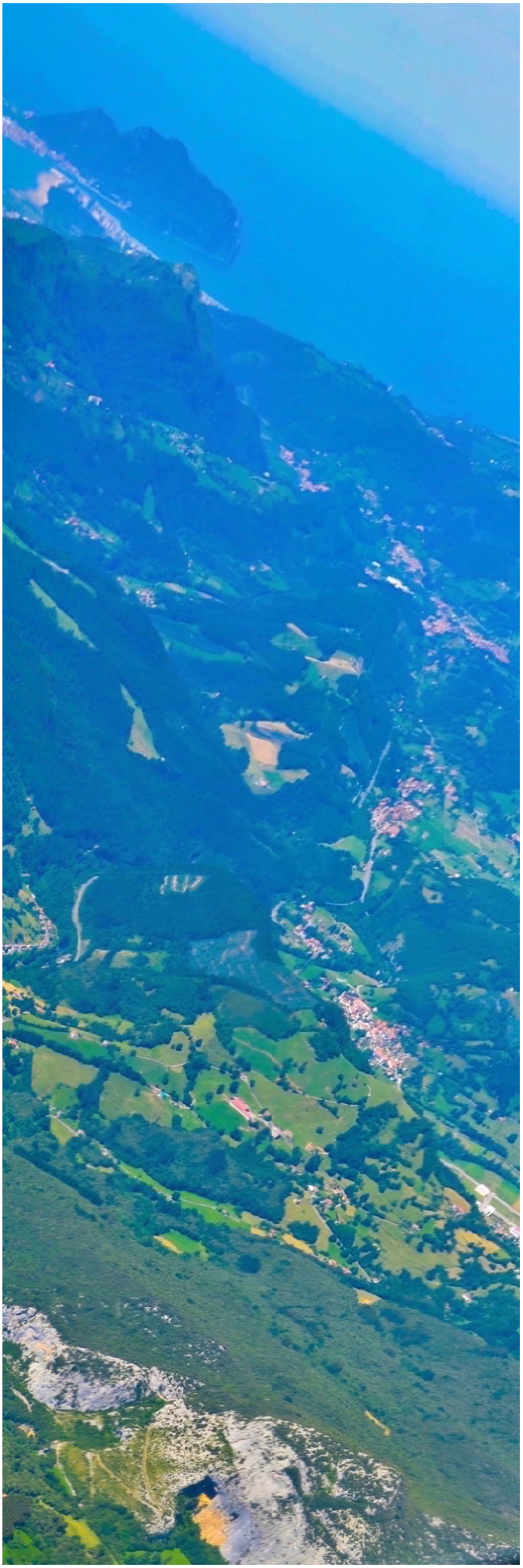
For further human behaviorally implications, the existence of such micro-environments might infer that not the large climatic events seem to be the triggering factors with which to understand past animal behavior and in consequence human subsistence and settlement in the Cantabrian region, but rather what were the

conditions in the inhabited micro-environments. Humans using different parts of the landscape, perhaps due to their different characteristics and animal distribution at the moment they occupied it and not how they looked like decades or centuries or millennia before or after. However, here was explored the further idea as to whether the direct link of the local landscape (=micro-environment) and its exploration permits one to reconstruct human hunting behavior. Above all, here I propose that the macro-mammal's eco-ethology is another triggering factor and as such a key instrument for relating landscape characteristics with human hunting behavior.

With the analysis of the stables isotopes it was demonstrated that the high topographic variability of the region provided a complex environmental mosaic landscape, which included varied isoscapes where animals dwelled. Hunted animals as such record the micro-environmental signal where they lived, which can be accessed with isotope analysis; they are the direct link to the environment where humans were living. Additional behavioral information about prey species provides not only a unique line of evidence, but a great opportunity to access information on animal behavior and human hunting practices. Within a harsh, but relatively stable environment, Lower Magdalenians used El Mirón repeatedly to hunt ibex and red deer.

With the help of these results, a discussion of human behavior change is enabled when comparing environmental and economic development in the following synthetic chapter 5. However, enhancing research that combines environmental data and animal behavior into analysis of hunting strategies towards the whole sequence of El Mirón Cave and other important Paleolithic sites in the region and beyond are leading analytical strategies to improve archeozoological studies in the future.

CHAPTER 5: LATE UPPER PLEISTOCENE PALEO-ECONOMIC SYSTEMS IN THE CANTABRIAN REGION



El Mirón, Asón River Valley and Monte Buciero at the coast.

CHAPTER 5:

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5 LATE UPPER PLEISTOCENE PALEO-ECONOMIC SYSTEMS IN THE CANTABRIAN REGION

This chapter aims to identify economic changes that took place in the Late Upper Pleistocene of the Cantabrian Region to understand how and why human populations adopted specific economic strategies and settlement systems. It is of particular interest how economic stress is archeologically manifested? Economic tension is assessed in terms of unbalances in cost/yield expenses, according to Optimal Foraging concepts, and are reviewed based on published zooarchaeological data, while some of these approaches were already outlined in publications (MARÍN-ARROYO 2009a; GEILING & MARÍN-ARROYO 2013; GEILING 2018).

The results on the economic patterns obtained in the zooarchaeological analyses at El Mirón cave are compared to the broader Cantabrian zooarchaeological data from other Paleolithic sites, applying three basic concepts: 1) biodiversity of the faunal composition, 2) resource species ranking and 3) seasonality. Economic stress in human populations could be due to different reasons, such as intensification of resource usage, human demographic increase, resource decrease due to climatic factors, over-hunting, reproduction stress of chief prey species, among other reasons (ENLOE 1997; OUTRAM 2003, 2004).

The diachronic palaeoeconomic evolution is compared and evaluated at two distinct levels, 1) on the intra-site level of El Mirón based on the studied fauna and 2) on an inter-site level with already published datasets from 128 Cantabrian sites. The sites topographic location and their characteristics are listed in the Appendix H.1 and H.2. Published radiocarbon dates (n=372) from 61 sites, faunal species quantification data (n=113) on macro-mammalian remains from 29 sites, the prey age representation (n=131) of 33 sites, and seasonal data (n=60) from 18 sites were used (references given by site in Table 5.1).

Table 5.1: References for site locality, C14 ages, and faunal data for sites in the Cantabrian Region, if available. The cultural representation of sites is indicated by: m- multiple occupations, s- single occupations, x-unknown dimension of occupation, and (x)-suggested occupations based sometimes only on 1± cultural specific find or on only radiocarbon dates.

Area	ID	Site	Reference	LMP	AUR	GRAV	SOL	Early MAGD	Late MAGD/AZI
Nalón valley	1	Peña de Candamo	(Corchón-Rodríguez et al. 2014)				x	x	
	2	El Conde	(Fernández Rey et al. 2005)	m	m				
	3	La Paloma	(Castaños 1980; Álvarez-Alonso 2014a)					m	x
	4	Oscura de Ania	(Álvarez-Alonso 2014a)				x	x	m
	5	Sofoxo	(Corchón-Rodríguez & Hoyos-Gómez 1972)					x	x
	6	Las Mestas	(González-Morales 1975; González-Pumariega Solís et al. 2018)					m	
	7	La Lluera	(Rodríguez Asensio & Barrera Logares 2013; Rodríguez Asensio et al. 2013)				m		x
	8	Las Caldas	(Mateos Cachorro 2005; Álvarez-Alonso 2014a)				m	m	
	9	Entrefoces	(Álvarez-Alonso 2014a)					x	
	10	La Viña	(Álvarez-Alonso 2014a)				x	x	
Llanera plain	11	El Olivo	(Alvarez-Alonso et al. 2014; Álvarez-Alonso 2014b)					x	
Sella valley	12	El Sidron	(Torres et al. 2010)	s					
	13	Cova Rosa	(Utrilla 1996; Álvarez-Fernández et al. 2015)				s	x	
	14	La Güelga	(Maroto et al. 2012; Álvarez-Alonso 2014a)	m	m		s	x	
	15	Collubil	(Utrilla 2004)				x	x	x
	16	El Cierro	(Álvarez-Alonso & Andrés-Herrero 2013; Álvarez-Fernández et al. 2016)				s	x	
	17	Les Pedroses	(Garate-Maidagan 2010)					x	
	18	El Buxu	(Soto 1984)				s	x	
	19	La Lloseta	(Garate-Maidagan 2010)					x	x
	20	Tito Bustillo	(Altuna 1976; Álvarez-Alonso 2014a)					m	x
	21	San Antonio	(González-Pumariega Solís & Pérez 2008)					m	
	22	Sopeña	(Pinto-Llona et al. 2012)	m		x			
La Llera coastal plain	23	Tres Calabres	(Rodríguez Asensio 1992; Garate-Maidagan 2010)				x		
	24	Cueto de la Mina	(Castaños 1982; Álvarez-Alonso 2014a)			s	m	x	x
	25	La Riera	(Altuna 1986; Straus 1986a; Straus & Clark 1986)				m	m	m
	26	Balmori	(Utrilla 2004)				x	m	
Cares valley	27	Covaciella	(Moure-Romanillo et al. 1996; Valladas et al. 2001)						art
	28	Los Canes	(Arias Cabal & Suárez 1995)						x
	29	Trauno	(González-Pumariega Solís & Pérez 2008)					m	
	30	Coimbre	(Álvarez-Alonso et al. 2016)					m	m
	31	Llonín	(Martínez & Rasilla Vives 2013)			s	s	m	x
Deva valley	32	Esquilleu	(Jordá-Pardo et al. 2008)	m	s				
	33	La Loja	(González-Pumariega Solís & Pérez 2008)					s	
Nansa valley	34	Fuente del Salín	(Moure-Romanillo & González-Morales 1992)			art			
	35	Chufín	(Quesada-López 1997)				x		
West-Central Cantabria coastal plain	36	Las Aguas	(de las Heras Martín et al. 2007; Rasines et al. 2009; Fernandez Vega et al. 2010)					m	
	37	Linar	(de las Heras Martín et al. 2007; Rasines et al. 2009)				(x)	x	
	38	Cualventi	(Rasines et al. 2009)					m	m
	39	Altamira	(Valladas et al. 1992, 2001; Moure-Romanillo et al. 1996; Altuna & Straus 2009)			m	s	m	
	40	La Estación	(Gobierno de Cantabria 2009)			art			
	41	La Lora (Santa Clotilde)	(Fernandez Vega et al. 2010; Fernández Acebo 2010)					x	x
	42	Sovilla	(González-Sainz et al. 2009)						x

Area	ID	Site	Reference	LMP	AUR	GRAV	SOL	Early MAGD	Late MAGD/AZI
Besaya valley	43	Hornos de la Peña	(Yravedra 2010)	s		s	s		
Pas valley	44	Las Monedas	(Moure-Romanillo et al. 1996; Carrión Santafé & Baena Preysler 1998; González-Sainz et al. 2003)				(x)		
	45	La Pasiega	(González-Echegaray & Perelló 1953; Straus 1974)				x		
	46	El Castillo	(Cabrera-Valdés 1984; Valladas et al. 1992, 2001; Klein & Cruz-Uribe 1994; Moure-Romanillo et al. 1996)	m	m	m	m	m	x
	47	Las Chimeneas	(Moure-Romanillo et al. 1996)				art		
	48	La Flecha	(Freeman & González-Echegaray 1967)	m					
Central Cantabria/Santander coastal plain	49	La Pila	(Lloret 1995)						m
	50	Cudón	(Montes Barquín et al. 2015)			x			
	51	Covalejos	(Sanguino & Montes 2005)	m	m		(x)	m	
	52	El Pendo	(Fuentes Vidarte 1980)	s	m	m	x	m	m
	53	El Ruso	(Yravedra et al. 2010)	s	s		m		
	54	El Juyo	(Klein & Cruz-Uribe 1987)					m	
	55	Morín	(Altuna 1971a, 1973)	m	m	m	s		x
	56	Fuente del Frances	(Straus 1983)				(x)	m	
	57	La Garma	(González-Sainz et al. 2003; Álvarez-Fernandez 2007)			m	s	m	
Miera valley	58	El Salitre	(Garate-Maidagan 2010)				s		x
	60	Rascaño	(González-Echegaray & Barandiarán 1981)		s	s	(x)	m	m
	59	Pielago	(Straus 1987)						x
Asón valley	61	Cubera	(Moreno & Gómez 2017)						art
	62	Cofresnedo	(Straus et al. 2006)		art				
	63	Los Emboscados	(Straus 1992; Smith 2003)					x	
	64	El Otero	(González-Echegaray et al. 1966; Yravedra & Castanedo 2010)	s	m				m
	65	Cobrantes	(Smith 2003)		m		m		
	66	La Chora	(González-Echegaray et al. 1962)						m
	67	Cullalvera	(Díaz & Astorqui 2012)						art
	68	La Haza	(García Diez & Eguizabal Torre 2007)				(x)		
	69	El Mirón	(Marín-Arroyo 2010; Straus & González-Morales 2012)	s		s	m	m	m
	70	Covalanas	(Bischoff et al. 2003)				art		
	71	La Luz	(Castanedo et al. 2006)				(x)		
	72	El Horno	(Straus et al. 2002)						m
	73	La Fragua	(Marín-Arroyo 2003, 2004, 2005)						m
	74	Perro	(Marín-Arroyo 2004)						m
	75	El Valle	(Fernandez Vega et al. 2010)						m
Carranza valley	76	Sotarriza-Covanegra	(Fernandez Vega et al. 2010)						x
	77	Morro del Horidillo	(González-Sainz & San Miguel Llamosas 2001)				art		
	78	Arco (A,B,C)	(González-Sainz & San Miguel Llamosas 2001; Garate-Maidagan 2010)				art		
	79	La Pondrá	(Garate-Maidagan 2010)				art		
	80	Venta Laperra	(Rios-Garaizar 2016)		s				
	81	El Polvorín	(Garate-Maidagan 2012)		m				
	82	El Rincón	(Gonzáles-Sainz & Maidagán 2009)				art		
Urdiales	83	El Cuco	(Castaños & Castaños 2007)			m			
	84	La Lastrilla	(Vila 1975; Arroyabe & Vizcaya 1993; Muñoz Fernandez & Montes Barquin 2007)				art		
	85	Urdiales	(Barquín et al. 2005; Valladas et al. 2013)				art		

Area	ID	Site	Reference	LMP	AUR	GRAV	SOL	Early MAGD	Late MAGD/AZI
Western Vizcaya interior	86	Arenaza	(Garate & Jiménez 2000)				art		
Bilbao coast	87	Kurtzia	(Muñoz et al. 1990)	x					
Central Vizcaya interior	88	Arlanpe	(Rios-Garaizar et al. 2011)				s		
	89	Axlor	(González-Urquijo et al. 2005)	m					
	90	Silibranka	(Barandiarán Maestu 1978; Eraso 1983; González-Sainz 1989)						x
	91	Askondo	(Garate Maidagan & Rios-Garaizar 2012)				art		
	92	Atxuri	(Straus 1990)				x		
	93	Bolinkoba	(Iriarte-Chiapusso & Arrizabalaga 2013; Iriarte-Chiapusso 2015)			m	s	s	
Oka valley	94	Atxeta	(Straus 1990)				(x)	s	
	95	Antoliñako	(Aguirre 1998, 2012)		s	m	m		
	96	Santimamiñe	(Castaños & Castaños 2011)		s	s	s	m	m
Lea valley	97	Abittaga	(Garate-Maidagan 2012)						m
	98	Santa Catalina	(Iriarte-Chiapusso 2014; Laroulandie 2014; Sanchez & Tham 2014)						m
	99	Lumentxa	(Garate-Maidagan 2012)					m	s
	100	Atxurra	(Ruiz Idarraga 1990; Garate-Maidagan 2012)					m	
	101	Armiña	(Garate-Maidagan 2012)						m
	102	Laminak II	(Berganza & Arribas 1994; Castaños 1994)						m
	103	Goikolau	(Garate-Maidagan 2017; López Quintana et al. 2017)						x
Deba valley	104	Lezetxiki	(D'Errico & Sánchez-Goñi 2003)	m	s	m	(x)		s
	105	Labeko Koba	(Barandiarán Maestu 1996)	s	m	s			
	106	Etxeberri	(Garate & Bourrillon 2010)						art
	107	Ermittia	(Altuna 1972)			s	s	x	
	108	Praile Aitz	(Iribarren et al. 2017)					x	
Near-Deba valley coastal hills	109	Urtiaga	(Altuna 1972; Corchón Rodríguez 1995)				(x)	m	m
Urola valley	110	Ekain	(Altuna & Mariezkurrena 1984)			m	(x)	s	m
	111	Danbolinzulo	(Garate-Maidagan 2010; Garate Maidagan 2018)				art		
	112	Amalda	(Altuna 1990)	s		m	s	s	
	113	Erralla	(Altuna 1972, 1985; Altuna et al. 1985; Altuna & Mariezkurrena 1985)					s	m
Oria valley	114	Usategi	(Aldia & Garaia 1995)	x					
	115	Altxerri	(González-Sainz et al. 2013)					x	
	116	Abauntz	(Utrilla et al. 2012)	m			s	m	m
Urumea valley	117	Ametzagaina	(Tapia et al. 2009; Calvo 2012)			x			
	118	Astigarraga	(Altuna 1971b)				art		
	119	Aitzbitarte III	(Altuna 1992; Altuna & Mariezkurrena 2011)			m	(x)	x	
		Aitzbitarte IV	(Altuna 1963)				s		
	120	Torre	(Straus 1990)			s	x		x
Navarra & French Basque Country	121	Alkerdi	(Cava et al. 2009)			s		x	
	122	Isturitz	(Normand et al. 2013; Garate-Maidagan et al. 2013), (Straus 1990)				x		
Ebro watershed	123	Palomera	(Corchón-Rodríguez et al. 2009)						m
	124	Arrillor	(Rios-Garaizar 2007)	x					
	125	Atxoste	(Utrilla et al. 2012)						x
	126	Coscobilo	(Straus 1990)		s				
	127	Legintxiki	(Cabello 1997)					x	
	128	Zatoya	(Mariezkurrena 2001; Corchón-Rodríguez 2002)			s			x

5.1 Hunting biodiversity

In the Cantabrian Region, the most common prey species found at Late Middle and Upper Paleolithic sites are the following ungulates: horse *Equus ferus*, red deer *Cervus elaphus*, roe deer *Capreolus capreolus*, aurochs *Bos primigenius* and bison *Bison bison* (summarized in one size-category as large bovines can rarely be distinguished by taxon from archeofaunal remains), ibex *Capra pyrenaica*, chamois *Rupicapra pyrenaica,* and wild boar *Sus scrofa*.

The **Inverse of Simpson's Index** (I.SimpInd) (SIMPSON 1949) is used to observe the dietary change. In El Mirón cave, the results of the I.SimpInd show a drastic turn when only looking at the MNI data compared to the evolution of NISP (Figure 5.1). NISP was included to verify I.SimpInd results and how much it would change when using a different quantification scale of the same data for improving interpretations. The origin of faunal data, how they were summarized to make them comparable among various sites, and their consequent I.SimpInd value are presented in an Appendix Table H.4.1.

All MNI: In El Mirón, the I.SimpInd of MNI decrease drastically from 8, in the Middle Paleolithic layers, to ~5 in the Early Upper Paleolithic layers to ~4 in the Solutrean levels for all species. In comparison to the index, which only using ungulate species shows that the assemblage components of other species, such are carnivores or small mammals, are much higher in older levels. With the beginning of the Magdalenian occupations, the I.SimpInd of all species generally drops lower, meaning that diversity of game species decreases. These results also show, however, other species that earlier were scarcely represented by only a few remains are now less common in El Mirón levels, mostly a few fragments that evidence not more than one individual per level. It is a known problem that rare species are overrepresented when using MNI as an indicator of species diversity (LYMAN 1994). Thus, Initial Magdalenian levels were excluded, where meager NISP numbers presumably skew the results and always should be interpreted with caution.

Ungulate MNI: For comparison, only the diversity of ungulate species procured by humans were considered to express hunting biodiversity. Ungulate biodiversity in terms of MNI decreases until the beginning of the Solutrean occupation at the site, increases steadily, and becoming highest in Level 127. Another increase was observed until the middle of Lower Magdalenian Level 17, and thereafter diversity decreases and stays low when including the published from the later levels (MARÍN-ARROYO 2010). This measure seems a good index for observing changes in dietary diversity, however, it is also based on MNI, and scarce species again are overrepresented.

All NISP: For El Mirón Cave, when exploring the I.SimpInd of all NISP, the observed faunal composition seems to be better to represent the reality of Paleolithic dietary contributions. Beginning in Level 130, the index is relatively high and much lower in the ephemeral Early Upper Paleolithic occupation in Level 129 and 128. After a short drop of the index in Level 127, the highest value of 4.2 was reached in Level 126, thus indicating the greatest faunal biodiversity identified in specimens were found for early Solutrean levels at El Mirón. After dropping, the I.SimpInd of all NISP stays almost constant at ~2.4 during subsequent Solutrean levels. While Levels 120, 21, 20, and 19 are possibly skewed due to low NISP, they show remarkably low diversity. Afterward, in the Lower Magdalenian occupations, the index basically evens to a value of ~2 indicating a dominance of two main game species, as is also the case in the burial deposit, Level 504. This trend is continued in Middle Magdalenian Levels 108 and 14 of El Mirón studied earlier by Marín-Arroyo (2010). In comparison, the later El Mirón occupations show related biodiversity patterns, meaning that two main game species were also preferentially hunted during all Magdalenian occupations of the site indicating that site location might have been favorable for such a dual meat-based subsistence, a scenario that has already been shown before by Marín-Arroyo (2010). And, when site locations were appropriate for this practice, it also implies that throughout the Magdalenian hunting bands acted in similarly optimal ways with respect to such

mixed (valley/montane) those environmental settings. During the Middle Magdalenian occupations, only Level 13 has an exceptionally high I.SimpInd of 3.9, which is possibly biased by the low NISP (N=59) number of this unit. However, Upper Magdalenian hunting diversity was slightly increased at the beginning and again decreased continuously with time. Final Magdalenian occupations, on the other hand, show an overall but rather punctuated trend towards greater biodiversity of hunted species; a phenomenon obviously in need of investigation considering how global environmental changes influenced biodiversity during that time period. Notably, those hunter-gatherer groups living before, during and after the Younger Dryas experienced rapid, impactful climatic fluctuations, certainly obligating them to adapt subsistence and settlement strategies that were interwoven in social exchange networks that in turn improved resilience of those groups (SAUVET 2017).

Ungulate NISP: This measure stays almost identical to the above-described I.SimpInd of all NISP, indicating that the one described above might be sufficient when calculating biodiversity in the future.

In summary, the observations made based on the biodiversity and its change through the occupations imply the following aspects of economic behavior at El Mirón cave: Although, the earliest occupations (MP-EUP) included a variety of game species that might infer a more opportunistic subsistence strategy, in fact it was carnivores that dominantly contributed to these accumulations. A similar strategy was employed during the earliest occupations of the cave by Solutrean people. This pattern changed during the course of the Solutrean. Thus, with Level 125, a more specialized hunting technique, which targeted primarily two main prey species, is observed. This strategy seems to have lasted throughout the Lower Magdalenian occupations and the beginning of the Middle Magdalenian. Only one interruption, due to an increase of the I.SimpInd, was identified in Level 13, after which there continued to be focused exploitation of mainly two main game species, which in El Mirón cave were red deer and Spanish ibex. Upper Magdalenian hunters exploited one more other game species in an early phase, but they mainly continued to hunt the two core game species. However, a trend in increasing biodiversity started with the Final Magdalenian.

Methodologically, the results lead me to infer that using NISP as a factor to calculate the biodiversity of human dietary resource exploitation assemblage reveals the importance of more adequate measures. An intensified use of some game species resulting in bone fracturing and more fragmentary specimens from more exploited animals will be present (MAREAN ET AL. 2001; OUTRAM 2004), reflecting the dominance in dietary contribution coming from one or more species. MNI values of rare species are commonly overrepresented, a phenomenon typically associated with MNI data (KLEIN & CRUZ-URIBE 1984; LYMAN 2008). However, instead of using all possible game species, relying on biodiversity calculations in only including regional-specific, commonly-appearing chief game ungulates seemed to be the solution to the problem. The I.SimpInd is very sensitive for biases when assemblages are small, making I.SimpInd of all NISP a sufficient indicator of dietary biodiversity.

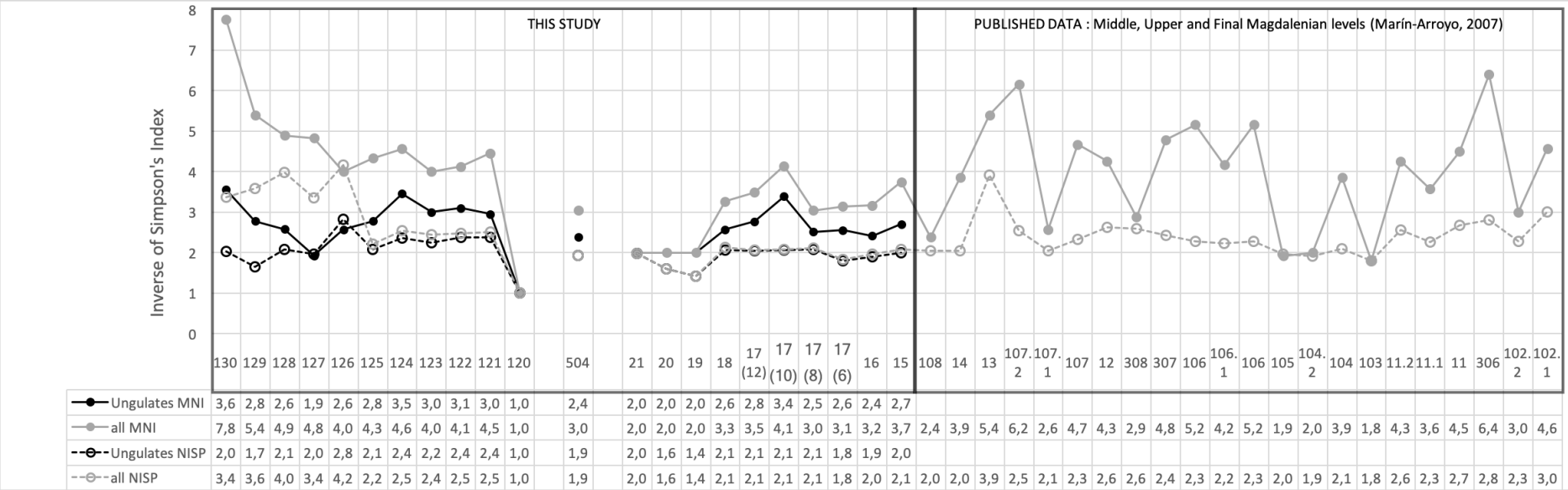


Figure 5.1: Inverse of Simpson's Index for El Mirón cave; for MNI and NISP, for all and for ungulates. (Level 504 is contemporary to Level 17)

For the Cantabrian Region, the results for the study of ungulate hunting evolution based on the I.SimpInd (Figure 5.2) show no specific trend in species biodiversity during the 33-24ka cal BP interval (Early Upper Paleolithic/ Gravettian). Although the reason for this phenomenon might be the limited faunal data available, it can be mainly distinguished between sits of either high or low biodiversity, but unclear if this is related to the duration of site occupation. This obvious separation might indicate, however, a clear bifurcated structure of sites due to functionality; either hunting camp or base camp or seasonal occupations, for example. The reduced biodiversity between 24-20ka cal BP (Solutrean through Lower Magdalenian) indicates a hunting specialization as not observed before, focusing on two or one main game species in almost every regional site. If harsh environments reduced hunting options in terms of biodiversity or if specialized hunting was imposed from foreign-Southwestern France groups once highly specialized in reindeer or horse hunting to local biodiversity and topography are just possibilities not tested yet. Anyway, this strategy seemed to reveal itself as a successful one, as Lower Magdalenian people continued and even intensified these practices. Starting about 18.2ka cal BP hunted species diversified again (during the Middle and Upper Magdalenian) marking another turnover point in economic practices.

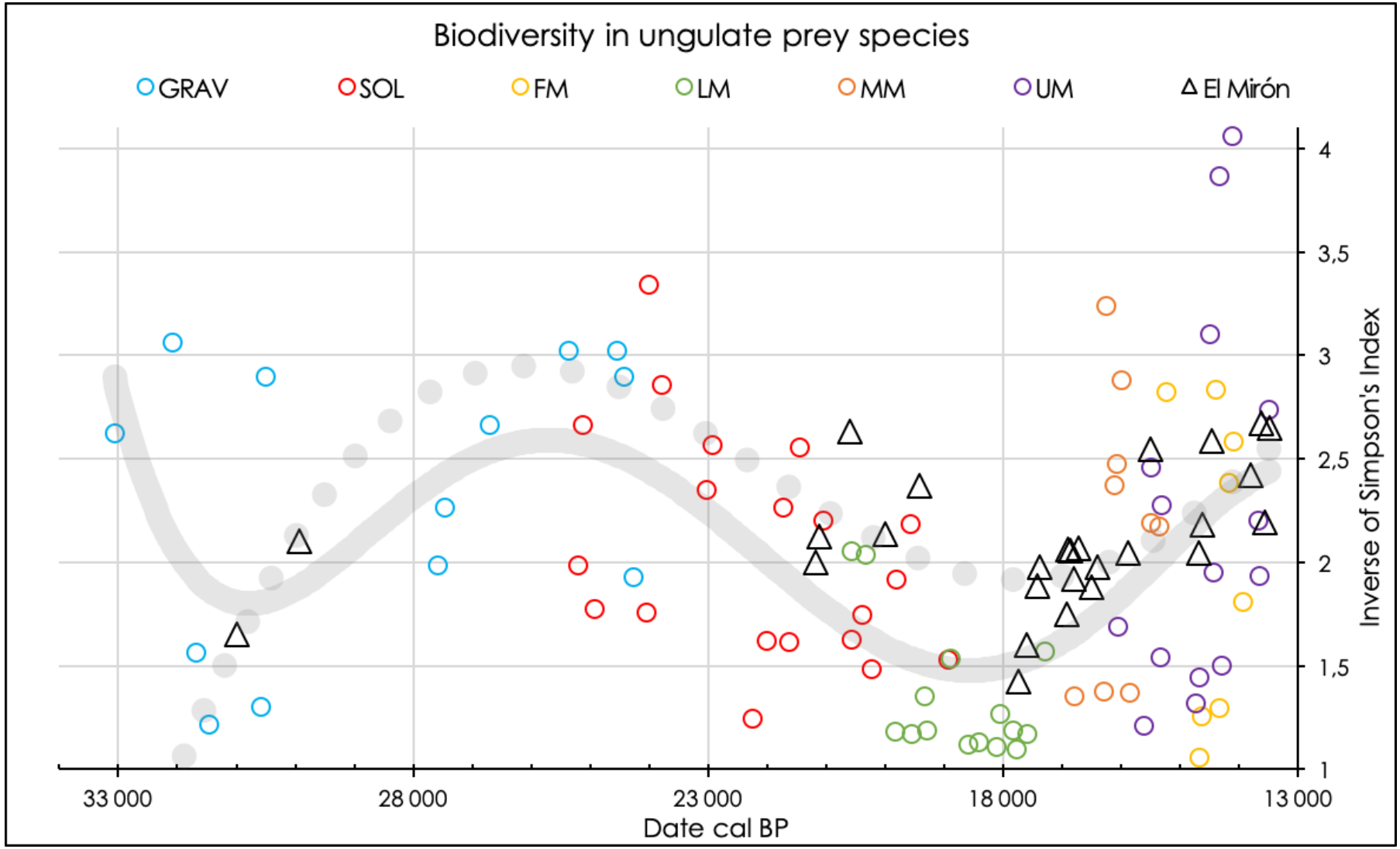


Figure 5.2: The Inverse of Simpson's Index shown for the Cantabrian Region. The dotted trend line for El Mirón, solid trend line for Cantabrian Region.

The phenomenon of hunting specialization needs further comment. The distribution of the regional Lower Magdalenian I.SimpInd values represent a real depression within the general trend curve pattern of the archaeological faunal assemblages. Such a strong specialization towards the hunting of only one main prey species at many sites, a pattern unique to that Lower Magdalenian period. What could be the reason for that? One explanation might be that hunting activity was always staged in places favorable for targeting a specific game species (due to local topography, for example), and as such, hunting success at those sites would mainly represent one species, similar to reindeer hunters in SW France. In such a manner, different site locations were occupied specifically with regard to their topographic location, and species were exploited systematically at those places (MARÍN-ARROYO 2009b). Figure 5.3 shows the dominance of terrain within the site catchment areas, indicated by a mean value of slope degree within a radius of 10km. This could explain why montane sites like Coimbre, Erallla, or Rascaño are dominated by ibex hunting and other contemporaneous occupied sites, such are La Paloma, El Juyo, El Pendo and La Riera on the coastal plains are dominated by red deer hunts (see STRAUS 1977, 1987). Although Santimamiñe is located close to the coast, the territory is quite steep and rocky in its immediate surroundings, yet the Lower Magdalenian is dominated by red deer (CASTAÑOS & CASTAÑOS 2011). Whether species diversity was reduced by climatic deteriorations is possible as climate ameliorations favored temperate species (GRAYSON ET AL. 2001; JONES 2016). Another reason for such focused hunting at many sites could be a purposely targeting of species for specific exploitation of animal resources such are hides, tendons, bone fat, antlers, or bones for hide-working and osseous tool production which were common tasks during the Lower Magdalenian. Obviously more clarification is needed.

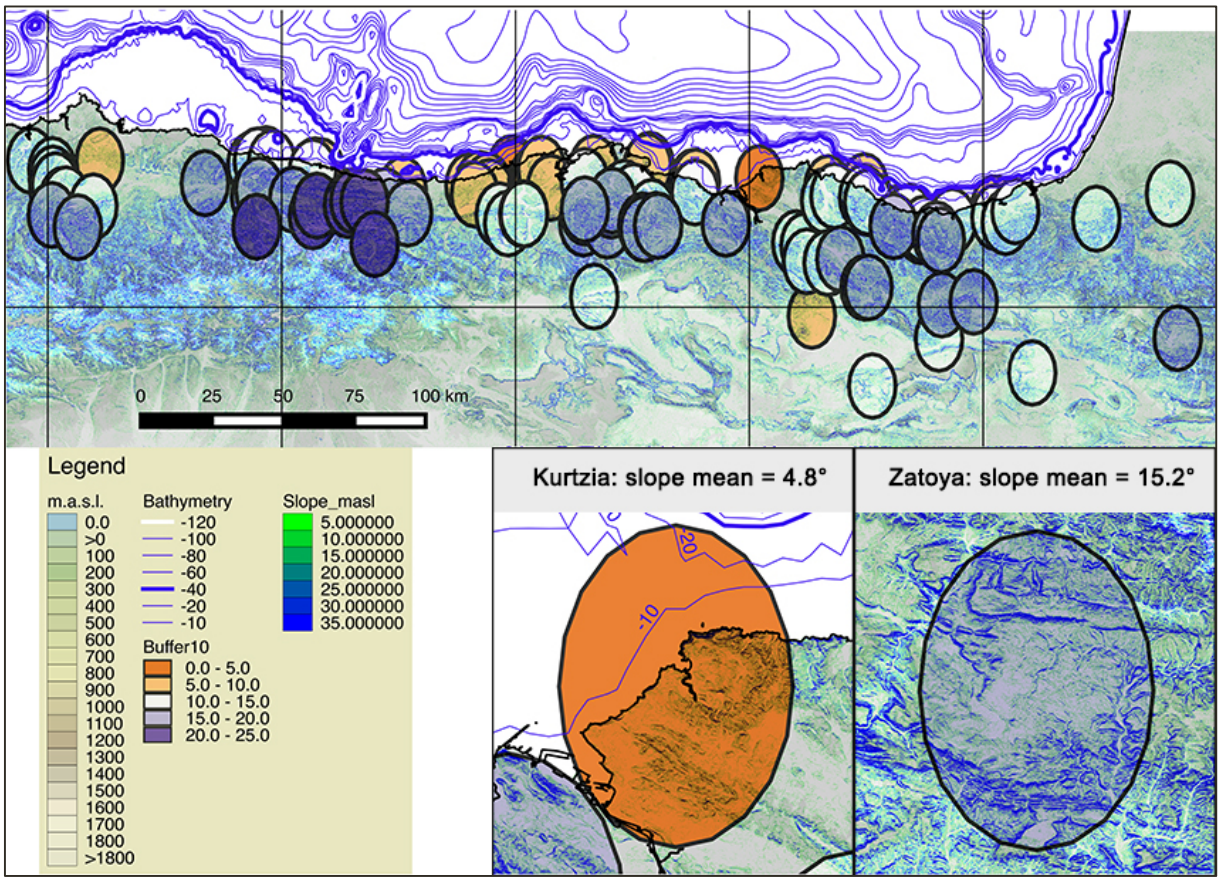


Figure 5.3: Slope analysis of sites from the Cantabrian Region (see Table 5.1). Buffer zone with a 10km radius reflects mean slope values, inferring terrain of site surroundings.

The I.SimpInd index is as high as two only for a few sites during the LM period: El Mirón, El Castillo, and Urtiaga, suggesting that site topography might have been favorable for more than one species living in the immediate surroundings and that hunters exploited this fact to their advantage.

The newly obtained data on the biodiversity of El Mirón Lower Magdalenian are located on the uppermost and middle range of biodiversity values obtained for the Cantabrian Region, thus showing a higher biodiversity than the rest of the sites. This might be due to the reason that El Mirón has a favorable topographic location close to two different but adjacent habitats, steep, rocky mountainside and broad, low river valley, appropriate for hunting two game species, ibex and red deer, respectively. It seems the topographic advantage of El Mirón Cave revealed itself, particularly during that period, and people started to occupy the mountain zone more permanently (MARÍN ARROYO 2008).

The detailed consideration of the results requires a short discussion of the outliers. Lower Magdalenian I.SimpInd values are mainly below a value of 1.5. There are two Lower Magdalenian outliers that can be found within the Solutrean time-range and hunting biodiversity distribution rather than in the Magdalenian. They might represent an early Magdalenian period, or their cultural attribution or radiocarbon date might be incorrect; one dataset is from El Castillo, Level 8: 16.850±220 BP; I.SimpInd= 2.04 and the other from Urtiaga, Level F: 17.050±140 BP; I.SimpInd= 2.06. On the other hand, during the review of the basal Urtiaga F material a few Solutrean pieces were identified in the literature by Straus (1992), and verified in the artifact collection by L.M. Fontes, the observed data would actually best fit the Solutrean subsistence strategy pattern observed, rather than the Lower Magdalenian. Thus, the reconsideration of Urtiaga level F's cultural attribution(s) is recommended.

In summary, according to the biodiversity of hunted species measured by I.SimpInd hunting was occasionally specialized during the Gravettian, increasingly specialized during the Solutrean, highly specialized during the Lower Magdalenian and diversified again with the beginning Middle Magdalenian. The Lower Magdalenian might mark the step towards intensification pattern that still needs to be refined to be better understood and other economic factors will be considered following.

5.2 Hunting pressure

Hunting pressure is trackable by economic tension in resource exploitation, for example, by investing more energy, while obtaining lower return rates from young or difficult to hunt animals; both patterns were considered here. Usually, human hunters would concentrate hunting in the most profitable prey such are prime-age adult individuals as biomass is highest by each hunted unit (STEELE 2002).

The percentage of young animals in the studied levels of El Mirón can be summarized as most of those anthropogenic levels seem to lie between 33.3% to 66.6% (Figure 5.4). While assemblages with NISP smaller than 50 specimens were excluded for analysis, all levels with a high, representative NISP and MNI contain some young animals. A few levels are outstanding, because they contain remarkably high or low frequencies of young animals, notably for the former case Levels 124 and 11.1 and for the latter, Levels 129, 127 and 14 in El Mirón. There may be different scenarios explaining this pattern. If new human groups started to occupy certain areas, they might start stalking first prime-age individuals (maybe male groups), before successively including younger ones (mother herds) as the older animals became scarce, as one scenario. Or another scenario could be that hunting season changed. However, such a pattern might be shown by increases in young animal percentages seen in the transitions from Levels 129 to 128, 127 to 125 and 14 to 13, demonstrating change in hunting patterns each time. If this differentiation is possible to make depends, however, on the degree of fine resolution of the stratigraphy, as the density of the Lower Magdalenian palimpsest occupations might blur such events. It might also be influenced by how often human groups occupied certain areas, depending on the settlement system, multi-year rounds, annual-rounds or multi-

seasonal stays that would obviously put different degrees of hunting pressure on local animal resources. The successively lower incorporation of young individuals from the Solutrean to the Lower Magdalenian might track the cultural manifestation of prime-age animal hunting, although this trend was not strictly continued during the Middle and Upper Magdalenian.

Young individuals of red deer and ibex do not seem to have been introduced into the site in the same manner. The oldest levels contain more young ibex than red deer. The lack of young red deer might occur when during a given occupation hunting was focused on prime-age individuals or was highly seasonal; for example, during short, specialized hunting stays at a site. Later, however, both game species were transported to the cave similarly until the beginning of the Solutrean, when the contributions of young individuals was comparable high. They show decreasing portions of the total game bag until the end of the Lower Magdalenian occupations. Lower Magdalenian levels generally show moderate contributions of young animals, which are highest for red deer in Level 16, possibly an indication of a certain degree of hunting pressure on red deer just before the end of the Lower Magdalenian. Levels 124 and 11.1 with high young animal percentages, demonstrate either a certain hunting pressure on only young animals or specialized hunting season.

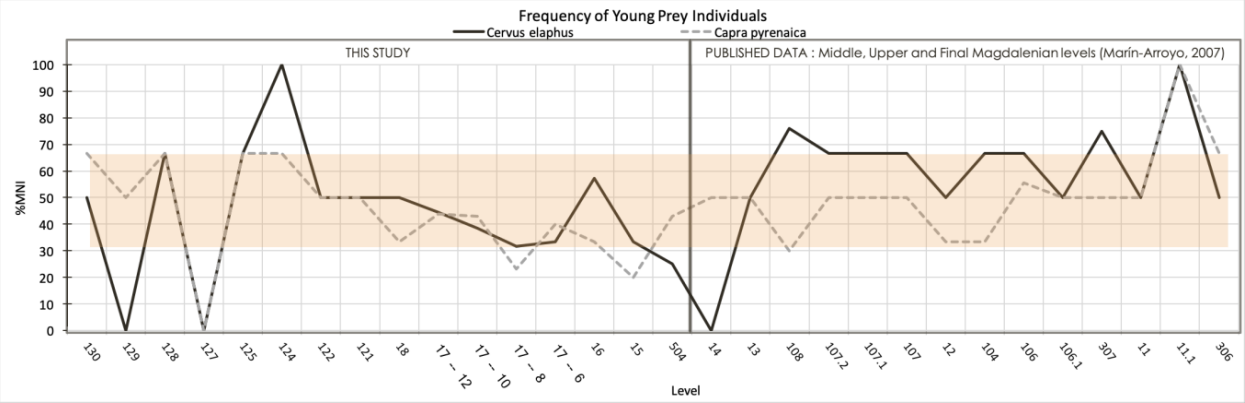


Figure 5.4: Frequency of young animals by levels in El Mirón cave; levels with NISP<50 were excluded.

Hunting pressure on young individuals has also been observed at several other sites in the Cantabrian Region. Sites generally contain between 20% to 40% of young animals in the faunal assemblages. However, there is a pattern of decreasing percentages from early to younger Solutrean occupations. Despite this observation, the high portions of young prey in Solutrean El Mirón levels with about 50% to 60% is outstanding. It may be questioned if the detailed laboratory work employed here, including the small fraction from general bags, just resulted in identifying more of the smaller bones. Good preservation conditions at El Mirón site might have also favored the preservation of such more fragile elements from the whole faunal assemblages. More detailed faunal analysis and modern excavation techniques for sites dating to that period would be useful for interpreting further such patterns.

However, the percentage of juvenile individuals in the faunal assemblage rises beginning during the Initial Magdalenian from less than 40% to almost 70% at the end of the Magdalenian (Figure 5.5). At the same time, the percentage of low ranked species, such are roe deer and wild boar increased, which are fast-small sized and dangerous, respectively. They increased with the Early Magdalenian to the Late Magdalenian from maximal ~10% to an average of ~20% (compare Figure 5.6). Especially wild boar was increasingly exploited during this time period. This shift, which signifies an increased use of low- ranked resources, could indicate an intensification of site occupation and greater tensions on the territory (MACARTHUR & PIANKA 1966; STINER

1994; MUNRO 2004, 2009), or alternatively, changes in the environment affected hunting behavior. This may be the case for both roe deer and wild boar, which appear more frequently in the Cantabrian sites throughout the reforestation process at the beginning of the Holocene (MARÍN-ARROYO 2009a), since roe deer and wild boar are true woodland species.

It seems that when site occupation intensity is low, high-ranked prey are preferred, with an intensification of site occupation, hunters added lower ranked-prey to cover energetic needs. It is also possible that scenarios like overhunting would explain the extension of resource usage to include more young individuals and low ranked species (GEILING & MARÍN-ARROYO 2013; MARÍN-ARROYO 2013), both parameters reflecting dietary stress and a shift to less productive subsistence behavior, as was argued earlier by Straus at La Riera (STRAUS & CLARK 1986).

Lower Magdalenian occupations, 19ka-18ka cal BP, however, show the most intensive site use, but not the highest portions of young animals. Demographically- driven hunting pressure on local game species does not seem to have been the case at this time. Regarding the subsistence system employed by Lower Magdalenian hunter-gatherers, resource intensification did not relay on incorporating younger animals during hunts, but rather involved exploiting each animal carcass more intensively. Especially, when comparing to marrow extraction, bone grease rendering might supplement and complement dietary intakes or other resource necessities in such a manner that selected animals for hunting for proper portions of size and fat content. This would explain the reduced hunting of young animals, known for having less fat content. Another explanation could be the strong seasonality of occupations that favor the presence of young animals during summer occupations, for example. Seasonality of site occupations need to be considered further and compared among sites in the Cantabrian Region.

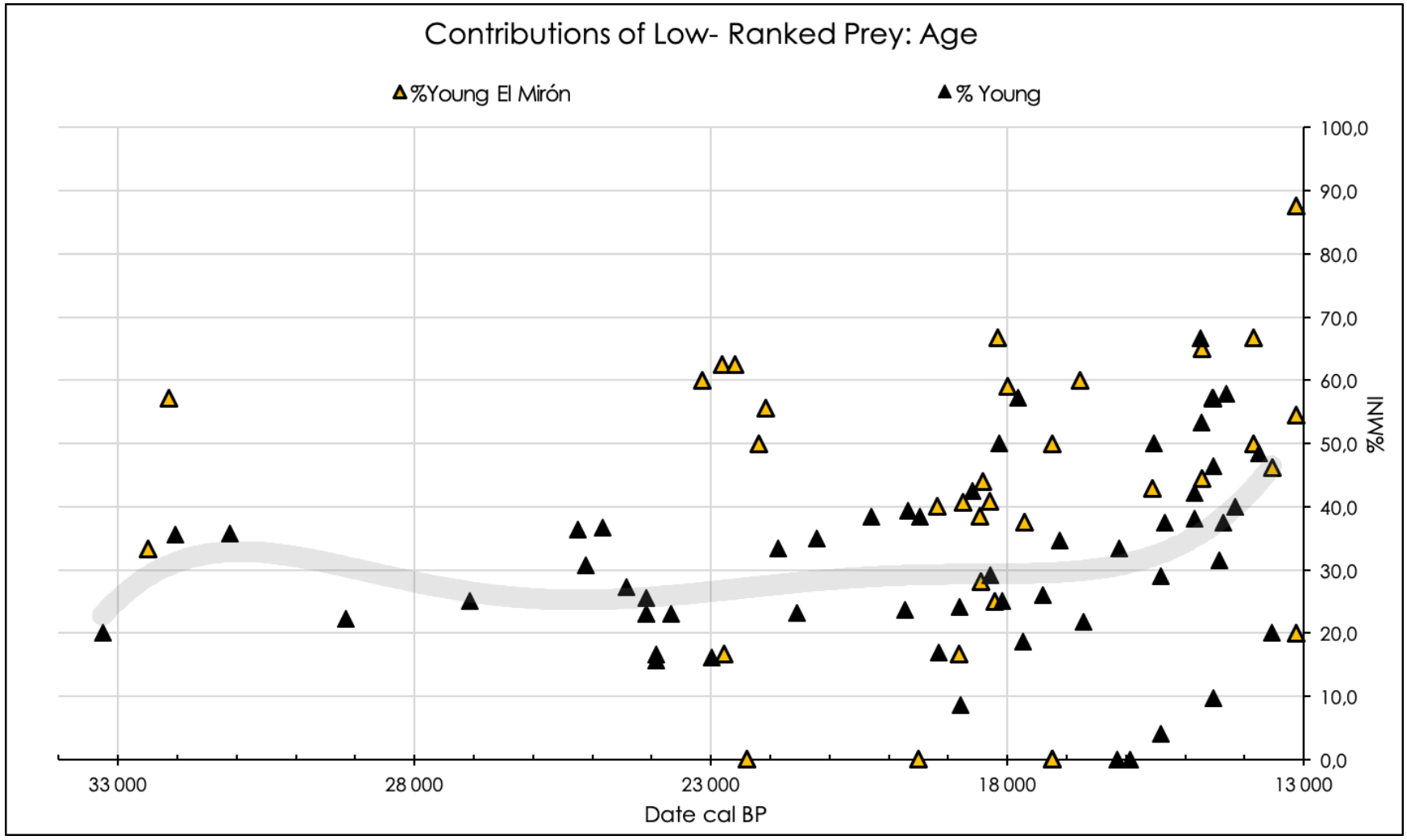


Figure 5.5: Contributions of low-ranked prey. %Young= juveniles and younger (solid line= trend).

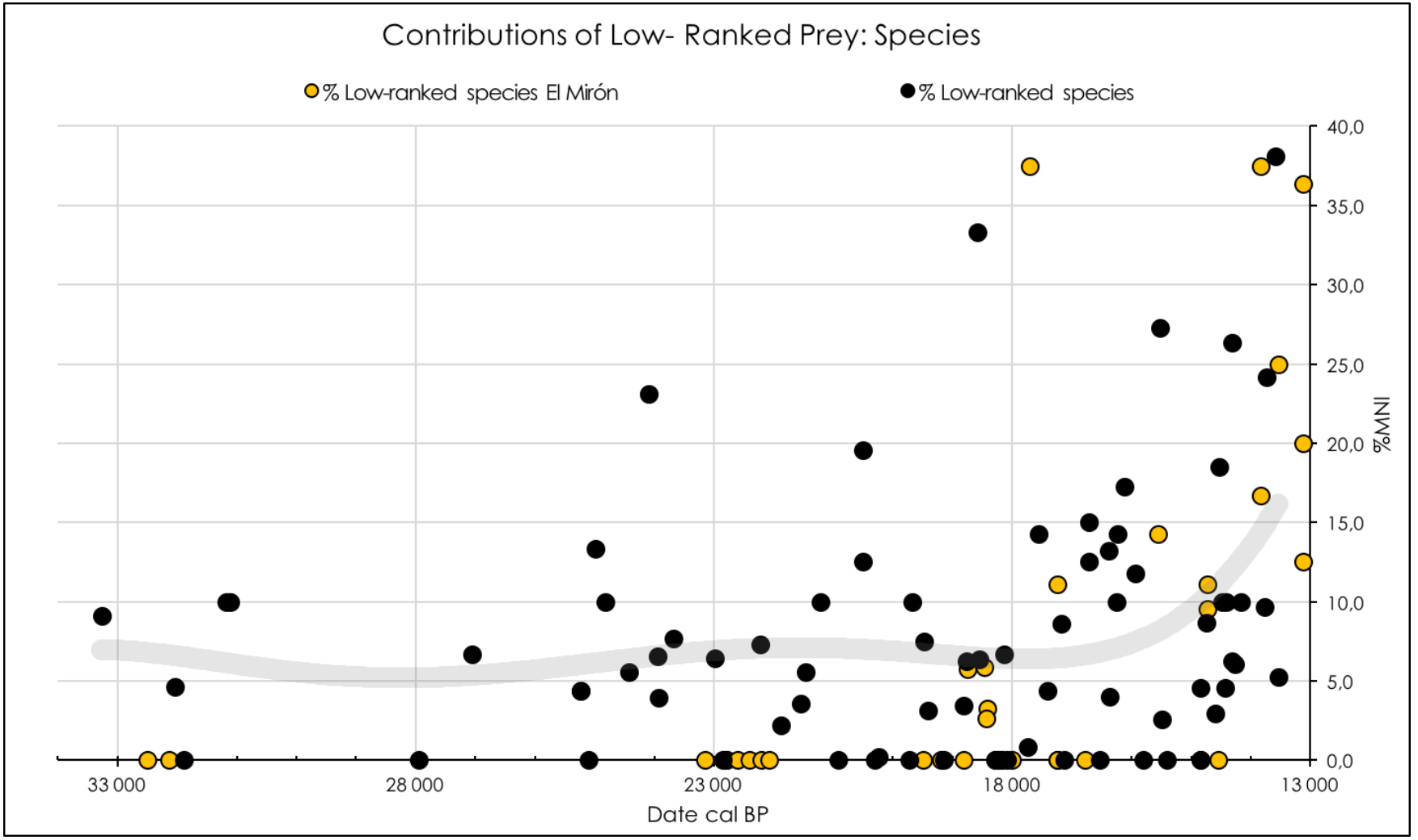


Figure 5.6: Contributions of low-ranked prey. Low-ranked species = roe deer and wild boar (solid line= trend).

5.3 Hunting season

The prevailing understanding of Cantabrian settlement systems was derived from a relatively small number of previous faunal studies, which suggested three types of Late Glacial sites (STRAUS & CLARK 1986; STRAUS 1986b, 1987, 1992; GONZÁLEZ-SAINZ 1989; MARÍN-ARROYO 2009c): First, red deer -dominated hunting sites together with substantial amounts of ibex supplemented sometimes by other species, such are large bovines or horse, situated in open, coastal, sometimes hilly areas such are: El Castillo, La Fragua, Santimamiñe, Lumentxa, Urtiaga, Ekain, Aitzbitarte, etc. Second, sites located in open terrain specialized on red deer as the main prey species: El Juyo, Altamira, El Pendo, Morín, Atxeta, etc. Finally, sites located in hillsides with significant presence of mountain species: Rascaño, Piélago, Bolinkoba, Silibranka, Letzetxiki, Ermittia, Amalda, Erralla, etc. La Riera showed that a site on the coastal plain but near a steep, high, rocky mountain range could have some levels dominated by red deer (plus other game and marine mollusks) and others by ibex (ALTUNA 1986; CLARK & STRAUS 1986). The presence of many residential sites in the Cantabrian coastal zone suggested a more sporadic or seasonal and logistic use of the mountain zone, as suggested by the relatively small number of inland sites that had been excavated by c. 1980. A turning point of this understanding of late Paleolithic land use was set in the zooarchaeological analysis of Middle, Late Magdalenian and Azilian levels at El Mirón cave, because it revealed evidence for residential functions in an inland, montane-habitat site during the summer (MARÍN-ARROYO 2009c, 2010). These findings suggest the need for a rethinking of previous interpretations of exclusive residential occupations on the coastal strip with short seasonal south-north movements (between the inland and the coastal zone) along the region's many river valleys possibly related to seasonal animal movements along these corridors (and based on modern ethological studies of the main game taxa (see FREEMAN 1973)). The common understanding of Paleolithic settlements opened up with the findings in El Mirón as we became aware of the possibility of montane areas as being residential settlement zones. Despite this updated state of the art, occupations were still thought to be limited to summer/ warm season occupations on the basis of Marin-Arroyo's first faunal studies of the uppermost Magdalenian and Azilian levels at the site. The evolution of seasonal occupations throughout more of the stratigraphic sequence will be presented here.

At El Mirón, Late Middle Paleolithic occupations show an autumn-winter signal. During the Early Upper Paleolithic, (albeit also based on very small samples) signals of all seasons are represented, but are dominated by autumn ones. The Solutrean people seem to have used El Mirón mainly during the winter-spring season, with only little evidence for autumn occupation; no summer signal has been observed, but there are several fetal bones from ungulates that normally gestate during winter. A very similar pattern is shown for the few Initial Magdalenian remains from the Outer Vestibule that were studied during this research project. The earlier occupations of the Lower Magdalenian also follow this pattern of dominant winter-spring signals; however, a slight tendency is visible towards increasing autumn and summer contributions later on in the LM and this greater warm-season evidence continued later on with mainly spring/summer occupations during the Middle, Upper and Final Magdalenian (MARÍN-ARROYO 2010). The seasonal signals are shown in the following Figure (compare Figure 5.7).

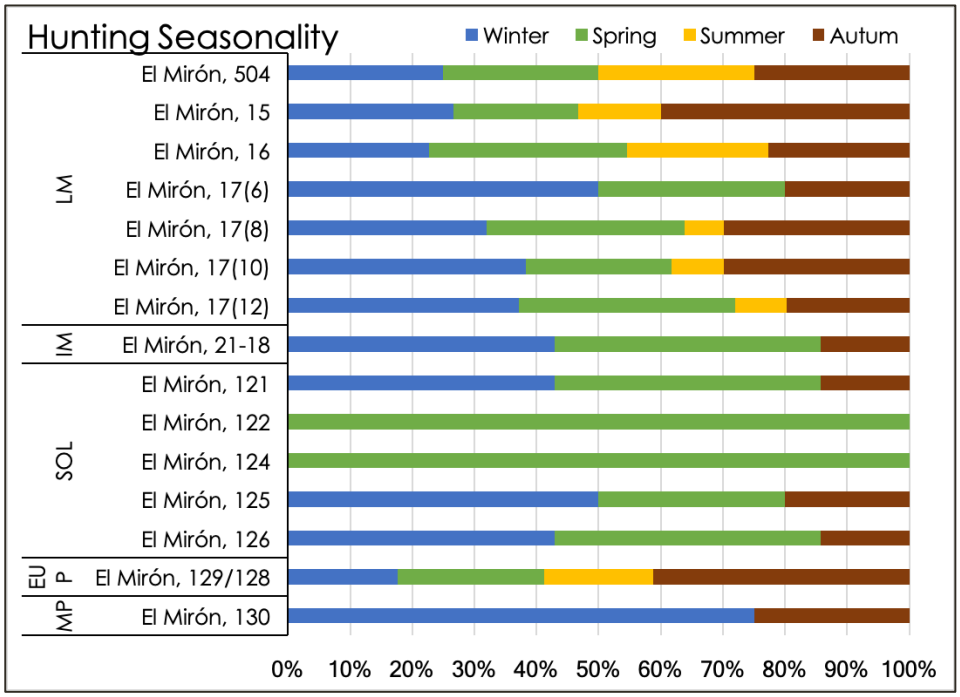


Figure 5.7: Seasonal contributions of red deer and Spanish ibex in El Mirón. EUP-Early Upper Paleolithic, SOL-Solutrean, IM-Initial Magdalenian, LM-Lower Magdalenian. Level 504 and Level 17 are contemporary.

For the Cantabrian Region, seasonal data are occasionally available for Paleolithic faunal assemblages, which were collected here to review the development of settlement systems through time (Figure 5.8). The few Early Upper Paleolithic seasonal data indicate mainly summer occupations in the coastal zone (La Riera), as well as in the lower river valleys (Aitzbitarte); only one winter contribution was found in Amalda cave, which is not very far from the modern coast of Guipuzcoa (ALTUNA 1990). During the Solutrean, only summer occupations for Amalda has been observed. Solutrean coastal sites (La Riera, Cueto de la Mina) show evidence of settlements during winter-spring-summer with only a few autumn contributions. Solutrean summer and autumn evidence seems to be stronger in Ekain, and Hornos de la Peña (YRAVEDRA 2010), which might reflect strategically moves through river valleys to the montane interior during the Solutrean, but also cold-season, short stays at El Mirón. The Lower Magdalenian occupations across the region show a mixture and strong presence of multi-seasonal occupation. Only a few single-season occupations are found, noticeable are El Pendo for winter, Abauntz and Tito Bustillo for summer, and Tito Bustillo for autumn season. Within the present collection of Cantabrian site data, it is remarkable that the spring season is not well-presented during this period, instead of El Mirón site. El Mirón in the montane zone were commonly occupied during winter-spring and rivers valleys being often visited during summer-autumn. This fact should be highlighted for two reasons. It is the first time evidenced by repeated use of the mountain zone during cold seasons, remarkable as the mountains were thought to be left unsettle during glacial and immediate post-glacial conditions. It indicates, on the other hand, an economic system of strategically land use as ibex can be effectively exploited dwelling in lower altitudes during cold seasons, and red deer are best chased while gathering and distracted during rut seasons. For the Middle Magdalenian, a spring-summer season was also suggested for this montane zone site. Las Caldas shows mainly summer-autumn-winter occupations, similar to Tito Bustillo, for that time. Upper Magdalenian hunter-gatherers seemed to have lived in the mountain in spring-summer and spend most of the summer, autumn, and possible winter season in the coastal plains. A stronger signal of winter occupations in plain areas is observed from the Final Magdalenian sites, where all other seasons are present. Mountain areas are restricted to spring-summer occupations for this time period.

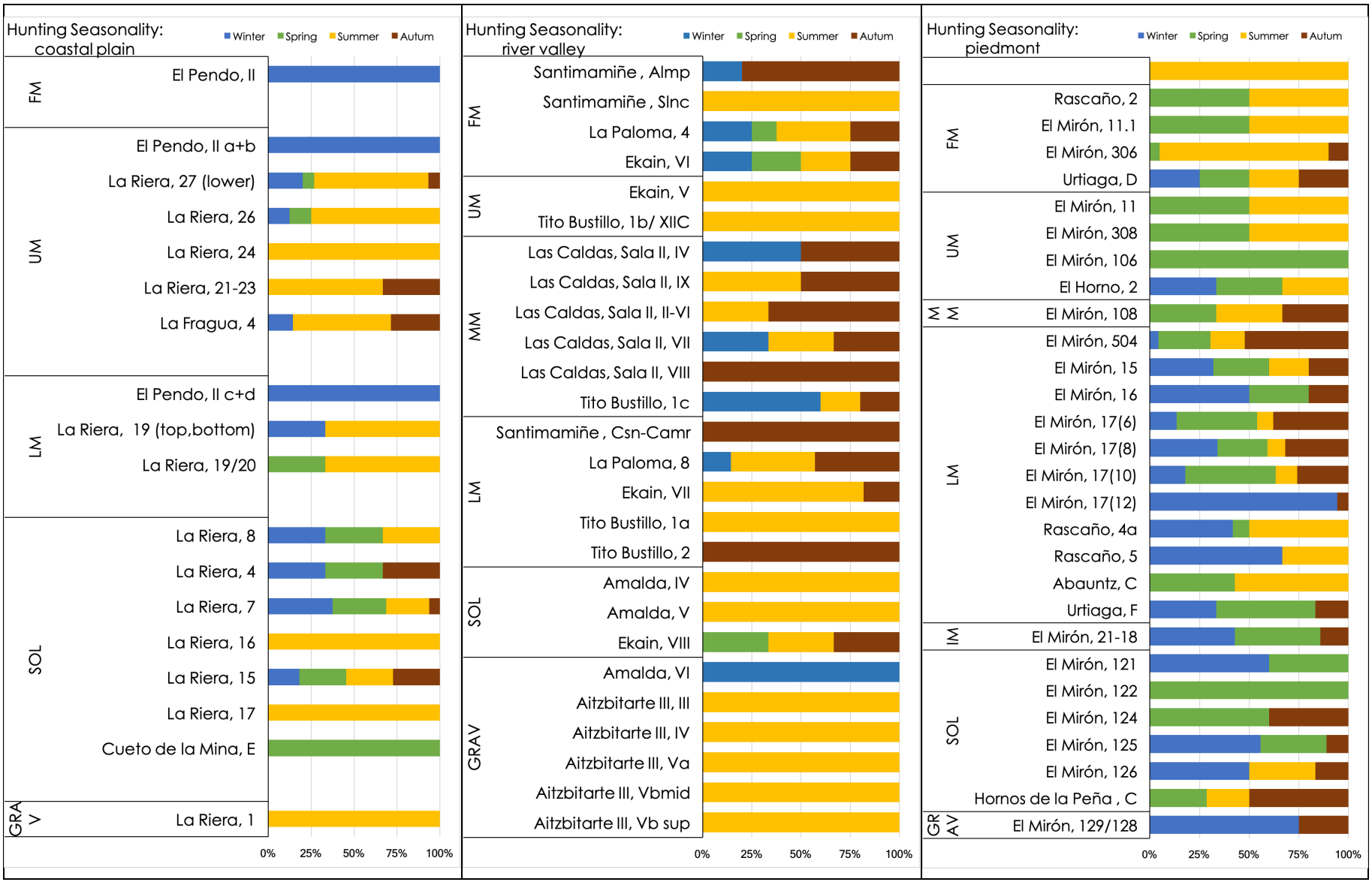


Figure 5.8: Seasonality ranking by cultural periods and site location. GRAV-Gravettian, SOL-Solutrean, LM-Lower Magdalenian, MM-Middle Magdalenian, UM-Upper Magdalenian, FM-Final Magdalenian

The occupation season indicates shifting site use between montane and coastal zones, presumably the result of human mobility and seasonal hunting practices in order to optimize resource usage. However, I do not observe a clear north-south movement related to summer-winter alterations, as suggested earlier by Straus (1992). Seasonal occupations and movements of human groups might be forced by other factors and more complex than only between movements between the coast and the mountain ranges.

Level 17 seasonality is outstanding herein as it shows more intensive, may be semi-permanent, year-round occupations of the mountain zone. And with such stability in the settlement patterns many of those resource intensification patterns being observed. However, local resources seemed to have been maintained more stable by applying for the Paleolithic advances technologies of grease rendering and cooking, for example. As was shown in previous chapters, the remaining characteristics of the Lower Magdalenian are that they adapted an economic strategy that maintained local resources during longer occupations with elaborated site activities. Such local identity might have produced territory boundedness at that time, possibly reflected in the red deer engravings limited to several sites of less than 150km distance to each other (GONZÁLEZ-MORALES & STRAUS 2009).

5.4 Territoriality and changing climate

The sequence of dynamic economic adaptations was aligned to a new radiocarbon chronology modeled (used dates see Appendix H.3) for El Mirón in comparison with regional data for contextualization of obtained faunal results, territoriality, and population density. The results of the radiocarbon age model are summarized in Figure 5.9. The settlement model for El Mirón cave, in particular, clearly shows clusters of radiocarbon dates, which are shortly considered and discussed here. Regional, chronological data appear to cluster, too. El Mirón was often part of those major regional settlement systems. Thus, it can be used as representative for the use of the montane zone for various settlement episodes during the course of the Paleolithic.

At El Mirón cave, the oldest hominin visits to the cave are associated with the Late Mousterian, and suite quite well within the regional settlement model of dispersed and temporally isolated occupations for archaic humans (i.e., Neanderthals), with Mousterian cultural manifestations ending 48 - 45ka cal BP (MARÍN-ARROYO ET AL. 2018b). Around 49ka cal BP, the beginning of the Northern Ice Surge event recorded within the marine drilling core on the Iberian margin just marks the onset of the HE5 cooling event (peaked at 45ka cal BP). In the Cantabrian Region, most Late Middle Paleolithic occupations generally have low densities of faunal remains and some presence of carnivore activities, suggesting that they represent more short-term visits of humans (for example, in the upper levels of Axlor cave) and carnivores were frequently involved in the accumulation of the bones in archaeological sites (STRAUS 1982). Only a few sites can be interpreted as long-term residential loci, namely El Castillo, El Pendo, and Morín in Central Cantabria (STRAUS ET AL. 2002) or Amalda and lower levels in Axlor cave in the Basque country (RIOS-GARAIZAR & GARCÍA-MORENO 2015). The newly compiled information on regional settlement distribution and chronology coupled with new faunal evidence at El Mirón demonstrate the common short and ephemeral use of cave sites during MIS3 with a few favored territories around the El Castillo, La Güelga, Esquilleu, Morín, Covalejos, Amalda and Axlor localities (MAROTO ET AL. 2012; HIGHAM ET AL. 2014; MARÍN-ARROYO ET AL. 2018b). Statements about settlement patterns during the Châtelperronian are still difficult to make, as this period is less-well evidenced within the archaeological record and there are very few credible radiocarbon dates; for the moment only Labeko Koba has a Châtelperronian AMS date treated with ultrafiltration to increase accurateness (WOOD ET AL. 2014; MARÍN-ARROYO ET AL. 2018b).

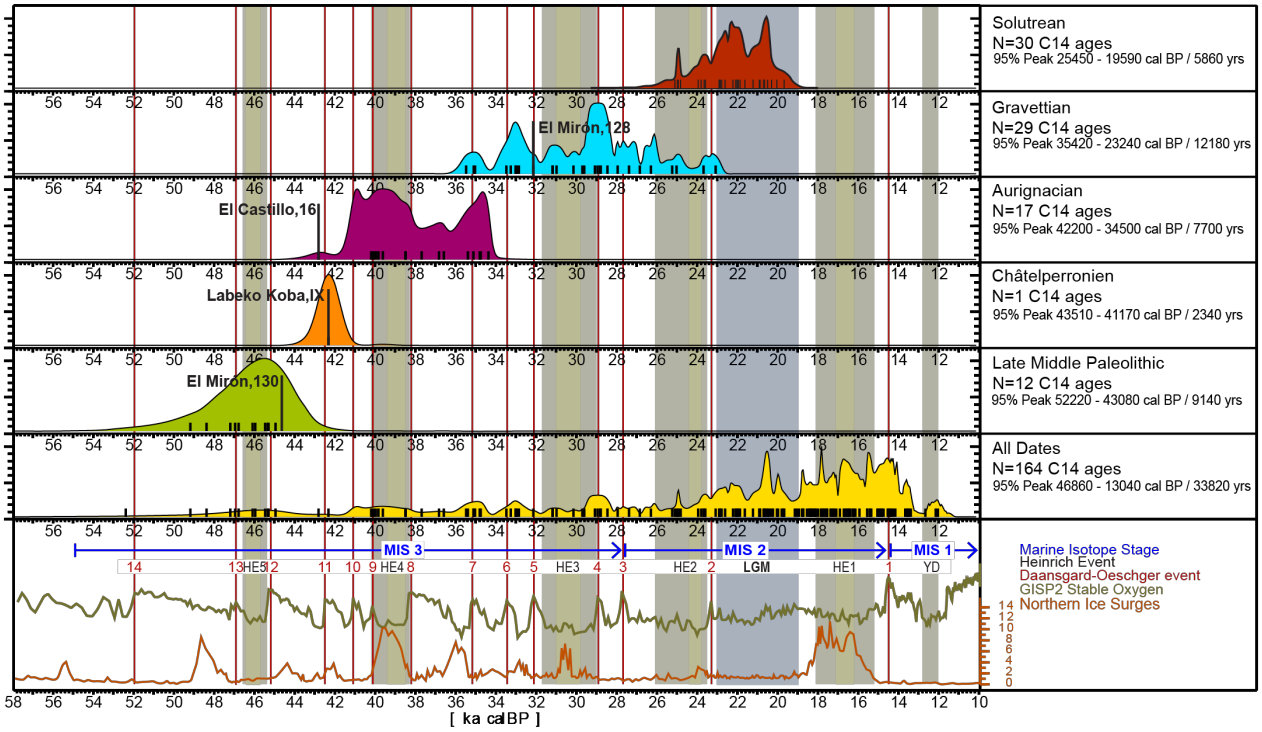


Figure 5.9: Multiple plot for Late Middle Paleolithic, Châtelperronian, Aurignacian, Gravettian and Solutrean radiocarbon- age model. Upper: Cumulative multigroup-calibrated probability distributions for radiocarbon-ages from the Northern Iberian culture periods. Lower: Age calibration uses the GISP2(Hulu) curve with the program CalPal2016 in green (WANG ET AL. 2001; WENINGER & JÖRIS 2008). Selected climate record: Marine Isotope stages in blue (SÁNCHEZ-GOÑI & HARRISON 2010), Dansgaard-Oeschger high stands corresponding to warmer phases in red, and Northern Ice Surges at the Iberian Atlantic Margin as proxy for cold surface water in orange. Darker shaded areas show particularly cold phases of Heinrich stadials (H1- H5). Light blue shading marks the range of the Last Glacial Maximum.

According to the here created regional age model, including current concerns about the Cantabrian chronology (MAROTO ET AL. 2012; WOOD ET AL. 2014; HIGHAM ET AL. 2014; MARÍN-ARROYO ET AL. 2018b; GUTIÉRREZ-ZUGASTI ET AL. 2018), the end of the Cantabrian Mousterian fall in times of rapid climatic change, of HE5 rapid cooling at 46 ka cal BP between DO13 and DO12 events of abrupt global warming (compare Figure 5.9). Even though caution should be taken with dates so close to the radiocarbon dating limit and with large standard deviations, however, some of these new dates were obtained with up to date preparation methods (i.e., AMS and ultrafiltration AMS), thus improving result precision (HIGHAM ET AL. 2011). Whether HE5 event (~46ka cal BP) triggered population withdrawal is still highly speculative given the tiny sample of dated sites, but Late Middle Paleolithic (Neanderthal) evidence of population relicts appear scattered in the Basque Country and repeated at El Castillo Cave before their demise from the Cantabrian Region.

As summarized by Marín-Arroyo (2018), (but also see MAROTO ET AL. 2012; WOOD ET AL. 2014, 2018; HIGHAM ET AL. 2014), after an occupational hiatus in the Cantabrian Region, a Châtelperronian (Labeko Koba: 42.6ka - 41.5ka cal BP)- Aurignacian overlap was proposed (compare also Figure 1.10). The Châtelperronian still needs to be better documented to allow for deducing economic patterning, which in general suggests at least temporally successful adaptive dietary practices.

The one Châtelperronian record from a possible hunting camp at Labeko Koba in the Basque country and the Early Upper Paleolithic Level 16 from El Castillo in Cantabria, are both associated with the DO11 event of rapid-warming and slow-cooling (RIOS-GARAIZAR ET AL. 2012; WOOD ET AL. 2014; MARÍN-ARROYO ET AL. 2018b). The one evidence of (presumed, but with no skeletal remains) early arrival of AMH at 42.8ka cal BP (Level 16

at El Castillo) physically would conceivably have implied contacts between the two human sub-species for a short time in the Cantabrian Region, although otherwise a hiatus seems to have existed between the Châtelperronian and Aurignacian. The Castillo Level 16 dates suggest a possible temporal overlap of human occupations in the region by those two cultures for around 1,000 years (MARÍN-ARROYO ET AL. 2018b). It is worth mentioning that besides the existence of the chronological hiatus, Late Middle Paleolithic and Aurignacian settlement evidence show some parallels, with many of the same major sites (e.g., El Castillo, Morín, El Pendo, La Viña) being occupied during both periods and they are located within wide valleys of the low-hill, coastal area, with few along the edge of the Cantabrian mountain range, both types of locations being in close proximity to rivers (ARRIZABALAGA ET AL. 2009).

Aurignacian occupation in the Cantabrian Region continued to appear sporadically and dispersed around 40ka (compare Figure 1.13), with the onset of HE4, but with slightly increased settlement intensity of greater human occupation, there are fewer obvious carnivore accumulations than what had been seen during the Middle Paleolithic (STRAUS 1982). The Aurignacian in the region shows many sites with short-term visits such are Lezetxiki, Labeko Koba or Ekain. Some of those even show specialized hunting activities, for example, ibex exploitation at El Esquilleu (YRAVEDRA 2005) or possibly Rascaño (ALTUNA 1981) or red deer at El Castillo (DARI ET AL. 2003)) and only a few contain a large quantity of archaeological remains. Basically, one major cluster of Aurignacian sites within daily-walking distances of one another around the present-day Bay of Santander include more complex multi-purpose loci, such as El Castillo, Morín and Covalejos.

The proper onset of the Aurignacian settlement within the region, though, seems to coincide with DO9 according to the radiocarbon model (Figure 5.9). Settlements are rarely recorded during the latter, climatically more severe part of HE4. Afterward, occupations become more frequent. While the last peak of Evolved Aurignacian radiocarbon dates groups around the DO7 event, a first wave of archeological layers identified as Early Gravettian occupations coincides with DO7 and a second wave with DO6, resulting in apparently contemporaneous Aurignacian and Gravettian industries in Cantabria. Close chronological dating at Aitzbitarte III and some cultural similarities seem to show technological and chronological continuity and suggesting some sort of socio-technological exchange across the Aurignacian–Gravettian transition in the Cantabrian Region (ALTUNA ET AL. 2013; RIOS-GARAIZAR ET AL. 2013; MARÍN-ARROYO ET AL. 2018b). This transition coincides with the onset of the DO7 event whose climatic fluctuations might have influenced changes in economic and technological adaptations and population dynamics. The Aurignacian ended around at 34.6–33.1ka cal BP. The proper onset of the Gravettian appears at 33ka cal BP across the region (ZILHAO 2006; WOOD ET AL. 2014; MARÍN-ARROYO ET AL. 2018b).

The Aurignacian-Gravettian transition appears to have been gradual as a cultural mosaic phenomenon with a reorganization of weapons technology (STRAUS 2018). Humans adapted to different ecological niches of MIS3 environments (HAWS 2012) when anatomically modern humans expanded their territory into southern Spain and Portugal (STRAUS ET AL. 2000a, 2000b; BRADTMÖLLER ET AL. 2012; MARREIROS & BICHO 2013). The number of sites increased during that period, incorporating recent discoveries of open-air sites, including Ametzagaina in San Sebastian (TAPIA ET AL. 2009), located at a raw material outcrop. Cluster of early Gravettian radiocarbon dates around climatic events (here DO7 and DO6) suggest that these human records might be somehow associated with climatic oscillations (BRADTMÖLLER ET AL. 2016; BICHO ET AL. 2017), as they influence diversity and accessibility of dietary resources.

While early Gravettian settlement evidence coincided with rapid climate changes (DO7, DO6), each followed by an occupational hiatus, at least in caves such as at El Mirón where alternating carnivore-human use continued, and there is a new presence of several open-air sites, especially in the Basque region - some associated with flint outcrops. If human cave use appears to have been especially important during severe climate conditions, maybe radiocarbon sequences from cave deposits record nothing more than the

response of human groups to external stimuli whilst settling much longer in the Cantabrian Region. In such a manner, Late Glacial sea-level fluctuations mean that large territories of pre-LGM, LGM, and post-LGM Cantabrian landscapes (i.e., ones possibly occupied at least during the Solutrean), are currently submerged. However, during the HE2 event, a greater intensity in human settlements is observed for the Cantabrian Region (STRAUS 1979), a fact which correlates with temporary high hunting biodiversity and preying on young ungulates. Between c. 25 and 23ka cal BP the record reveals the decreasing portion of young animals, low-ranked species, and species diversity as indicative of changes in economic adaptations. Just at the onset of the LGM, with varied faunal assemblages showing similar biomasses, the size of groups that visited El Mirón, for example, stayed stable. Based on density and amount of material found at sites, some are likely to reflect rather short hunting visits (STRAUS ET AL. 2013; STRAUS 2019), while others probably saw longer stays, for example, Altamira, Las Caldas, the Llera cluster (La Riera/Cueto de la Mina/Tres Calabres/Balmori) (ALTUNA & STRAUS 1975; STRAUS & CLARK 1986; CORCHÓN-RODRÍGUEZ 2017).

Early Upper Paleolithic people, possibly Gravettians, stayed briefly at El Mirón during a cold spell immediately before the DO5 warming event, around 32ka cal BP (if the one radiocarbon date is correct). Further Gravettian occupations appear more frequently with the beginning HE3 and continued until the end of HE2, indicating at least repeated settlement in the region. Human occupations generally were sporadic and rather short, likely indicating single visits to caves. Multiple occupational layers of other Gravettian sites, such as Aitzbitarte III, Antoliñako, Bolinkoba, El Castillo, El Pendo, Cueto de la Mina, and La Viña, possible represent the major sites of this time period in northern Atlantic Iberia (STRAUS 2018). At present, according to recently published radiocarbon dates, an occupation hiatus of several thousand years is seen at the Middle to Early Upper Paleolithic transition at El Mirón cave. Nevertheless, it needs to be considered that these cultural periods were only identified in the deep sondage excavation of two square meters at the rear of the vast Cave Vestibule in a drafty, ill-lit area. For this reason, these levels probably give only limited insights about their accumulators and its context. To date, no major residential site dating to the Mousterian or Early Upper Paleolithic is known from the upper Asón drainage, where El Mirón cave is located (STRAUS ET AL. 2002).

After the Early Upper Paleolithic, an increase in the number of levels and sites attests a more frequent settlement of Cantabria. This is associated with the Solutrean, after a transition from the Gravettian cultural period during the HE2 event (RASILLA-VIVES & STRAUS 2004; CALVO & PRIETO 2013). Similarly, there are debates about cultural transitions in younger periods, including between the Gravettian and Solutrean, as well as between the Solutrean and Magdalenian. Many questions as to what may have triggered these cultural changes remain still unanswered (RIPOLL LÓPEZ & RIPOLL-PERELLÓ 1990; RASILLA-VIVES & STRAUS 2004; QUESADA-LÓPEZ 2006; CALVO & PRIETO 2013). However, the transition from the Gravettian to the Solutrean appears to have occurred in the form of early pre-LGM settlement pulses, with the first records falling just at the sharp onset of HE2 (25ka cal BP) and the next in the climatically more extreme second part of an HE2 event (23.8ka cal BP). Later during the course of the Solutrean, occupations continued with an unprecedented intensity in settlement density (or at least in terms of site numbers), which lasted through the whole LGM (STRAUS ET AL. 2000a, 2000b, 2015; SCHMIDT 2015; STRAUS 2019).

Since the first Solutrean may have appeared in like in 'temporary pulses' in the region, occupations during the LGM were more frequent. However, Solutrean hunter-gatherers seem to be more scattered temporally across the landscape, with many ephemeral site occupations. Whether even larger over-regional territory occupations generated a pattern of temporary human absence or only environmental deteriorations forced them to live mainly in caves creating grouped radiocarbon dates, still needs to be clarified. It would be reasonable that climatic changes obligated hunter-gatherers to search for shelters (rather than at open-air sites, which had begun to more numerous preserved in the Gravettian record) and that settlement patterns were thus adapted. The late phase of HE2 might have been such a time of strong climatic fluctuations. The two-phase pattern (change from wet/cold to dry/cool) of Heinrich events H4, H2 and H1 can be explained by

the re-location of the Atlantic Gulf Stream back and forth between southern Portugal 35-37°N and to Galicia 42°N latitude (EYNAUD ET AL. 2009; NAUGHTON ET AL. 2009), which caused changes in temperature and precipitation.

At El Mirón, a third group of dates ranging between 23.2–22.1ka cal BP (19 230±50 uncal BP and 18 390±300 uncal BP) can be attributed to approximated short visits to the cave during the relatively early Solutrean. They were somewhat more intensive occupations, with multiple, stratigraphically distinguishable occupational layers and a greater chronological time spread from more repeated visits to El Mirón cave, maybe by short stays of hunting parties compared to the older levels (STRAUS & GONZÁLEZ-MORALES 2009; STRAUS ET AL. 2011, 2013). Thus, the Solutrean occupations at El Mirón seem rather brief, repeatedly and of special-function (a hunting camps with large numbers of broken Solutrean points and few other artifacts) rather than residential (STRAUS ET AL. 2002). It could also have been a 'way station' en-route between the clusters of major Solutrean sites in central Cantabria and central Vizcaya, although the proposed better route at this time would have been along the then-emerged continental shelf. That corridor, the area of now submerged lands beyond the modern coastline, was wide enough (c.5-10km north of the present shore) enough to provide extensive feeding grounds and living spaces of potential game species in close distance to the sea that was accessible during that time significantly lowered sea level. More Solutrean sites might be located there. There are hints of Solutrean occupations on the inner edge of the Asón coastal zone in Cobrante and La Chora. Many occupations are scarce in (diagnostic) artifacts and often have Cantabrian Solutrean sites (NR=40) less than 10 Solutrean points, as Straus (2019) reviewed recently. So, it can be concluded that Solutrean occupations (with exceptions such as Altamira, Cueto de la Mina/La Riera, Las Caldas, Aitzbitarte) are generally not that rich in archaeological remains, often being rather short and non-repetitive in nature. There are certain areas where bands seem to have clustered (e.g., the Middle Nalón, the Posada de Llanes and Ribadesella areas, the central Cantabria plain, central Vizcaya, and the area between San Sebastian and Isturitz in the French Basque Country), but there may have been 'marchlands' between these clusters which were used (e.g., for hunting) less intensively and traversed for reasons of flint procurement and social activities. Solutrean people seemed to use smaller daily catchment areas and practices more frequent residential movements, which would be coherent with smaller group sizes, and may allow higher fertility rates (SUROVELL 2000). Nevertheless, these occupations seem to appear in clusters around some locations that were favored for settlement. Some of the most important Solutrean sites in the region are Las Caldas, La Viña, La Riera/ Cueto de la Mina/ Tres Calabres, and Altamira. Those localities, however, are part of larger social networks as those hunter-gatherer groups were exchanging or transporting lithic raw materials across large distances (Portugal-Cantabrian Region-Southwestern France), and varied environments (AUBRY ET AL. 2015). Those notable transregional networks were no less than large-distance social exchange networks (for not only materials, but also mates and ideas), making them highly resilient societies despite their small group sizes (SAUVET 2017).

The major Solutrean occupation started during the HE2 event. During the LGM (*sensu lato*) the Solutrean settlement continued, but suddenly the Initial Magdalenian culture began, still within this cold phase (compare Figure 5.10).

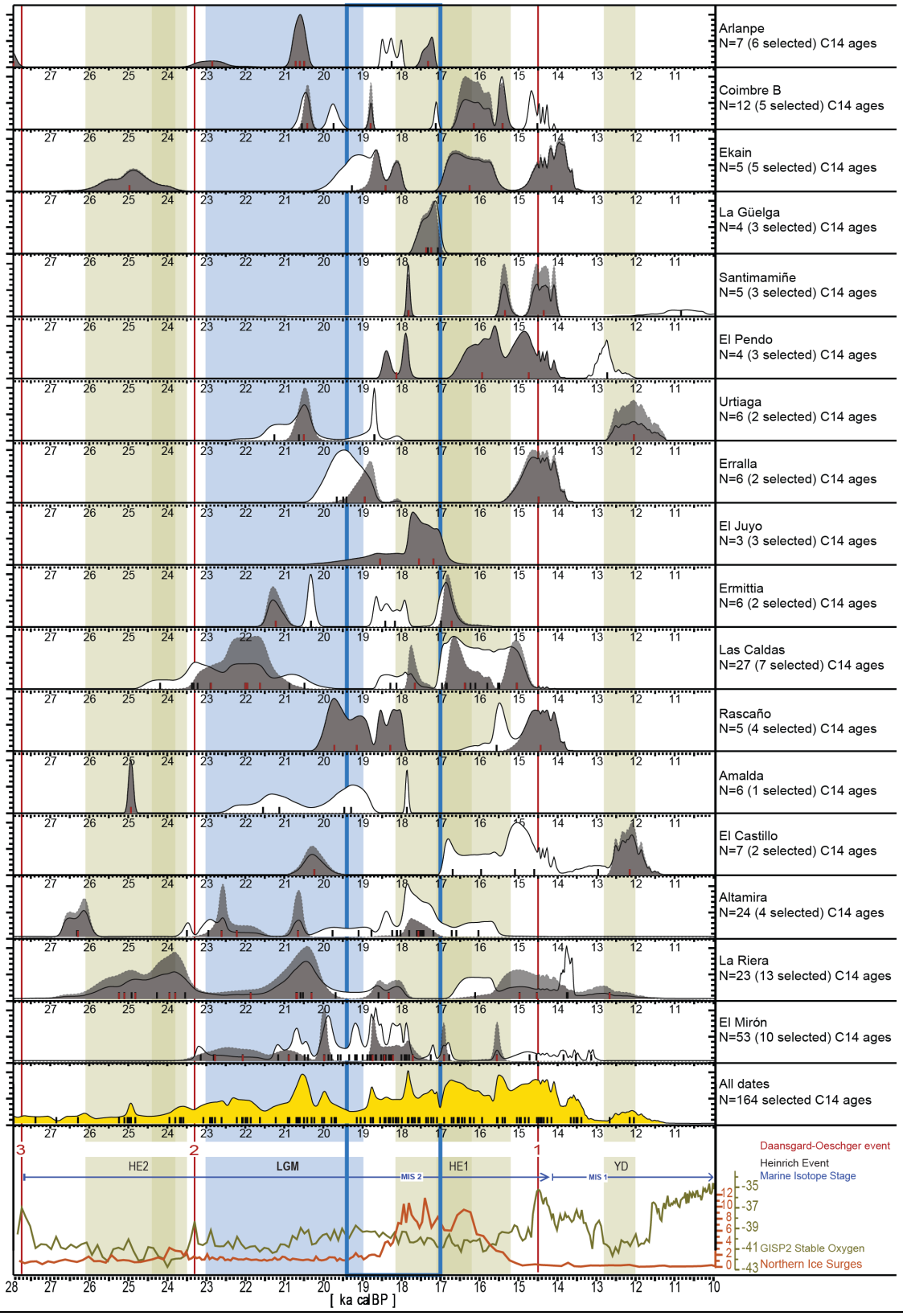


Figure 5.10: Multiple plot for Solutrean-Magdalenian radiocarbon-age model. Upper: Cumulative multigroup-calibrated probability distributions for radiocarbon-ages from Paleolithic sites in the Cantabrian region. Lower: Age calibration uses the GISP2(Hulu) curve with the program CalPal2016 in green (WANG ET AL. 2001; WENINGER & JÖRIS 2008). Selected climate record: Marine Isotope stages in blue (SÁNCHEZ-GOÑI & HARRISON 2010), Dansgaard-Oeschger high stands corresponding to warmer phases in red, and Northern Ice Surges at the Iberian Atlantic Margin as proxy for cold surface water in orange. Darker shaded areas show particularly cold phases of Heinrich stadials (H2- H1). Light blue shading marks the range of the Last Glacial Maximum.

After a depositional hiatus, detected within the Vestibule Rear of El Mirón cave, between the Solutrean and the Initial Magdalenian, a possible 'transitional' phase at around 21ka cal BP (i.e., Mid-Vestibule Trench Level 313 based on only one m² and thus lacking in any diagnostic artifacts) and Initial Magdalenian cultural remains dating to ~20ka cal BP in the Vestibule Front, marking the beginning of a new era with a clear break *vis à vis* the previous cultural manifestations and when visits to the cave began to intensify. In the Cantabrian Region, there are some few radiocarbon dates that seem to correspond to this period, although assigned to different cultural units, that group around a brief period around ~20.5ka cal BP (Table 5.2).

Table 5.2: Occupations in the Cantabrian Region contemporaneous to El Mirón Solutrean occupations.

Archaeological record	Culture	Calibrated date (ka cal BP)
Las Caldas Pasillo 4	Solutrean	20.49 ka cal BP
Coimbre B Co.5.B.1	Transitional	20.4 ka cal BP
La Riera 17	Solutrean	20.3 ka cal BP
Altamira 6	Solutrean	20.65 ka cal BP
El Castillo 8c beta	Initial Magdalenian	20.24 ka cal BP
Arlanpe III	Solutrean	20.5 ka cal BP
Ermittia V	Solutrean	20.32 ka cal BP
Uritaga F inf	Initial Magdalenian/Solutrean	20.5 ka cal BP

During the Solutrean-Initial Magdalenian transition, the process of 'de-solutreanization' seems to have taken place, which is defined as the gradual replacement of toolset components, from Solutrean points to antler sagaies, and variability in lithic assemblages, possibly due to functional differences among sites and occupations (STRAUS ET AL. 1978; UTRILLA 2004; AURA-TORTOSA ET AL. 2012; DOMINGO ET AL. 2012; CORCHÓN-RODRÍGUEZ 2017). Whether the shift to cultural manifestations we call Magdalenian was due simply to changes in aspects of culture such as technology and artistic expression or to a human population shift (or even replacement) is still difficult to determine.

It marks another major transition although, only manifested by a few artifact assemblages dating to ca. 17ka uncal BP (El Rascaño, El Mirón, Urtiaga). They are key sites in the debate about the origin of the Lower Cantabrian Magdalenian as to whether it was a continuation of the French Badegoulian or a development out of the local Solutrean (BOSSELIN & DJINDJIAN 1997, 2000; STRAUS & CLARK 2000; STRAUS & GONZÁLEZ-MORALES 2010; DUCASSE 2013; JARRY ET AL. 2013; DUARTE MATÍAS E. 2014; STRAUS ET AL. 2014; CORCHÓN-RODRÍGUEZ 2015).

As stated earlier, the onset of the Initial Magdalenian, took place during the latter part of the Last Glacial Maximum, after the onset of fully glacial LGM conditions, contemporaneously to the late Solutrean in the region (Figure 5.11), and occupation at the montane site El Mirón intensified greatly.

A later peak in occupation at the end of the LGM corresponds to a group of dates ranging from 19.3 to 19ka cal BP, including Levels 18 and 21 identified as Initial Magdalenian occupations at El Mirón, which actually cluster within the time range of the beginning of the Lower Magdalenian in the Cantabrian Region and might be attributed to it although lacking the classic diagnostic artifacts of the Cantabrian Lower Magdalenian. These levels were dug only in a deep sondage of less than one square meter adjacent to the southern cave wall in the Outer Vestibule excavation area. The Initial Magdalenian deposits were also dug in a two-square meter area in the Vestibule Rear excavation area, and a sample of the faunal remains are under study by M. Carvalho, whose results, once published, will be important to understand better this transitional phase.

The exiting wealth of faunal data reveals a general trend (from 25 to 18ka cal BP) toward a subsistence strategy with greater specialization in the two most available and more profitable game species (red deer and ibex), seemingly independent of the cultural context that had already begun during the Solutrean and ended in the Lower Magdalenian.

Against the background of comparably stable climate conditions, mainly between the LGM and HE1 (i.e., Oldest Dryas), the increase in Lower Magdalenian archaeological occupations is remarkable, many of them within daily walking distance of one another with distinct principal site functions (hunting, residential base, aggregation, sanctuary, etc.) often dominated by one main prey species (STRAUS 1986; UTRILLA 1994). The regionally restricted distribution of striated hind engravings on red deer scapulae seems to reflect a territory that stretched westward from El Mirón. This territory (Cantabria and eastern Asturias) seems to have been distinct from that of the Lower Magdalenian settlements to the east in the Basque country without such works of portable art (GONZÁLEZ-MORALES ET AL. 2006; GONZÁLEZ-MORALES & STRAUS 2009; RIVERO VILÁ ET AL. 2019). Then, the striated hinds (also found on walls of caves such as Altamira and El Castillo) could be interpreted as a sign of a local group identity or preference of art style, different from the ones east of El Mirón, yet raw material procurements strategies imply regular exploitation of resources in that area by Cantabrian (and even Asturian) sites, including El Mirón (FONTES ET AL. 2016).

Lower Magdalenian occupations were found in each excavation area of the Vestibule (as well as in a niche in the cave wall filled with dated remnant sediments above the floor of the erosional slope between the rear of the Vestibule and in the Inner Cave) at El Mirón. The Initial Magdalenian occupations turned into massive, repeated, long-term Lower Magdalenian ones. Such intensification in the use of the cave led to the formation of a substantial palimpsest horizon, dating to a rather short period of around 500 years, from 18.8ka cal BP to 18.3ka cal BP, when El Mirón cave presumably was a major hub site in the regional settlement system and the possible main site in the Asón valley, just as El Valle (some eight km downstream) would become the main site in the Upper Magdalenian and Azilian.

Table 5.3: Occupations in the Cantabrian Region contemporaneous to Lower Magdalenian levels at El Mirón Cave.

Archaeological record	Calibrated date (ka cal BP)
Las Caldas Sala II Level XIII	18.3 ka cal BP
La Lloseta	18.3 ka cal BP
Tito Bustillo (Middle Magdalenian shell dates)	18.4-18.3 ka cal BP
La Riera Level 19	18.6-18.3 ka cal BP
Coimbre B Level Co.B.4	18.8 ka cal BP
Altamira 1924 excavations	18.7 ka cal BP
Altamira direct art	18.3 ka cal BP
El Juyo Level 6	18.6 ka cal BP
Rascaño 3	18.3 ka cal BP
Paloma	18.7 ka cal BP
Arlanpe I	18.3 ka cal BP
Ermittia III	18.4-18.2 ka cal BP
Urtiaga Level F sup	18.7 ka cal BP
Ekain Level VII	18.4 ka cal BP
Praileaitz I Vestibule	18.3 ka cal BP

Archaeological evidence contemporaneous with the El Mirón Lower Magdalenian palimpsest is abundant in the region. An intensification pattern of cave occupations is evidenced, as shown by the levels in Table 5.3,

during this Lower Magdalenian phase, bridging the gap between the end of the LGM and the onset of HE1. The intensive use of caves might have climatic reasons as the beginning of the classic Lower Magdalenian occupations coincide with the decline of the LGM, i.e., Oldest Dryas, a still quite cold and arid period in the Cantabrian Region (SÁNCHEZ-GOÑI & HARRISON 2010). However, the very rich Lower Cantabrian Magdalenian deposits appear in a twofold climatic context: the early phase directly after the Last Glacial Maximum and the later one at the beginning of the HE1 event.

The Middle Magdalenian coincides with the bulk of HE1 event, corresponding to cold oceanic surface waters, causing very cold and probably dry climate conditions in this region (NAUGHTON ET AL. 2007) also known as the 'Mystery interval' from 18.2 to 15.4ka cal BP (DENTON ET AL. 2006), which is also indicated by a hiatus in speleothem records due to aridity (MORENO ET AL. 2010). For that time period, radiocarbon dates overlap from the later part of the Lower Magdalenian and the onset of the Middle Magdalenian occupations within the Cantabrian Region (compare Figure 5.10). A group of dates at El Mirón cave, from 17.9 to 17.7ka cal BP, are tentatively associated with a Middle Magdalenian without diagnostic artifacts, indicating a prior occupational gap and then low occupation densities (Figure 5.13). During the Middle Magdalenian, settlement intensity drops down again with an average frequency of about five layers per 1000years. Reasons for this decline may have been of climatic, social, demographic, or other origins. Clearly, the center of the Middle Magdalenian world (both culturally and in terms of dense, major sites) seems to have been along and in the French Pyrenees. As HE1 climate change events could have been reasons for rapid sea level and other environmental changes that could have forced humans to migrate into other areas, if they were not just occupying open-air sites anyway and for which there are no records. But not using caves would be counter-intuitive, if it was very cold, although also relatively dry. Social factors could have led humans to retreat into living in smaller groups, while maintaining long-distance contacts, including the French Pyrenees and Aquitaine. Or there could even have been some population collapse due to over-exploitation and thus decline of local animal resources. Other reasons could also be an exodus of people from the refugia area towards southwestern France. Significant and probably rapid sea-level changes (inonverage 9-20m) are associated with Heinrich events (SHACKLETON 1987; SIDDALL ET AL. 2008; BAGNIEWSKI ET AL. 2015). Especially the meltwater pulses between 14.6 and 13.5 ka, when global sea level may have increased by as much as 16-24m, could have been experienced by a human during lifetime and probably influenced settlement activity of local hunter-gatherers least in coastal areas.

Diet changed profoundly, incorporating a wider range of animals, but it was not really before the Upper Magdalenian that roe deer and wild boar appear more frequently. Subsistence economies diversified contemporarily with climate ameliorations including more warm-climate species. Similarly, have been evidenced remarkable diversification processes especially after 13 ka cal BP in Late Würm and Early Holocene by increasing shellfish and bird exploitation (CLARK 1971, 1975; FREEMAN 1973; STRAUS 1977). Long- term regional population growth (STRAUS 1977) and/or depleted terrestrial resources possible triggered such economic and settlement changes.

Another circa 1,000year occupational gap appeared before Upper and Final Magdalenian visits to El Mirón cave at the end of HE1. The levels of these periods have much lower densities of cultural material and faunal remains than the previous ones. Visits to the cave decreased further in Azilian times, and practically ended during the early Holocene Mesolithic period.

Finally, in the region during the Upper and Final Magdalenian the number of archaeological levels recorded rises slightly (STRAUS ET AL. 2000a, 2000b, 2002), showing a final Paleolithic surge in human occupation of the area, maybe reflecting a real demographic increase. Upper and Final Magdalenian deposits beginning at the end of HE1 show a concentration of deposits dating around DO1. At 14.5ka, the Atlantic meridional overturning circulation got reactivated and humidity and temperatures increased presumably rapidly,

particularly terminating the dry and cold period of the Mystery Interval (DENTON ET AL. 2006). However, it should be remarked that for such radiocarbon models, the data are evidence of presence, but the absence of data is not necessarily evidence of the absence of human groups.

The El Mirón cave excavation units are set into the context of the regional cultural evolutionary scheme based upon its extensive sequence of radiocarbon assays (STRAUS & GONZÁLEZ-MORALES 2018). The Initial Magdalenian is poorly represented in the region (STRAUS ET AL. 2014) and has a transitional character, being more-or-less contemporaneous to some Final Solutrean occupations (compare Figure 5.11) in the region. It is often argued that technological continuity among Cantabrian late Solutrean and early Magdalenian lithic industries does not support a population replacement at that time (STRAUS 1992; CORCHÓN-RODRÍGUEZ 2015), but a population decline or demise, population fusion events, new networks or changes in settlement habits might have forced the appearance of a new cultural tradition, namely the Magdalenian. Compared to the previous Early Upper Paleolithic occupations and even the Solutrean, there seems to have been another significant increase in regional human settlement (and probably population), it appears to be attributed to the Lower Magdalenian, with ~22 archaeological layers per 1000years. These records imply major changes in the regional settlement systems after the Last Glacial Maximum following on from the Solutrean, with many caves being even more intensively inhabited and some for the first time.

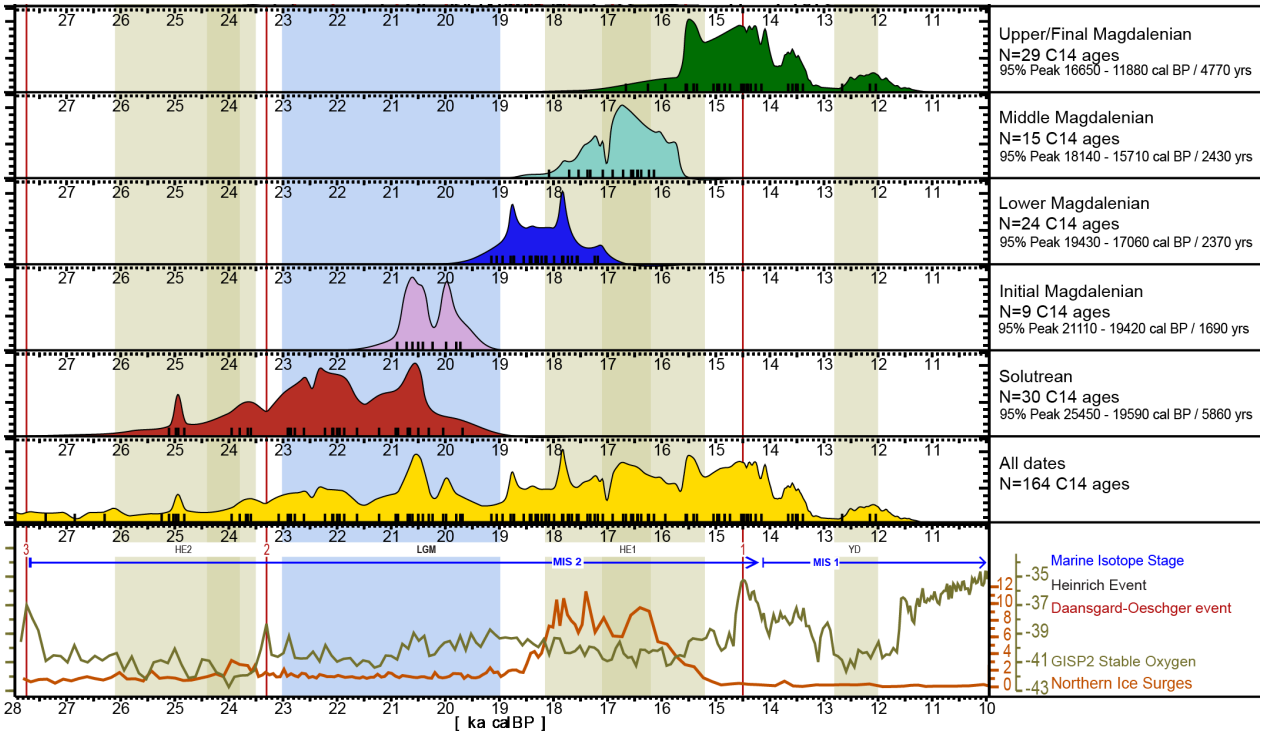


Figure 5.11: Multiple plot for Solutrean-Magdalenian radiocarbon- age model. Upper: Cumulative multigroup-calibrated probability distributions for radiocarbon- ages from the Cantabrian culture periods. Lower: Age calibration uses the GISP2(Hulu) curve with the program CalPal2016 in green (WANG ET AL. 2001; WENINGER & JÖRIS 2008). Selected climate record: Marine Isotope stages in blue (SÁNCHEZ-GOÑI & HARRISON 2010), Dansgaard-Oeschger high stands corresponding to warmer phases in red, and Northern Ice Surges at the Iberian Atlantic Margin as proxy for cold surface water in orange. Darker shaded areas show particularly cold phases of Heinrich stadials (H2- H1) and YD-Younger Dryas cold event. Light blue shading marks the range of the Last Glacial Maximum.

The following age boundaries of cultural periods for the Cantabrian Region (Table 5.4), obtained throughout radiocarbon age modeling (as stated above), were used to arrange the chronological paleoeconomic reconstructions.

Table 5.4: Summary of calibrated age boundary approximations before present based on modeled ages of 95% probability range for cultural periods in the Cantabrian Region. See also Figure 5.9 and Figure 5.11.

Culture	C14 age ka uncal BP		published ka cal BP		95% probability of modeled ka cal BP	
	start	end	start	end	**start**	**end**
Late Mousterian	/	48.7-41.8	/	47.9-45.1	**/**	**52.2-43.1**
Châtelperronian*	38.1	37.4	42.9-41.7	42.4-41.4	**43.5**	**41.2**
Aurignacian	38.6	30.1	43.3-40.5	34.6-33.1	**42.2**	**34.5**
Gravettian	31.6	19.2	36.8-35.0	23.1	**35.4**	**23.2**
Solutrean	21	16.4	25.1	19.7	**25.5**	**19.6**
Magdalenian	17.4	10.3	20.9	12	**21.1**	**11.9**
***dates from only one level: Labeko Koba IX (for reasoning, see Marín-Arroyo et al. 2018b)**						

The data used are summarized below (Table 5.5). Site density and settlement in the Cantabrian Region changes diachronically, according to the number of Late Upper Pleistocene occupational levels registered in the region. Attention needs to be drawn; however, to what degree the number of archaeological layers and the number of radiocarbon ages actually reflect group sizes or true occupational density. Nonetheless, data suggest similarly low densities until the Solutrean with which an increase up to 8 layers per 1000 years is registered. Magdalenian occupations show increased density with 15 layers per 1000 years, but proportionally high densities during the Lower Magdalenian, indicating mobility or settlement changes for that period.

Table 5.5: Selected data used for the settlement model and age model for the Cantabrian Region rely on available radiocarbon dates. (Note that not all known sites are included.)

Period	Settlement model				C14 age model
	Number sites	Number levels	**Number layers per 1kyr**	95% prob. of kyr duration	based on number of dates
Late Middle Paleolithic	16	27	**3**	9.1	12
Châtelperronian	5	8	**3**	2.3	1
Aurignacian	14	20	**3**	7.7	17
Gravettian	25	32	**3**	12.2	29
Solutrean	35	48	**8**	5.9	30
Initial Magdalenian	19	26	**15**	1.7	9
Lower Magdalenian	40	52	**22**	2.4	24
Middle Magdalenian	19	34	**14**	2.4	15
Upper/Final Magdalenian	44	73	**15**	4.8	29

Some caveats must be considered when dealing with these kinds of questions. Inter-site conservation differences, for example, the presumed lack of open-air sites or the presence/absence of diagnostic artifacts that are essential for the cultural attribution of levels in the absence of C14 dates, are both non-amendable circumstances which might alter the settlement record to be observed (STRAUS 1979). In recent years many attempts at targeting reconstructions of variability in Paleolithic demographic (STRAUS ET AL. 2000a, 2000b;

GAMBLE ET AL. 2005; MELLARS & FRENCH 2011; SHENNAN ET AL. 2013; CREMA ET AL. 2014; FRENCH 2016; CUCART-MORA ET AL. 2018; STRAUS 2019). No matter what is chosen to model, exact group sizes for each dated occupational layer will remain unclear, but their density in modeled probability distributions might give insights into settlement structures within the region at certain time periods. For example, recent attempts at reconstruction of paleodemography identified four population increase and two population decrease events for the Cantabrian Region; 18-17.6 BP, 17.4-16.3 BP, 15.6-15.3 BP, 13.7-13.5 BP show an increase in population size, while during the periods of 11.7-11.3 BP and 9.3-8.6 BP, smaller populations sizes were identified (FERNÁNDEZ-LÓPEZ DE PABLO ET AL. 2019). However, occupations prior to the Magdalenian occupations in that region have not yet been considered by this methodology.

Finally, for considering further settlement changes and density for the Cantabrian coast, an important basic fact is fluctuating coastlines. It has been modeled that since MIS4, sea level height rose significantly only after 10ka to less than -40m under the current sea level (LAMBECK ET AL. 2014; BENJAMIN ET AL. 2017). This indicates that the coastline to the Cantabrian sea was usually located generally about 5-20km further seaside during the major part of the Last Glacial (SHACKLETON 1987; SHACKLETON ET AL. 2000). For a better picture of that situation, Table 5.6 shows the distances to the -40m and -120m shoreline from modern coastal cities.

Table 5.6: Different distances of the Cantabrian Sea coastline in relation to modern coastal cities.

	Distance to the coastline at different sea level high stands	
Current Coastal Cities	-40 m	-120 (LGM)
Gijon	27.4 km	28.5 km
Santander	12.8 km	15.6 km
Laredo	9.9 km	16.5 km
San Sebastian	6.6 km	10.9 km

During the Last Glacial, with significant sea-level regression, the northern Cantabrian coastline was quite different from the current one, but comparably close to the modern shore *vis à vis* the situation of the present western shore of adjacent Aquitaine due to the narrow, steep-edged configuration of the continental shelf of the tectonically uplift Cantabrian Region. For Figure 5.12, the sea-level was estimated on local topography to be located at -40m and -120m below the present level. These ancient shorelines are displayed on the maps by the blue and white lines, respectively.

Important to note is the fact that none of the Paleoltihhic sites were coastal sites during glacial sea-level lowstand, with all of the currently known sites were located at that time 10km or more from the shore. Actually, only Riera and surrounding sites were near-coastal spots, which had the shore of eastern Asturias in daily walking distance. The sea was always part of the La Riera Cave territory, because steep side valleys of the underwater Torrelavega canyon form a chasm in the sea-floor in this part of the coast. In combination with the coastal mountain range in that area, there was only a narrow corridor for west-eastern movements along the coast between mountains and the sea, for animals and humans. These features could explain the repeated and exceptional use of La Riera site (STRAUS & CLARK 1986). Supplementary exploitation of marine resources was within the daily radius of gathering activities throughout the whole Upper Paleolithic and was even easier in the early Holocene (ORTEA 1986). Its importance developed since the time of Glacial Maximum, with recurrent occupations from groups that firmly integrated the coastal corridor into their settlement system, while older mobility patterns might have had stronger reliance on the rivers systems.

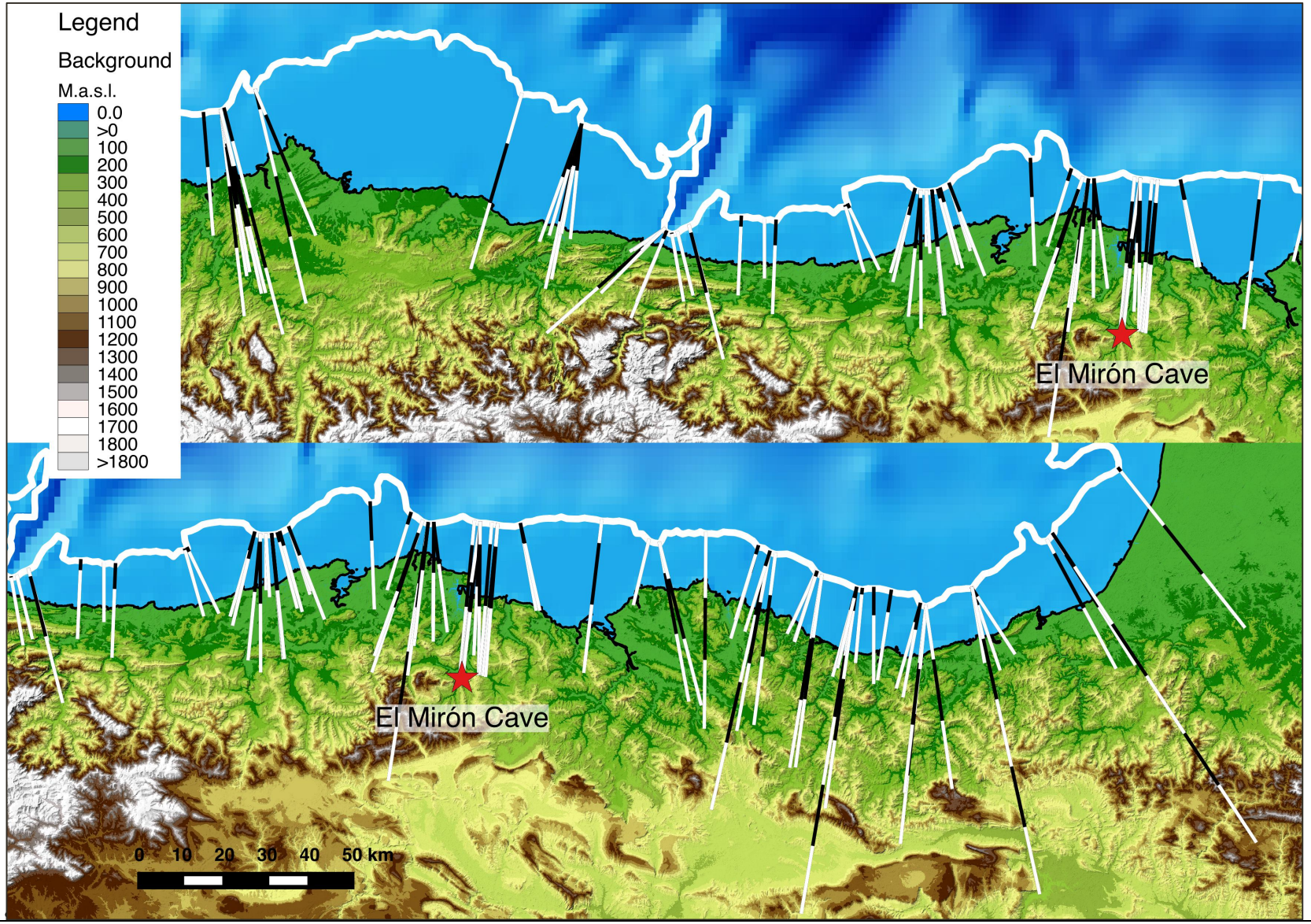
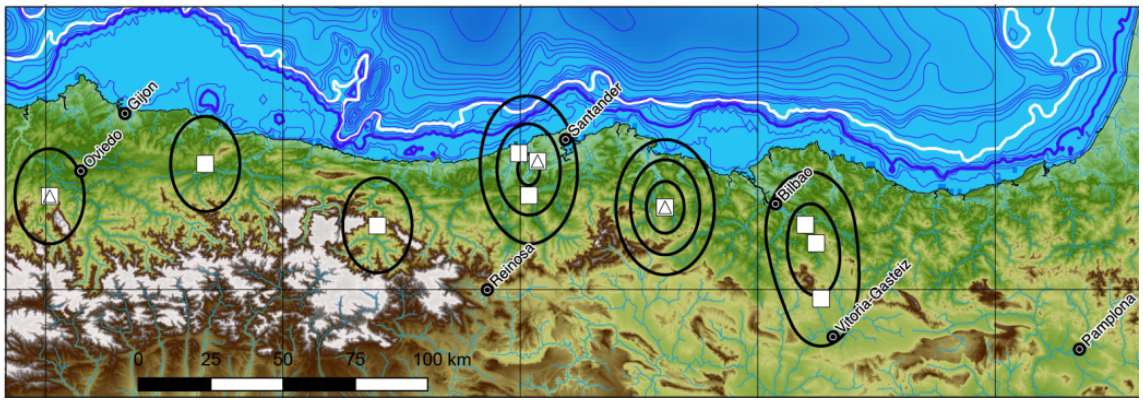


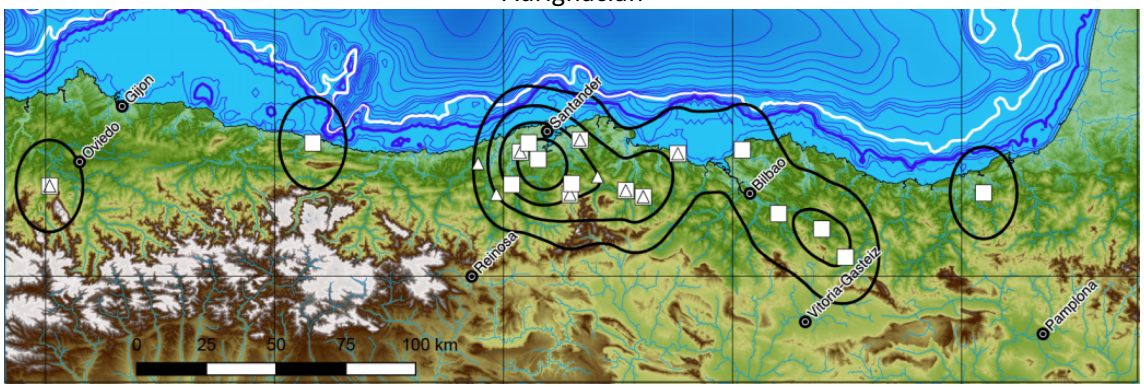
Figure 5.12: Some examples of how much the distance to the sea changes during the Last Glacial Maximum due to sea-level low stands. Minimum distances between sites and nearest LGM shore is shown by black-white bars, changing color every 5km.

Despite a general intensification of human settlement in this region during the late Upper Pleistocene (Figure 5.13), some interesting settlement patterns appear, when plotting settlement distributions by cultural periods. The graphic shows contour lines that correspond to density in sites within a distance of 20km from one to another site. This distance refers to walkable distances for one day, for example, to move base camps from one place to another. The settlement pattern is dispersed during the Late Middle Paleolithic, but show one major area of increased density in occupations roughly between of 150km length from west to east, including part of Cantabria and the Basque Country. Gravettian settlements already had more of such connected territories. While with Solutrean settlement further increase, a settlement pattern of separation into a western (Asturias), central (eastern Asturias and Cantabria) and eastern (Basque Country) zone is noticeable, which just intensifies with Initial, Lower, Upper and Final Magdalenian occupations, with comparable low densities during the Middle Magdalenian. Such settlement distribution patterns, however, are always also an artifact of taphonomy and research history.

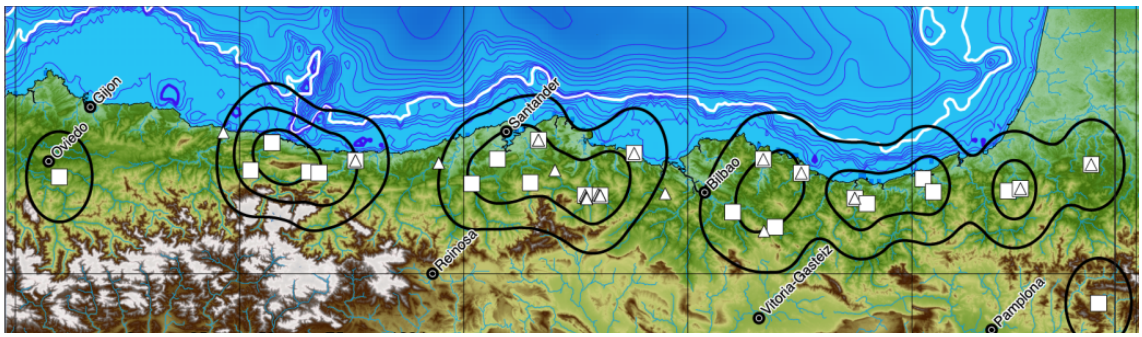
Late Middle Paleolithic



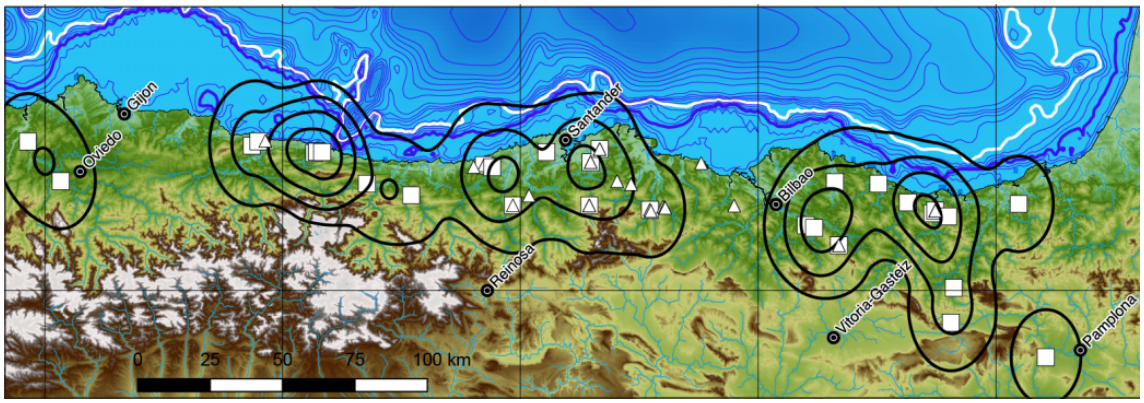
Aurignacian



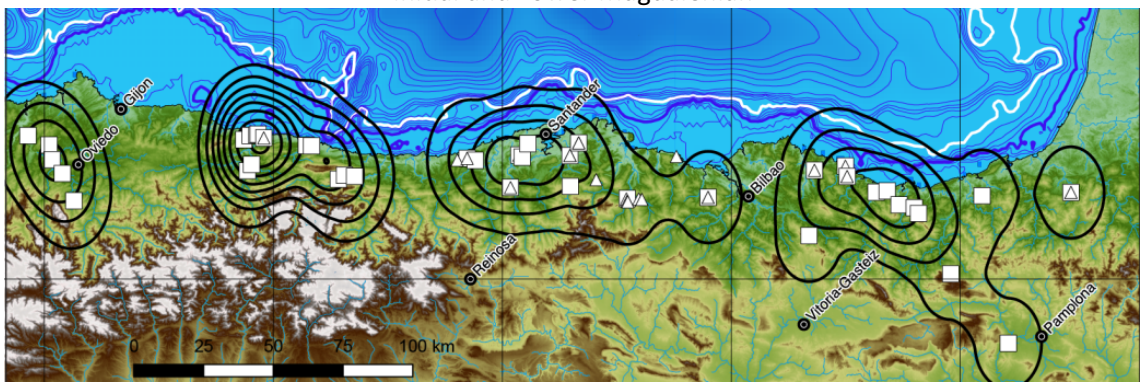
Gravettian



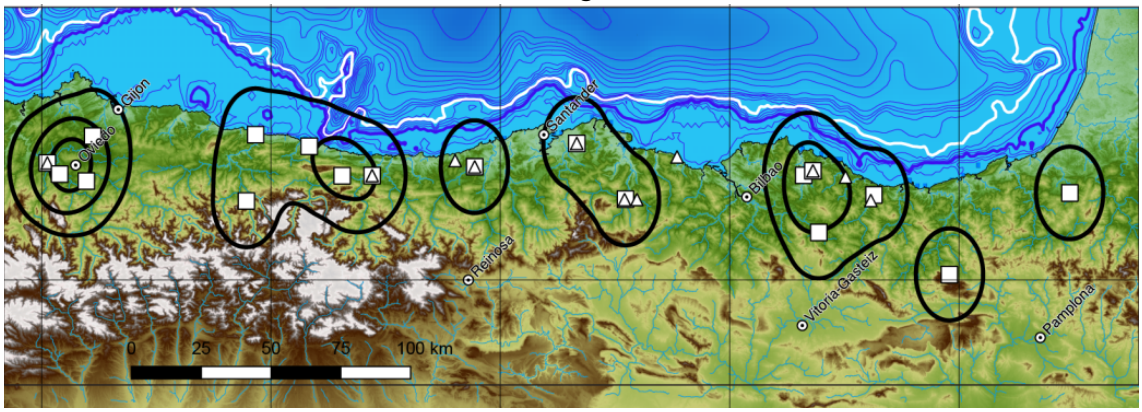
Solutrean



Initial and Lower Magdalenian



Middle Magdalenian



Upper and Final Magdalenian

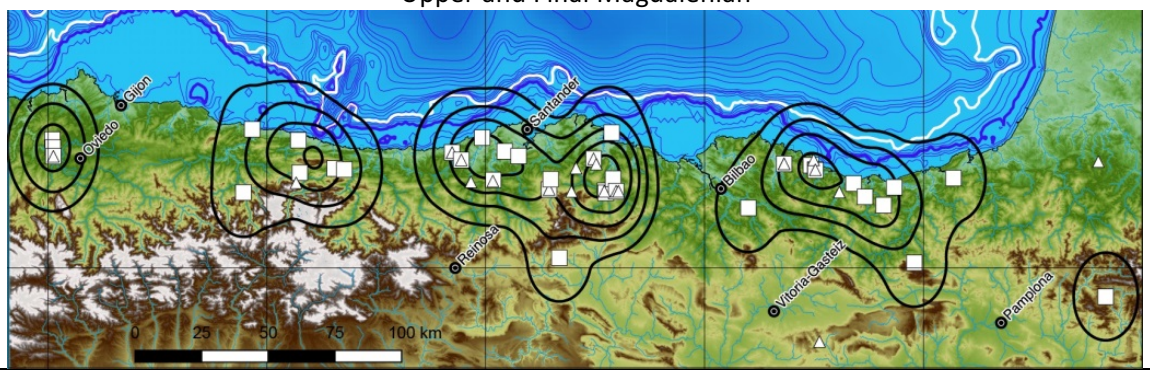


Figure 5.13: Settlement distributions plotted by cultural periods. Contour lines correspond to density in sites within a distance of 20km from one to another site (~walkable distance in one day). Squares show habitation sites and triangles sites with cave art. Both were combined to visualize spatial dimensions of different cultural manifestations.

The late Upper Pleistocene settlement history of the Cantabrian region, nevertheless, can also be seen from a different view, especially when combing data about space and time. It is remarkable that archaeologically well-defined levels, with up-to-date radiocarbon dates, appear to cluster often around DO-events. These DO's are characterized by rapid warming events (SÁNCHEZ-GOÑI & HARRISON 2010). Nonetheless, after 24ka cal BP, during the early Solutrean, a general increase in human occupations is suggested, which corresponded to the HE2. HE events are defined as the appearance of cold sea surface temperatures in the North Atlantic triggered by massive ice shield releases in the oceanic waters (HEMMING 2004). The onset of the Initial Magdalenian evidence can be found in the final stages of the LGM with considerable continuity throughout the Oldest Dryas in the Lower Magdalenian. A lower density in occupation is observed during the Middle Magdalenian period, a period coinciding with HE1 and may be less favorable for the people to live in this region. Nevertheless, the later part of the HE1 climatic event coincides also with the start of the Upper/Final Magdalenian in the region, which continues until the end of the Younger Dryas.

Figure 5.14 summarized settlement 'waves' (=SETx) for the Cantabrian Region based on selected, reliable radiocarbon dates (Table 5.1) for the whole timeframe of this work (~53ka to 10 ka cal BP) plotted by the longitude of archaeological site locations. A higher temporary resolution which focuses at the onset and course of the Magdalenian (~22ka to 13 ka cal BP) is also provided (Figure 5.15). Both illustrations show settlement changes when the climate was unstable. Climatic deterioration being countered mostly by rapid expansion (SET5,7,9,10,13) of the occupied territory westwards. Some climate events, however, caused rapid retreat events of Late Middle Paleolithic-Early Upper Paleolithic populations (SET1-4, 6,8) and later namely the late LGM (SET11) and DO1 (SET17) event reflected by a withdrawal in the settlement record eastwards, reminding of sweep events (PREMO & HUBLIN 2009). Slow, gradual expansion of occupied territories might reflect either major local population growth (SET12) or expansion from one cultural-social system (SET15) to another as contemporary settlement suggests.

A few aspects should be considered before deciphering the triggers of human behavior change. To which degree rapid climate change only favored the more intensive use of caves instead of open-air sites might be questioned, as the major caveat of such radiocarbon studies is that such the empirical data mostly were obtained from cave site excavations (and only a few sites, such as La Riera and especially El Mirón have many radiocarbon dates, a fact which is related to the dating philosophy and budgets of the excavators). From such a chronological perspective, contemporaneous cluster of radiocarbon dates revealed insights into certain, regional settlement structures. It needs to be taken into account that the radiocarbon record can be diminished by different factors such as research history, preservation of archaeological sites (caves versus open-air sites, although the latter are nearly absent in the region), the representativeness of selected cultural well-attributed levels and many more. Also, being aware of according to which calibration curve was used, the result can vary (SCHMIDT ET AL. 2012). In such a manner, with the help of a radiocarbon (CalPal) age model, it is often observed that when calibrated radiocarbon dates group together, they are closely located to major climatic changes such as Heinrich or Daansgard-Oeschger events, of cold or warm rapid climate shifts, respectively. Major increases in regional settlement intensity (mainly in cave sites) are observed during the LGM by the Solutrean culture, after the LGM by the Lower Magdalenian and at the end of HE1 by Upper Magdalenian cultures. Major decline in settlement occurred at the end of the Late Middle Paleolithic and after HE3, besides more or less increasing intensity in site density (STRAUS ET AL. 2000a, 2000b).

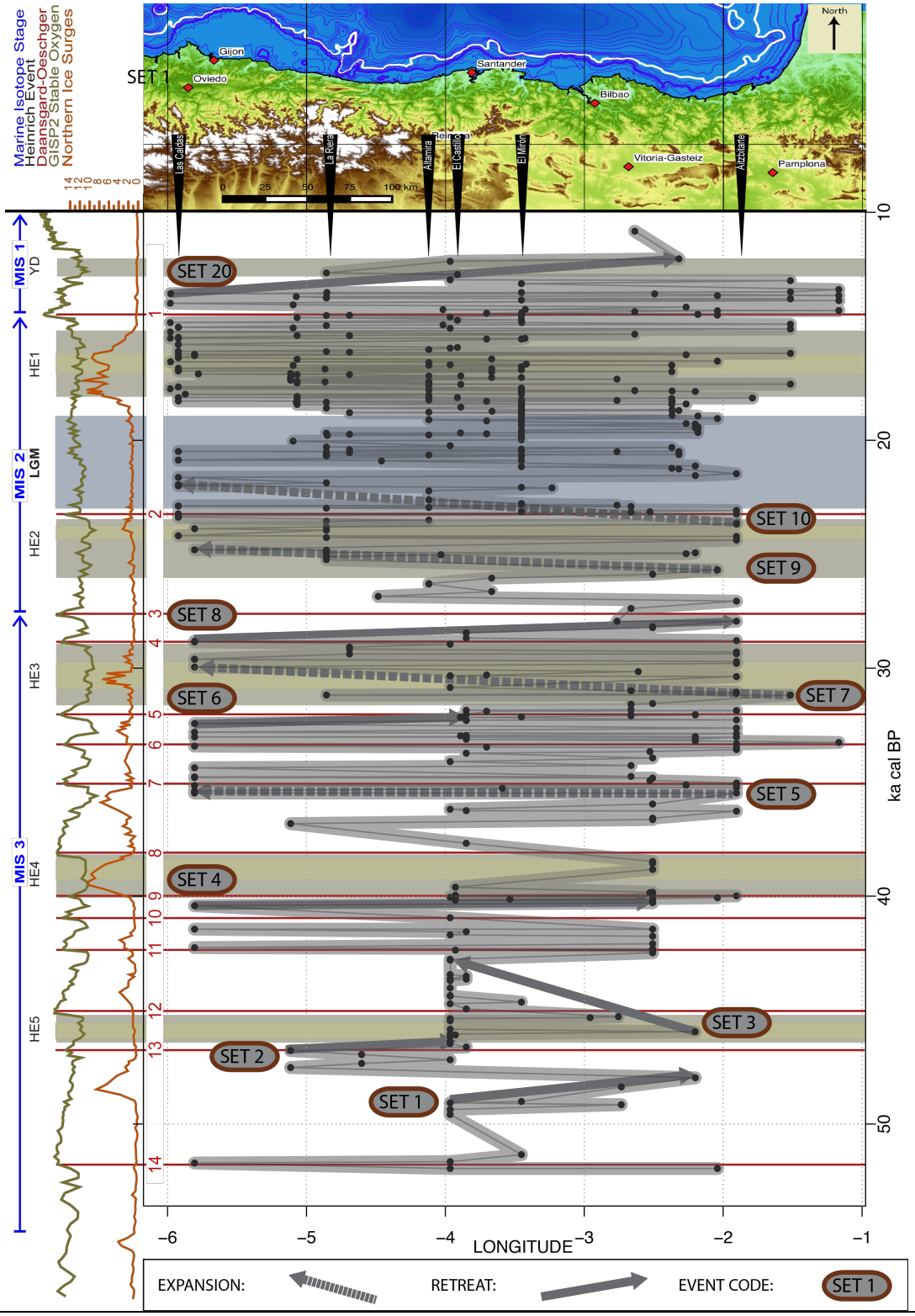


Figure 5.14: Changes in settlement pattern in the Cantabrian Region correlated with climate events from Late Middle Paleolithic to Magdalenian. Marine Isotope stages (SÁNCHEZ-GOÑI & HARRISON 2010), red numbers mark Dansgaard-Oeschger high stands corresponding to warmer phases, the GISP2 stable oxygen record based on the Hulu atmospheric curve (REIMER ET AL. 2013) and Northern Ice Surges at the Iberian margin. Darker shaded areas show particularly cold phases of Heinrich stadials (H1- H5). Blue marks the range of the Last Glacial Maximum. Expansion and retreat events are indicated by the "SET" number and were referred to in the text. Radiocarbon dates from the Cantabrian Region were calibrated with CalPal (2007). Onset of major settlement changes (~ in cal BP): SET1 -50ka, SET2 -46ka, SET3 -45ka, SET4 -40ka, SET5 -34ka, SET6 -32ka, SET7 -31ka, SET8 -29ka, SET9 -25ka, SET10 -22ka, SET11 -20ka, SET12 -19.5ka, SET13 -18ka, SET14 -17ka, SET15 -16ka, SET16 -14.3ka, SET17 -14.1ka, SET18 -13.8ka, SET19 -13.3ka, SET20 -13ka.

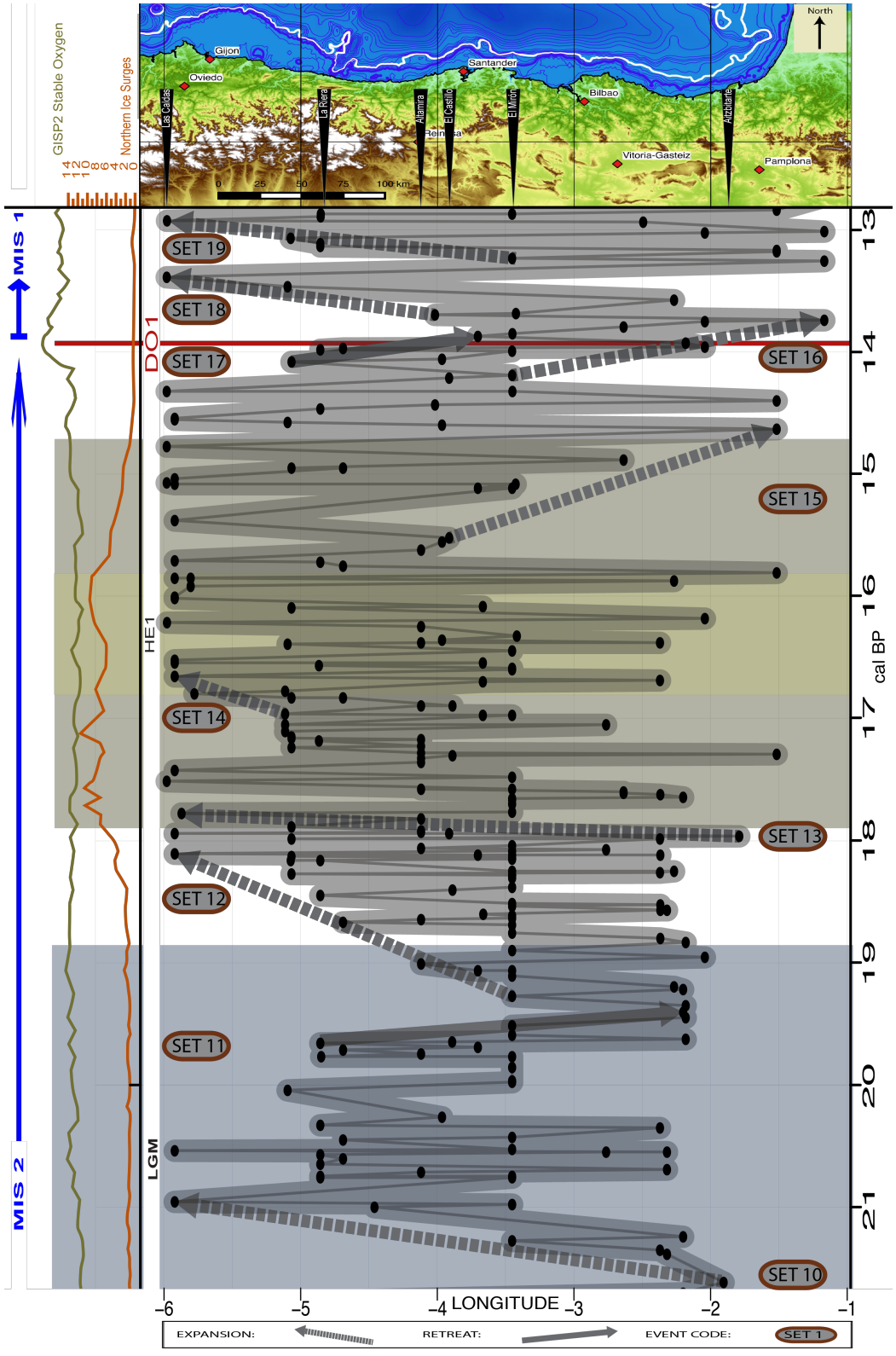


Figure 5.15: Solutrean to Magdalenian. Changes in settlement pattern in the Cantabrian Region correlated with climate events: Marine Isotope stages (SÁNCHEZ-GOÑI & HARRISON 2010), red numbers mark Dansgaard-Oeschger high stands corresponding to warmer phases, the GISP2 stable oxygen record based on the Hulu atmospheric curve (REIMER ET AL. 2013) and Northern Ice Surges at the Iberian margin. Darker shaded areas show particularly cold phases of Heinrich stadials (H1- H5). Blue marks the range of the Last Glacial Maximum. Expansion and retreat events are indicated by the "SET" number and were referred to in the text. Radiocarbon dates from the Cantabrian Region were calibrated with CalPal (2007). Onset of major settlement changes (~ in cal BP): SET10 - 22ka, SET11-19.7ka, SET12 -19.5ka, SET13 -18ka, SET14-17ka, SET15-16ka, SET16-14.3ka, SET 17 -14.1ka, SET 18-13.8ka, SET 19-13.3ka.

5.5 Conclusions on paleo-economic change

In summary, this chapter reported on multi-evidence analysis of economic changes. A radiocarbon age-model visualized their chronological positions for Cantabrian sites allowing determine possible correlation with climatic events. Secondly, based on faunal remains, economic dynamics have been reconstructed by the conjunction of multifactorial datasets, which reflect accumulative changes in human behavior and revealed moments of economic stress. The sequence of economic behavior and climatic events are outlined here.

From an economic perspective, the Cantabrian Region was exploited using hunting strategies classified as opportunistic during Middle and Early Upper Paleolithic. The small faunal assemblages at El Mirón showed, however, that such opportunistic behavior might not have been the results of only human activities, but also of carnivores that repeatedly used the same living spaces, sometimes overprinting anthropogenic evidence. Focus on taphonomic studies should disentangle activities of multiple accumulation agents, which are crucial and may impair further economic assumptions. Settlement at these moments, presumably, were based on isolated, multi-annual rounds or mainly at open-air sites, that have not preserved an archaeological record for consideration. Late Middle Paleolithic presence is characterized by sporadic visits to caves as also manifested at the sites of Amalda and Axlor, for example.

After the arrival of the Early Upper Paleolithic in the Cantabrian Region around circa 40ka, with the onset of HE4, evidence of Aurignacian occupation in the Cantabrian Region appears sporadically, dispersed with slightly increased settlement intensity and with proof of short-term hunting camps. One major cluster of Aurignacian sites within daily-walking distances of one another around the present-day Bay of Santander include more complex multi-purpose loci, such as El Castillo and Covalejos.

While early Gravettian settlement evidence coincides with the DO7 and DO6, both episodes were followed by an occupational hiatus, at least in the caves. Climatically driven behavior has been proposed for this cultural period (BRADTMÖLLER ET AL. 2012). The presence of a few open-air sites, however, suggests that many more might have once existed. At El Mirón, for example, rather short human visit appeared at moments, when mostly carnivores inhabited the cave. It is possible that Gravettian people quite permanently settled in the region, but rarely used caves as shelters that would have preserved their cultural manifestations, as suggested by the many, very rich East and Central European Gravettian open-air sites (SIMON ET AL. 2014) plus those of the Périgord. DO or HE events, moments of rapid temperature changes, maybe caused increased precipitation, storms, or other adverse phenomena that obligated humans to search for long-term shelter. Maybe radiocarbon curves generated from cave deposits record not more than times when people took in-between shelter periods of moving around quite 'permanently' in the Cantabrian Region.

In such manner, sea-level fluctuations revealed that pre-LGM cultural periods, i.e., the Solutrean, might have had large territories that are currently non-accessible--locked underwater. For example, very many edible mollusks have been found in La Riera Cave throughout the archaeological sequence beginning in the Solutrean, noting (1) site locality was always fairly close to the shore and (2) indicating some shells were repeatedly exploited as secondary or back-up food resources because only representing smallest dietary portions (STRAUS & CLARK 1986). The same is true, for example, at Altamira.

During the HE2 event, a greater intensity in human settlements is observed for the Cantabrian Region (STRAUS 1979). At that time, since 25ka cal BP, there was less hunting of young animals, slightly higher amounts of low-ranked species, and a decrease in species diversity reveal new economic adaptations. Those local cultural units seemed adapted well to their environment carrying out specialized economic strategies with varied faunal assemblages showing similar biomasses, indicating that group sizes may have stayed stable. According to density and amount of material found at sites, some of which are likely related to rather short hunting visits, for example at El Mirón (STRAUS ET AL. 2013), and others probably served longer stays, for example,

Altamira, Las Caldas, La Riera, or Cueto de la Mina (STRAUS & CLARK 1986; ALTUNA & STRAUS 2009; CORCHÓN-RODRÍGUEZ 2017).

After the DO2 event, rapid warming after a cold period, specialized economies developed with low game species diversity, fewer low -ranked species, and only at El Mirón cave with high percentages of young animals. Economic changes occurred, however, already during the LGM after the onset of fully glacial conditions, with the manifestation of the Initial Magdalenian contemporary with or close in time to the final Solutrean. While some cultural traits imply some sort of long-distance transport, high-quality flint resources were not always used, and in their place in the lithic industry, local, poor-quality raw material resources were used especially for macro-lithic (archaic) tools (FONTES 2016). There was a general trend to subsistence strategy change, seemingly unconnected from the cultural context, whereby the zooarchaeological record and derived hunting patterns reveal a progressive trend toward a greater specialization in the two most available and more profitable species (red deer and ibex) that had already begun during the Solutrean. The Lower Magdalenian is outstanding in the Cantabrian Region, for many reasons. This stage is culturally better characterized than previous ones, establishing the first evidence of Magdalenian in many stratigraphic sequences. Mayor characteristics are (1) dominance in scrapers (especially thick forms) over burins (not including nucleiform endscrapers that were often only bladelet cores) and important presence of denticulates, (2) dominance of single-beveled, quadrangular-section sagaies with geometric or tectiform engraved decorations and (3) massive faunal deposits (UTRILLA 1994). The increase in archaeological sites is remarkable; many of them within daily walking distance of one another. Technology and associated mobility strategies varied likely in relation to site function and to challenging localities, respectively. It is the first period in which contemporaneous sites contain different lithic industries that allow us to speak about distinct principal site functions, for example, base camps (aggregation or long-term residential), hunting camp (kill site), or (art) sanctuary place (STRAUS 1986b; UTRILLA 1994). This is essential for an imagination of a geographically divided and structured landscape use based on economic activities carried out by hunter-gatherers inhabit the area (ÁLVAREZ-ALONSO 2014a). It is especially interesting that the Lower Magdalenian phenomenon occurred under comparably stable climate conditions, mainly between the LGM and HE1.

After the LGM, specialized hunting behavior stayed particularly important during the Magdalenian. The Middle Magdalenian appearance in the Cantabrian Region is almost contemporary to a major Northern Ice Surge event manifesting climatic changes. During this period, sites exhibit intensified subsistence strategies, centered on the consumption of mainly red deer or ibex, with smaller contributions from other ungulates. With the Upper/Final Magdalenian, the large settlement areas are connected along the narrow corridor of the coastline, attesting much of an actual regional settlement system.

During the Upper Magdalenian, diet changed, incorporating a wider range of animals, which previously were not part of the terminal Upper Paleolithic diet, such as roe deer and wild boar; subsistence economy, one may say, become more diversified. Those are notable patterns of change in subsistence strategies. Still, such events may coincide with the trend of terminal Pleistocene climate amelioration that favored the presence of more warm-climate species, and hunters have caught what was available. Similarly, have been evidenced by the increasing exploitation of shellfish and birds in the Cantabrian Region, displaying intensified resource procurement in Late Würm and Early Holocene as supposed earlier (CLARK 1971, 1975; FREEMAN 1973; STRAUS 1977). Especially after 13 BP, further diversification in resource use indicates the intensive exploitation of the coastal zone during the Mesolithic, when littoral hunter-gatherer lifestyle spread here as in other coastal regions with significant adaptation to these ecotone environments (COHEN 1977). The reasons for those changes might have been overpopulation or depleted terrestrial resources. As a consequence, remarkable diversification processes established sustained changes in economy and settlement.

The explanation for such economic changes are still varied. Long- term regional population growth (STRAUS 1977), climatic changes, social networks, mobility patterns, seasonality, etc. seemed to be multiple factors that triggered human behavior in the late Upper Pleistocene. With such multi-evidence data sets as provided here, one might be able to synthesize the triggering element(s) of human behavior changes in a heuristic manner. A detailed statement about possibilities that might have caused human behavior change will follow in the synthesis chapter of this dissertation.

CHAPTER 6: SYNTHESIS AND CONCLUSION



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6 SYNTHESIS AND CONCLUSION

The results of this research and how they contribute to our understanding of hunter-gather economic development are presented here. The quantitative data obtained on prey taxa, age, skeletal part transport, seasonality, butchering type, and in-site attrition, all these classes of information enable to provide new insights about resource acquisition, exploitation, maintenance and disposal behavior of the foraging economies practiced at El Mirón Cave by human groups. On-site use and site function analyses improved our understanding of the role of El Mirón within the context of the regional settlement system of Cantabrian Spain. Furthermore, this dissertation provides new information about Late Glacial paleoenvironments and animal ethology. This synthesis and conclusion chapter discusses the hypothesis set up at the beginning of this dissertation about economic adaptations and human behavior changes concerning changing climatic and environmental conditions. The dissertation adds new data to the previous archeozoological studies carried out by J. Altuna and K. Mariezkurrena (2012) for the Holocene levels and by A.B. Marín-Arroyo (2010) for Pleistocene/Holocene transition and the end of the Tardiglacial at El Mirón Cave (STRAUS & GONZÁLEZ-MORALES 2012) to complete the long archaeological sequence from the Late Middle Paleolithic to the Magdalenian at El Mirón. In this dissertation, especially the analysis of the rich Lower Magdalenian horizon in the outer vestibule of the cave provides the basis for a thorough interpretation of human economic strategies during part of Oldest Dryas, at a high level of detail.

6.1 Adaptations in economic behavior

Late Middle Paleolithic and Early Upper Paleolithic (~52-23.3 ka cal BP)

The archeozoological and taphonomic study confirms that the most important game species during the Late Middle and Upper Paleolithic in El Mirón and the Cantabrian region was red deer, as indeed it was the dominant cervid species throughout Iberia and the whole Mediterranean region. In the small area excavated in El Mirón, Late Middle Paleolithic (Level 130), possible EUP (129), and Gravettian (128) always show between 30% to 40% of individuals are macro-mammals corresponding to five to ten small- to medium-sized ungulates per occupation level, generally indicating low-density site occupations, that were probably short and ephemeral.

The main game species in these oldest levels occasionally display both carnivore and anthropogenic marks, with human had primary access to these resources, but carnivores alternatingly using the same living spaces probably for shelter, as previously proposed (e.g., STRAUS 1982). In Level 130, direct evidence of human activities is present in the form of bone flakes associated with bone marrow cracking and indirect by burnt bone remains. The few cut marks and impact negatives on bones, identified as anthropogenic alterations, imply mainly meat and marrow exploitation of animal resources. The low intensity of butchering marks within this faunal assemblage makes it challenging to infer further behavioral implications about the accumulators.

In El Mirón Cave Level 129, evidence of human modifications on faunal remains increase slightly compared to the underlying Level 130, which is especially interesting as the excavators described it as archaeologically sterile (due to the near- lack of lithic artifacts in the 2m² excavated). Levels 129 and 128 contain a very similar pattern of modifications with cut marks on long bones and ribs, impact marks on long bones and phalanges, bone flakes, and burnt remains. Nevertheless, evidence of human-carnivore interaction also exists, with carnivore tooth pits and cut marks on some (few) specimens (indicating low frequency of occupations). The evidence of human activities in Level 129, is more likely the beginning of a slight intensification of human occupation of the cave that continued in the overlying level. Level 128 is chronologically attributed by one radiocarbon assay to the DO5 event and by very few lithic artifacts to the Gravettian (~32 ka cal BP). While those Early Upper Paleolithic occupations prominently record disarticulation activities, inhabitants of the

cave also produced some filleting and skinning marks on bones. Gravettian hunters were doing very clean butchering - indicated by a few marks, probably for transport of food elements from the site. Preparing food for further transport could be a reasonable explanation for the pattern observed and imply rather short stays.

During the Late Middle Paleolithic and Gravettian, at El Mirón, hunting took place in different seasons, possibly indicating a more sporadic, non- seasonal, mobility system of circularly structured landscape- use with one or two regional sites that were revisited during annual rounds, no doubt temporarily. The known, large, multi-layered Late Middle Paleolithic occupations are El Castillo, Covalejos, Morín, Axlor, Letzetxiki, and Abauntz. These sites are not all near-coastally located but proximate to river streams, the proposed dwelling areas of medium to large ungulates, suggesting that coastal exploitation had no or only minor economic relevance at that time. River systems seem to be vital criteria in human settlement systems, possible as migration corridors or water accessibility, as demonstrated in spatial inter-site analysis (TURRERO ET AL. 2013).

The new economy and settlement data support the idea that Late Middle, as well as Early Upper Paleolithic economies, were opportunistic in the Cantabrian region (FREEMAN 1973; STRAUS 1977), with a few favored territories around La Güelga, Esquilleu, El Castillo, Morín, Covalejos, Amalda, or Axlor (MAROTO ET AL. 2012; HIGHAM ET AL. 2014; MARÍN-ARROYO ET AL. 2018b). Moreover, small faunal assemblages, as also exemplified at El Mirón, demonstrate the commonly short and ephemeral use of other cave sites during MIS3 (MARÍN-ARROYO ET AL. 2018a).

The regional synthesis of settlement distribution and chronology compiled in this dissertation, support the evidence of Middle Paleolithic population relicts have been scattered in the Basque Country (Arrillor and Amalda) and repeated at El Castillo Cave before their demise from the Cantabrian Region, which leaving the HE5 event (~46ka cal BP) triggered population withdrawal a highly speculative reasoning, given the tiny sample of dated sites. Evidence of the Early Upper Paleolithic transition, exemplified by early Aurignacian occupation in the Cantabrian region, continued to appear sporadically and dispersed from 42.8ka to 40.1ka, before the onset of HE4, when slightly increased the settlement intensity and record of short-term hunting camps. Evidence of site clustering in archeologically plausible settlement systems, however, becomes more apparent during Aurignacian and Gravettian times (El Castillo, El Pendo, Morin, Letzetxiki, and Labeko Koba) than before, now increasingly with sites in near-coastal locations. One primary cluster of Aurignacian sites within daily-walking distances of one another around the present-day Bay of Santander (i.e., the relatively broad coastal plain of central Cantabria Province) include more complex, multi-purpose loci, such as El Castillo, Morin and Covalejos.

During the Gravettian, alternating carnivore-human use of caves continued. Besides, there is a new presence of a few open-air sites. While early Gravettian settlement evidence coincided with rapid climate changes (DO7, DO6), the in-between apparent absences of dates suggest possibly occupational hiatus. Because of this data, human cave use appears to have been especially relevant for Gravettian groups during severe climate conditions. Nevertheless, if radiocarbon sequences from cave deposits record intensified use of shelters by human groups as a response to climate changes, while settling endured much longer in the Cantabrian region, it is difficult to answer. Testing such a thesis, however, is limited in light of the rare presence of open-air sites. Late Glacial sea-level fluctuations suggest that vast territories of pre-LGM, LGM, and post-LGM Cantabrian landscapes, i.e., are currently submerged and will not reveal this information. Nevertheless, since the Early Upper Paleolithic settlement systems move a bit further inland, to include a little more of the montane terrain and piedmont of the Cantabrian Cordillera, at least occasionally or situationally and some of the previously occupied sites (La Viña, Llonín, El Castillo, El Pendo, Morín, Antoliñako, and Amalda) continued to be used by Solutrean groups.

Solutrean (25.5-19.6ka cal BP)

At El Mirón, already during the earlier Solutrean (Levels 127-126), human groups intensified **resource exploitation,** establishing new subsistence strategies, with a concentration on one or two main prey species established in the later Solutrean (Levels 125-121), with red deer and ibex comprising more than 50% of MNI, associated with colder climatic conditions during the LGM. However, chamois was also commonly accumulated, comprising between 12% and 25% of the individuals.

Hunting biodiversity changed noticeably for the first time with the later Solutrean occupations, but beginning with Levels 126 and 125. The higher biomass obtained, with each level having 3-4 individuals from each red deer and ibex, indicates either each site use was denser, longer, or inhabited areas of the cave went further inside into the cave's vestibule rear as these occupations took place just at the onset of the LGM. Despite the caveat of the Solutrean assemblages examined here origin from only four m² of the large cave vestibule of approximately 200 m² dimensions, they represent an appropriate archaeological sample of the Solutrean occupations from a montane site with remarkable implications.

Further economic changes appear at the transition from Levels 127-126 to 125-121 in El Mirón cave. At the Solutrean at El Mirón, more than other domestic activities, the evidence of intensive butchering is complementary to the high percentage of retouched pieces, denticulates, and notches found within the lithic assemblages (STRAUS ET AL. 2013). Filleting marks dominate Solutrean cut mark patterns, but with evidence of fewer disarticulation activities, possibly indicating the occurrence of disarticulation activities at the kill sites. Human groups brought some skeletal elements to the cave (as 'trail food'?) for relatively short stays and mainly final, on-site consumption of food (meat, marrow), where they discarded the bones. Within the same levels also occurred an increased number of bone flakes attesting more elaborated food preparation or animal processing, inferring cooking evidence, and somewhat longer stays of yet logistic trips at the onset of the LGM (Level 125). Evidence related to **increased attrition on the skeletal profile identified** by rank correlation and Bayesian modeling of skeletal representation shows further intensification in resource exploitation strategies. The more intense processing of within-bone nutrients by humans caused increased attrition, which is contrary to expected higher attrition in older assemblages when correlated to time and natural processes. The appearance of grease rendering processes, already known since the early Gravettian at Vale Boi, Portugal (MANNE ET AL. 2006), as indicated by the Solutrean occupations, could explain why somewhat longer occupations occurred when human groups spend more time for such resource processing tasks. Such performance of complex tasks during visits add upon evidence of further time-consuming domestic activities through antler usage for *sagaie* production (in addition to the numerous stone Solutrean points) and seasonality data of prey animals.

During the early Solutrean, the montane species-rich site El Mirón was occupied first during the earlier autumn through spring (cold season), but later mainly during spring-summer (warm season- Levels 122-121). Solutrean, often red-deer dominated, residential sites identified on the coastal plain in Asturias (La Riera and Cueto de la Mina) seemed to have been complemented by summer logistic trips into near-interior river valleys (as represented by Amalda, Ekain in Guipuzcoa) and cold season visits to the piedmont areas for exploiting ungulate species in steep, rocky terrains. However, these respective site clusters are very far apart and located in orographically very different sectors of northern Spain, thus they may be not actually complementary, but only suggestive of possible patterns in light of now-submerged coastal plains on the Basque side. At the onset of the LGM, with the earliest Solutrean occupations at El Mirón, the site got firmly integrated into late Upper Paleolithic local settlement systems, as did many others such as Las Caldas, Llonín, La Riera, Cueto de la Mina, and Altamira. Additionally, the Mirón evidence samples a pattern of territorial widening, suggesting profound changes in the settlement system. Since the average movement between patches is a direct function of available energy in the local environment (HAMILTON ET AL. 2016), such an

increase in mobility could feasibly attest shortages in dietary opportunities, if related to severe glacial environmental conditions. The evidence of the pollen sequence in El Mirón also indicates such a worsening of climate conditions by even further decreasing humidity within a generally open landscape with scattered pine stands on valley floors and lower, south-facing slopes below the cave (STRAUS ET AL. 2013). El Mirón micromammal evidence supports a relatively arid-cold landscape, with decreasing wood- and wetlands (CUENCA-BESCÓS ET AL. 2008, 2009). Records from more near-coastal areas, however, show the trace persistence of the more temperate tree species hazel and alder at such sites as La Riera, Amalda, and Morin (LEROI-GOURHAN 1966, 1986; DUPRÈ 1990). Especially during the onset of the LGM, nutritional stress could have been present, and humans adapted exploitation strategies to maintain an economic balance. It is worth mentioning that El Mirón Level 125 bones specifically had dirt-calcite concretions possibly from seasonal warmth that evaporated surface or ponded waters high in calcium carbonate, actually a common phenomenon in karstic contexts. However, the excellent bone preservation indicates no erosion by water as well as climatic and environmental evidence reveal an unusually cold and dry local environment. Humans would have had to bring water to the site for cooking, making water as a resource a considerable component of the economic strategy. Further analysis of Solutrean levels regarding cooking and grease rendering activities would be interesting to decipher human behavior during such advanced climate changes.

Especially the detailed analysis of the faunal micro-fraction was the methodological improvement applied here, enabling the author to show that groups repeatedly stopped at El Mirón, exploited local ibex, cooked, ate, and left. Those groups were highly mobile hunters, probably using larger home range areas as previously thought. This inference strengthens Straus' long-proposed conclusions (STRAUS 1977, 1983) on differences in variation in Solutrean assemblages are a result of site function as people moved to diverse locations to carry out distinctive activities both seasonally and situationally. Based on density and amount of material found at sites, some are likely to reflect rather short hunting visits as concluded earlier (STRAUS ET AL. 2013), while other sites probably saw longer stays, for example, Altamira, Las Caldas, La Riera-Cueto de la Mina, or Isturitz (ALTUNA & STRAUS 1975; STRAUS & CLARK 1986; CORCHÓN-RODRÍGUEZ 2017). The abundant, excellent quality flint probably from outcrops in the western Basque area and central Cantabria, 40-70km from El Mirón, infer sizable band territories or inter-band trade resampling the large exchange networks of lithic raw materials (AUBRY ET AL. 2015).

At El Mirón, the earliest Solutrean occupations (Levels 127 and 126) include an impressive amount (NR=29) of personal ornaments, namely shells served as beads (STRAUS ET AL. 2013). There was probably an increase in cave artworks in regional sites (including the art on the walls of the adjacent caves of La Luz, Covalanas, and La Haza in Ramales) along with a limited increase in portable art objects. Such increases in artistic expressions contemporary with changes in the settlement and subsistence systems could be an effect of the society's social re-organization and establishing of extended networks (SAUVET 2019).

The new regional economic results correlate temporary high hunting biodiversity and preying on young ungulates as signs related to subsistence stress during the HE2 event. This period was previously classified as a moment of more intense human occupations in the relatively favorable environment of the Cantabrian region (STRAUS 1979). Between c. 25 and 23ka cal BP, however, faunal evidence reveals the decreasing portion of young animals, low-ranked species, and species diversity as a sign of economic adaptations. Just at the onset of the LGM, with varied faunal assemblages showing similar biomasses, the size of groups visited El Mirón, for example, stayed stable. The assembled information led to conclude, an entirely new settlement scenario with long-distance social networks (for exchanging not only materials but also mates and ideas), increased mobility of smaller groups and dietary diversification, establishing the Solutrean as a highly resilient cultural unit facing a particularly challenging LGM environment by probably unintentionally applying optimization strategies. Since this economic change follows optimization principles, it may be associated with establishing alternative economic solutions confronting population growth in Iberia (STRAUS ET AL. 2000a,

2000b). The emerging settlement changes, as some populations moved further into the interior of Iberia, at similar frequencies in both the south and north of the Peninsula (SCHMIDT ET AL. 2012), possibly added upon it. Coherent to the dietary modifications, Solutrean age human groups also readjusted their economic behavior in terms of a technological shift in hunting equipment by adding invasively retouched and shouldered stone projectile points and possibly a new weapon-delivery technology (i.e., atlatl) (STRAUS & GONZÁLEZ-MORALES 2012a).

However, the low density in the archaeological record of many sites (SCHMIDT ET AL. 2012; STRAUS 2019) suggests that still few, small bands of humans practiced frequent residential movements (SUROVELL 2000), or that, along with evolving hub sites, increasing logistic mobility favored a pattern of hunting parties that recurrently traversed larger catchment areas than in earlier times. The contemporary adaptations towards increasing dietary specialization in the most profitable prey, however, reflect also a search for the highest dietary return rates. Regional demographic growth added upon the previous factor and possibly led to changes in socio-cultural relations, which ultimately discharged a reorganization of the regional techno-social-economic system as recognized in the archaeological record with the onset of the Magdalenian.

Initial Magdalenian (20.1-19.7ka cal BP)

Archeologists culturally subdivide the Magdalenian in northern Spain in terms of changes in human behavior, technology, settlement, and subsistence that occurred during that period into Initial, Lower, Middle, Upper, and Final Magdalenian. After the onset of full glacial LGM conditions, manifestations of the Initial Magdalenian or Badegoulian were partially contemporary to final Solutrean ones in different regions of SW Europe (e.g., Cantabrian and Mediterranean Spain, SW, Central and SE France), and human occupation intensified at the montane site of El Mirón after the Solutrean.

The start of the Initial Magdalenian occupations at El Mirón correlates with red deer- and ibex- focused hunting, meat-marrow, as well as possibly grease exploitation. However, the materials analyzed here are sparse, and concern only the contact zone with the overlying and rich Lower Magdalenian sequence marked by an increase in NISP in Level 18 in the Outer Vestibule (Cabin) area. (Results of the Vestibule Rear [Corral] Initial Magdalenian (Level 119) faunal analysis by M. Carvalho are currently unavailable.)

The Magdalenian, a geographically more widespread cultural tradition than the Solutrean because of the post-LGM recolonization of northerly and upland regions of Western Europe, with broadly shared cultural manifestations, was more widely transgressive in time and space. The Initial Magdalenian was the product of mobile hunter-gatherers seemingly organized into groups that traversed landscapes in some areas like scouts in search of new resources and hunting territories. The regional economic analysis, however, showed signs of continuity in hunting behaviors. Economies aligned with a general trend (from 25 to 18ka cal BP) of subsistence strategy change toward a greater specialization in the two most available and profitable game species (red deer and ibex), a trend that had already begun during the Solutrean and that would peak in the Lower Magdalenian, at El Mirón as in other sites in the Cantabrian region.

Lower Magdalenian (19.2-18ka cal BP)

At El Mirón, the massive Lower Magdalenian occupations in the 9.5m² Outer Vestibule ('Cabin') excavation area shows evidence of heavily focused hunting of red deer and ibex, with infrequent Paleolithic prey species chamois, horse, and Bos/Bison always playing a minor role in subsistence, as determined from analysis of more than 200,000 faunal remains—the central focus of this dissertation. Beside subdividing the massive Level 17 into smaller sublevels of about 5cm-thickness for a c. 50% sampling of its whole faunal assemblage, every second surrogate contained relatively high MNIs of 35 to 42 individuals with 25-35% red deer and 35-48% ibex portion during the early Lower Magdalenian occupations. Still representing repeated, significant human stays, during later Lower Magdalenian occupations (Level 17- subsample 6 Levels 16 and 15) site use

changed, with 19 to 30 individuals included with 15-25% red deer and 44-53% ibex per sub-level. In these levels were observed shorter seasonal visits with a stronger summer signal than before, but less people visit the cave, or they moved the center of bone disposal to other areas of the vestibule could also be the reason for lower numbers since those minimum estimates come from only a small portion of the area of the cave's vast vestibule. For example, Lower Magdalenian faunal remains from Level 115 from the Vestibule Rear ('Corral') excavation area currently under study by E.L. Jones and the data are not yet available, but the assemblage is very abundant in ibex and red deer, too. The useful hunted biomass was certainly higher when considering taphonomic reduction processes, although it is impossible to determine the exact number of killed animals in any individual episode of site occupations in light of many unexcavated areas. This circumstance, however, supports the use of samples and relative portions of inference on human behavior patterns.

With the help of the present study, the richness of Lower Magdalenian data collected allow us to draw the picture of a complex *chaîne opératoire* of Lower Magdalenian economic activities related to subsistence.

Resource acquisition. Specialized red deer and ibex hunting was fully established as the dominant economic strategy of the Lower Magdalenian at El Mirón as throughout Cantabrian Spain, with remains of other ungulates, carnivore species, lagomorphs, birds and fish being relatively rare. However, salmon (of considerable size) seem to be the most common of these secondary food complements. The reconstructed meat-dominated diet, including about 20% of other food resources of the buried Lower Magdalenian Red Lady of El Mirón Cave, possibly resamples that economic pattern. Detailed taphonomic analyses show that carnivore activity at the cave was particularly low; ungulate bones were primarily the result of human accumulations. Hunting focused more on matriarchal ibex herds than in red deer, and shed red deer antlers were collected for raw material.

Skeletal profile analysis suggests that transport decisions differed between species. By Bayesian modeling of skeletal representation, Lower Magdalenian occupations showed a tendency towards transportation of complete carcasses for ibex, and more selective transport for red deer, favoring appendicular elements. The proximate habitat of ibex (on the steep, rocky slopes immediately surrounding the cave) favored complete transport of this smaller ungulate, as transport costs were low. A higher selection of the weightier red deer's skeletal parts would save the energetic cost of more distant transport from hunting ground locations, probably on the Ruesga Valley floor or its lower slopes.

Lower Magdalenian humans preferentially occupied the site from the end of the autumn-beginning of winter season until spring, possibly (semi-)continuously. Possibly they took advantage of the fact that red deer typically gather in larger groups for mating purposes in fall to kill many in the valley. They also killed ibex that dwelled in higher altitude pastures during the rest of the year, but that would be driven downslope by snow cover in late fall-early spring. Autumn-winter kills provide the utmost amount of body fat during times of resource stress, when bone fat would be a highly predictable food source (OUTRAM 2002) (as well as being a pigment component mixed with ochre or as a lamp fuel). Spring kills and fetal bones signifying late winter deaths of pregnant females are also attested and indicate longer stays than in some of the later Magdalenian levels (MARÍN-ARROYO 2010).

Although the Lower Magdalenian established the first evidence of human presence in several stratigraphic sequences in the Cantabrian region, possibly because of larger group sizes, band clustering, high population densities, and maximum connectedness (UTRILLA 1994), it seems that more complex settlement characteristics became decisive and provoked settlement changes. For instance, despite relatively low precipitation and the scarcity of woodland species of ungulates at El Mirón cave, the presence of micro-fauna species that inhabit the edges of watercourses indicates running streams nearby the site (IRIARTE-CHIAPUSSO ET AL. 2015). The El Mirón catchment area possibly enjoyed a meltwater supply or groundwater drainage

within a generally dry and cold environment, which could have produced a micro-environment with relative lusher local vegetation. If changes in economic strategies required, for instance, water supply for cooking tasks, greater visibility for spotting game, or just the combination of locality- specific ungulate biomass abundance with complementary foods such as salmon, all could explain why El Mirón as a favorable residential site at that time. In consequence, multifaceted site occupations, the great diversity of on-site activities, and intensive exploitation of resources imply larger group sizes. The whole band or larger group was less likely to be highly mobile in general, i.e., a decline in residential mobility in favor of more task-group logistical mobility is logical. El Mirón is outstanding as a hub or base residential camp, at times may have been an aggregation site (sensu CONKEY 1980), and perhaps it was also a ritual 'sanctuary', because of the red ochre -stained burial with a possible grave marker. The high biomass productivity at the site locus could have helped that El Mirón became part of a settlement system with long-term, geographically restricted, oscillatory, seasonal occupations (BUTZER 1982: p. 238 Figure 13-2F). The Lower Magdalenian bands had defined territories; they may have traversed them on well-established subsistence schedules ('rounds') for visiting specific ecozones for exploitation of resources at different times of the year. The landscape use and mobility pattern logistics integrated lithic raw material exploitative strategy and increasingly fine-tuned towards optimizing prey species exploitations seasonally. The Lower Magdalenian economic territory of central and eastern Cantabria Province included such sites as Altamira, El Castillo, El Juyo, El Rascaño and El Mirón, each of which contained evidence of reduction sequences of same lithic materials indicating circulating transport of same raw materials among sites and repeated visits to each or long-distance trade (FONTES 2016A). However, osseous raw material use increased independence from those fixed raw material outcrop locations by using hunting implements derived from the principal prey species (red deer) itself by using antler weaponry, as an abundant osseous industry is present at El Mirón (STRAUS ET AL. 2018). Besides its technological advancement, the resultant logistic progression is that antler raw material is cheaper than non-local stone, as it can be collected in the nearby red deer habitats as well as it is a substitute for wood in tree-poor landscapes.

In consequence, economic progression and technological advance permitted settlement systems to become somewhat more independent of lithic raw material locations by gathering high-quality flysch and other flints via logistic excursions or trade (opposed to 'residential' movement of whole groups to outcrops), and by exhaustively exploiting those non-local raw materials by the thrifty use as bladelet inserts in antler points. Such economic changes would allow higher sedentary behavior with more on-site productive activities, thus, in turn, favoring demographic growth. The significant impact of increased local resource use efficiency allowed greater sedentism manifested by dense site occupations, so characteristic for that period (STRAUS ET AL. 2006).

Exploitation of animal resources. The animal remains brought to El Mirón during the Lower Magdalenian were intensively exploited. Skinning marks found on red deer and ibex extremity bones indicate both the access to meat, bone grease, marrow, and the provision of hides. Animal hides are useful for manufacturing clothes, portable shelters, containers for transport, or cooking (i.e., stone-boiling). Presumed manufacturing processes included sewing hide parts together, as Lower Magdalenian levels contained some awls and many needles (some whole or fragments with an eye), many of them broken by pressure with bending fractures indicating use (STRAUS ET AL. 2018). The presence of end-polished bones additionally indicates the burnishing or smoothing of skins.

Disarticulation and filleting activities are abundant within all the studied levels. Level 504 (the human burial area), separated from the other Lower Magdalenian levels by a large limestone block, is comparable to Level 17-8 in terms of quantities of disarticulating and filleting marks. This similar butchering pattern is interesting, as radiocarbon dates suggest the contemporaneity of assemblages from Levels 17-8 and 504. When stripping of meat, sometimes the periosteum was removed, too. Evidence by numerous, often long-(re)used hearths

with fire-cracked rocks also suggests on-site food consumption for this multipurpose site (STRAUS & GONZÁLEZ-MORALES 2007; NAKAZAWA ET AL. 2009). Osseous weapon point fragments, furthermore, presumably broke during hunts, got embedded in the meat, when the butcher discarded them after the animal parts were prepared for consumption as already outlined (STRAUS ET AL. 2018). A comparably low frequency of burning marks was found on bones themselves, possibly indicating roasting of still meat-bearing, articulated extremities, whereby bones only experience indirect heating and filleting of meat occurs after cooking.

Maintenance of resources. The osseous industry of Lower Magdalenian levels is comprised mainly of antler weaponry, bone tools, organic ornaments made from teeth in addition to shells (FONTES ET AL. 2015; GUTIÉRREZ-ZUGASTI & CUENCA-SOLANA 2015; STRAUS ET AL. 2018). They used the groove and splinter technique to extract blanks from red deer shed antlers. The sequence of grooving – percussion – shaping – smoothing, seems to best describe the *chaîne opêratoire* for producing the *sagaies* of Lower Magdalenian Level 17, as leftovers of each of these production steps are frequent among the faunal material. About the reuse of some items, as evidenced by re-sharpened antler points, some more investigation is needed (see also STRAUS ET AL. 2018). Bone modifications found testify to an elaborate industry of organic remains. Long bones from the main prey animals were tested for bone (needle) blank production based on unfinished grooves mainly on metapodial shafts. Other bones were also shaped or simply used, and such are ulnas or metapodia as awls, long bone shafts used as wedges, retouchers, or other unknown activities. For the Cantabrian Lower Magdalenian, common endscrapers, according to functional analysis (DOMINGO ET AL. 2012), were objects used for bone and woodworking after first exploited as bladelet cores. Such a behavioral pattern remarking resource thriftiness compared to previous more lavish Solutrean point productions as a sign of cultural reorganization and economic adaptations. The multi-functional character of the stone tools in the absence of nearby high-quality flint resources might also indicate the need to transport or procure via trade small (light-weight) cobbles or cores from distant outcrops. Such a highly mobile tool-kit, more independent of local resources, requires in-depth planning, awareness of limited resource availability with resulting conservation and austerity measures of the economic budget.

Since humans are known to use open-cracked long bone cavities efficiently, often identified animal resource exploitation of bone marrow with green fractures, impact marks, and negative scars. The repeated finding of a mixture of varied fracture patterns on the same bones, however, indicate previous heating of bones to facilitate bone breakage and extraction of jellified marrow, corresponding to the effects from radiant heating for less than 10min or ~10min of boiling (OUTRAM 2002; FERNANDEZ-JALVO & ANDREWS 2016). The statistically weak correlations of the skeletal profile representation with the meat index and MGUI values, in contrast, suggest an underrepresentation of meat-rich body parts (BINFORD 2012). A common explanation would be that humans transported meat-rich skeletal elements to secondary consumption sites (PHOCA-COSMETATOU 2004), but alternative taphonomic hypotheses also could have altered the skeletal profile. Effects of attrition in the studied sub-levels of Level 17 as well as 16 and 15 demonstrating that substantial comminution of bones reduces identification rates, and selective destruction influences the skeletal profile. Positive correlation of the red deer fragmentation ratio NISP/MNE to the marrow index is regular, while ibex correlate less. An increase in grease index values started, however, with the Initial Magdalenian occupations at El Mirón site (at least in the small samples from the Cabin area). The combined evidence of small bone fragment sizes, spatial patterning of bone micro-fragments and blow marks on cancellous bone, plus the abundance of fire-cracked rocks, particularly suggest grease rendering activities and exhaustive food cooking during the Lower Magdalenian at El Mirón (NAKAZAWA ET AL. 2009; GEILING ET AL. 2016) that were responsible for the observed skeletal profile and massive bone discard areas.

Abandonment. Since the Lower Magdalenian deposits at El Mirón resample a multi-purpose, the **discard** pattern of animal food remains can be informative of areas, intensity, and dimensions of consumption (BINFORD 2009: p. 202). The site is rich in highly organic, charcoal- stained, with masses of lithic and osseous

artifacts, portable art objects, ochre chunks and stains, personal adornments, hearths, fire-cracked rocks, sediments with many fragile bones, and art objects supporting the conclusion that the Lower Magdalenian deposits (mainly Level 17) enjoyed excellent preservation conditions (GONZÁLEZ-MORALES & STRAUS 2009).

The burial area in the vestibule rear SE corner seems to have been generally used more as a disposal place, rather than a living space for daily activities. Mostly perfectly preserved bone surfaces infer more undisturbed accumulation, before someone prepared the burial into that area. The shallow primary burial itself was disturbed partially by a carnivore and then by humans extracting the cranium and other large bones of the 'Red Lady', with ultimate reburial of the remaining bones. The use of this area seems to have changed after the deposition of the corpse there. Differential spatial use of cave areas is indicated by the abundance of axial animal body parts in sediments of the burial area (MARÍN-ARROYO & GEILING 2015), suggesting deposition of butchering leftovers; this is in sharp contrast to the observations made in the Cabin area indicating use as a working area for grease rendering. The sunlit vestibule front area, in comparison, experienced more frequent movement of people, and thus the bones accumulated within this living and working space suffered more trampling and movement, which altered bone surfaces. Selected spaces in the cave were maintained or reused, which would suggest a degree of site-use continuity. The bone working zone, with a distinct circular concentration of bones with impact marks and bone flakes, overlaps with abundant cobbles used presumably several times to open bone marrow cavities, as well as with many repeatedly used hearths that structured activity areas. A possible wall in the Corral area may also evidence such structuring (STRAUS & GONZÁLEZ-MORALES 2018). The evidence for dumping events indicates cleaning episodes at the site, hence implying some degree of planned longevity and repetition of the use of this space. The Lower Magdalenian fauna from Levels 15 and 16 represent a late phase of this occupation, somewhat different by faunal and taphonomic characteristics.

Although the Cantabrian Lower Magdalenian horizon in El Mirón is often referred to as massive palimpsest, during the present study, a sequential comparison elucidated changes in human behavior throughout the Lower Magdalenian. The most paramount findings concerning subsistence, during the Lower Magdalenian occupations of El Mirón, include the following:

> **A)** Intense on-site hunting pressure on ibex began with the onset of the Lower Magdalenian, with a sharp rise in the number of accumulated animals compared with underlying levels. This increase is reminiscent of the changes in site-use within the equally massive Lower Magdalenian horizon in El Juyo (FREEMAN 1985; KLEIN & CRUZ-URIBE 1985) and which can also be suspected in the extensive deposits at such sites as El Castillo and Altamira.
>
> **B)** During the late Lower Magdalenian, ibex amount decreased until the beginning of Middle Magdalenian occupations having less than ten individuals per level. Whether the intense hunting pressure reduced this species' abundance in the area around the cave or environmental fluctuations changed ibex behavior cannot yet be determined. Hunting pressure, evidenced by an increased slaughter of young animals, is not observed and seems unlikely. Ibex hunting almost got minor importance from the Upper Magdalenian onwards, with one to three individuals accumulated per level (MARÍN-ARROYO 2010).
>
> **C)** Intensive site use took place at the cave, but this is not reflected by having the highest portions of young animals. There is a pattern of sustainable resource intensification that did not rely on incorporating more younger animals during hunts, as it is often a sign of resource stress, but rather involved exploiting each animal carcass more intensively. This evolving dietary strategy target efficient resource exploitation is a manifestation of slightly increasing effort to obtain an additional low return of low risk and is possibly related to relatively larger group sizes.

D) Red deer exploitation changed from, a fuller body transport in the early Lower Magdalenian, to a more selective one in the following occupations, suggesting progressively more field butchery and differential transport from kill sites, possibly a sign of economic adaptations towards optimized landscape use or local resource depletion and higher transport costs.

E) Red deer and ibex had skinning marks and other indeterminate cut marks on carpal and tarsal bones. Disarticulation marks on ibex, however, are comparably high in the earliest Lower Magdalenian occupations (Level 17-12). Cut mark distributions change on ibex, with disarticulation marks becoming notably less in the upper (sub-)levels of the Lower Magdalenian. Whether slaughtering techniques or individuals' butchering skills improved or butchering locations within the cave changed through time, remains unknown.

F) The amount of biomass from hunted prey declined with the following occupations in Levels 17-6, 16, and 15 (according to MNI as said in B), despite being dominated by MNI ibex (specifically only in those late Lower Magdalenian occupations). This pattern could be interpreted as an emergence of highly logistic exploitation at this montane site, because it implies shorter visits or smaller groups with more focused ibex hunting, in contrast to most of Level 17, dominated by red deer in terms of biomass. Other sites do not show such hunting adaptations during the Lower Magdalenian, where either red deer or ibex always dominate the assemblage by biomass, for example, in Rascaño (ALTUNA 1981).

G) The vertical separation of Level 17 by sublevels permitted the detection of activity shifts by spatial analysis, mainly among locations of hearths, working, walking, and dumping zones (GEILING ET AL. 2016, 2018). Level 17 shows a successive intensification of site use. Very localized activities have been identified just at the 'beginning' of this palimpsest accumulation (lower part of Level 17) that progressively arranged into a more structured pattern of site-use, with a presumed cooking area as one of its centers as suggested by a high degree of fragmentation of the bones associated with fire-cracked rocks found within this level (NAKAZAWA 2007; GEILING ET AL. 2018). This activity area, however, shifted with continued occupation eastward towards the inner part of the cave vestibule, with faunal remains increasingly mixed and damaged, possibly by trampling. The intensity of the occupation in this area of the cave dropped off drastically at the end (top) of Level 17. Levels 15 and 16 marks the beginning of decreased use and even eventual long-term abandonment of the site during late Lower Magdalenian, where many bone surfaces with calcite crusts indicate repeated water presence. Such shorter or less frequent site episodes nonetheless display a bone distribution pattern similar to that of Level 17, with a possible cooking zone surrounded by bone-cracking activities, centered east of the excavated area as identified by spatial distribution analysis (GEILING ET AL. 2016).

The high density of human occupation of Level 17 suggests either long-term or frequent Lower Magdalenian use of this cave. But, why would different activities shifted across space and time within the cave? Given the fixed aspects of shelter (cave roof area), light, and walls in the cave, other aspects might have also influenced the segregated use of space within El Mirón cave. Seasonal or climatic temperature changes or the intensity of water drips from the cave ceiling might have influenced the displacement of activities further inside or outside the cave (GEILING ET AL. 2018). However, more prolonged occupations by larger groups are likely to have encompassed multiple actions, including meat, marrow, and grease extraction activities, as well as areas where garbage build-up. The initial occupation changed from having more localized activities to an elaboration of site structure that possibly involved more people, including multi-generational social groups (males, females, adults, children) using this area of the cave. A probable demographic reason could be that different group

sizes determined space use within the cave site, and larger groups would show more structured space use.

H) At El Mirón, the seasonality of occupation changed from mostly in the cold season (late autumn to early spring) to repeat, but briefer site visits in late summer-autumn, winter, and late spring use during the late Lower Magdalenian, just at the onset of HE1 event. Maybe site function changed towards highly logistic exploitation of seasonally abundant resources around the El Mirón, reflecting the ending of the Lower Magdalenian cultural phenomenon. Such late summer-autumn season occupations of the montane zone are more similar to the earlier established model of late-spring and summer Magdalenian occupations (MARÍN-ARROYO 2009a, 2009b) (i.e., less or no winter occupation) and a difference in the mode of territorial movements in the Asón valley. Social groups may have changed their mobility pattern by giving up more extended multi-month stays in favor of more strictly seasonal moves, between the coastal and montane zones of the Asón valley. The later Magdalenian regional settlement system appears to have been more strongly structured by seasonality. Sites with dominant seasonality appear along river valleys, as likely animal migration corridors into the interior: during summer-autumn (i.e., Las Caldas in central Asturias), the montane zone during winter-spring first and later during late spring-summer (i.e., El Mirón), and both summer and winter occupations appear at near- (or semi-near-) coastal locations (i.e., La Riera, El Pendo). A broader set of regional, seasonal data would be helpful to refine such settlement patterns, currently based very tentatively on only a few well-studied sites whose assemblages spread out over long periods and in different sectors of the whole Cantabrian region.

The Lower Magdalenian occurred during comparably stable climate conditions, mainly between the LGM and HE1 (Oldest Dryas). The present regional analysis approves a remarkable increase in the regional archaeological occupations, many of them within daily walking distance of one another and often with one overwhelmingly dominant prey species. This combination implies primarily strategic site uses, which support previous interpretation with distinct primary site functions as hunting, hub or base camps, aggregation loci, or cave art sanctuaries (STRAUS 1986; UTRILLA 1994). Interestingly indicate the additional obtained result on strontium isotopes that the main prey species ibex was hunted locally to El Mirón on nearby carbonate sedimentary rocks, but seldom hunted horses with different elevated signatures probably origin from dwelling areas on mixed sedimentary rocks located west from the Asón river valley. With strong arguments, researchers suggest a Lower Magdalenian regional band territory extending westward from El Mirón to eastern Asturias through locally distributed artworks of striated engravings of hinds on red deer scapula, a pattern which contrasts with the contemporaneous settlements to the east in the Basque country that are lacking such artifacts (GONZÁLEZ-MORALES ET AL. 2006; GONZÁLEZ-MORALES & STRAUS 2009; RIVERO VILÁ ET AL. 2019). Thus, the striated hind engravings are supposed to be a sign of a local group identity or preferred art style, different from the groups on the east of El Mirón, with which trading networks possibly existed. Such intensified long-distance contact is coherent with the interpretation that lithic raw material procurement strategies regularly exploited eastern resources (i.e., the high-quality flints of the Basque coastal flysch and trans-cordilleran outcrops) by Fontes (2016). When synthesizing previous knowledge and the results from this study, we might conclude that the 'artwork-subsistence territory' of El Mirón was reaching to the West resampling possibly the movements of the core group, but the 'lithic raw material territory' was also reaching to the east resampling mostly logistic trips or more likely more extensive trading networks. The implications obtained here on the Lower Magdalenian at El Mirón and its regional context adds manifold to our previous understanding of this cultural period, leaving to discuss how the end and the transition to the Middle Magdalenian occurred.

The underlying Middle Magdalenian occupations at El Mirón (Level 14 in the Cabin) display comparable low archaeological and faunal densities (MARÍN-ARROYO 2010; STRAUS & GONZÁLEZ-MORALES 2012b) than the Lower Magdalenian ones described here, indicating temporary abandonment and changes in the use of this space (or of the whole cave). Only one Middle Magdalenian occupation horizon of El Mirón, Level 108 (Corral), reached the amount of hunted biomass high as it is typical of the Lower Magdalenian sub-samples from Level 17, with MNIs of 25 red deer, ten ibexes and four chamois (MARÍN-ARROYO 2010). This level is indeed outstanding as red deer has by far the most substantial contribution of biomass, since, before at the site, the two main prey species, red deer and ibex, were hunted equally. The increased portion of young animals at the same level and in some other sites are signs of conservative adaptations, indicating economic stress, possibly due to demographic pressure during the Magdalenian.

Middle, Upper, and Final Magdalenian (18.1-11.9ka cal BP)

Further dietary changes, however, occurred later in **Middle, Upper, and Final Magdalenian times**, by incorporating a somewhat more comprehensive range of animals with lower-ranked return. It was not really before the Upper Magdalenian that roe deer and wild boar (real woodland species) appear more frequently in the record, and Late Magdalenian diets became increasingly diversified. Genetic evidence signals the existence of the Iberian refugium alongside those of the Apennine and Balkan peninsulas, with the Cantabrian region playing a marked role in the post-LGM resettlement of central Europe beginning during the Middle Magdalenian, since plants, animals, and human populations are related to that local gene pool (CONSUEGRA ET AL. 2002; ACHILLI ET AL. 2004; MEIRI ET AL. 2013; POSTH ET AL. 2016; FU ET AL. 2016). After an occupational hiatus at El Mirón indicated by the consecutive radiocarbon record, the Upper Magdalenian show evidence of diverse disarticulation marks displaying on-site processing activities and differential transport of prey body elements. This evidence suggests that with the DO1 warming event, seasonal visitors to El Mirón established a residential site during summers, maybe complemented by nearby El Horno occupations in early spring (COSTAMAGNO & FANO 2005; MARÍN-ARROYO 2009a). At El Mirón in the terminal Magdalenian and Azilian, there is evidence of intensive field processing, with consumption on-site after selective transport of selected carcass elements (MARÍN-ARROYO 2010)

The observed diversification in subsistence economies is contemporarily with climate ameliorations to include more warm-climate species at the end of the Late Glacial. Similarly, there is regional evidence of remarkable dietary diversification processes especially after 13 ka cal BP and subsequent Younger Dryas (YD) cooling in Late Würm and continuing into the Early Holocene, with significant coastal adaptations of maritime hunter-gatherers by increasing shellfish and bird exploitation (CLARK 1971, 1975; FREEMAN 1973; STRAUS 1977; GUTIÉRREZ-ZUGASTI 2010; GARCÍA-ESCÁRZAGA 2020)—spectacularly demonstrated at the Basque region site of Santa Catalina (GOCHI & PASTOR 2014; SANCHEZ & THAM 2014) or La Riera in Asturias (STRAUS & CLARK 1986). Such changing subsistence strategies during the Upper and Final Magdalenian and Azilian might signal the reorganization of the economic and settlement system, with preferred use of the montane zone during summers, since Late Magdalenian and Azilian occupations are very abundant in both coastal and interior upland settings, throughout Cantabrian Spain.

Depletion of terrestrial resources adding upon long- term regional population growth (STRAUS 1977) possibly triggered such economic and settlement changes. All these components seem to be part of adaptations towards a more seasonally restricted and scheduled use of El Mirón and other sites resampling that the higher economic adaptations of this period rely on changes in mobility strategies to optimize exploitation of distributed resources within a well-known landscape.

With the end of the Magdalenian is the final stage of significant behavior changes observed by this study, when settlement, subsistence, and cultural (belief, artistic) systems ultimately seem to have collapsed, although not necessarily all at the same time in all places. Substantial cultural instability at the end of the

Magdalenian appears to be the result of dramatic climatic change and major system reorganizations that occurred with the beginning of the Holocene.

The results of the archeozoological study propose complex dynamic relationships of environmental, demographic, and social factors establishing human paleoeconomic behaviors. Significant economic changes and human behavioral adaptations occurred in the following order as summarized in Table 5.1:

Table 6.1: Chronology of economic adaptations and climate events.

Age (cal BP)	Climate event	Cantabrian Region	El Mirón Cave
45ka	HE5	opportunistic economies, ephemeral camps and few hub sites, Last Neanderthals	
42.8-40.1ka		opportunistic economies, broader settlement systems	
32ka	DO5		ephemeral occupation, relative high young
25ka	HE2	moderate percentage in young, temporary high hunting biodiversity	
24ka	HE2	decrease of percentage in young, reduced hunting biodiversity	
23ka	DO2/LGM onset	low portion of young	more animals of young age, more bone attrition
20.5ka	LGM	moderate portion in young, peak of more low-ranked species	
20-19ka	end LGM	low hunting biodiversity	scouts (local raw materials)
19ka-18.8	rapid sea-level rise, cooling, aridity	more sites with a higher portion of young animals, low hunting biodiversity, few low-ranked species	dual game exploitation, massive bone accumulations, cold season occupations
18.5-18ka	HE1 onset, ice surge	low hunting biodiversity	shorter, seasonal visits, calcite concretions
17.9-17.5ka	HE1, AMOC collapse, aridity	increase in hunting biodiversity and low-ranked species	
16.5ka	slow sea-level rise	further increase in hunting biodiversity	
15-14.2ka	DO1, Bölling warming	further increase in the portion of young, more hunting of low-ranked species	seasonal restricted to UM summer residential visits
after 13ka	YD	coastal adaptations of maritime hunter-gatherers by increasing shellfish and bird exploitation	

According to the presented data, this sequence of economic changes show that economic strategies were dynamically adapted and intrinsically linked to impactful climatic events, confirming their direct and indirect influence on human behavior. Here were included a set of carefully selected archaeological sites in the Cantabrian Region to overcome the critical caveat by the risk of extrapolating general patterns from a single site, whose specific function changed situationally (e.g., from special-purpose locus to multi-purpose residential base camp, from short- to long-term, from task group bivouac to full band, multi-family hub locus,

from warm to cold season camp), and the accidental biases caused by sampling the range of in-site activities and garbage deposited over a broad area (employing relatively small excavations and not to mention the blending effects of palimpsest deposits).

6.2 Importance of micro-environments

While impacts of changing climate during the LGM exacerbated living conditions to a minimum in the periglacial zone of central-northern Europe and drastically reduced human settlement (GAMBLE ET AL. 2004; JÖRIS ET AL. 2009), the climatic effects of the LGM were far milder in the northern Iberian refugia, with limited glaciers in the Cantabrian Cordillera and Picos de Europa during this period (SERRANO ET AL. 2015).

The results obtained during this analysis improved our understanding of micro-environmental conditions of the catchment area around El Mirón and animal behavior by: 1) analytical techniques of stable isotopes on tooth enamel (in total 194 sequential samples) coupled with 2) phytolith composition in 23 samples of dental calculus of prey ungulates and 3) novel geochemical analysis of bone coloration.

(1) For the Lower Magdalenian, the intra-tooth oxygen variation in hunted ungulates, as a direct link to the environments in which humans were exploiting, attested seasonal climatic fluctuations that were low in the horse, moderate in red deer and highest in Spanish ibex. The initial hypothesis that horses, as obligate drinkers reflect the most original signal of the environment by imbibing meteoric waters, was rejected, because of the possible insufficient presence of meteoric waters, due to overall environmental aridity and likely admixing of meltwaters into water bodies used for drinking. Ibex represent a signal with high variability, superimposed by variability in behavior. It seems that red deer browsing activity represents intermediately enriched $\delta^{18}O$ (VSMOW) values of plant water, but closely related to paleoenvironment conditions.

The more significant oxygen fluctuation in ibex values suggests the behavioral superimposition of $\delta^{18}O$ records by practicing vertical mobility or seasonal dietary changes. The seasonal mobility reasonably explains the observed constrain of the birth season in ibex. As such, those animals from different stratigraphic positions in the Lower Magdalenian deposits of El Mirón (with around 750 years duration) were living in similar environments, in the same region. Some animals might represent related hunting events (i.e., multiple kills), supporting the idea of more intensive or more prolonged occupation of the cave. Those results also support the interpretation that during the Lower Magdalenian, seasonal climate amplitude stayed similar and relatively stable under an overall cold and relatively arid climate, but in an environment in which humid meadows were more prevalent along valley floors. Areas from the coastal plain up to the piedmont, were likely favorable habitat for red deer, as well as for ibex that would have moved downslope during the cold season. Oxygen stable isotope variation suggests that ibex sought feeding opportunities at higher altitudes during summertime, but on bedrock local to El Mirón, whereas horse was a non-local dweller according to additional strontium isotope analysis.

The results support the general idea of grander vegetation cover along river valleys, reflecting more locally protected areas with relicts of pre-LGM woodlands. If such riverine areas obtained meltwater supplies, released by slightly warmer springs and summers, a denser or lusher vegetation cover could have persisted, especially despite relatively dry climates (IRIARTE-CHIAPUSSO ET AL. 2015; DOMINGO ET AL. 2015). Such favorable micro-environmental conditions could be the reason of why hunter-gatherers firmly integrated El Mirón into the local settlement system since Solutrean times. The results fit well with the northern Iberian climate records of sediment, pollen, glacier stages, and marine cores (HOYOS GÓMEZ 1995; EYNAUD ET AL. 2009; SERRANO ET AL. 2015). These indicate a change from cold early Solutrean (HE2) to moderately cool and humid- later Solutrean (LGM) and to cold-dry Lower Magdalenian (beginning of HE1) environments with episodes of slight climate amelioration (HOYOS GÓMEZ 1995; MORENO ET AL. 2012; DOMINGO ET AL. 2015). A mosaic-like landscape with wood, grass, and heathlands, given the high relief and coastal setting of the region, is repeatedly

reconstructed for the Cantabrian Upper Paleolithic (MUÑOZ-SOBRINO ET AL. 2007; PROVAN & BENNETT 2008; ÁLVAREZ-LAO & GARCÍA 2010; CARRIÓN ET AL. 2010; GONZÁLEZ-SAMPÉRIZ ET AL. 2010; RODRÍGUEZ-SÁNCHEZ ET AL. 2010) and supported by the results obtained here.

(2) However, the new results from dental calculus of ungulate teeth show a decrease through time in the proportion of arboreal phytoliths suggesting a (further) decline in (relict) forested areas, proposed to have occurred at the time of deposition of base and middle of Level 17 (Lower Magdalenian) at El Mirón Cave. Both results obtained indicate relatively more humid conditions, compared with late Lower Magdalenian stays, as well as contemporaneous occupations at La Paloma cave in Asturias, located 200km west of El Mirón (DOMINGO ET AL. 2015), suggesting a more favorable micro-environment around El Mirón Cave. Reduced precipitation could have triggered such an effect of increased overall regional aridity, due to decreased (sea surface) water evaporation caused by winter seas ice and the 18.8-18.7ka cal BP event of 'instant' cooling (colder than LGM) which was also unfavorable for glacial growth (SERRANO ET AL. 2015). The variation in the arboreal components (leaves) in ibex diet could also be the results of individual animal behaviors; for example, males versus females or old versus young – although only adult teeth were analyzed (MARTINEZ & OTHERS 2000; GARCÍA CARRERO 2013; MOÇO ET AL. 2013). Micromammal studies at El Mirón confirmed increasing aridity and opening of the landscape during the Lower Magdalenian occupations (suggested by the rising number of open-habitat dwellers from Levels 116 to 110 in the Corral area) (CUENCA-BESCÓS ET AL. 2012). Lower Magdalenian hunting success might also possibly be linked to the progressive deforestation of vegetation relicts in the river valleys below the cave, which increased visibility further. Base-camps with excellent landscape visibility, in strategic locations, became especially essential during that period and sometimes developed into major residential camps (GARCÍA-MORENO 2013). A pattern as it was the case of the El Mirón and El Castillo Cave, for example.

Further aridity developed from 17.5 to 14.5ka cal BP, known as the Mystery Interval (DENTON ET AL. 2006), which roughly coincided with the Middle and Upper Magdalenian period and is characterized by greatly lessened precipitation, as the hiatus in speleothem growth at El Pindal Cave demonstrates (MORENO ET AL. 2010, 2012).

(3) The results from the collaborative project "ColoMiron" (=Coloration of bones at El Mirón), in which Prof. Seva-Ramón and members of the Archeometry Unit of the University of Alicante confirmed that mineral manganese- stained bones blacken is due the presence of oxidizing bacteria, organic matter, and humidity, helped to decipher bone coloration change through time. Those results also aligned with previous observations identified of biological manganese oxidation, which requiring humidity and organic matter for decomposition (SHAHACK-GROSS ET AL. 1997; TEBO ET AL. 2004; LÓPEZ-GONZÁLEZ ET AL. 2006; MARÍN-ARROYO ET AL. 2008, 2014; FERNÁNDEZ-JALVO & ANDREWS 2016). The introduction of such organic garbage into cave deposits can be the result of human activities, too.

The depositional locations in the cave differently influenced bone coloration, mainly in terms of the distance to the cave entrance and the effects of external climate conditions, such are sunlight or temperature. The Middle Paleolithic and Early Upper Paleolithic levels, at the rear vestibule, show none or only very light bone colorations, possibly the result of the absence or low presence of organic remains, minerals in the deposits and relatively dry conditions. Beginning of Level 127, the coloration of the bones increases steadily. These bones are mostly yellow-brown, influenced by iron minerals and humic acids. The bones from the Solutrean Levels 125 to 121 show a dark staining with coloration of chocolate-brown to black-brown. The black color types, highest in Level 125, suggest an increase in either the amount and the frequency of organic materials deposited and humid sediment conditions that favored the growth of oxidizing bacteria. The presence/ absence of these bacteria also can be influenced by temperatures, humidity, and the availability of feeding grounds, which would be organic leftovers in the case of El Mirón. Thus, with early Solutrean occupations, a

micro-environment was created that included higher input of organic remains whose bacteria decomposed over time, very similar to observations made in later Magdalenian levels (MARÍN-ARROYO ET AL. 2008: p. 805; FERNANDEZ-JALVO & ANDREWS 2016: p. 157). In contrast, the outer vestibule bones are of a natural white-beige color in the Initial Magdalenian, but changes during the Lower Magdalenian sequence (Levels 17 to 15) towards mainly brown and grey colors. The variation in color is likely due to the proximity of the Cabin area to the cave mouth, whose sediments would seem to be more affected by (seasonal and diurnal) climatic fluctuations, with less stability in humidity and temperature, thus supporting only a limited presence of oxidizing bacteria, within turn limited staining resulting in grey shades of bone colorations.

The results show that coloration shades vary with (broader) cultural periods, with caution due to micro-environmental differences between the different excavation areas from which the faunal remains originated. Natural (white) bone coloration can be associated with relatively dry conditions and low organic content, brown with humid and decomposing organic materials, and black with more decomposing organic materials and long-term humid conditions. In summary, black staining processes increase with more stable micro-environmental conditions, deeper inside and darker sectors of caves, with the presence of more organic materials, and require the presence of water for activation. These are specific conditions of the caves water environment, local climate conditions, sediments, and biological activities (animal and humans), which the author refers to as **nano-environment** (as described in detail in Chapter 4 about Taphonomy). Those nano-environmental conditions according to color classifications represent criteria that are detectable with the naked eye, but were validated here by geochemical analysis and a color table for classification. The analysis also showed that these kinds of studies have their limit by highlighting relative environmental conditions, best applied to a single site, with few exiting comparable studies. Interpretation in conjunction with weathering processes and calcite concretions, both infer drying-out events (BEHRENSMEYER 1978), improved such multidisciplinary analysis. To conclude, rapid nano-environmental changes are traceable on individual bones as a sequence of staining (to black colorations) and bleaching by grey colorations. Future research that further investigate the sequence of grey shadings can improve the understanding of changes in nano-environments.

Curious implications of nano-environments, referring to specific on-site conditions and human activities were derived from bone coloration in the Cabin (vestibule front) area, which is located in the sunlit area of El Mirón close to the southern cave wall, away from the axis of the cave's drainage system. The bone colors indicate relatively drier conditions for the early Lower Magdalenian occupations (Levels 17-12 and 17-10), and slightly higher amounts of percolating and shallow water for the following Lower Magdalenian occupations (Levels 17-8, 17-6, 16 and 15). These observations coincide partially with the stable isotope and phytolith records of this study, which suggest that the early Lower Magdalenian began during a particularly dry period. The sediments above belong to the Middle Magdalenian and also indicate cold and dry conditions, placing a possible event of increased water presence in the Cabin area between these two phases. Whether short, seasonal abundance of water caused, the observed increasing humidity is difficult to say, since all the climate proxies indicate overall aridity for this time (IRIARTE-CHIAPUSSO ET AL. 2015). Since the slight increase in water presence during this period is not well attested in other environmental records, but cooking might be attested by signs of grease- rendering activities as described in results of this work and was suggested previously (NAKAZAWA ET AL. 2009), a human-related context is possible. Human- introduced or use of water could be responsible for grey shadings on bone surfaces. If water were human-introduced instead of natural dripping, it would explain why relatively brief and rapid nano-environmental changes appeared. Such changes possibly resampled major cooking events that triggered the diagenetic pattern of this palimpsest deposit.

To conclude, the evidence obtained from this study confirm relatively stable climate conditions but do indicate some changing environmental parameters throughout the Lower Magdalenian sequence of Level 17

at El Mirón Cave by stable isotope, phytolith and bone coloration analyses, which highlight the importance of micro- and nano- environments to decipher human behavior related to site use. Such analyses, additionally, improve our understanding of environment-animal-human relationships.

6.3 Reasons for economic adaptations

In light of the above-demonstrated adaptations in human economic behavior, but also in awareness of taphonomic processes reducing the archaeological evidence's completeness, the cultural manifestation of the human use or manipulation of natural resources related to their daily subsistence changed throughout the Paleolithic. In the introduction of this work were three cross-linked presumptions established for debating the triggers of such cultural change, which include environmental, demographic, and social factors as underlying reasons to economic behavior change—as part of an overall approach to understanding the economic adaptation system as discussed further synergistically.

Regarding **the role of the environmental factor (Hypothesis 1)** on human behavior change, the results of this study showed that Cantabrian hunter-gatherers hunted red deer and ibex in similarly low frequencies during the Late Middle Paleolithic, the Gravettian and the early Solutrean at El Mirón, and species biodiversity was relatively high, but related to the surroundings of the site. Such subsistence patterns reflect the opportunistic exploitation of resources in the site catchment areas during short residential stays. While during the Solutrean hunting became gradually specialized in the region, at El Mirón, the new data show that site use intensified and chamois (albeit in small numbers) appear increasingly along with the always-most-important ibex and red deer hunting, the species of higher return rates. This change is a sign of increased dietary breadth by including lower quality prey, usually ignored when more profitable prey species are available. The smaller, less biomass-yielding caprine (chamois) is similarly agile to ibex in mountainous terrain, and increased preying on chamois is economically seen as a sign of dietary stress. A similar pattern of increased use of energetically lower-ranked species (chamois, roe deer, and wild boar) is also observable during HE3, the onset of the LGM, and at the beginning of the Holocene in the Cantabrian region.

When deciphering further the Solutrean increase on preying chamois at El Mirón, which occurred at the actual onset of the LGM, it is essential to understand animal ethology. Chamois has a broader habitat range, to include lower altitudes and even woodlands, than ibex. By this reasoning, the climate could have driven change in species evenness in the catchment area where humans continued to hunt whatever was available (STRAUS 1996; GRAYSON ET AL. 2001). In order to intercept such an environmentally deterministic explanation, increasing acquisition of low-return prey could also reflect a change in human mobility, with either, first, very short, or, second, prolonged stays in the montane zone. During short stays, when hunting parties just exploited the cave's direct surroundings by reducing search time, they probably consumed or left behind in the cave low-return carcass parts and carried energetically high return parts elsewhere either as trail food or to provision base camps closer to the coast. During extended stays, the hunting focus would shift away from most profitable prey, as it declines due to hunting pressure. However, the relatively stable amount of biomass accumulated at El Mirón during the Solutrean does not indicate a change in group size, but maybe prolongation of stay during visits to the cave. In light of supposed human retreat from more northerly regions of Western Europe (range contraction) into southern refugia or the existence of relatively favorable human habitats in Cantabrian Spain increased local population density are both reasonable explanations, given the pattern that larger settlements in favorable terrain (Altamira, Cueto de la Mina/La Riera, Las Caldas, et al.) appeared. An increasingly logistic (even long- distance) pattern of mobility to supply larger base camps would be coherent with Solutrean demographical increase, and in turn favor it by allowing the non-hunters of the group to expand childcare and gathering capacities, for example, such may be seen in La Riera by significant episodes of marine mollusk exploitation (ORTEA 1986). A greater archaeological visibility of site function likely

allows a more differentiated settlement pattern, as previously proposed by Straus (1983) and mobility patterns reflect either 'sociality' or 'territoriality' between groups. Such resultant sociality or territorial confinement are signs of major behavioral reorganization defying the observed severe climatic conditions, which decreased environmental viability and limited hunting territories.

Chamois, generally became less represented later on, while hunting of ibex, as a typical montane dweller, was intensive with the beginning of the Lower Magdalenian. The dual game exploitation system at El Mirón site during the Lower Magdalenian is uncommon, in contrast to the overall Cantabrian sites where one species usually dominates, as already summarized by Straus (1987). Red deer was the most common regional main game species, so it too was in Late Middle Paleolithic, Gravettian, Solutrean, and all other Magdalenian levels. Ibex dominate the late Lower Magdalenian levels by biomass at El Mirón, and declined from there onwards steadily until the Middle and Upper Magdalenian. For example, ibex focused hunting in steep mountainous locations such as Rascaño, Ermittia, Collubil, or Bolinkoba is a pattern representing logistic mobility. Red deer dominate MNI and hunted biomass from the onset of the Middle Magdalenian, by no doubt in contrast to the site's location on a steep, rocky cliff face of a 1000m-high mountain. The wider catchment area of the site, however, consists of river valleys and piedmont areas favorable for red deer dwelling. With the Holocene onset, red deer remained the sole dominant ungulate prey species.

The steep terrain around El Mirón cave also likely influenced which prey body sizes were transported from afar, to avoid the high energetic cost (OUTRAM 1997; LUPO 2006). Red deer exploitation changed, from fuller carcass transport in the earlier levels, towards a more selective one in the later levels of the Lower Magdalenian, suggesting more field butchery and differential transport from kill-sites as an adaptation towards more efficient exploitation strategies. Based on the 9.5m² excavated Cabin area of this large site, interpretation is relative, obviously not representing the whole space that was potentially (and really) occupied and which different disposal behaviors among areas of the cave were likely. For example, the faunal remains from the burial area (SE corner of the Vestibule rear) show the most axial body parts represented (MARÍN-ARROYO & GEILING 2015); this is in sharp contrast to what is observed in the Cabin area, indicating differential spatial use within the cave Vestibule. Archaeologists have to keep in mind the proportionate part represented by the excavated (faunal) assemblage.

Changes in composition of faunal assemblages can also occur when butchering, processing, and disposal behavior changes with species, when age determines the degree of exploitation, such as young animals for meat and older ones also for grease, tendons, and antlers, thus influencing the distribution of skeletal remains. With growing human group sizes, differential space use might become more elaborated. Activities might have shifted to inwards or outwards the cave according to the seasonality of occupation or general climate. The intra-site spatial analysis identified at least part of the Cabin excavation area as a special-purpose location for grease- rendering, where maybe not the whole set of killed animals were processed and discarded, but mainly adult animals rich in fat may have been processed there, instead of young animals. Especially for the Magdalenian occupations, the application of the same analytical procedure of detailed taphonomic and spatial analysis in future interpretation can improve identifying similar or different activity ranges in other parts of the cave. Such work is underway for two levels in the Corral area by E.L. Jones and M. Carvalho.

In terms of biodiversity, at El Mirón red deer and ibex were always the main game species for the primary meat-based- portion of the human diet (MARÍN-ARROYO 2010; STRAUS ET AL. 2013; MARÍN-ARROYO & GEILING 2015; MARÍN-ARROYO ET AL. 2018a), supplemented by plant foods and fungi (GARCÍA-GONZÁLEZ ET AL. 2015; POWER ET AL. 2015). The pattern of dual-game exploitation is to be expected based on the site's topographic location (MARÍN-ARROYO 2009b, 2009a), but this study has revealed specific changes in prey selection, handling, and exploitation throughout time.

This study permitted identification of the reasons regarding the biodiversity in hunting, where dietary strategies were opportunistic, specialized and diversified as reflection to patterns roughly driven by climate change and energetic capacities of local environments. Other measures for evaluating hunting behavior, for example, the intensity of animal exploitation strategy, can vary among specialized hunting strategies and, as such, define the economic strategies as a more complex set of responses, not solely to climate change. The new results of oxygen stable isotope variation in animal teeth also indicate substantial seasonal climate differences. However, throughout the Lower Magdalenian, neither major changes in duration or intensity of seasonal fluctuation nor major shifts in annual mean values were observed, infer relatively stable climate. Such a better understanding of seasonal climate fluctuations allows further insights into animal ethology, for example, the seasonally altitudinal migration of ibex. Ibex would be seasonally abundant and more comfortable to hunt beginning at the fall rut and lasting to spring, while dwelling at lower altitudes (STRAUS 1987).

Further interpretations include the fact that horses might have dwelled in coastal plains and -broad river valley bottoms, feeding on grasses and sedges. They were probably more abundantly hunted during the humans' stays at near-coastal locations. The same applied to other larger ungulates, such are aurochs or bison, which seldom brought to the montane Mirón site, as coherent with optimal foraging strategies. Red deer would be a reasonably reliable resource for hunters familiar with the landscape, while dwelling both in the coastal zone and in piedmont areas along the floors of the broad valley such as Ruesga—the Middle Asón. Together the analyses show that animal behavior constitutes a relevant link between environmental conditions and human site occupation and use. Moreover, many of the major river valleys might have preserved lusher vegetation that attracted animals and human dwelling, equally serving as a refugia area under severe climate conditions (as well as a significant source of fuelwood with their riparian stands of trees).

In the sense of Hypothesis 1, it is agreed that humans adapted their behavior each time after being triggered by external stimuli, such as climate, to return to optimal exploitation strategies. Other parameters such as regional demography and social networks, however, are not independent from subsistence adaptation strategies and will be further discussed.

Regarding the **role of the demographic factor (Hypothesis 2),** it is generally agreed that demographic impulses and population plasticity (FREEMAN 1973, 1981; CLARK & YI 1983; STRAUS 1983; CLARK 1986; CLARK & STRAUS 1986) triggered human behavior. Population density provides broader implications for understanding the processes of cultural evolution. Thus, the Cantabrian region experienced an intensification of settlement with noticeably more site numbers than before during the Solutrean, although most were of low intensity (STRAUS ET AL. 2000b), which support the existence of the Iberian refugium. Human resilience to climate and environmental fluctuations and genetics have been in focus of recent archaeological research (SCHMIDT & ZIMMERMANN 2019; FERNÁNDEZ-LÓPEZ DE PABLO ET AL. 2019). The robust identification of demographic signals from the analysis of the archaeological record remains methodologically challenging. The here applied method overcomes some of these limitations, based on biomass calculations (FREEMAN 1973: p. 22; MARÍN-ARROYO & GONZÁLEZ-MORALES 2009: p. 54). The demographic structures are inferred by the amount of obtained 'energetic output' (=total caloric yield per unit time) per site and level, as realized during this study for El Mirón Cave. Calculations were taken with caution, as is usually done with MNI estimations (KLEIN & CRUZ-URIBE 1984); they are informative and provide minimal appraisals, with no attempt to define exact group sizes. In the absence of justified quantitative data of energetic contribution from plant foods or other resources, results were calculated for theoretical 100%, 80%, 50%, and 20% animal protein-based diets, with contributions from other known (e.g., fish) and (yet) unknown resources. The observed increase in population size with the Lower Magdalenian, however, did not correlate with increased resource diversity (STRAUS 1977; CLARK & YI 1983) as expected by the demographic hypothesis.

Remarkably, the progression of the Lower Magdalenian at El Mirón did not reflect a classic dietary widening by the incorporation of more ungulate or other species. Maybe other large ungulates were simply not abundant in Cantabrian Spain, in contrast to more commonly found horses and bovines of the Mousterian and Early Upper Paleolithic at several regional sites (ALTUNA 1972; FREEMAN 1973, 1981; STRAUS 1977). This period shows a widening in resource exploitation by applying alternative solutions, which increased energetic output per unit hunted and relieved hunting pressure on main game species. Such changes in the economic strategy lead to an increase in the local carrying capacity of the inhabited environment. The prime changes with such a strategy would be less hunting cost, higher labor costs, higher output, and less risk per unit hunted. These are factors that stabilize food procurement, as there is a general risk reduction strategy involved, as well as possibilities for storing energetic units during more extended stays at one site. Labor costs can be dispersed among more people, for example, young and old members of the group when demography increases.

Longer stays at sites might have led to territorial constraints and marked territoriality of locations with abundant resources, provoking general resource stress by population pressure (AURA ET AL. 1998) or territory constriction (MARÍN-ARROYO 2008; STRAUS 2012). Those processes favor sustainable exploitation strategies to remain the local territory carrying capacity, and the application of alternative subsistence strategies became advantageous, which can include shifts to intensified resource exploitation and, eventually, domestication of animals.

Subsistence strategies notably adapted towards scheduled use of territories, further enlargement of the social network, seasonal movements along river valleys, and resource diversification during the Middle to Upper Magdalenian. All are possible signs of further increased population pressure in the Cantabrian region. This situation could have favored post-LGM resettlement of northern and central Europe supposedly during the Middle Magdalenian from descendants from the 'Red Lady' buried at El Mirón Cave as genetic evidence suggests (FU ET AL. 2016).

In the sense of Hypothesis 2, it is agreed that regional demographic growth and greater population sizes brought tensions to the favorable territories of higher environmental carrying capacity by increased hunting pressure on most profitable prey species. This change was repeatedly seen by increased incorporations of the non-adults of lower energetic return-rates of preferred prey species into the subsistence at the onset of the LGM at El Mirón montane site, at the end of the LGM, and the warming of DO1 (Bölling). In summary, confirm the obtained results the hypothesis H2 about the relationship between demography and economic strategies. Population density was growing beginning in the Solutrean in the Cantabrian region (STRAUS ET AL. 2000a, 2000b, 2015b; STRAUS 2019), with evidence that hunting specialization occurred, which possibly ultimately provoked economic adaptations towards territorial confinement for succeeding Magdalenian groups. Since the demographic factor had, additional to the environmental, an influence on human subsistence change, it remains to be discussed the role of the social parameters for behavioral adaptations.

Regarding **the role of socio-cultural factors (Hypothesis 3)**, to decipher the role of the social factor in human behavior change, we try to understand how social actions transform socio-economic and socio-cultural realities (SCHIFFER & SKIBO 1987; SCHIFFER ET AL. 2001). Technological inventions and socio-cultural developments appear independently of external stimuli, i.e., they are not the result of a necessity. Although, if advantageous, they successively improve hunting strategies according to the hypothesis H3.

Such cultural restrictions or manifestations remain difficult to confirm with 'hard' scientific data. However, the detailed knowledge about the Lower Magdalenian in the Cantabrian region might enable, at least, some speculation on this issue. Lower Magdalenian implies some sort of a band-based social structure that often came along with larger group sizes. The 'Red Lady' buried at El Mirón shows multiple kinds of evidence of a 'special' status within her social group, even by the mere fact that she was buried as the only instance known

for the whole, rich Magdalenian record in Iberia. The unusual nature of that woman as she was interred with a possible grave marker, red ochre covering, possible flower offering, re-buried with extraction of the cranium and long bones for possible display elsewhere suggest her 'high' or special status within the group, perhaps even well after her death (STRAUS et al. 2015a). This possibly refined social structure came along with a defined regional band territory identification, as suggested by one type of distinctive art object (red deer scapulae with striation engraved images of red deer hinds and similar images engraved on cave walls) produced by Lower Magdalenian people only in a restricted principal dispersal region of circa 140 km-long x 25-50 km-wide from western Asturias to eastern Cantabria (GONZÁLEZ-MORALES ET AL. 2006; GONZÁLEZ-MORALES & STRAUS 2009; RIVERO VILÁ ET AL. 2019). The presence of lithic raw materials transported long-distance from extreme southwestern France and of mollusk shells from the Mediterranean Sea (presumably via the Ebro Corridor) inferred significant maintenance of large social networks, both of which probably indicate down-the-line trade as opposed to actual long-distance travels by individuals from El Mirón (GUTIÉRREZ-ZUGASTI & CUENCA-SOLANA 2015). This research identified a grooved reindeer incisor ornament, representing the only item of reindeer identified at El Mirón. This ornament, along with the atl-atl in Level 17 of very similar manufacture to the ones in Le Placard and Roc-de Marcamps, France, (which also has identical grooved reindeer incisors), this find possibly indicates the existence of down-the-line exchanges with groups occupying southwestern France (GONZÁLEZ-MORALES & STRAUS 2009). These characteristics of the Lower Magdalenian show that the people had a great potential to adapt or exchange ideas with other groups, notably from southwestern France, but also clearly defined and distinguished themselves from others by artistic expression. New ideas, made up by local people themselves or adopted as a result of contacts with other groups, regarding any economic aspect, nonetheless could have been rapidly spread widely.

Regarding the hypothesis, there is a not perceptible variable that would cause new actions to become established or not. However, more people in a society successively (and selectively) will probably adapt a profitable economic strategy if available, for example, by adopting new weapon technology. A modern human behavioral analog might be how 'desire paths' are created (i.e., when people take shortcuts in parks with curving walkways), which fits best the society within a particular time and space framework (NICHOLS 2014). Within a cultural evolutionary perspective, cultural change might be explained through diffusion, migration, or by independent cultural development.

When individuals confront problems, they actively choose how to solve them and do not merely react to a stimulus such as changing climate (WERLEN 1993: p. 9), but they react on the changing conditions itself wrapped in other behavioral changes. Human groups social contacts intervene in the life-world of them manifested by similarities in personal ornaments and other artworks (SAUVET 2019), if a holistic human-material-relationship in all times and all places (SCHIFFER 1999) is inferred. The causes for changing behavior furthermore have a historical dynamic because every reaction precedes certain information about the pre-settings of the situation, environment, and social world from the social memory of the group (REDMAN & KINZIG 2003). These arguments give the social factor a vital role in behavior change, as the author suggests, by adding a progressive or conservative component, by which the former try to break with old conventions and the latter seek to hold with the same.

In the sense of Hypothesis 3, it is agreed that the social factor is pervasive in human behavior change. El Mirón showed as a measure of that factor a social inter-group differentiation, a social band territory, and an over-regional social (trading) network allowing the exchange of ideas. Behavioral changes embedded in their occasionally complex cultural environment include prior knowledge, preserved and mediated by the social group. Behavioral changes also have a historical dimension since humans are versatile in adapting to several environment-demographic settings, sharing know-how in resource exploitation strategies through social networks, and advantage elements endure in the human behavioral repertoire. During this study of reasoning for behavioral change, all the factors of environmental, demographic, and social origin seemingly

appear interwoven, particularly as a reasoning for economic changes. Those economic relationships vary dynamically, are directed by changes in resource availability, and are further discussed regarding the works main hypothesis.

Regarding the role of **adaptation in economic strategies to maximized energetic return rates** (main hypothesis), the following discussions are subject to some general assumptions.

First, the evolution of economies is in favor of improving them, as long as unproductive economies will fade: meaning to adjust subsistence strategies in case of negative return rates. If optimization in foraging economic is advantageous, it enables the 'survival of the fittest', those groups would contribute disproportionally more offspring to the meta-population, while others would fade. Such selective sweep events minimize accumulated genetic diversity and could explain why modern humans still have a comparatively low level of genetic diversity (PREMO & HUBLIN 2009). Second, different stimuli influence economic adaptions, and human behavior combines roughly external and internal stimuli. External ones are climate and landscape. Internal ones are social structure and networks. The crucial fact is that both can overlap, multiply and accelerate human reactions. Third, ecological rationality is the foundation for economic decision-making (concerns the match between strategy and environment) (GIGERENZER & TODD 1999; GIGERENZER & SELTEN 2002), but also follows intrinsic dynamics, which is to say that decision making needs to be rational as to provide undoubtedly food basics in order for the group to survive. The obtained energy should compensate for the energy spent. Modern behavioral analysis shows that risk aversion regulates economic decisions. The certainty effect describes how humans underweight outcomes that are merely probable, either of higher or no benefit, with certain ones, although of lower benefit (KAHNEMAN & TVERSKY 2012). Humans are generally conservative by sticking to once-successful strategies as long as possible (REDMAN & KINZIG 2003), in what is 'tried and tested' as seen by the incorporation of younger, less beneficial individuals among preferred game species during the late Upper Pleistocene. Essential, yet, are progressive components of behavioral change that focus on starting new things by 'trial and error'.

For answering the main hypotheses, this dissertation work reconstructed a series of economic adaptations. Major economic adaptations away from opportunistic hunting behavior began with the climate deteriorations (HE2 event & Last Glacial Maxima) that presumably lowered temperatures, precipitation, and density of local plant and animal biomasses, but also with demographic increase. Due to greater resource patchiness in the landscape and supposed increased hunting pressure, Solutrean groups showed the first sign of economic stress by increasing young portions in their diet. Human groups had to increase mobility, when hunter-gatherer moves between patches are the direct function of available energy in the local environments (KELLY 1995: p. 128). An expansion of the economic territory also increases contacts with other groups and enlarges their social network. The greater distances to travel to sought-after resources increased those groups' logistic mobility, as well as causing longer stays at individual sites for the core of the group, probably of the non-chief-hunters. More extended stays of groups at sites allow denser foraging activities in the close site catchment areas, assumedly increase food security, and improve childcare (KELLY 1995: p. 255). Those adaptations favor population increase, but at slow rates of growth, as still-harsh environmental conditions and still-frequent residential mobility (with the necessity of long birth-spacing intervals and periods of lactation) are limiting factors. The Initial Magdalenian groups seemed dispersed in the region. However, El Mirón Levels 117-119.3 seem to have been formed by more prolonged or more intensive occupations, but only with limited economic data available. They seem more unacquainted in the landscape and frequently moved base camps by exploiting immediate site surroundings that included acquiring raw materials through direct outcrop access, as seen in Urtiaga Level F (FONTES 2016b). Both archaeological constructs of cultural entities focused on hunting and grease- rendering activities; whether these are products of assimilation is not determinable from the current data. With the Lower Magdalenian, occupations appear even longer,

semi-permanent stays at favored places, economics were systematically adapted to local environments and so improved, which possibly favored regional demographic increase.

Some causal reasons have stronger impacts than others and are likelier to evoke reactions in human behavior. Those key stimuli have environmental, demographic, and social origins. When seeing economic adaptations in a hermeneutic way, two crucial observations are relevant: First, there may exist smaller and bigger interacting dimensions of adaptations, which is supported by the understanding that different factors cause adaptive behavior on different levels in time and space (ALLEN ET AL. 2014). Second, it seems contrary to postulate shifts in climate dictate human cultural appearances, when assuming high social and cultural human adaptive capabilities. But, especially those two observations can be key to understand human behavior patterns and to agree to the proposed main hypothesis by which economics are essential in changes in human behavior, directed by changes in resource availability, and past hunter-gatherers (usually or ultimately) subconsciously optimized energy return rates. All those inferences highlight the dynamic character in human economies detailed following.

6.4 Human ecodynamics in late Upper Pleistocene economies

The results obtained here suggest increasing complexity in the exploitation of primary animal products, besides meat and marrow, and the processing thereof. Such intensive exploitation of the region's most abundant ungulate species, red deer, follows optimization principles. Based on the differing hunting strategies, diets were more opportunistic until the end of the Gravettian, a time of relatively cold climate and low population densities. Solutrean hunter-gatherers started to specialize in hunting towards more intensified resource exploitation using a strategy of slaughtering one main game species; from this moment onwards, population increase was remarkable in the Cantabrian region. Major Solutrean sites are often in near-coastal or low- altitude locations (such as Cueto de la Mina/ La Riera, Altamira, Aitzbitarte, or Las Caldas) and accompanied by several logistic camps sometimes located at higher altitudes, especially as in the case of El Mirón (STRAUS 1979). With the Lower Magdalenian, intensive exploitation of resources (grease-rendering) defied the limited carrying capacity of the local environment successfully by increasing processing costs. The whole range of economic adaptations ultimately increased population density further, although it coincides with the progressing deforestation of the Cantabrian region and increased aridity. While the alteration of some external or internal (cultural) factors caused humans to shift away from optimality in the applied economic strategies, the observed change in subsistence systems often aim to return to maximize energy intake or reduce costs, all of which mirrors optimal foraging behavior predictions (CHARNOV & ORIANS 1973; WINTERHALDER 1981; SMITH ET AL. 1983; JOCHIM 1988; BETTINGER 1991; KELLY 1995). Other behavioral manifestations also show such phenomena, like the simplification of lithic technology, diminishing of art, or decreasing mobility at the end of Magdalenian (CLARK 1983; STRAUS 1992; GONZÁLEZ-MORALES ET AL. 2004).

Such optimization principles are testable beyond single-site location towards regional mobility patterns. With new data from the archeozoological analysis is questioned the universality of the prevailing "valley territory" hypothesis, which assumes animal and human migrations between winter quartiers at the coastal zone and residential summer exploration at the montane zone (FREEMAN 1973: p. 197; STRAUS 1975, 1986; BUTZER 1982; BAILEY & DAVIDSON 1983; MARÍN-ARROYO 2009) predicted for Magdalenian settlement systems in the Cantabrian region (STRAUS, GONZÁLEZ-MORALES, MARÍN-ARROYO, ET AL. 2015). The new seasonal results show, however, that this postulation is oversimplified in two ways, mainly in time and space. Human behavior adapts much more dynamically.

On a chronological axis, the Magdalenian, obviously a larger entity with shared cultural manifestations, can be roughly subdivided into an early and late phase as human behavior toolsets, settlement, subsistence changes showing that some dominant developments are intrinsic to that period. Summer and autumn animal

deaths evidenced at El Mirón justify Straus' valley territory hypothesis for the Late Magdalenian (MARÍN-ARROYO 2009a), but the Early Magdalenian differs from that. The Lower Magdalenian display multi-seasonal, but mainly autumn-winter-spring occupations. Such more intensive visits attest that human groups occupied the northern edge of the Cantabrian Cordillera also in the cold season and for more extended periods, establishing an extensive hub site at 260m above present sea level (about 370 above Late Glacial sea level) in a location surrounded by 1000m peaks. Despite the commonsense idea to better avoid the montane zone during the winters, maybe there were advantages in occupying that area during that time of the year, for example for shelter from coastal storms, biomass concentration (ibex and chamois in lower-than-summer habitats and red deer ability to live in the broad, 100m.a.s.l. Ruesga Valley below the cave), permanent freshwater and possible fuelwood availability. This interpretation aligns with general human behavior understanding that seasonal climatic fluctuations and distribution of resources (FLANNERY 1968) across the landscape determined human settlement systems and mobility patterns (MACARTHUR & PIANKA 1966; THACKER 2000), where exploitation strategies were adapted accordingly (CHARNOV 1976; SMITH ET AL. 1983: p. 631).

On a spatial axis, north-south movements of groups are not the only option, since El Mirón Cave, located in the Upper Asón valley, also has good east-west connections through the piedmont areas by river valleys and passes toward the areas of Magdalenian site concentration in central Vizcaya and central Cantabria respectively (STRAUS & GONZÁLEZ-MORALES 2012a). However, robust evidence demonstrates that those people traversed vast areas and that their logistic mobility was also complex (FONTES ET AL. 2016). The montane site of Rascaño Cave of much smaller size, as a multi-seasonal hunting stands in the close Miera river valley, possibly not hosted large groups, but were logistically exploited (ALTUNA 1981). The coast was exploited at least for the red ochre used for the 'Red Lady' burial obtained from Monte Buciero above the present Asón estuary (SEVA ROMÁN ET AL. 2019) and for marine shells mainly for ornament manufacture (GUTIÉRREZ-ZUGASTI & CUENCA-SOLANA 2015). The existence of several Magdalenian sites (El Otero, La Chora, La Fragua) around the present Asón estuary attests to the idea that humans who occupied El Mirón at other times lived on the coastal plain some 15-20 km downstream of the Ramales de la Victoria sites. Lithic raw material resources were explored dynamically from coastal outcrops, Barrika and Sonabia, as well as from trans-cordilleran Basque region outcrops at high altitudes to the southeast: Treviño and Urbasa, and from even more distant sites located in southwestern France: Chalosse and possibly the Bidache flysch, as evidenced in a few examples (RISSETTO 2005; FONTES 2016b; FONTES ET AL. 2016, 2018). Long-distance social contacts, possibly like among modern hunter-gatherer groups, enabled inter-group 'alliances of affinity' as insurance in crises, and are also demonstrated by art style similarities (SAUVET ET AL. 2008). El Mirón has especially good connections to the present-day Basque Country to the east via the Carranza valley (which is lined by cave art and Upper Paleolithic living sites) and to the west towards the Asón headwaters and other tributaries. Further-south connections are also possible via relatively low Los Tornos Pass, which would give access to the upper Ebro basin and the interior Basque/Castilian region flint outcrops. The Cantabrian landscape mosaic was traversed in search for many resources during the Early Magdalenian, rather than only via coast-mountain movements, possibly oriented more towards intensive animal processing activities in cave sites. However, this scenario might have changed with the beginning of the Middle Magdalenian, and human groups may have followed a more constrained exploitation pattern, as suggested before by the "valley territory" hypothesis. Moreover, this also seems to have been true for the Late Magdalenian phases.

Much longer occupation durations reconstructed for the Lower Magdalenian El Mirón are a rupture in the settlement system toward a sizeable residential site placed in the mountain zone of probably semi-permanent character (BUTZER 1982). For the first time, this pattern is observed and questioned as to why humans preferred cold seasons occupation in this area: for social, ecological, or economic reasons? The determining factor of group sizes might be not significant, as other large caves can be found in coastal areas to take shelter during winters. Possible, but difficult to justify, there might be reasons of territorial conflicts

with groups or memorial relationships to the buried 'Red Lady' to occupy that zone temporarily. However, from an ecological point of view, cold seasons might be good times for ibex hunting, as they move to lower altitudes during winters, making them easier targets. Ibex was exploited intensively at El Mirón, serving more than only as a marginal or risk-reduction strategy (QUESADA-LÓPEZ 1997). An often less-considered resource is water availability in the settlement system. During the Lower Magdalenian, which environments were notable dry, possible with meager precipitation, the proximity of freshwater springs might have favored some locations over others. More likely, it seems to have been a planned residential occupation with logistic exploitation of this mountain zone and extended landscapes, as a manifestation of an economic driven settlement and mobility strategy.

Economic influence on the settlement strategy can be even more compound as other resource demands, availability and diversity are just marginally understood, such as water, other prey species availability (salmon, for example), or others, and for this yet unknown reason we cannot fully predict. However, the Lower Magdalenian also clearly represents a reorganization of the settlement system from the previous Solutrean and vis à vis the following Middle Magdalenian.

These dynamic adaptions in economies have some implications for general human behavior. Since optimal exploitation strategies lead to imbalance under changing environmental conditions, either behavioral adaptation should line up to external changes of the system, or the current economic system is resilient enough to compensate for these factors. In such a way, dynamic adaptation in the economy or 'ecodynamics' can explain human behavioral changes, which are triggered by climate changes. This analysis and the synthesis of published fauna data produced some general observations: Warm climate brings forth greater vegetation diversity favoring animal diversity. Increasing vegetation cover and forest closeness, however, produced more difficulties for hunting. Colder climate accelerates deforestation processes, usually not rapid, can improve hunting success, because more open landscapes seemed to facilitate spotting of prey, other subsistence systems got relevant, and sites with excellent visibility evolved to more prominent hubs (for example, El Mirón during the Lower Magdalenian). Ecological zones on land are dependent on and defined by precipitation intensity, variability, and annual amounts. Plentiful precipitation can support a diversity of vegetation cover, providing more food for herbivores and hunting grounds for humans. Climate change can produce water-related stress in ecosystems. Concentration or restriction of animals and humans to productive zones with water resource accessibility becomes evident. If vegetation is restricted to those areas, so will occupation by ungulates and large-game hunters. Climate instability challenged the adaptation scenario for hunter-gatherers, and higher residential and logistical mobility on a pan-regional as well as an intra-regional level get visible. Changing environments lead to dietary stress resulting in diversified hunting activities as well as fission into smaller groups/bands that improve human survival. The Solutrean, in particular, might be the cultural result of groups that (re)organized their subsistence strategy in response to the climate deterioration that rise with the onset of the LGM. Contrarily, relative climate stability favor established systems since time allow for adaptive success, improvement of knowledge and inventions, which resulted in intensified resource exploitation and population growth, as seen during the Cantabrian Lower Magdalenian. Adaptation does not necessarily mean the return to the previous economic pattern, but to optimal strategies that raise the level of resilience of these groups, making them successful. It was repeatedly observed that changing climatic parameters prompt a diversification in resource exploitation, followed by using a new focus towards returning to optimal strategies. Such optimal behaviors, in consequence, vary with landscape variability and patchiness of resources since humans are capable of adapting and effectively exploit their environment (HAMES & VICKERS 1982; MARÍN-ARROYO 2013). Human behavior has an intrinsic resilience component that is versatile enough to adapt to complex situations possible based on *ad hoc-observations* as well as collective memory.

Human mobility, in terms of regular movements of small groups of around 25 people (KELLY 1995; BINFORD 2001), is, however, the feature of connectedness and to explore new opportunities, for example, for new habitats to live. At the same time allow social networks the fusion of groups creating regional bands (up to around 500 members (KELLY 1995; BINFORD 2001)) or closer networking would increase their resilience during unstable conditions as a successful socio-cultural strategy during prehistory (such probably occur during transitional cultural periods and produce 'mixed' assemblages) (WIDLOK ET AL. 2012). More effective networking during tough economic moments seemed, at first sight, to be contrary to selfish, -purely economic behavior, but can underline that economic dynamics are driving forces of human social-ecosystem. Repeatedly observed expansion and retreat events have been detected in the settlement along the West-East corridor of the Cantabrian region in interaction with southwestern France, inferring the dimensions of the broader cultural supra-region (i.e., the classic Franco-Cantabrian region or culture-area). Responses to long term effects of climatic events can be cultural-social balanced by adaptation in shorter sequenced changes of adaptation implying multiple rather than single-factor responses as referred to in the literature as 'multi-cause models' (BICHO ET AL. 2017). In many cases, rapid climate events were responded by humans with migrations, presumably associated with species movements, but whether this reflects to follow the preferred hunting species or search for new living areas is difficult to say. The mosaic landscape of the Cantabrian region, limited the distances over which people had to traverse to ensure their subsistence basis and so favored life in this refugium area. In the long-term, this is a survival scenario, which infers that cultural evolution is intrinsically linked to the groups' socio-cultural dynamic adaptability exposing their resilience to respond to environmental challenges, resource diversity, and accessibility. This interpretation agrees with others that the carrying capacity of the landscapes that provide the animal biomass used by humans has a key component as an initiator for human behavior change (BICHO ET AL. 2017; RENDU ET AL. 2019).

The present discussion infers climate change as a key reason that can determine why societies have stable and unstable moments. The former, as shown in the Cantabrian region, mostly favored settlement and supposed demographic increase, and the latter, population migrations and mobility as was validated by chronometric settlement reconstructions. Such stable moments might also allow, as a suggestive explanation, that after realizing the necessary adaptation to the ad-hoc inhabited environment, human capacities were freed to allow effort in experiments, new weapon technologies, or hunting techniques could be tested. Such new ideas, however, only became established when proven advantageous, either under economic stress favoring the groups applying them or over time with a slower adaptation through intra-group interactions (also group fissions) and population growth.

Humans seemed to respond with migration (or range contraction) towards refugia zones when environmental conditions reduced resource availability in the occupied region and mobility is changed, since environmental richness and patchiness of resources determine the degree of resource availability within the foraging radius (HAMILTON ET AL. 2016). Climatic deterioration is countered mostly by rapid settlement expansion of the occupied territory westwards along the Cantabrian corridor. Some climate events, however, caused rapid retreat events reflected by a withdrawal in the settlement record eastwards. Slow, gradual expansion of occupied territories might reflect significant local population growth and settlement across the Cantabrian region. Higher population densities can lead to economic stress, but also to more complex social structures, which were possible both reasons for further behavioral adaptations. Such growth comes with further specialization, which then is more vulnerable towards changing environmental conditions, and new adaptions are necessary to balance energetic return rates. The more accumulated behavioral changes, the more they appear detectable in the archaeological record.

The fact that humans reacted towards impactful climatic changes indeed shows their resilient behavior in being capable of adapting to new situations in nature. The influence of climatic events, however, cause reactions that are visible on a large scale, because climate events affect landscape and vegetation, and so

animal behavior. Resilient hunter-gatherers will adapt their strategies dynamically towards those changes manifested principally by mobility strategies as part of their economic system.

Whether economic stress was favorable or not for humankind depends on the resilience of the socio-economic-technological system in terms of how groups or societies confronted it. The populations that reacted conservative could have stand climatic or other stressors until they diminished, but they would never outgrow them. Progressive reactions, indeed, often increased economic efficiency and produced a certain degree of independence from such external stressors. Still, with accumulated complexity and dependence on other parameters, systems can also become more vulnerable.

6.5 Conclusion on human behavior change

Along the previous pages have been extracted varied aspects of human behavior from the archaeological evidence in chronological sequences to elucidate the moments of behavioral changes and their causes, for addressing one of the central questions in human evolution. Explaining models circulate, however, whether climatic, demographic, or social factors had the highest impact on human behavioral adaptations.

While LGM climate conditions drastically reduced hunting territories, human settlement restrained to southern European regions, including the Northern Iberian refugia, from which many species resettled post-LGM central Europe as genetic evidence supports. While the Cantabrian region experienced an intensification of settlement with noticeably more site numbers than before in those moments, site occupations mostly were of low intensity. According to the high topographic relief and resulting in patchy environments, the impacts of environmental deteriorations are different across landscapes, and the dynamics of these situations are particularly outstanding to recognize the human-environmental relationship under such impactful climatic events.

The present work was able to show that Paleolithic hunter-gatherers continued their hunting habits as long as main game species habitats were conserved, but they did widen their patch use under certain circumstances. Meaning that distinctive regions were affected in a timely alternating manner, and humans were able to respond with long-distance movements, settlement changes, adaptation in mobility patterns to seasonally fluctuating resources, and by diversification-intensification processes. Precisely, the high-relief, mosaic landscape highlights the role played by the hydrological network and topographic relief of the Cantabrian region. Such specific regional settings permitted the preservation of diversity during severe climatic conditions when other regions (northern-central Europe) did not. Concretely, seasonal climatic fluctuations and distribution of resources across the landscape determined human settlement systems and mobility patterns, where intensity in the exploitation state the third component, which determines the economic strategies. They are all components of economic strategies that reflect, however, optimization principles in human behaviors by adapting to landscape variability and patchiness of resources to exploit their environment effectively.

The chrono-economic analysis compiled here provide details about such behavioral inferences. After the Middle Paleolithic, opportunistic exploitation of the region was no longer an option, and human groups adapted their economic strategy to ensure their subsistence, beginning with HE2 and the onset of the Last Glacial Maxima, resulting in progressively intensification of settlements and resource exploitation during the Magdalenian. The Lower Magdalenian occupations at El Mirón had the character of a significant residential camp at a mountain site fed by logistic trips or trade to specific resource patches of a well-known landscape, allowing larger communities to develop increasingly complex social systems. Such social structures might also be reflected in the special treatment of the ‘Red Lady’ in an elaborate cave burial and re-burial. Notably, the outstanding identification of a regional Cantabrian Lower Magdalenian band, by the symbolic markers of

the red deer hind engraved scapulae, might also reflect a high level of social identification and territorial demarcation as a result of more prolonged site occupations.

By the present analysis, following the relationship of key components can be drawn. Figure 6.1 illustrates that group size, degree of specialization, and seasonal distribution of resources across the landscape were activating factors for human mobility, as they determined the duration of site occupation until the energy return rate drops beyond efficient exploitation in the local catchment area. Territoriality is the result of cultural-demographic conditions depending on the regional population pressure, social connectedness, and exchange network. Those subsystems, however, are subject to climatic conditions that determine the richness of environmental viability, as well as the distribution of resources in patches and thus structure hunter-gatherer settlement systems.

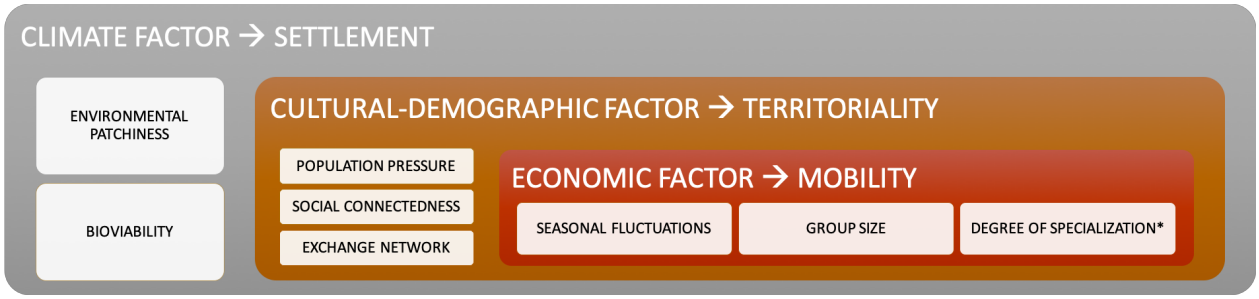


Figure 6.1: Synthetic schematic relationship of crucial components affecting human economics and behavior. *The degree of dietary specialization varies from exploitation focus on certain game species, on age groups to the variety of animal products used, and the plant component.

The results of the archeozoological analysis show that economic changes are well-suited to ascertaining human behavior change in El Mirón Cave and the Cantabrian region, and some hermeneutic derivate is useful to model human behavior. 1) Economic stress triggered by climate deterioration and possible increased population density, as well as rapid climate change, was mostly responded by diversification processes, which is seen by dietary diversification as rapid responses at ~25ka by Solutrean-age people and more profound changes at ~16ka cal BP during the later Magdalenian. Instead, climate stability favored intensified exploitation of local resources in a well-known landscape as well as social identity, possibly also accelerated by population density increase, such as was seen during the Early Magdalenian under post-LGM conditions. Human social systems, however, determined the complexity with which demographic aspects and social networks were interwoven in economic strategies.

2) Further is human behavior change intrinsically reasoned by climate change but compensated by different cultural and biological factors, for example, human mobility, in terms of how the material culture returns towards optimal exploitation patterns. It is possible a mark of human versatility to react to different climatic parameters that affect behavior change, but the existing social-ecological-technological systems lead the chain of cultural reactions and manifestations. Notably was observed, however, that rapid climate changes create a variety of human reactions within short periods, which pronounce the climate-cultural-response visible in the archaeological record of cave deposits in the Cantabrian region.

The search for crucial motivations in resource exploitation and subsistence behavior adaptation revealed relative stability in the subsistence systems, especially during stable climates. The phenomenon of economic stress becomes archaeologically visible when overall economic activities appear inefficient. Thus, increasingly incorporating low-return animals produces lower return rates compared to the energy spent for hunting them, which are ignored otherwise, for example, when hunting roe deer or chamois.

The here assembled observations are based on a detailed archaeological site record combined with regional data improving such inferences. However, the archaeological record is usually fragmentary and always represents a sample of complex systems, even from a well-contextualized site such is El Mirón. So, it remains a major caveat of this analysis that large areas of LGM contemporary human occupations are possibly buried in today submerged lands beyond the modern coast, as well as open-air sites, are generally underrepresented, causing that those interpretations derive mainly from archeological cave deposits, so common in the Cantabrian Region. However, this is also the same reason for focusing develop on the multidisciplinary approach in human behavioral analysis. The author recommends further concentrating methodological development in identifying micro-events that improve specific human activities by use-wear analysis, the on-site and off-site dimension of activities by spatial analysis, local micro-environmental conditions by stable isotope, phytoliths, or biogeochemical analysis, and densifying radiocarbon chronology to refine the temporal sequence of climate, demographic and cultural events. Multidisciplinary studies focusing on specific events in human history, such as was demonstrated in the El Mirón comprehensive study of the 'Red Lady' burial, can point to increasing extensive knowledge of past human behavior. Such multi-methodological approaches in macro-mammal faunal analysis on explicit human activities will enable archeologists to represent many behavioral aspects beyond the current horizon of many archeo(zoo)logical analysis. However, this work seeks to encourage archaeologists to improve methodologies to focus on these aspects in future analysis.

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SUMMARY

Subsistence strategies are an important link between past environmental conditions and human activities recorded by archaeologically remains of exploited dietary (animal) resources, making them a fundamental aspect of Prehistoric research, which focuses on human adaptations to fluctuating climates. How late Upper Pleistocene climate-demographic-socio-cultural components influenced human behavior, how multidisciplinary methods contribute to the understanding of human ecodynamics in the past, and how synthesized evidence refine reasoning for human adaptations shows this dissertation entitled "Human Ecodynamics in the Late Upper Pleistocene of Northern Spain: An Archeozoological Study of Ungulate Remains from the Lower Magdalenian and other Periods in El Mirón Cave (Cantabria)".

The research approach to decipher the changing economic practice, as reflected in subsistence strategies, is defined in Chapter 1. An overview of the current state of interpretation of the economic development in the region of Cantabria shows that a successful proof of arguments of human behavioral changes is still challenging to provide today (Chapter 2). The present work overcomes this state with high-resolution data of economic adjustments reflected by the degree of optimization studied from the Late Middle Paleolithic, Early Upper Paleolithic, Solutrean, and Magdalenian in the cave El Mirón and the broader context of the Cantabrian Region. Chapter 3 presents the context of the faunal material of macro-mammals studied in the El Mirón cave (Cantabria, Spain), as well as the methodological improvements that extend the scope of traditional faunal analysis through careful extraction of information from archaeological mammal remains. The results of the on-site spatial, taphonomic and biogeochemical analysis improved in particular the reconstruction of specific activities and micro-environmental conditions in the El Mirón cave during the Magdalenian period (Chapter 4). Finally, Chapter 5 compiles the diachronic dynamics of economic changes for the Cantabria Region, based on the radiocarbon-dated archaeological remains and the associated paleoenvironmental conditions between 52 and 12 ka cal BP. This procedure contextualizes the local but high-resolution results on the subsistence behavior of El Mirón with significant regional economic changes to finally model and discuss explanations for human behavioral changes. The synthesis in Chapter 6 explains how environmental conditions, demography, and social parameters have influenced economic adjustments and how each contributes to a viable model of human behavior change, summarized in Chapter 7.

Foremost, this dissertation contributes to the methodological improvement of the analysis of macro-mammalian faunas in different research directions. Sorting strategies for archaeological bone remains, spatial, microscopic, and biogeochemical multi-component analyses (stable isotopes, phytolites, and bone staining) provide new details about Paleolithic animal ethology and site diagenesis. Spatial distribution patterns of shattered bones, bone size, and the detection of bone fat residues add several lines to the evidence of bone fat extraction activities by humans at the site. The multifaceted metadata analysis focused on identifying economic stress and improved interpretation of the published data by considering the energetic return rates and the degree of resource intensification in El Mirón and other sites in the Cantabria Region. In particular, the evidence from the occupations of the Lower Magdalenian in El Mirón allowed to draw up a detailed *chaîne opératoire* of strategies for the use of animal carcasses based on faunal data, which covers all activities, including the procurement of raw materials, the production of weapons, hunting, skinning, defleshing, cracking open bone cavities, crushing cancellous bone, cooking, burning, eating, throwing away food leftovers and finally trampling. Finally, to reconstruct the entire process, every component is considered, from bone micro-fragments derived from larger pieces of bone, i.e., from once complete anatomical elements, to whole animals hunted and transported to the site by past hunter-gatherers.

In El Mirón, the economic results show the predominance of the exploitation of maternal herds of red deer and ibex during the cold seasons, which led to skeletal profiles that are mainly the result of human transport decisions, depending on the species and the intensity of the exploitation technique. Humans were the primary accumulator in all occupation strata, with low carnivorous activity being relatively highest in the late Middle and early Upper Paleolithic when humans stayed only briefly and ephemeral. After that, human visits to the cave developed from short residential to hunting camps during the Solutrean, and from more complex residential camps and to a proper base camp with more intensive exploitation of resources as part of a more comprehensive Lower Magdalenian resource management system, later replaced by a more scheduled seasonal use of the mountain zone. In Solutrean and Magdalenian, a more complex pattern of local activities is evident, ranging from intricate cut-mark patterns, the breaking and cooking of bones by humans to bone modifications by vultures. Bone staining analysis even extended insights into the settlement history and local environmental settings. The Lower Magdalenian spatial analyses of finds show the growing complexity in site use, implying larger groups during a period of particularly severe and cold and dry climate, with relatively stable seasonal climate variations, as the present multi-element micro-environmental analysis shows.

During the Lower Magdalenian, El Mirón served as an extensive cold season residential camp, supplied by logistical excursions to specific resource patches of a known landscape, allowing larger groups to develop increasingly complex social systems. Such social structures could be reflected in the special treatment of the 'Red Lady' in an elaborate cave burial and reburial, which is unique for this time in Iberia. The extraordinary, regionally limited symbolic engravings of striated red deer hypothetical show a regional group of the Cantabrian Lower Magdalenian with a high degree of social and territorial identity due to more prolonged site occupations and a higher demographic density. Such social structures and demography, as well as seasonal fluctuations and the distribution of resources in the landscape, are triggering factors for human settlement systems and mobility patterns. The nature of the adjustments in exploitation strategies to return to optimal behavior reflects how humans resist fluctuations in environmental conditions and increasing population density, which in turn are stimulated by landscape variability and resource fragmentation, as humans can effectively exploit their environment.

From an environmental perspective, the mosaic landscape in Northern Spain suggests that regional conditions allowed the preservation of ecological diversity under severe climatic conditions, while other regions (north-central Europe) did not. These refuge environs illustrate the role of the hydrological network and the topographical relief of the Cantabrian Region, which is always under the varying effects of the Northern Atlantic. Since critical environmental deterioration varies from landscape to landscape and environmental conditions were more severe after than during the Last Glacial Maximum in the Cantabrian Region, people were able to respond with large-range movements and settlement changes.

The present study helps to unravel significant changes in regional subsistence strategies practiced in the Cantabria Region during the late Upper Pleistocene: The first significant change is a food specialization that began around 25ka cal BP during the Solutrean and global rapid climate changes (HE2), the LGM and continued during the transition to the Lower Magdalenian with cold and relatively dry climate. Such rapid climate changes decrease the biodiversity of local resources and enhance the mobility of macromammals, while human groups increase specialized hunting and logistical mobility, perhaps to supply some sites with longer occupations. Initially, these adjustments included the use of low yielding food, which was later replaced by improved food processing. Whether this also favored local population growth, in addition to population shifts into refuge areas, remains unclear. In particular, the dense archaeological deposits of Lower Magdalenian after the Last Glacial Maximum in El Mirón and other sites such as Altamira, El Castillo and El Juyo are evidence of increased resource exploitation by larger groups. This economic specialization began in Solutrean, continued, and reached its peak in Lower Magdalenian, indicating a transcultural continuum

among the red deer economies of Northern Spain. The second profound change took place during the late occupations of Lower Magdalenian. At the beginning of the HE1 event, these groups reduced their visits to the mountainous areas to summer stays. The pattern of seasonal mobility and extended summer visits of the montane zone that characterize Middle and Late Magdalenian of the region is established, which systematically exploits the distributed resources within the occupied territory. Beginning with Middle Magdalenian, these later periods show a third economic change with increased hunting pressure and less energetically productive patterns. Hunter-gatherer groups were less selective in terms of prey species or age than before, exploiting increasingly low-rated resources, which may also be associated with the territorial expansion of temperate species as climate improvements progressed. However, they initially hunted non-adult animals of preferred game species. Although food diversification through the increased use of complementary resources such as shellfish, fish, birds, plants and small game was typical, and some were quite substantial in a few locations such as La Riera, Altamira, El Juyo and Sta. Catalina never provided as much food as the two common large ungulates, red deer and ibex. This gradual economic relocation and less intensive site use, accompanied by techno-cultural, ecological, and demographic changes, may indicate intensive supra-regional migrations, e.g., by repopulating central and northern Europe from the southern refuge areas, as genetic evidence suggests. These strategies are generally economic patterns of subsistence diversification that provide resilience and defy the unpredictability of climate impacts.

The search for substantial incentives for adaptation in the exploitation of resources shows that subsistence systems achieve stability, especially in moments of a more stable climate. Presumably, only the completion of the necessary ad hoc adaptation to the inhabited environment enable experiments in new technologies or techniques. However, new ideas that later grow into sustainable solutions will probably only be accepted if they are beneficial to groups either under economic stress, over time through group-internal interactions, or group splitting. Regional settlement and economic systems also show that the diversification of subsistence is a crucial in the development of sustainable solutions. Economic stress becomes archaeologically visible when activities for energy production appear inefficient by reduced yield rates, e.g., by including species/animals with lower yields compared to the energy used for their hunting. From a long-term perspective, sustainable economies opt for higher yield rates by adjusting their economic behavior.

An archeozoological research approach and multidisciplinary evidence helped to decipher details of past economic changes in prey taxa selection, age of animals, biomass, prey transport, butchering, animal parts processing, seasonality of site occupancy and site function during different stages of colonization, which were correlated with local paleoecology conditions and anchored by radiocarbon chronology. The synthesis of transcultural adaptation in hunter-gatherer economies allows to derive a relevant dynamic relationship concerning regional settlement, economy, population density, and social networks. The analysis led to the conclusion that the degree of viability in changing environments and the patchiness of resources guides general economic behavior as manifested in human mobility strategies and site use. These adjustments also correlate with the intensity of food exploitation techniques and population size. This dissertation reviewed and complemented the existing knowledge to understand the dimensions and structure of transcultural adaptive human behavior to specific circumstances, beyond prevailing culturally limited economic studies in their broader environmental context; it also recognized any archaeological evidence as reduced by taphonomic processes, which can only ever be a sample of past human activities.

Future work should focus methodological development on the identification of human activities of high temporal and spatial resolution in the context of local micro-environmental conditions and intensive radiocarbon recordings, in order to decipher the temporal sequence of cultural specific as well as transcultural economic changes in the light of climatic, demographic and cultural change and to promote hermeneutic debate beyond the current horizon of knowledge.

RESUMEN

Las estrategias de subsistencia son un importante vínculo entre las condiciones ambientales del pasado y las actividades humanas registradas en los restos arqueológicos de los animales explotados por los grupos del pasado lo que los convierte en un aspecto fundamental de la investigación prehistórica centrada en las adaptaciones humanas a los climas fluctuantes. En esta tesis titulada "Human Ecodynamics in the Late Upper Pleistocene of Northern Spain: An Archeozoological Study of Ungulate Remains from the Lower Magdalenian and other Periods in El Mirón Cave (Cantabria)" se ha tratado de responder cómo las fluctuaciones climáticas, la demografía y los componentes socioculturales del Pleistoceno Superior tardío influyeron en el comportamiento humano, cómo los métodos multidisciplinaes contribuyen a la comprensión de la ecodinámica humana del pasado y cómo las evidencias arqueológicas revelan cuales fueron las razones de las adaptaciones humanas al medio.

En el capítulo 1 se define el enfoque para descifrar la práctica económica cambiante, reflejada en las estrategias de subsistencia. La revisión del estado actual sobre la interpretación del desarrollo económico en la región cantábrica muestra la prueba del razonamiento por el cual explicar los cambios en el comportamiento humano continúa siendo complejo (Capítulo 2). El presente trabajo supera este estado con datos de alta resolución sobre las adaptaciones económicas analizadas desde el Paleolítico medio final, Paleolítico superior inicial, Solutrense y Magdaleniense en la Cueva del Mirón; y en el amplio contexto de la región cantábrica, como reflejo de la adaptación humana al medio. El capítulo 3 presenta el análisis faunístico de los macromamíferos estudiados en la Cueva del Mirón (Cantabria, España) y las mejoradas metodólogas que amplían el alcance del análisis faunístico tradicional mediante la extracción meticulosa de información de los mencionados restos arqueofaunísiticos. Los resultados de los análisis espaciales, tafonómicos y biogeoquímicos han aportado más información sobre la reconstrucción de las actividades de los grupos humanos y las condiciones microambiéntales en la Cueva del Mirón durante el Magdaleniense (Capítulo 4). El Capítulo 5 expone los cambios económicos en la región cantábrica basados en las dataciones por radiocarbono de restos arqueológicos y sus condiciones paleoambiéntales asociadas, entre 52 y 12 ka cal BP. Este procedimiento contextualizó los resultados locales, con una mayor resolución sobre el comportamiento de subsistencia de El Mirón con cambios económicos regionales significativos para finalmente modelar y discutir las explicaciones del cambio de comportamiento humano. La síntesis en el Capítulo 6 explica cómo las condiciones ambientales, la demografía y los parámetros sociales dieron forma a las adaptaciones económicas y cómo cada una de ellas contribuye al modelo viable de cambio en el comportamiento humano, como se resume en el Capítulo 7.

Además, esta tesis contribuye a mejorar las metodológicas en el análisis de los restos de macromamíferos en diversas direcciones de investigación. Las estrategias de clasificación de los restos arqueológicos, los análisis espaciales, microscópicos y biogeoquímicos de múltiples componentes (isótopos estables, fitolitos y coloración ósea) proporcionan nuevos datos sobre las actividades humanas del Paleolítico. Los patrones de distribución espacial de los restos de animales consumidos, los microfragmentos óseos, el tamaño de los huesos y el estudio de los residuos de grasa de los restos óseos aportan múltiples evidencias de las actividades de extracción de la grasa de animales en el yacimiento arqueológico. El análisis compuesto de metadatos se centró en la identificación del esfuerzo económico y en la mejora de la interpretación de los datos publicados a través de la medida de las tasas de retorno energético y el grado de intensificación de los recursos en El Mirón y otros lugares de la región cantábrica. Principalmente el registro de las ocupaciones del Magdaleniense inferior en El Mirón permitió abarcar a partir de los datos faunísticos una larga cadena operativa de estrategias de explotación de restos de animales, que incluye todas las actividades de adquisición de materias primas, producción de armamento, caza, desmembramiento, descortezado, fracturación ósea, machacado de huesos esponjosos, cocción, quema, consumo, desecho de sobras y,

finalmente, pisoteo. Finalmente, para reconstruir el proceso completo, todos los componentes son considerados, desde microfragmentos óseos originados a partir de piezas de hueso más grandes o elementos anatómicos completos, hasta animales cazados completos y transportados al yacimiento por los antiguos cazadores-recolectores.

En El Mirón, los resultados económicos revelan el predominio de la explotación de los rebaños maternales con sus crías de ciervos y cabras durante las estaciones frías, lo que da lugar a unos perfiles esqueléticos resultado de las decisiones humanas en el transporte de los restos y la intensificación de las técnicas de explotación. Los humanos eran el principal agente de acumulación en todos los niveles, con escasa presencia de actividades de carnívoros, siendo esta más alta en los niveles del Paleolítico medio final y superior inicial cuando las ocupaciones humanas eran cortas y efímeras. Las visitas humanas a la cueva se desarrollaron más tarde desde los lugares de ocupación breves a los campamentos de caza durante el Solutrense, hasta las estancias residenciales prolongadas y la intensificación de la explotación de los recursos en un campamento base adecuado dentro de un sistema de gestión de recursos más extenso durante el Magdaleniense inferior, que más tarde es sustituido por un uso estacional más programado en la zona montañosa. En los niveles del Solutrense y Magdaleniense aparece un patrón de actividades más complejo, que va desde los complejos patrones de marcas de corte, la fracturación y cocción de los restos óseos por parte de los humanos, hasta las modificaciones de los huesos por parte de los buitres. El análisis de coloración ósea amplió la comprensión de la historia de la ocupación de los sitios. El análisis espacial en el yacimiento mostró la creciente complejidad, implicando a grupos cada vez más grandes, en el uso del sitio durante el período del Magdaleniense inferior en particular en periodos de climas severos, fríos y secos, con fluctuaciones climáticas estacionales relativamente estables como lo demuestra el presente análisis microambiental llevado a cabo.

Durante el Magdaleniense inferior, El Mirón sirvió como un extenso campamento residencial para la temporada fría, con movimientos planeados en busca de recursos específicos en un paisaje bien conocido que permitía a comunidades más grandes desarrollar sistemas sociales cada vez más complejos. Estas estructuras sociales podrían reflejarse en el tratamiento especial de la "Dama Roja" en un elaborado entierro y reentierro en la cueva, único para esa época en la península ibérica. Los extraordinarios marcadores simbólicos, regionalmente delimitados, de las escápulas grabadas del ciervo de una hipotética banda regional del Magdaleniense inferior cantábrico muestran un alto nivel de identidad social y territorial que refleja ocupaciones de sitios más prolongadas y una mayor densidad demográfica. Esas estructuras sociales y la demografía, así como la fluctuación estacional y la distribución de los recursos en el paisaje, fueron factores desencadenantes de los sistemas de asentamiento humano y las pautas de movilidad. Mediante cambios en las estrategias de explotación, los humanos resistieron las fluctuaciones de las condiciones ambientales, así como la presión de la población, para volver a un comportamiento óptimo estimulado por la variabilidad del paisaje y la irregularidad de los recursos, ya que los humanos son capaces de adaptarse y explotar eficazmente su entorno.

El presente estudio contribuye a desentrañar los cambios en las estrategias regionales de subsistencia, perceptibles durante el Pleistoceno superior tardío en la región cantábrica: El primer cambio significativo es una especialización alimenticia que comenzó alrededor de 25 kcal BP, durante el Solutrense y los rápidos cambios climáticos asociados (HE2), el ultimo máximo glacial y continuó durante la transición al Magdaleniense inferior con climas fríos y relativamente secos. Dichos cambios climáticos rápidos disminuyen la biodiversidad de los recursos locales y refuerzan la movilidad de los macromamíferos, así como los grupos humanos incrementaron la caza especializada y la movilidad logística, para quizás abastecer algunos sitios de ocupaciones más prolongadas, que inicialmente aumentaron el uso de alimentos de menor rendimiento para luego mejorar el procesamiento de los mismos. Si esto también favoreció el aumento demográfico de la población local, además de los desplazamientos de la población a las zonas de refugio, sigue siendo indistinto.

Pero, los densos depósitos arqueológicos tras el último máximo glacial del Magdaleniense inferior en El Mirón, y otros sitios como Altamira, El Castillo y El Juyo atestiguan la intensificación de la explotación de los recursos por parte de grupos de mayor tamaño. Esta especialización económica comenzó durante el Solutrense, y continuó y alcanzó su punto máximo durante el Magdaleniense inferior, estableciendo un continuo transcultural entre las economías basadas en la caza de los ciervos en el norte de la península. El segundo cambio profundo ocurrió durante las últimas ocupaciones del Magdaleniense inferior. Al comienzo del evento HE1, los grupos del Magdaleniense inferior final redujeron sus visitas a la zona montañosa para llevar a cabo explotaciones estacionales más limitadas. El patrón de movilidad estacional más restringido y las visitas prolongadas durante el verano a la zona montañosa que caracterizan los registros del Magdaleniense medio-superior-final se establecieron como una explotación sistemática de los recursos distribuidos dentro del territorio ocupado. Comenzando con el Magdaleniense Medio, las ocupaciones posteriores muestran un tercer cambio de mayor presión de la caza y patrones de producción menos energéticos. Los grupos de cazadores-recolectores eran menos selectivos que antes en cuanto a las especies y edad de las presas, incluyendo los recursos de rango bajo, posiblemente acompañando una expansión territorial de las especies características de climas templados, incluyendo estos animales en su dieta. Aunque hay una diversificación de la dieta atestiguada por el aumento del uso de recursos complementarios como mariscos, peces, aves, plantas, la caza menor fue importante, y algunos yacimientos tuvo una representación significativa como en La Riera, Altamira, El Juyo y Sta. Catalina, sin llegar a representar tanta comida como los dos grandes ungulados comunes, el ciervo y la cabra montés. Este cambio económico y el uso menos intensivo de los sitios fue gradual acompañado de cambios tecno-culturales, ambientales y demográficos, que quizás indican migraciones intensivas pan-regionales, por ejemplo, como el reasentamiento en Europa del norte y central desde las áreas de refugio del sur, como lo señalan las evidencias genéticas. Se trata, por tanto, de patrones económicos de subsistencia de amplio espectro, que proporcionan resistencia y desafían la imprevisibilidad del clima.

Desde una perspectiva ambiental, la búsqueda de incentivos de adaptación en la explotación de recursos, sugiere que las condiciones regionales permitieron la preservación de la diversidad durante las condiciones climáticas severas, cuando otras regiones (Europa norte-central) no lo hicieron. Estas condiciones de refugio ponen de manifiesto el papel que desempeña la red hidrológica y el relieve topográfico de la región cantábrica. Dado que el deterioro ambiental es diferente en los distintos paisajes y que las condiciones ambientales posteriores del último máximo glacial fueron más severas que durante el mismo período en la región cantábrica, los seres humanos pudieron responder con movimientos migratorios de larga distancia y cambios en los asentamientos.

La adaptación de los modos de subsistencia revela que estos sistemas alcanzan la estabilidad, especialmente durante los momentos de climas más estables. La realización de la adaptación necesaria al entorno habitado ad-hoc permite experimentar con nuevas armas o técnicas de caza. Sin embargo, las nuevas ideas que crecen hasta convertirse en soluciones sostenibles probablemente se establecen cuando son ventajosas, ya sea bajo una tensión económica que favorece a los grupos que las aplican o más lentamente con el tiempo a través de las interacciones intragrupo (también fusión de grupo) y el crecimiento de la población. Los sistemas de asentamiento regional y las estrategias económicas también demuestran que la diversificación de la subsistencia está relacionada con la imprevisibilidad del clima y la disponibilidad de los recursos. Esa tensión económica se hace visible en el registro arqueológico cuando las actividades económicas parecen ineficientes por la disminución de las tasas de rendimiento, ejemplificada por la incorporación de especies/animales de rendimiento cada vez más bajo en comparación con la energía gastada para cazarlos. Desde una perspectiva a largo plazo, las economías sostenibles siempre optan por tasas de rendimiento más altas modificando su comportamiento económico.

Mediante una aproximación arqueozoológica y las evidencias multidisciplinares se han descifrado los cambios económicos del pasado en cuanto a la elección de los taxones de presa, la edad de los animales, la biomasa, el transporte de las presas, la carnicería, el procesamiento de los animales, la estacionalidad de la ocupación y la función del yacimiento a lo largo del tiempo, correlacionados con las condiciones paleoambiéntales locales y contextualizados por la cronología del radiocarbono. La síntesis de la adaptación transcultural en las economías de los cazadores-recolectores infieren dinámicas relativas al asentamiento regional, la economía, la densidad de población y las redes sociales. El análisis ha llevado a la conclusión de que el grado de viabilidad en entornos cambiantes y con diversos recursos dirige el comportamiento económico general, como se manifiesta en las estrategias de movilidad humana y el uso de los sitios de ocupación. Estas adaptaciones también se correlacionan con la intensidad de las técnicas de explotación de alimentos y el tamaño de la población. En esta tesis se examinaron y complementaron los conocimientos existentes para mejorar la percepción de las dimensiones y la estructura del comportamiento humano adaptativo transcultural a situaciones específicas más allá de los estudios económicos culturalmente restringidos, aportando un contexto ambiental más amplio; también ha consideró que toda prueba arqueológica se veía reducida por los procesos tafonómicos, que sólo pueden ser una muestra de las actividades humanas del pasado.

El trabajo futuro debería concentrarse en el desarrollo metodológico de la identificación de ala resolución de las actividades humanas en el tiempo y el espacio, en el contexto de las condiciones microambiéntales locales y las dataciones sistemáticas por radiocarbono para descifrar la secuencia temporal de los cambios económicos transculturales a la luz de los cambios climáticos, demográficos y culturales, y fomentar así el debate hermenéutico más allá del actual horizonte de conocimientos.

ZUSAMMENFASSUNG

Ein grundlegender Aspekt der prähistorischen Forschung im Bereich der Anpassung des Menschen an sich stets verändernde Klimaverhältnisse sind Subsistenzstrategien. Diese stellen eine wichtige Verbindung zwischen frühen Umweltbedingungen und menschlichen Aktivitäten dar, überliefert unter anderem durch archäologische Überreste ausgebeuteter, tierischer Nahrungsressourcen. Wie spät-jungpleistozäne Klimaschwankungen, Demographie und soziokulturelle Komponenten das menschliche Verhalten beeinflussten, wie multidisziplinäre Methoden zum Verständnis der Ökodynamik des Menschen vergangener Epochen beitragen und wie synthetisierte Beweise das Verständnis für menschliche Anpassungen verfeinern, zeigt diese Dissertation über die Ökodynamiken der Menschen im späten Oberpleistozän Nordspaniens, durch eine archäozoologische Studie an Überresten von Huftieren aus dem Unteren Magdalénien und anderen Epochen in der Höhle El Mirón (Kantabrien, Spanien).

Der Forschungsansatz zur Entschlüsselung der sich wandelnden wirtschaftlichen Praxis, wie sie sich in den Subsistenzstrategien widerspiegelt, wird in Kapitel 1 definiert. Ein Überblick über den aktuellen Stand der Interpretation der wirtschaftlichen Entwicklung in der Region Kantabrien zeigt, dass ein erfolgreicher Nachweis von Argumenten der menschlichen Verhaltensänderungen bis heute schwer zu erbringen ist (Kapitel 2). Die vorliegende Arbeit überwindet diesen Zustand mit umfangreichen Daten wirtschaftlicher Anpassungen, reflektiert durch den Grad der Optimierung, aus dem späten Mittelpaläolithikum, dem frühen Jungpaläolithikum, dem Solutréen und Magdalénien in der Höhle El Mirón und im erweiterten Kontext der Region Kantabrien. Kapitel 3 stellt den Kontext des Faunenmaterials von Makro-Säugetieren vor, das in der Höhle El Mirón untersucht wurde, sowie die methodischen Verbesserungen, die den Umfang der traditionellen Faunenanalyse durch sorgfältige Extraktion von Informationen aus archäologischen Säugetierresten erweitern. Die Ergebnisse der standortinternen räumlichen, taphonomischen und

biogeochemischen Analysen verbesserten insbesondere die Rekonstruktion spezifischer Aktivitäten und Mikro-Umweltbedingungen in der Höhle El Mirón in der Zeit des Magdaléniens (Kapitel 4). Schließlich stellt Kapitel 5 die diachrone Dynamik der wirtschaftlichen Veränderungen für die Region Kantabrien zusammen, die auf den mit Radiokohlenstoff datierten, archäologischen Hinterlassenschaften und den damit verbundenen Paläoumweltbedingungen zwischen 52 und 12 ka cal BP basiert. Dieses Verfahren kontextualisiert die lokalen, aber aussagekräftigen Ergebnisse zum Subsistenzverhalten von El Mirón mit signifikanten regionalen, wirtschaftlichen Veränderungen, um schließlich Erklärungen für menschliche Verhaltensänderungen zu modellieren und zu diskutieren. Die Synthese in Kapitel 6 erklärt, wie Umweltbedingungen, Demographie und soziale Parameter wirtschaftliche Anpassungen beeinflussten und (Kapitel 7) wie diese Einflussgrößen zu einem tragfähigen Modell der Veränderung menschlichen Verhaltens beitragen.

In erster Linie trägt diese Dissertation zur methodologischen Verbesserung der Analyse von Makro-Säugetierfaunen in verschiedenen Forschungsrichtungen bei. Sortierstrategien für archäologische Knochenüberreste, räumliche, mikroskopische und biogeochemische Mehrkomponentenanalysen (stabile Isotope, Phytolithen und Knochenfärbung) liefern neue Details über Tierökologie und Diagenesis im Paläolithikum. Räumliche Verteilungsmuster von zerschmetterten Knochen, Knochengröße und der Nachweis von Knochenfettrückständen fügen mehrere Linien zu den Beweisen der menschlichen Aktivitäten zur Knochenfettgewinnung an der Fundstelle hinzu. Die vielschichtige Metadatenanalyse konzentrierte sich auf die Identifizierung von wirtschaftlichem Druck und eine verbesserte Interpretation der bereits veröffentlichten Daten, mittels der Betrachtung energetischer Rücklaufquoten und des Grades der Ressourcenintensivierung in El Mirón und anderer Standorte in der Region Kantabrien. Vor allem die Nachweise aus den Besiedlungen des Unteren Magdaléniens in El Mirón erlaubten es, anhand von Faunendaten eine ausführliche *Chaîne opératoire* der Nutzungsstrategien für Tierkadaver zu erstellen, die alle Aktivitäten umfasst, die mit der Beschaffung von Rohstoffen, der Herstellung von Waffen, der Jagd, der Zerlegung, der Entfleischung, dem Aufbrechen von Knochenhöhlen, der Zerkleinerung von Spongiosa, dem Kochen, dem Verbrennen, dem Verzehr, dem Wegwerfen von Speiseresten und schließlich dem *Trampling* zu tun haben. Um die Tierverarbeitung umfassend zu rekonstruieren, wird schließlich jede Komponente betrachtet, von Knochenmikrofragmenten, die aus größeren Knochenstücken stammen, also von einst vollständigen anatomischen Elementen, bis hin zu ganzen Tieren, die von früheren Jägern und Sammlern gejagt und an den Fundort transportiert wurden.

In El Mirón zeigen die wirtschaftlichen Ergebnisse die vorherrschende Nutzung von Rotwild- und Steinbock-Muttertierherden während der kalten Jahreszeiten, die zu Skelettprofilen führten, die hauptsächlich das Ergebnis von menschlichen Transportentscheidungen in Abhängigkeit von der Tierart und Intensivität der Ausbeutungstechnik sind. Der Mensch war der primäre Akkumulator in allen Besiedlungsschichten, wobei die geringen Aktivitäten der Fleischfresser im späten Mittel- und frühen Jungpaläolithikum relativ am höchsten waren als der Mensch nur kurz und flüchtig blieb. Danach entwickelten sich die Besuche der Menschen in der Höhle El Mirón von kurzen Wohnlagern zu Jagdlagern während des Solutréens, und von komplexeren Wohnlagern zu richtigen Basislagern während des Unteren Magdaléniens, mit einer intensiveren Ausbeutung der Ressourcen im Rahmen eines umfassenderen Ressourcenmanagementsystems, das später durch eine planmäßigere saisonale Nutzung der Gebirgszone ersetzt wurde. Im Solutréen und Magdalénien zeigt sich ein komplexeres Muster von örtlichen Aktivitäten, das von komplexen Schnittmarkenmustern, dem Aufbrechen und Kochen von Knochen durch den Menschen bis hin zu Knochenmodifikationen durch Geier reicht. Die Analyse der Knochenfärbung erweiterte sogar den Einblick in die Besiedlungsgeschichte und örtlichen Umweltbedingugen der Fundstelle. Die räumlichen Analysen der Funde des Unteren Magdaléniens lassen eine wachsende Komplexität in der Standortnutzung erkennen. Dies impliziert, während einer Periode besonders rauen, kalten und trockenen Klimas mit relativ

stabilen jahreszeitlichen Schwankungen, wie die vorliegende Multielement-Mikroumweltanalyse zeigt, die Anwesenheit größerer Gruppen.

Während des Unteren Magdaléniens diente El Mirón in der kalten Jahreszeit als ausgedehntes Wohnlager, dass durch logistische Exkursionen in bestimmte Ressourcengebiete einer vertrauten Landschaft versorgt wurde und größeren Gruppen die Entwicklung zunehmend komplexerer sozialer Systeme ermöglichte. Solche sozialen Strukturen könnten sich in der besonderen Behandlung der ‚Roten Dame aus der Höhle El Mirón', einer aufwändigen und einzigartigen Höhlen- und Wiederbestattung im Iberien dieser Zeit, widerspiegeln. Die außergewöhnlichen, regional-begrenzten, symbolischen Gravuren von schraffierten Rothirschen könnten auf eine hypothetische Regionalgruppe des kantabrischen Unteren Magdaléniens hinweisen, ausgestattet mit einem hohen Maß an sozialer und territorialer Identität, was auf längere Standortbesetzungen und eine höhere demographische Dichte zurückzuführen wäre. Solche sozialen Strukturen und Demographien, ebenso wie saisonale Schwankungen und die Verteilung von Ressourcen in der Landschaft, sind auslösende Faktoren für menschliche Siedlungssysteme und Mobilitätsmuster. Die Art der Anpassung der Ausbeutungsstrategien, um zu optimalen Verhaltensweisen zu gelangen, spiegelt wider, wie der Mensch Schwankungen der Umweltbedingungen und wachsender Bevölkerungsdichte standhält. Stimuliert durch die Variabilität der Landschaft und die Begrenztheit der Ressourcen, ist der Mensch in der Lage seine Umwelt effektiv zu nutzen.

Aus ökologischer Sicht deutet die Mosaiklandschaft Nordspaniens darauf hin, dass die regionalen Gegebenheiten die Erhaltung der ökologischen Vielfalt unter schweren klimatischen Bedingungen erlaubten, während dies in anderen Regionen (Nord-Mitteleuropa) nicht der Fall war. Diese Zufluchtsbedingungen veranschaulichen die Rolle des hydrologischen Netzwerks und des topographischen Reliefs der Region Kantabrien, die zu allen Zeiten unter dem Einfluss der unterschiedlichen Auswirkungen des Nordatlantiks standen. Da kritische Umweltveränderungen von Region zu Region verschiedene Auswirkungen haben und diese nach dem letzten glazialen Maximum in der Region Kantabrien schwerwiegender ausfielen als währenddessen, konnten die Menschen mit weiträumigen Bewegungen und Siedlungsänderungen reagieren.

Die vorliegende Studie trägt dazu bei, die erheblichen Veränderungen in den regionalen Subsistenzstrategien zu entflechten, die zu Zeiten des späten Jungpleistozäns in der Region Kantabrien spürbar waren: Die erste bedeutende Veränderung ist eine Ernährungsspezialisierung im Solutréen, die um 25ka cal BP während globaler und rapider Klimaveränderungen (HE2) begann und sich bis zum Übergang in das Untere Magdalénien mit kaltem und relativ trockenem Klima fortsetzte. Solche raschen Klimaveränderungen vermindern die Artenvielfalt der lokalen Ressourcen und erhöhen die Mobilität der Makrosäuger, während menschliche Gruppen die spezialisierte Jagd und die logistische Mobilität erhöhen, möglicherweise um einige Standorte mit länger andauernder Besiedlung weiterhin zu versorgen. Anfänglich beinhalten diese Anpassungen auch die Verwendung wenig ertragreicher Nahrung, die später durch eine verbesserte Nahrungsmittelverarbeitung ersetzt wurde. Ob dies auch das lokale Bevölkerungswachstum begünstigte, zusätzlich zu den Bevölkerungsaufkommen in den Refugialgebieten, bleibt unklar. Jedoch verweisen die vorallem die dichten archäologischen Vorkommen des Unteren Magdaléniens nach dem glazialen Maximum in El Mirón und andere Stätten wie Altamira, El Castillo und El Juyo zeugen von einer verstärkten Ressourcenausbeutung durch größere Gruppen. Diese wirtschaftliche Spezialisierung begann im Solutréen, setzte sich weiter fort und erreichte ihren Höhepunkt im Unteren Magdalénien, was auf transkulturelle Kontinuität in den Rothirsch-Ökonomien Nordspaniens hinweist. Der zweite tiefgreifende Wandel fand während des späten Unteren Magdaléniens statt. Zu Beginn des HE1-Ereignisses reduzierten diese Gruppen ihre Aufenthalte in den Bergregionen auf die Sommermonate. Es etabliert sich ein Muster von saisonaler Mobilität und reduzierter Gebirgslandaufenthalte im Mittleren und Späten Magdalénien der Region, welches

die verteilten Ressourcen innerhalb des besetzten Gebiets systematisch ausbeutet. Beginnend mit dem Mittleren Magdalénien zeigen diese späteren Perioden eine dritte ökonomische Veränderung mit erhöhtem Jagddruck und weniger energetisch-produktiven Mustern. Jäger- und Sammlergruppen waren weniger selektiv in Bezug auf Art und Alter der Beute als zuvor. Sie nutzen zunehmend niedrig eingestufte Ressourcen, was möglicherweise auch mit der territorialen Ausdehnung von Arten der gemäßigten Zone, im Zuge fortschreitender Klimaverbesserungen, einhergeht, obgleich sie jedoch zunächst nicht-ausgewachsene Tiere von bevorzugten Wildarten jagten. Die Diversifizierung der Ernährung durch die verstärkte Nutzung ergänzender Ressourcen, wie Schalentiere, Fische, Vögel, Pflanzen und Kleinwild war typisch und an einigen wenigen Standorten, wie La Riera, Altamira, El Juyo und Santa Catalina recht gewichtig. Trotz allem stand dadurch nie so viel Nahrung zur Verfügung, wie durch die Bejagung der gängigen großen Huftiere Rothirsch und Steinbock. Diese allmähliche wirtschaftliche Verlagerung und weniger-intensive Standortnutzung, begleitet von techno-kulturellen, ökologischen und demographischen Veränderungen, deutet möglicherweise auf überregionale, intensive Migrationen hin, zum Beispiel die Wiederbesiedelung von Mittel- und Nordeuropa aus den südlichen Refugien, wie genetische Hinweise es nahelegen. Es handelt sich bei diesen Strategien im Allgemeinen um wirtschaftliche Muster der Diversifizierung der Subsistenz, die zu einer größeren Widerstandsfähigkeit führten und der Unvorhersehbarkeit der Klimaauswirkungen trotzten.

Anpassungen in der Ressourcennutzung zeigen, dass Subsistenzsysteme Stabilität erreichen, insbesondere in Momenten stabileren Klimas. Vermutlich ermöglicht erst die Vollendung der notwendigen Ad-hoc-Anpassungen an die bewohnte Umgebung Experimente mit neuen Technologien oder Techniken. Neue Ideen, die zu nachhaltigen Lösungen heranwuchsen, setzten sich möglicherweise nur durch, wenn sie von Vorteil für die Gruppen waren, entweder bedingt durch wirtschaftlichen Druck, bedingt durch gruppeninterne Interaktionen im Laufe der Zeit, oder bedingt durch Gruppenabspaltungen. Regionale Siedlungssysteme und Wirtschaftsstrategien zeigen auch, dass die Diversifizierung der Subsistenz besonders in Zeiten unberechenbaren Klimas und erhöhter Ressourcenbeanspruchung vorkommt. Wirtschaftlicher Druck wird archäologisch sichtbar, wenn Aktivitäten zur Energiegewinnung durch verringerte Ertragsraten ineffizient erscheinen, zum Beispiel durch die Nutzung von Arten/Tieren geringeren Ertrags im Vergleich zu der für ihre Bejagung aufgewendeten Energie. Langfristig entscheiden sich nachhaltige Ökonomien für höhere Ertragsraten, indem sie ihr wirtschaftliches Verhalten anpassen.

Ein archäozoologischer Forschungsansatz und multidisziplinäre Beweise halfen detaillierte vergangene wirtschaftliche Veränderungen bezüglich der Wahl der Arten, des Alters, der Biomasse, des Transports, des Schlachtens, der Verarbeitung, der saisonalen Standortbesetzung und der Standortfunktion diachron zu entschlüsseln. Diese wurden mit lokalen paläoökologischen Bedingungen und mittels der Radiokohlenstoff-Chronologie verankert. Die Synthese der transkulturellen Anpassung in Jäger-Sammler-Ökonomien lässt eine relevante, dynamische Beziehung hinsichtlich regionaler Besiedlung, Wirtschaft, Bevölkerungsdichte und sozialer Netzwerke ableiten. Der Grad der ökologischen Tragfähigkeit und die Begrenztheit der Ressourcen lenken das allgemeine wirtschaftliche Verhalten und manifestieren sich in den Strategien der menschlichen Mobilität und der Standortnutzung. Diese Anpassungen korrelieren auch mit der Intensität der Nahrungsausbeute und der Bevölkerungsgröße. Diese Dissertation ergänzt das vorhandene Wissen um Dimensionen und Strukturen des transkulturell-anpassungsfähigen menschlichen Verhaltens an spezifische Gegebenheiten jenseits vorherrschender, kulturbezogener, ökonomischer Studien in ihrem breiteren Umweltkontext. Ferner erkennt die Arbeit jeden archäologischen Nachweis aufgrund der taphonomischen Prozesse als begrenzt aussagefähig an, da dieser stets nur einen Auszug vergangener menschlicher Aktivitäten darstellen kann.

Zukünftige Arbeiten sollten sich in der methodischen Entwicklung auf die Identifizierung menschlicher Aktivitäten hoher zeitlicher und räumlicher Auflösung im Kontext lokaler Mikro-Umweltbedingungen und

intensiver Radiokohlenstoff-Aufzeichnungen konzentrieren, um die zeitliche Abfolge kulturspezifischer und transkulturell-wirtschaftlicher Veränderungen im Lichte des klimatischen, demographischen und kulturellen Wandels zu entschlüsseln und um die hermeneutische Debatte über den gegenwärtigen Wissenshorizont hinaus zu fördern.

CHAPTER 8: REFERENCES

8 References

8.1 Bibliography

AARIS-SØRENSEN, K., MÜHLDORFF, R. & PETERSEN, E.B. (2007): The Scandinavian reindeer (Rangifer tarandus L.) after the last glacial maximum: time, seasonality and human exploitation. – *Journal of Archaeological Science*, **34**/6: 914–923. doi: 10.1016/j.jas.2006.09.014.

ABRAMS, G., BELLO, S.M., DI MODICA, K., PIRSON, S. & BONJEAN, D. (2014): When Neanderthals used cave bear (Ursus spelaeus) remains: Bone retouchers from unit 5 of Scladina Cave (Belgium). – *Quaternary International*, **326–327**: 274–287. doi: 10.1016/j.quaint.2013.10.022.

ACEVEDO, P. & CASSINELLO, J. (2009): Biology, ecology and status of Iberian ibex Capra pyrenaica: a critical review and research prospectus. – *Mammal Review*, **39**/1: 17–32. doi: 10.1111/j.1365-2907.2008.00138.x.

ACHILLI, A., RENGO, C., MAGRI, C., BATTAGLIA, V., OLIVIERI, A., SCOZZARI, R., CRUCIANI, F., ZEVIANI, M., BRIEM, E. & CARELLI, V. (2004): The molecular dissection of mtDNA haplogroup H confirms that the Franco-Cantabrian glacial refuge was a major source for the European gene pool. – *The American Journal of Human Genetics*, **75**/5: 910–918.

ADÁN, G.E., ÁLVAREZ-LAO, D., TURRERO, P., ARBIZU, M. & GARCÍA-VÁZQUEZ, E. (2009): Fish as diet resource in North Spain during the Upper Paleolithic. – *Journal of Archaeological Science*, **36**/3: 895–899. doi: 10.1016/j.jas.2008.11.017.

AGENCIA ESTATAL DE METEOROLOGÍA (AEMET) (2011): Atlas climático ibérico: temperatura del aire y precipitación (1971-2000). – Madrid (Instituto Nacional de Meteorología).

AGUDO PÉREZ, L. (2015): ¿Sólo humanos y carnívoros? Estudio de otros agentes acumuladores en yacimientos prehistóricos. Análisis tafonómico de nidos históricos de quebrantahuesos (Gypaetus barbatus) del sureste peninsular. – Master's Thesis: Santander (Universidad Cantabria).

AGUIRRE, M. (1998): El yacimiento paleolítico de Antoliñako koba (Gautegiz-Arteaga): secuencia estratigráfica y dinámica industrial : avance de las campañas de excavación 1995-2000. – *Illunzar*/4: 39–81.

AGUIRRE, M. (2012): Ocupaciones gravetienses de Antoliñako koba: Aproximación preliminar a su estratigrafía, cronología e industrias. – In: Pensando el Gravetiense: nuevos datos para la región cantábrica en su contexto peninsular y pirenaico. – pp. 216–228, (Ministerio de Educación, Cultura y Deporte).

AIELLO, L.C. & WHEELER, P. (2003): Neanderthal thermoregulation and the glacial climate. – In: VAN ANDEL, T.H., DAVIES, W. & AIELLO, L. (eds): Neanderthals and modern humans in the European landscape during the last glaciation: archaeological results of the Stage 3 Project. – pp. 147–166, Cambridge (McDonald Institute for Archaeological Research).

ALADOS, C.L. & ESCÓS, J. (2012): Cabra montés–Capra pyrenaica Schinz, 1838. – *Enciclopedia Virtual de los Vertebrados Españoles.* Retrieved December 10, 2014, from http://vertebradosibericos.org.

ALCALDE DEL RÍO, H. (1906): Las pinturas y grabados de las cavernas prehistóricas de la provincia de Santander: Altamira, Covalanas, Hornos de la Peña, Castillo. – Santander.

ALCALDE DEL RÍO, H., BREUIL, H. & SIERRA, L. (1911): Les Cavernes de la Région Cantabrique (Espagne). – 468 pp. Mónaco (Imprimerie Vve. A. Chêne).

ALDEZABAL, A. & GARIN, I. (2000): Browsing preference of feral goats (Capra hircus L.) in a Mediterranean mountain scrubland. – *Journal of Arid Environments*, **44**/1: 133–142. doi: 10.1006/jare.1999.0573.

ALDIA, G.P. & GARAIA, B.A.-E. (1995): CARTA ARQUEOLOGICA DE GIPUZKOA II. Cuevas: Usategi. – *Munibe*/Suplemento no 10: 3.

ALHAIQUE, F. (1997): Do Patterns of Bone Breakage differ between Cooked and Uncooked Bones? An Experimental Approach. – *Proceedings of the 7th ICAZ conference*: 49–56.

ALLEN, C.R., ANGELER, D.G., GARMESTANI, A.S., GUNDERSON, L.H. & HOLLING, C.S. (2014): Panarchy: Theory and Application. – *Ecosystems*, **17**/4: 578–589. doi: 10.1007/s10021-013-9744-2.

ALLENDE ÁLVAREZ, F. (2008): Una aproximación a la caracterización climática de un sector de la montaña central cantábrica. – *Estudios Geográficos*, **LXIX**/265: 357–383. doi: 10.3989/estgeogr.0442.

ALMAGRO, M. (1976): Los omóplatos decorados de la cueva de" El Castillo". Puente Viesgo (Santander). – *Trabajos de Prehistoria*, **33**: 9 (Consejo Superior de Investigaciones Científicas. Instituto Español de …).

ALONSO, D.Á. (2018): The Cantabrian Magdalenian: lateglacial chronology in Northern Iberian Peninsula. – *Portugalia: Revista de Arqueologia do Departamento de Ciências e Técnicas do Património da FLUP*, **27**: 5–18.

ALPERSON-AFIL, N., SHARON, G., KISLEV, M., MELAMED, Y., ZOHAR, I., ASHKENAZI, S., RABINOVICH, R., BITON, R., WERKER, E., HARTMAN, G., FEIBEL, C. & GOREN-INBAR, N. (2009): Spatial Organization of Hominin Activities at Gesher Benot Ya'aqov, Israel. – *Science*, **326**/5960: 1677–1680. doi: 10.1126/science.1180695.

ALTUNA, J. (1963): Fauna de mamíferos del yacimiento prehistórico de Aitzbitarte IV. – *Munibe*, **15**: 105–124.

ALTUNA, J. (1971a): Los mamíferos del yacimiento prehistórico de Morín. – In: Cueva Morín. – pp. 369–398, Santander (Publicaciones del Patronato de las cuevas prehistóricas de la provincia de Santander).

ALTUNA, J. (1971b): El reno en el Würm de la Península Ibérica. – *Munibe*, **23**/1: 71–90.

ALTUNA, J. (1972): Fauna de mamíferos de los yacimientos prehistóricos de Guipúzcoa: con catálogo de los mamíferos cuaternarios del Cantábrico y del Pirineo Occidental. – San Sebastian (Sociedad de Ciencias Naturales Aranzadi).

ALTUNA, J. (1973): Fauna de mamíferos de la Cueva de Morín. – In: Cueva Morín: Excavaciones 1969. – pp. 281–290, Santander (Publicaciones del Patronato de las cuevas prehistóricas de la provincia de Santander).

ALTUNA, J. (1976): Los mamíferos del yacimiento prehistórico de Tito Bustillo (Asturias). – In: Excavaciones en la Cueva de" Tito Bustillo" (Asturias). – pp. 151–93, Oviedo: Instituto de Estudios Asturianos.

ALTUNA, J. (1978): Dimorphisme sexuel dans le squelette postcéphalique de Capra pyrenaica pendant le Würm final. – *Munibe*, **30**/4: 201–214.

ALTUNA, J. (1981): Restos óseos del yacimiento prehistórico del Rascaño. – In: El Paleolitico Superior de la Cueva del Rascaño (Santander). – pp. 215–270, Santilla del Mar (Santander) (Centro de investigacion y museo de Altamira).

ALTUNA, J. (1985): Capitulo 2: Dataciones del C14. Comparación con las dataciones de otros yacimientos. – In: Cazadores magdalenienses en la cueva de Erralla (Cestona – País Vasco). – pp. 25–28, San Sebastian.

ALTUNA, J. (1986): The mammalian Faunas from the Prehistoric site of la Riera. – In: La Riera Cave- Stone age hunter-gatherer adaptation in northern Spain. – pp. 237--274, (Arizona State University. Department of Anthropology).

ALTUNA, J. (1990a): La caza de herbívoros durante el Paleolítico y Mesolítico del País Vasco. – *Munibe*, **42**: 229–240.

ALTUNA, J. (1990b): La cueva de Amalda (Zestoa, País Vasco): ocupaciones paleolíticas y postpaleolíticas. – 276 pp. San Sebastián (Editorial Eusko Ikaskuntza).

ALTUNA, J. (1992): Dataciones de radiocarbono para el Perigordiense Superior del País Vasco. – *Munibe*, **44**: 31–32.

ALTUNA, J. (1994): La relación fauna consumida-fauna representada en el Paleolítico superior cantábrico. – *Complutum*, **5**: 303–311.

ALTUNA, J. (1998): Faunas de mamíferos y cambios ambientales durante el Tardiglacial cantábrico. – In: El final del Paleolítico cantábrico. Transformaciones ambientales y culturales durante el Tardiglacial y comienzos del Holoceno en la Región Cantábrica. – pp. 77–117, Santander (Servicio de Publicaciones de la Universidad de Cantabria).

ALTUNA, J., BALDEÓN, A., MARIEZKURRENA, K. & DE CIENCIAS ARANZADI, S. (1985): Resumen y conclusiones. – In: Cazadores magdalenienses en la cueva de Erralla (Cestona – País Vasco). – pp. 199–206, San Sebastian (Sociedad de Ciencias Aranzadi).

ALTUNA, J., CUENCA-BESCÓS, G., ELORZA, M., GARCÍA PIMIENTA, J.C., LOBO, J., MARIEZKURRENA, K., PÉREZ-RIPOLL, M., SANCHIZ, B., GONZÁLEZ-MORALES, M.R. & STRAUS, L.G. (2004): Post-pleistocene faunas from the archeological site of El Mirón cave (Ramales de la Victoria, Cantabria, Spain): a preliminary summary. – *Zona arqueológica*, **4**/2: 40–49.

ALTUNA, J. & MARIEZKURRENA, K. (1984): Bases de subsistencia de origen animal en el yacimiento de Ekain (CAPITULO VIII). – In: El yacimiento prehistórico de la Cueva de Ekain (Deba, Guipúzcoa). Sociedad de Estudios Vascos, Serie B. – pp. 211–280,.

ALTUNA, J. & MARIEZKURRENA, K. (1985): Capitulo 8: Bases de subsistencia de los pobladores de Erralla: macromamiferos in Cazadores magdalenienses en Erralla (Cestona, Pais vasco). – In: Cazadores magdalenienses en la cueva de Erralla (Cestona – País Vasco). – pp. 87–117, San Sebastián.

ALTUNA, J. & MARIEZKURRENA, K. (2011): 9. Estudio de los macromamíferos del yacimiento de Aitzbitarte III (excavación de la entrada). – In: Ocupaciones humanas en Aitzbitarte III (País Vasco) 33.600-18.400 BP (zona de entrada a la cueva). – p. Vitoria-Gasteiz (Eusko Jaurlaritza, Kultura Saila, Eusko Jaurlaritzaren Argitalpen Zerbitzu Nagusia).

ALTUNA, J. & MARIEZKURRENA, K. (2012): Macromammalian remains from the Holocene levels of El Mirón cave. – In: El Mirón cave, Cantabrian Spain: The site and its Holocene archaeological record. – pp. 288–318, Albuquerque (University of New Mexico Press).

ALTUNA, J. & MARIEZKURRENA, K. (2017): Bases de subsistencia de origen animal durante el Magdaleniense en la cueva de las caldas. – In: La Cueva de las Caldas (Priorio, Oviedo): ocupaciones magdalenienses en el Valle del Nalón. – pp. 55–119, (Ediciones Universidad de Salamanca).

ALTUNA, J., MARIEZKURRENA, K., DE LA PEÑA, P. & RIOS-GARAIZAR, J. (2013): Los niveles gravetienses de la cueva de Aitzbitarte III (Gipuzkoa). Industrias y faunas asociadas. – In: Pensando el Gravetiense: nuevos datos para la región cantábrica en su contexto peninsular y pirenaico. – pp. 184–204, (Santander Madrid).

ALTUNA, J. & STRAUS, L.G. (1975): The Solutrean of Altamira: the artifactual and faunal evidence. – *Zephyrus: Revista de prehistoria y arqueología*/26: 175–182.

ÁLVAREZ ALONSO, D. & ARRIZABALAGA, Á. (2012): Aproximación al debate sobre la transición Solutrense-Magdaleniense en la Cornisa Cantábrica (España)= The issue on the Solutrean to Magdalenian transition in the Cantabrian Region (Spain). – In: Espacio Tiempo y Forma. Serie I, Prehistoria y Arqueología. – pp. 171–182, Madrid (UNED).

ÁLVAREZ-ALONSO, D. (2007): Cantabrian Lower Magdalenian. Chronology context and structure. – *Munibe*, **58**: 127–142.

ÁLVAREZ-ALONSO, D. (2014a): El final del Paleolítico superior: El Magdaleniense en Asturias. – In: ÁLVAREZ-ALONSO, D. (ed.): LOS GRUPOS CAZADORES-RECOLECTORES PALEOLÍTICOS DEL OCCIDENTE CANTÁBRICO Estudios en Homenaje a Francisco Jordá Cerdá en el centenario de su nacimiento. 1914-2014. – pp. 171–204, (UNED).

ÁLVAREZ-ALONSO, D. (2014b): Olivo cave (Llanera). A new Magdalenian site in the center of Asturias. – *NAILOS. Estudios Interdisciplinares de Arqueología*, **1**: 181–192.

ALVAREZ-ALONSO, D., ANDRÉS, M., ALVAREZ-FERNANDEZ, E., GARCIA-IBAIBARRIAGA, N., JORDÁ-PARDO, J.F. & ROJO-HERNÁNDEZ, J.A. (2014): 'Secondary Camps' in Cantabrian Magdalenian: Preliminary Results of the Excavation in Olivo Cave (Llanera, Asturias) - LOS "CAMPAMENTOS SECUNDARIOS" EN EL MAGDALENIENSE CANTÁBRICO: RESULTADOS PRELIMINARES DE LA EXCAVACIÓN EN LA CUEVA DEL OLIVO (LLANERA, ASTURIAS). – In: CIEN AÑOS DE ARTE RUPESTRE PALEOLÍTICO. – pp. 359–367, (Universidad Salamanca).

ÁLVAREZ-ALONSO, D. & ANDRÉS-HERRERO, M. DE (2013): La transición Solutrense-Magdaleniense en la cueva de El Cierro (Ribadesella, Asturias, España). – *Espacio Tiempo y Forma. Serie I, Prehistoria y Arqueología*, **1**/5: 399–411.

ÁLVAREZ-ALONSO, D., YRAVEDRA, J., JORDÁ PARDO, J.F. & ARRIZABALAGA, A. (2016): The Magdalenian sequence at Coímbre cave (Asturias, Northern Iberian Peninsula): Adaptive strategies of hunter–gatherer groups in montane environments. – *Quaternary International*, **402**: 100–111. doi: 10.1016/j.quaint.2015.09.084.

ÁLVAREZ-FERNÁNDEZ, E. (2001): "Altamira revisited" : nuevos datos, interpretaciones y reflexiones sobre la industria ósea y la malacofauna. – *Espacio Tiempo y Forma. Serie I, Prehistoria y Arqueología*, **14**: 167–184.

ÁLVAREZ-FERNÁNDEZ, E. (2002): Perforated Homalopoma sanguineum from Tito Bustillo (Asturias): mobility of Magdalenian groups in northern Spain. – *Antiquity*, **76**/293: 641–646. doi: 10.1017/S0003598X00091043.

ÁLVAREZ-FERNANDEZ, E. (2006): Los objetos de adorno-colgantes del Paleolítico superior y del Mesolítico en la Cornisa Cantábrica y en el Valle del Ebro: una visión europea. – Diss.: Salamanca (Universidad de Salamanca).

ÁLVAREZ-FERNANDEZ, E. (2007): La explotación de los moluscos marinos en la cornisa cantábrica durante el gravetiense: primero datos de los niveles E y F de La Garma A (Omoño, Cantabria). – *Zephyrus: Revista de prehistoria y arqueología*/60: 43–58.

ÁLVAREZ-FERNÁNDEZ, E., ÁLVAREZ-ALONSO, D., BÉCARES, J., CARRAL, P., CARRIOL, R.-P., CHAUVIN, A., CUBAS, M., CUETO, M., DOMINGO, R., DOUKA, K., ELORZA, M., JORDÁ-PARDO, J.F., MURELAGA, X., PORTERO, R., RIVERO, O., TAPIA, J., TARRIÑO, A. & TEIRA, L.C. (2016): Nouvelles données sur le Magdalénien inférieur de la Région

Cantabrique : le Niveau F de la grotte de El Cierro (Ribadesella, Asturies, Espagne). – *L'Anthropologie*, **120**/5: 537–567. doi: 10.1016/j.anthro.2016.09.001.

ÁLVAREZ-FERNÁNDEZ, E. & FERNÁNDEZ-GARCIA, R. (2013): Marine resource exploitation in Cantabrian Spain during the Solutrean. – *La Société d'études et de Recherches Archéologiques sur le Paléolithique de la Vallée de la Claise (ed.): Le Solutréen*, **40**: 397–407.

ÁLVAREZ-FERNÁNDEZ, E., PÉREZ, J.B., RAPADO, M.C., PARDO, J.F.J., OLLERO, P.U. & ARIAS-CABAL, P. (2015): New data on the late Upper Palaeolithic in the river Sella lower valley (Asturias, Spain) - Nuevos datos sobre el final del Paleolítico Superior en el curso bajo del río Sella (Asturias, España). – *Férvedes: Revista de investigación*, **8**: 123–132.

ÁLVAREZ-LAO, D.J. & GARCÍA, N. (2010): Chronological distribution of Pleistocene cold-adapted large mammal faunas in the Iberian Peninsula. – *Quaternary International*, **212**/2: 120–128. doi: 10.1016/j.quaint.2009.02.029.

ANDERSEN, K.K., SVENSSON, A., JOHNSEN, S.J., RASMUSSEN, S.O., BIGLER, M., RÖTHLISBERGER, R., RUTH, U., SIGGAARD-ANDERSEN, M.-L., PEDER STEFFENSEN, J., DAHL-JENSEN, D., VINTHER, B.M. & CLAUSEN, H.B. (2006): The Greenland Ice Core Chronology 2005, 15–42 ka. Part 1: constructing the time scale. – *Quaternary Science Reviews*, **25**/23–24: 3246–3257. doi: 10.1016/j.quascirev.2006.08.002.

ANDRÉS, M., GIDNA, A.O., YRAVEDRA, J. & DOMÍNGUEZ-RODRIGO, M. (2012): A study of dimensional differences of tooth marks (pits and scores) on bones modified by small and large carnivores. – *Archaeological and Anthropological Sciences*, **4**/3: 209–219. doi: 10.1007/s12520-012-0093-4.

ANDRÉS-HERRERO, M. DE (2009): El Chatelperroniense en la región cantábrica. Estado de la cuestión. – *Munibe*, **60**: 35–50.

ANDRÉS-HERRERO, M. DE, ÁLVAREZ-ALONSO, D., ARRIZABALAGA, A., BECKER, D., WENIGER, G.-C. & YRAVEDRA, J. (2017): Site catchment analysis and human behaviour during the Upper Palaeolithic in the Cantabrian Region: Coímbre cave (Asturias, Spain) as case study. – In: PEREIRA, T., TERRADAS, X. & BICHO, N.F. (eds): The Exploitation of Raw Materials in Prehistory: Sourcing, Processing and Distribution. – pp. 368–381, Cambridge (Cambridge Scholars Publishing).

ANDRÉS-HERRERO, M. DE, BECKER, D. & WENIGER, G.-C. (2018): Reconstruction of LGM faunal patterns using Species Distribution Modelling. The archaeological record of the Solutrean in Iberia. – *Quaternary International*, **485**: 199–208. doi: 10.1016/j.quaint.2017.10.042.

ANDREWS, P. & FERNÁNDEZ-JALVO, Y. (2012): How to Approach Perimortem Injury and Other Modifications. – In: BELL, L.S. (ed.): Forensic Microscopy for Skeletal Tissues. – pp. 191–225, Totowa, NJ (Humana Press). doi: 10.1007/978-1-61779-977-8_12.

ANDREWS, P. & MARTIN, L. (1991): Hominoid dietary evolution. – *Philosophical Transactions of the Royal Society of London.*, **334**/1270: 199–209. doi: 10.1098/rstb.1991.0109.

ANGELA, D. & LONGINELLI, A. (1990): Oxygen isotopes in living mammal's bone phosphate: Further results. – *Chemical Geology: Isotope Geoscience section*, **86**/1: 75–82. doi: 10.1016/0168-9622(90)90007-Y.

ANTHONY, D.W. (1990): Migration in Archeology: The Baby and the Bathwater. – *American Anthropologist*, **92**/4: 895–914.

ANTOLÍN, F., BLANCO, À., BUXÓ, R., CARUSO, L., JACOMET, S., LÓPEZ, O., MARLASCA, R., PALOMO, A., PIQUÉ, R., SAÑA, M. & TERRADAS, X. (2013): The Application of Systematic Sampling Strategies for Bioarchaeological Studies in the Early Neolithic Lakeshore Site of La Draga (Banyoles, Spain). – *Journal of Wetland Archaeology*, **13**/1: 29–49. doi: 10.1179/1473297113Z.0000000002.

ARIAS-CABAL, P. (1992): Elefantes, ciervos y ovicaprinos: economía y aprovechamiento del medio en la Prehistoria de España y Portugal. – 328 pp. (Ed. Universidad de Cantabria).

ARIAS-CABAL, P. & ALVAREZ-FERNANDEZ, E. (2004): Iberian Foragers and Funerary Ritual—a Review of Paleolithic and Mesolithic Evidence on the Peninsula. – *The Mesolithic of the Atlantic Façade: Proceedings of the Santander Symposium. Arizona State University Anthropological Research Papers*, **55**: 225–249.

ARIAS-CABAL, P., ARMENDARIZ, A., BALBÍN, R. DE, FANO, M.A., FERNÁNDEZ-TRESGUERRES, J., GONZÁLEZ-MORALES, M.R., IRIARTE, M.J., ONTAÑÓN-PEREDO, R., ALCOLEA, J., ÁLVAREZ-FERNÁNDEZ, E., ETXEBERRIA, F., DOLORES-GARRALDA, M., JACKES, M. & ARRIZABALAGA, A. (2009): Burials in the cave: New evidence on mortuary practices during the Mesolithic of Cantabrian Spain. – In: Mesolithic Horizons: Papers presented at the Seventh International Conference on the Mesolithic in Europe. – pp. 650–656, Oxford (Oxbow Books).

ARIAS-CABAL, P. & ONTANÓN, R. (eds) (2004): La materia del lenguaje prehistórico. El arte mueble paleolítico de Cantabria en su contexto. – Santander (Gobierno de Cantabria).

ARIAS-CABAL, P. & ONTAÑÓN-PEREDO, R. (2014): La Garma: un proyecto orientado al estudio del arte paleolítico, su contexto y su conservación - La Garma: A Research Programme on Palaeolithic Art, its Context and its Preservation. – In: Cien años de arte rupestre paleolítico. – pp. 173–194, Salamanca.

ARIAS-CABAL, P., ONTAÑÓN-PEREDO, R., ALVAREZ-FERNANDEZ, E., CUETO, M., ELORZA, M., GARCÍA-MONCÓ, C., GÜTH, A., IRIARTE, M.J., TEIRA, L.C. & ZURRO, D. (2011): Magdalenian floors in the Lower Gallery of La Garma. A preliminary report. – In: Site-internal spatial organization of hunter-gatherer societies: case studies from the European Palaeolithic and Mesolithic : papers submitted at the session (C58) "Come in - and find out: Opening a new door into the analysis of hunter-gatherer social organisation and behaviour", held at the 15th U.I.S.P.P. conference in Lisbon, September 2006. – pp. 31–52, Mainz; Regensburg (Verlag des Römisch-Germanischen Zentralmuseums).

ARIAS-CABAL, P. & SUÁREZ, C.P. (1995): Excavaciones arqueológicas en Arangas, Cabrales (1991-1994): las Cuevas de los Canes, el Tíu Llines y Arangas. – In: Excavaciones arqueológicas en Asturias 1991-94. – pp. 79–92,.

ARMITAGE, P.L. (1975): The extraction and identification of opal phytoliths from the teeth of ungulates. – *Journal of Archaeological Science*, **2**/3: 187–197. doi: 10.1016/0305-4403(75)90056-4.

ARRIZABALAGA, A., ALTUNA, J. & ARESO, P. (2000): Labeko Koba (País Vasco): hienas y humanos en los albores del paleolítico superior. – 395 pp. San Sebastián (Sociedad de Ciencias Aranzadi, Zientzi Elkartea).

ARRIZABALAGA, A., BERNALDO DE QUIRÓS, F., BON, F., IRIARTE, M.J., MAÍLLO-FERNÁNDEZ, J.-M. & NORMAND, C. (2009): Early evidence of the Aurignacian in Cantabrian Iberia and the North Pyrenees. – In: - Turning Points and New Directions. – pp. 255–292, Oxford (Oxbow Books).

ARROYABE, J.T.M. & VIZCAYA, J.F.A. (1993): Cueva de La Lastrilla. Sangazo (Sámano). Revisión y actualización del arte parietal. – *Boletín cántabro de espeleología*, **9**: 47–56.

ASHBY, S.P. (2013): Some Comments on the Identiication of Cervid Species in Worked Antler. – In: CHOYKE, A.M. & O'CONNOR, S. (eds): From these bare bones: raw materials and the study of worked osseous objects. – pp. 208–222, Oxford (Oxbow Books).

AUBRY, T., LUÍS, L., LLACH, J.M. & MATIAS, H. (2015): Adaptation to Resources and Environments during the Last Glacial Maximum by Hunter-Gatherer Societies in Atlantic Europe. – *Journal of Anthropological Research*, **71**/4: 523–544. doi: 10.3998/jar.0521004.0071.404.

AUDOUZE, F. & ENLOE, J.G. (1997): High resolution archaeology at Verberie: limits and interpretations. – *World Archaeology*, **29**/2: 195–207.

AURA-TORTOSA, J.E. (2007): Badegouliens et Magdaléniens du versant méditerranéen espagnol. – *Bulletin de la Société préhistorique française*, **104**/4: 809–824. doi: 10.3406/bspf.2007.13625.

AURA-TORTOSA, J.E. (2010): Uno de los nuestros. Notas para una arqueología de las prácticas funerarias de los cazadores prehistóricos de la península ibérica. – In: Restos de vida, restos de muerte: la muerte en la Prehistoria:[exposición celebrada en el] Museu de Prehistòria de València del 4 de febrero al 30 de mayo de 2010. – pp. 31–44, Valencia (Museu de Prehistòria de València).

AURA-TORTOSA, J.E., TIFFAGOM, M., JORDÁ PARDO, J.F., DUARTE, E., FERNÁNDEZ DE LA VEGA, J., SANTAMARÍA-ÁLVAREZ, D., RASILLA-VIVES, M. DE LA, VADILLO, M. & PEREZ-RIPOLL, M. (2012): The Solutrean–Magdalenian transition: A view from Iberia. – *Quaternary International*, **272–273**: 75–87. doi: 10.1016/j.quaint.2012.05.020.

AURA-TORTOSA, J.E., VILLAVERDE, V., GONZÁLEZ-MORALES, M.R., SAINZ, C.G., ZILHÃO, J. & STRAUS, L.G. (1998): The Pleistocene–Holocene transition in the Iberian Peninsula: continuity and change in human adaptations. – *Quaternary International*, **49**: 87–103.

AVERBOUH, A., GOUTAS, N. & MARQUEBIELLE, B. (2016): Rod debitage by extraction: An overview of different cases identified for the Upper Palaeolithic and the Mesolithic in Europe. – *Quaternary International*, **403**: 57–67. doi: 10.1016/j.quaint.2015.08.072.

AYLIFFE, L.K., LISTER, A.M. & CHIVAS, A.R. (1992): The preservation of glacial-interglacial climatic signatures in the oxygen isotopes of elephant skeletal phosphate. – *Palaeogeography, Palaeoclimatology, Palaeoecology*, **99**/3: 179–191. doi: 10.1016/0031-0182(92)90014-V.

AZORIT, C.E. (2011): Guía para la determinación de la edad del ciervo ibérico (cervus elaphus hispanicus) a través de su dentición: revisión metodológica y técnicas de elección. – *Anales de la Real Academia de Ciencias Veterinarias de Andalucía Oriental*, **24**/24: 235–264.

BACA, M., POPOVIĆ, D., BACA, K., LEMANIK, A., DOAN, K., HORÁČEK, I., LÓPEZ-GARCÍA, J.M., BAÑULS-CARDONA, S., PAZONYI, P., DESCLAUX, E., CRÉGUT-BONNOURE, E., BERTO, C., LENARDIĆ, J.M., MIĘKINA, B., MURELAGA, X., CUENCA-BESCÓS, G., KRAJCARZ, M., MARKOVIĆ, Z., PETCULESCU, A., WILCZYŃSKI, J., KNUL, M.V., STEWART, J.R. & NADACHOWSKI, A. (2020): Diverse responses of common vole (Microtus arvalis) populations to Late Glacial and Early Holocene climate changes – Evidence from ancient DNA. – *Quaternary Science Reviews*, **233**: 106239. doi: 10.1016/j.quascirev.2020.106239.

BACHELLEIRE, F., BON, F., DESCHAMPS, M., EIZENBERG, L., HENRY-GAMBIER, D., MOURRE, V., NORMAND, C., PELEGRIN, J., PRIMAULT, J. & SCANDIUZZI, R. (2009): Archaeological signatures of hunting activities applied to comparisons of mousterian, chatelperronian and aurignacian industries in the Pyrenees: the nature of hunting tools and site functions. – In: Hunting Camps in the Prehistory Current archaeological approaches Proceedings of the International Symposium. – pp. 131–167, Toulouse (University Toulouse II - Le Mirail).

BACKWELL, L. & D'ERRICO, F. (2005): The origin of bone tool technology and the identification of early hominid cultural traditions. – In: From tools to symbols: from early hominids to modern humans. – pp. 238–275, Johannesburg (Witwatersrand University Press).

BAENA, J., CARRIÓN, E., CUARTERO, F. & FLUCK, H. (2012): A chronicle of crisis: The Late Mousterian in north Iberia (Cueva del Esquilleu, Cantabria, Spain). – *Quaternary International*, **247**: 199–211. doi: 10.1016/j.quaint.2011.07.031.

BAGNIEWSKI, W., MEISSNER, K.J., MENVIEL, L. & BRENNAN, C.E. (2015): Quantification of factors impacting seawater and calcite $\delta^{18}O$ during Heinrich Stadials 1 and 4. – *Paleoceanography*, **30**/7: 895–911. doi: 10.1002/2014PA002751.

BAILEY, G. (2007): Time perspectives, palimpsests and the archaeology of time. – *Journal of Anthropological Archaeology*, **26**/2: 198–223.

BAILEY, G. & GALANIDOU, N. (2009): Caves, palimpsests and dwelling spaces: examples from the Upper Palaeolithic of south-east Europe. – *World Archaeology*, **41**/2: 215–241.

BAILEY, G.N. & DAVIDSON, I. (1983): Site exploitation territories and topography: Two case studies from palaeolithic spain. – *Journal of Archaeological Science*, **10**/2: 87–115. doi: 10.1016/0305-4403(83)90044-4.

BAKER, J.R. & BROTHWELL, D.R. (1980): Animal Diseases in Archaeology. – London (Academic Press).

BALASSE, M. (2002): Reconstructing dietary and environmental history from enamel isotopic analysis: time resolution of intra-tooth sequential sampling. – *International Journal of Osteoarchaeology*, **12**/3: 155–165. doi: 10.1002/oa.601.

BALASSE, M., BOURY, L., UGHETTO-MONFRIN, J. & TRESSET, A. (2012): Stable isotope insights ($\delta^{18}O$, $\delta^{13}C$) into cattle and sheep husbandry at Bercy (Paris, France, 4th millennium BC): birth seasonality and winter leaf foddering. – *Environmental Archaeology*, **17**/1: 29–44. doi: 10.1179/1461410312Z.0000000003.

BALASSE, M., OBEIN, G., UGHETTO-MONFRIN, J. & MAINLAND, I. (2012): Investigating Seasonality and Season of Birth in Past Herds: A Reference Set of Sheep Enamel Stable Oxygen Isotope Ratios. – *Archaeometry*, **54**/2: 349–368. doi: 10.1111/j.1475-4754.2011.00624.x.

BALASSE, M., SMITH, A.B., AMBROSE, S.H. & LEIGH, S.R. (2003): Determining Sheep Birth Seasonality by Analysis of Tooth Enamel Oxygen Isotope Ratios: The Late Stone Age Site of Kasteelberg (South Africa). – *Journal of Archaeological Science*, **30**/2: 205–215. doi: 10.1006/jasc.2002.0833.

BALBÍN-BEHRMANN, R. DE, ALCOLEA-GONZÁLEZ, J. & GONZÁLEZ PEREDA, M.A. (2003): El Macizo de Ardines, un lugar mayor del arte paleolítico europeo. – In: El Arte Prehistórico desde los incios del siglo XXI. Primer Symposium Internacional de Arte Prehistórico de Ribadesella. – pp. 91–151, Ribadesella (Asociación Cultural de Amigos de Ribadesella. Asturias).

BALDEÓN, A. (1993): El yacimiento de Lezetxiki (Gipuzkoa, País Vasco): los niveles musterienses. – *El yacimiento de Lezetxiki (Gipuzkoa, País Vasco): los niveles musterienses*, **45**: 3–97.

BALLARD, W.B. (1995): Bone Marrow Fat as an Indicator of Ungulate Condition-How Good is it? – *Alces*, **31**: 105–109.

BAMFORTH, D.B., BECKER, M. & HUDSON, J. (2005): Intrasite Spatial Analysis, Ethnoarchaeology, and Paleoindian Land-Use on the Great Plains: The Allen Site. – *American Antiquity*, **70**/03: 561–580. doi: 10.2307/40035314.

BANKS, W.E., AUBRY, T., D'ERRICO, F., ZILHÃO, J., LIRA-NORIEGA, A. & TOWNSEND PETERSON, A. (2011): Eco-cultural niches of the Badegoulian: Unraveling links between cultural adaptation and ecology during the Last Glacial Maximum in France. – *Journal of Anthropological Archaeology*, **30**/3: 359–374. doi: 10.1016/j.jaa.2011.05.003.

BANKS, W.E., D'ERRICO, F., PETERSON, A.T., KAGEYAMA, M., SIMA, A. & SÁNCHEZ-GOÑI, M.-F. (2008): Neanderthal Extinction by Competitive Exclusion. – *PLoS ONE*, **3**/12: e3972. doi: 10.1371/journal.pone.0003972.

BANKS, W.E., D'ERRICO, F. & ZILHÃO, J. (2012): Human climate interaction during the Early Upper Paleolithic: testing the hypothesis of an adaptive shift between the Proto-Aurignacian and the Early Aurignacian. – *Journal of Human Evolution*, **30**/1: e17.

BANKS, W.E., ZILHÃO, J., D'ERRICO, F., KAGEYAMA, M., SIMA, A. & RONCHITELLI, A. (2009): Investigating links between ecology and bifacial tool types in Western Europe during the Last Glacial Maximum. – *Journal of Archaeological Science*, **36**/12: 2853–2867. doi: 10.1016/j.jas.2009.09.014.

BAÑULS-CARDONA, S., LÓPEZ-GARCÍA, J.M., BLAIN, H.-A., LOZANO-FERNÁNDEZ, I. & CUENCA-BESCÓS, G. (2014): The end of the Last Glacial Maximum in the Iberian Peninsula characterized by the small-mammal assemblages. – *Journal of Iberian Geology*, **40**/1. doi: 10.5209/rev_JIGE.2014.v40.n1.44085.

BARANDIARÁN, J.M. (1953): El hombre prehistórico en el País Vasco. – 280 pp. (Editorial Vasca Ekin).

BARANDIARÁN, J.M. (1978): Excavaciones en el Abrigo de Silibranka (Mañaria, Vizcaya). – *Kobie. Revista de Ciencias Bilbao*, **8**: 5–101.

BARANDIARÁN-MAESTU, I. (1967): 4. Ensayo de sistematizacion tipologica de las industrias oseas Paleomesoliticas. – In: El paleomesolitico del pirineo occidental: base para una sistematización tipológica del instrumental oseo paleolítico. – pp. 283–380, (Seminario de Prehistoria y Protohistoria, Facultad de Filosofía y Letras).

BARANDIARÁN-MAESTU, I. (1996): Le Paléolithique supérieur au Pays Basque et dans le bassin de l'Ebre (1990-1995). – In: Le Paléolithique supérieur européeen : Bilan quinquennal 1991-1996 ; [Congrès de Forli, Sept. 1996]. – pp. 319–322,.

BARANDIARÁN-MAESTU, I., FREEMAN, L.G., GONZÁLEZ-ECHEGARAY, J. & KLEIN, R.G. (eds) (1985): Excavaciones en la Cueva Del Juyo. – Madrid (Dirrecion general de bellas Artes, Archivos y Bibliotecas).

BARBOUR, M.M. (2007): Stable oxygen isotope composition of plant tissue: a review. – *Functional Plant Biology*, **34**/2: 83–94. doi: 10.1071/FP06228.

BAR-OZ, G. & MUNRO, N.D. (2007): Gazelle bone marrow yields and Epipalaeolithic carcass exploitation strategies in the southern Levant. – *Journal of Archaeological Science*, **34**/6: 946–956. doi: 10.1016/j.jas.2006.09.006.

BARQUÍN, R.M., EXPÓSITO, J.M.M. & FERNÁNDEZ, E.M. (2005): Cueva Urdiales: (Castro Urdiales, Cantabria) : estudio geo-arqueológico y arte rupestre paleolítico. – Castro Urdiales (Concejalía de Medio Ambiente y Patrimonio Arqueológico).

BARRETT, J.H. (1993): Bone weight, meat yield estimates and cod (Gadus morhua): a preliminary study of the weight method. – *International Journal of Osteoarchaeology*, **3**/1: 1–18.

BARSKY, D., GARCIA, J., MARTÍNEZ, K., SALA, R., ZAIDNER, Y., CARBONELL, E. & TORO-MOYANO, I. (2013): Flake modification in European Early and Early–Middle Pleistocene stone tool assemblages. – *Quaternary International*, **316**: 140–154. doi: 10.1016/j.quaint.2013.05.024.

BARTON, C.M. & JOAN BERNABEU AUBÁN (1999): Landscape dynamics and socioeconomic change: an example from the Polop Alto valley. – *American Antiquity*, **64**: 609–634.

BARTON, C.M., RIEL-SALVATORE, J., ANDERIES, J.M. & POPESCU, G. (2011): Modeling Human Ecodynamics and Biocultural Interactions in the Late Pleistocene of Western Eurasia. – *Human Ecology*, **39**/6: 705–725. doi: 10.1007/s10745-011-9433-8.

BARTON, C.M., ULLAH, I.I. & BERGIN, S. (2010): Land use, water and Mediterranean landscapes: modelling long-term dynamics of complex socio-ecological systems. – *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, **368**/1931: 5275–5297. doi: 10.1098/rsta.2010.0193.

BARTRAM, L.E., KROLL, E.M. & BUNN, H.T. (1991): Chapter 4: Variability in camp structure and bone food refuse patterning at Kua San hunter-gatherer camps. – In: KROLL, E.M. & DOUGLAS PRICE, T. (eds): The Interpretation of Archaeological Spatial Patterning. – pp. 77–148, (Springer).

BAR-YOSEF, O., VAN PEER, P., BLEED, P., CONARD, N.J., DAVIDSON, I., DE BEAUNE, S.A., MONNIER, G., POPE, M., SHOTT, M. & BAR-YOSEF, O. (2009): The chaîne opératoire approach in Middle Paleolithic archaeology. – *Current Anthropology*, **50**/1: 103–131.

BAXTER, M.J., BEARDAH, C.C. & WRIGHT, R.V.S. (1997): Some Archaeological Applications of Kernel Density Estimates. – *Journal of Archaeological Science*, **24**/4: 347–354.

BECKER, D., DE ANDRÉS-HERRERO, M., WILLMES, C., WENIGER, G.-C. & BARETH, G. (2017): Investigating the Influence of Different DEMs on GIS-Based Cost Distance Modeling for Site Catchment Analysis of Prehistoric Sites in Andalusia. – *ISPRS International Journal of Geo-Information*, **6**/2: 36 (Multidisciplinary Digital Publishing Institute). doi: 10.3390/ijgi6020036.

BECKER, D., VERHEUL, J., ZICKEL, M. & WILLMES, C. (2015): LGM paleoenvironment of Europe - Map. – *CRC806-Database*. . doi: 10.5880/SFB806.15.

BEHRENSMEYER, A.K. (1978): Taphonomic and ecologic information from bone weathering. – *Paleobiology*, **4**: 150–162.

BEHRENSMEYER, A.K., DENYS, C. & BRUGAL, J.-P. (2018): What is taphonomy and What is not? – *Historical Biology*, **30**/6: 718–719. doi: 10.1080/08912963.2018.1432919.

BEHRENSMEYER, A.K., GORDON, K.D. & YANAGI, G.T. (1986): Trampling as a cause of bone surface damage and pseudo-cutmarks. – *Nature*, **319**/6056: 768–771 (Springer).

BELLO, S.M., PARFITT, S.A. & STRINGER, C.B. (2011): Earliest Directly-Dated Human Skull-Cups. – *PLoS ONE*, **6**/2. doi: 10.1371/journal.pone.0017026.

BENAZZI, S., DOUKA, K., FORNAI, C., BAUER, C.C., KULLMER, O., SVOBODA, J., PAP, I., MALLEGNI, F., BAYLE, P., COQUERELLE, M., CONDEMI, S., RONCHITELLI, A., HARVATI, K. & WEBER, G.W. (2011): Early dispersal of modern humans in Europe and implications for Neanderthal behaviour. – *Nature*, **479**/7374: 525–8. doi: 10.1038/nature10617.

BENDREY, R., VELLA, D., ZAZZO, A., BALASSE, M. & LEPETZ, S. (2015): Exponentially decreasing tooth growth rate in horse teeth: implications for isotopic analyses: Exponentially decreasing tooth growth rate in horse teeth. – *Archaeometry*, **57**/6: 1104–1124. doi: 10.1111/arcm.12151.

BENJAMIN, J., ROVERE, A., FONTANA, A., FURLANI, S., VACCHI, M., INGLIS, R.H., GALILI, E., ANTONIOLI, F., SIVAN, D., MIKO, S., MOURTZAS, N., FELJA, I., MEREDITH-WILLIAMS, M., GOODMAN-TCHERNOV, B., KOLAITI, E., ANZIDEI, M. & GEHRELS, R. (2017): Late Quaternary sea-level changes and early human societies in the central and eastern Mediterranean Basin: An interdisciplinary review. – *Quaternary International*, **449**: 29–57. doi: 10.1016/j.quaint.2017.06.025.

BENTLEY, R.A. (2006): Strontium Isotopes from the Earth to the Archaeological Skeleton: A Review. – *Journal of Archaeological Method and Theory*, **13**/3: 135–187. doi: 10.1007/s10816-006-9009-x.

BERGADÀ, M.M., VILLAVERDE, V. & ROMÁN, D. (2013): Microstratigraphy of the Magdalenian sequence at Cendres Cave (Teulada-Moraira, Alicante, Spain): Formation and diagenesis. – *Quaternary International*, **315**: 56–75. doi: 10.1016/j.quaint.2013.09.017.

BERGANZA, E. & ARRIBAS, J.L. (1994): Características de las ocupaciones del yacimiento de Laminak II (Berriatua, Bizkaia). – *Kobie Paleoantropol.*, **21**: 243–253.

BERNALDO DE QUIRÓS, F. (1982): Los inicios del Paleolítico superior cantábrico. Edición: 1. – 347 pp. Madrid (Ministerio de Educación, Cultura y Deporte. Área de Cultura).

BERNALDO DE QUIRÓS, F. (1992): Estrategias económicas en el Pleistoceno Superior de la Región Cantábrica. – *Elefantes, ciervos y ovicaprinos: economía y aprovechamiento del medio en la Prehistoria de España y Portugal:[ponencias presentadas al seminario realizado en Laredo entre los días 9 y 12 de septiembre de 1991 en el marco de los Cursos de Verano de la Universidad de Cantabria]*, **15**.

BERNALDO DE QUIRÓS, F. & MAÍLLO-FERNÁNDEZ, J.M. (2009): The transitional Aurignacian and the middle-upper palaeolithic transition model in Cantabrian Iberia. – In: Sourcebook of Paleolithic Transitions. – pp. 341–359, New York (Springer).

BERNALDO DE QUIRÓS, F., MAÍLLO-FERNÁNDEZ, J.-M., CASTAÑOS, P. & NEIRA, A. (2015): The Gravettian of El Castillo revisited (Cantabria, Spain). – *Quaternary International*, **359–360**: 462–478. doi: 10.1016/j.quaint.2014.07.060.

BETTINGER, R.L. (1991): Hunter-Gatherers: Archaeological and Evolutionary Theory. – 284 pp. (Springer Science & Business Media).

BETTINGER, R.L. (2009): Hunter-gatherer Foraging: Five Simple Models. – 111 pp. (Eliot Werner Publications).

BETTINGER, R.L. & BAUMHOFF, M.A. (1982): The Numic Spread: Great Basin Cultures in Competition. – *American Antiquity*, **47**/03: 485–503. doi: 10.2307/280231.

BEVAN, A., CREMA, E., LI, X. & PALMISANO, A. (2013): Intensities, interactions and uncertainties: some new approaches to archaeological distributions. – In: Computational Approaches to Archaeological Spaces. – pp. 27–52, (Walnut Creek: Left Coast Press.).

BICHO, N., CARVALHO, A.F., GONZÁLEZ-SAINZ, C., SANCHIDRIÁN, J.L., VILLAVERDE, V. & STRAUS, L.G. (2007): The Upper Paleolithic Rock Art of Iberia. – *Journal of Archaeological Method and Theory*, **14**/1: 81–151. doi: 10.1007/s10816-007-9025-5.

BICHO, N., CASCALHEIRA, J., MARREIROS, J. & PEREIRA, T. (2017): Rapid climatic events and long term cultural change: The case of the Portuguese Upper Paleolithic. – *Quaternary International*, **428**: 3–16. doi: 10.1016/j.quaint.2015.05.044.

BICHO, N. & HAWS, J.A. (2012): The Magdalenian in central and southern Portugal: Human ecology at the end of the Pleistocene. – *Quaternary International*, **272–273**: 6–16. doi: 10.1016/j.quaint.2012.02.055.

BICHO, N., HAWS, J.A. & HOCKETT, B. (2006): Two sides of the same coin—rocks, bones and site function of Picareiro Cave, central Portugal. – *Journal of Anthropological Archaeology*, **25**/4: 485–499. doi: 10.1016/j.jaa.2006.03.009.

BICHO, N., MANNE, T., MARREIROS, J., CASCALHEIRA, J., PEREIRA, T., TÁTÁ, F., ÉVORA, M., GON\CCALVES, C. & INFANTINI, L. (2013): The ecodynamics of the first modern humans in Southwestern Iberia: The case of Vale Boi, Portugal. – *Quaternary International*, **318**: 102–116.

BICHO, N., MARREIROS, J., CASCALHEIRA, J., PEREIRA, T. & HAWS, J. (2015): Bayesian modeling and the chronology of the Portuguese Gravettian. – *Quaternary International*, **359–360**: 499–509. doi: 10.1016/j.quaint.2014.04.040.

BINFORD, E.M. (2007): Dynamics of land use among Maya of Southern Belize. – PhD Thesis: 222 (University of Florida).

BINFORD, L.R. (1962): Archaeology as Anthropology. – *American Antiquity*, **28**/02: 217–225. doi: 10.2307/278380.

BINFORD, L.R. (1968): Chapter 16: Post-Pleistocene adaptations. – In: Archaeology in Cultural Systems. Reprint. – pp. 313–341, Chicago (Routledge).

BINFORD, L.R. (1978): Dimensional Analysis of Behavior and Site Structure: Learning from an Eskimo Hunting Stand. – *American Antiquity*, **43**/3: 330–361. doi: 10.2307/279390.

BINFORD, L.R. (1980): Willow Smoke and Dogs' Tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formation. – *American Antiquity*, **45**/1: 4–20. doi: 10.2307/279653.

BINFORD, L.R. (1981a): Bones: ancient men and modern myths. – 320 pp. New York (Academic Press).

BINFORD, L.R. (1981b): Behavioral archaeology and the" Pompeii premise". – *Journal of anthropological research*, **37**/3: 195–208.

BINFORD, L.R. (1983): In pursuit of the past. Decoding the Archaeological record. – 256 pp. New York (Thames & Hudson).

BINFORD, L.R. (1984): Butchering, sharing, and the archaeological record. – *Journal of Anthropological Archaeology*, **3**/3: 235–257. doi: 10.1016/0278-4165(84)90003-5.

BINFORD, L.R. (1985): Human ancestors: Changing views of their behavior. – *Journal of Anthropological Archaeology*, **4**/4: 292–327. doi: 10.1016/0278-4165(85)90009-1.

BINFORD, L.R. (2001): Constructing frames of reference: an analytical method for archaeological theory building using ethnographic and environmental data sets. – 584 pp. (Univ of California Press).

BINFORD, L.R. (2009): Debating Archaeology. – 556 pp. (Routledge). doi: 10.4324/9781315430652.

BINFORD, L.R. (2012): Nunamiut ethnoarchaeology. Reprint of Academic Press edition from 1978. – 509 pp. Clinton Corners, N.Y (Percheron Press).

BINFORD, L.R. & BERTRAM, J.B. (1977): Bone frequencies and attritional processes. – In: For theory building in archaeology. – pp. 77–153, San Diego (Academic Press).

BIRD, M.I., BOOBYER, E.M., BRYANT, C., LEWIS, H.A., PAZ, V. & STEPHENS, W.E. (2007): A long record of environmental change from bat guano deposits in Makangit Cave, Palawan, Philippines. – *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, **98**/1: 59–69. doi: 10.1017/S1755691007000059.

BISCHOFF, J., GARCÍA DÍEZ, M. & GONZÁLEZ-MORALES, M.R. (2003): Aplicación del método de series de Uranio al grafismo rupestre de estilo paleolítico: el caso de la cavidad de Covalanas (Ramales de la Victoria, Cantabria). – *Veleia: Revista de prehistoria, historia antigua, arqueología y filología clásicas*/20: 143–150.

BLAISE, E. & BALASSE, M. (2011): Seasonality and season of birth of modern and late Neolithic sheep from south-eastern France using tooth enamel $\delta^{18}O$ analysis. – *Journal of Archaeological Science*, **38**/11: 3085–3093. doi: 10.1016/j.jas.2011.07.007.

BLANKHOLM, H.P. (1991): Intrasite spatial analysis in theory and practice. – (Aarhus University Press).

BLASCO, R., DOMÍNGUEZ-RODRIGO, M., ARILLA, M., CAMARÓS, E. & ROSELL, J. (2014): Breaking Bones to Obtain Marrow: A Comparative Study between Percussion by Batting Bone on an Anvil and Hammerstone

Percussion: Breaking bones to obtain marrow. – *Archaeometry*, **56**/6: 1085–1104. doi: 10.1111/arcm.12084.

BLASCO, R., FERNÁNDEZ PERIS, J. & ROSELL, J. (2010): Several different strategies for obtaining animal resources in the late Middle Pleistocene: The case of level XII at Bolomor Cave (Valencia, Spain). – *Comptes Rendus Palevol*, **9**/4: 171–184. doi: 10.1016/j.crpv.2010.05.004.

BLASCO, R., ROSELL, J., SAÑUDO, P., GOPHER, A. & BARKAI, R. (2016): What happens around a fire: Faunal processing sequences and spatial distribution at Qesem Cave (300 ka), Israel. – *Quaternary International*, **398**: 190–209. doi: 10.1016/j.quaint.2015.04.031.

BLASCO-SANCHO, M.F. (1992): Tafonomía y prehistoria: métodos y procedimientos de investigación. – 254 pp. Universidad de Zaragoza (Departamento de Ciencias de la Antigüedad (Prehistoria)).

BLONDIAUX, J. & CHARLIER, P. (2008): Palaeocytology in skeletal remains: microscopic examination of putrefaction fluid deposits and dental calculus of skeletal remains from French archaeological sites. – *International Journal of Osteoarchaeology*, **18**/1: 1–10. doi: 10.1002/oa.931.

BLUMENSCHINE, R.J. (1995): Percussion marks, tooth marks, and experimental determinations of the timing of hominid and carnivore access to long bones at FLK Zinjanthropus, Olduvai Gorge, Tanzania. – *Journal of Human Evolution*, **29**/1: 21–51. doi: 10.1006/jhev.1995.1046.

BLUMENSCHINE, R.J., MAREAN, C.W. & CAPALDO, S.D. (1996): The Identification of Cut Marks , Percussion Marks , and Carnivore Tooth Marks on Bone Surfaces. – : 493–507.

BLUMENSCHINE, R.J. & SELVAGGIO, M.M. (1988a): Percussion marks on bone surfaces as a new diagnostic of human behaviour. – *Nature*, **333**: 763–765.

BLUMENSCHINE, R.J. & SELVAGGIO, M.M. (1988b): Percussion marks on bone surfaces as a new diagnostic of hominid behaviour. – *Nature*, **333**/6175: 763–765. doi: 10.1038/333763a0.

BLUMENTHAL, S.A., CERLING, T.E., CHRITZ, K.L., BROMAGE, T.G., KOZDON, R. & VALLEY, J.W. (2014): Stable isotope time-series in mammalian teeth: In situ $\delta^{18}O$ from the innermost enamel layer. – *Geochimica et Cosmochimica Acta*, **124**: 223–236. doi: 10.1016/j.gca.2013.09.032.

BOBROWSKY, P.T. (1982): Olsen and Olsen's Identity Crisis in Faunal Studies. – *American Antiquity*, **47**/01: 180–183. doi: 10.2307/280068.

BOCHERENS, H. (2003): Isotopic biogeochemistry and the paleoecology of the mammoth steppe fauna. – *Deinsea*, **9**: 57–76.

BOCHERENS, H. (2009): Neanderthal dietary habits: review of the isotopic evidence. – In: The evolution of Hominin diets. – pp. 241–250, (Springer).

BOCHERENS, H., FIZET, M. & MARIOTTI, A. (1994): Diet, physiology and ecology of fossil mammals as inferred from stable carbon and nitrogen isotope biogeochemistry: implications for Pleistocene bears. – *Palaeogeography, Palaeoclimatology, Palaeoecology*, **107**/3–4: 213–225. doi: 10.1016/0031-0182(94)90095-7.

BOCHERENS, H., FOGEL, M.L., TUROSS, N. & ZEDER, M. (1995): Trophic Structure and Climatic Information From Isotopic Signatures in Pleistocene Cave Fauna of Southern England. – *Journal of Archaeological Science*, **22**/2: 327–340. doi: 10.1006/jasc.1995.0035.

BOSCH, M.D., NIGST, P.R., FLADERER, F.A. & ANTL-WEISER, W. (2012): Humans, bones and fire: Zooarchaeological, taphonomic, and spatial analyses of a Gravettian mammoth bone accumulation at Grub-

Kranawetberg (Austria). – *Quaternary International*, **252**: 109–121. doi: 10.1016/j.quaint.2011.08.019.

BOSSELIN, B. & DJINDJIAN, F. (1997): Une révision du Solutréen de Laugerie-Haute et le problème des transitions Gravettien-Solutréen et Solutréen-Badegoulien en Aquitaine. – *Bulletin de la Société préhistorique française*, **94**/4: 443–454.

BOSSELIN, B. & DJINDJIAN, F. (1999): Une révision de la séquence de la Riera (Asturies) et la question du Badegoulien cantabrique. – *Bulletin de la Société préhistorique française*, **96**/2: 153–173. doi: 10.3406/bspf.1999.10939.

BOSSELIN, B. & DJINDJIAN, F. (2000): La question du Badegoulien cantabrique : réponse à L.G. Straus et G.A. Clark. – *Bulletin de la Société préhistorique française*, **97**/2: 297–301.

BOYD, W.E., LENTFER, C.J. & TORRENCE, R. (1998): Phytolith analysis for a wet tropics environment: methodological issues and implications for the archaeology of Garua Island, West New Britain, Papua New Guinea. – *Palynology*, **22**/1: 213–228.

BRADTMÖLLER, M. (2014): Höhlenlager des Gravettien. Muster jungpaläolithischer Höhlennutzung am Beispiel des Gravettien Nordspaniens. – Diss.: Hamburg (Verlag Dr. Kovac).

BRADTMÖLLER, M., GRIMM, S. & RIEL-SALVATORE, J. (2017): Resilience theory in archaeological practice – An annotated review. – *Quaternary International*, **446**: 3–16. doi: 10.1016/j.quaint.2016.10.002.

BRADTMÖLLER, M., MARREIROS, J., PEREIRA, T. & BICHO, N. (2016): Lithic technological adaptation within the Gravettian of the Iberian Atlantic region: Results from two case studies. – *Quaternary International*, **406**/Part A: 3–24. doi: 10.1016/j.quaint.2015.08.075.

BRADTMÖLLER, M., PASTOORS, A., WENINGER, B. & WENIGER, G.-C. (2012): The repeated replacement model – Rapid climate change and population dynamics in Late Pleistocene Europe. – *Quaternary International*, **247**: 38–49. doi: 10.1016/j.quaint.2010.10.015.

BRAIN, C.K. (1981): The hunters or the hunted?: An introduction to African cave taphonomy. – 365 pp. (University of Chicago Press).

BRÄUER, L. (2006): Sobotta Lernkarten - Spielend durch die Anatomie. – München (Urban & Fischer Verlag/Elsevier GmbH).

BRAUN, D.R., HARRIS, J.W.K., LEVIN, N.E., MCCOY, J.T., HERRIES, A.I.R., BAMFORD, M.K., BISHOP, L.C., RICHMOND, B.G. & KIBUNJIA, M. (2010): Early hominin diet included diverse terrestrial and aquatic animals 1.95 Ma in East Turkana, Kenya. – *Proceedings of the National Academy of Sciences of the United States of America*, **107**/22: 10002–7. doi: 10.1073/pnas.1002181107.

BRESLAWSKI, R.P. & PLAYFORD, T. (2018): Probabilistic models of seasonal Bison exploitation based on fetal prey osteometry and reproductive phenology. – *Archaeological and Anthropological Sciences*, **10**/8: 1851–1866 (Springer).

BREUIL, H. & OBERMAIER, H. (1935): The cave of Altamira at Santillana del Mar, Spain. – Madrid (Tipografía de Archivos).

BRICKER, H.M., MELLARS, P. & PETERKIN, G.L. (1993): Introduction: The Study of Palaeolithic and Mesolithic Hunting. – *Archeological Papers of the American Anthropological Association*, **4**/1: 1–9.

BRINK, J.W. (1997): Fat Content in Leg Bones of Bison bison, and Applications to Archaeology. – *Journal of Archaeological Science*, **24**/3: 259–274. doi: 10.1006/jasc.1996.0109.

BRITTON, K., GRIMES, V., DAU, J. & RICHARDS, M.P. (2009): Reconstructing faunal migrations using intra-tooth sampling and strontium and oxygen isotope analyses: a case study of modern caribou (Rangifer tarandus granti). – *Journal of Archaeological Science*, **36**/5: 1163–1172. doi: 10.1016/j.jas.2009.01.003.

BRITTON, K., GRIMES, V., NIVEN, L., STEELE, T.E., MCPHERRON, S., SORESSI, M., KELLY, T.E., JAUBERT, J., HUBLIN, J.-J. & RICHARDS, M.P. (2011): Strontium isotope evidence for migration in late Pleistocene Rangifer: Implications for Neanderthal hunting strategies at the Middle Palaeolithic site of Jonzac, France. – *Journal of Human Evolution*, **61**/2: 176–185. doi: 10.1016/j.jhevol.2011.03.004.

BROUGHTON, J.M. (1994): Late Holocene Resource Intensification in the Sacramento Valley, California: The Vertebrate Evidence. – *Journal of Archaeological Science*, **21**/4: 501–514. doi: 10.1006/jasc.1994.1050.

BROWN, W.A.B. & CHAPMAN, N.G. (1991a): The dentition of red deer (Cervus elaphus): a scoring scheme to assess age from wear of the permanent molariform teeth. – *Journal of Zoology*, **224**/4: 519–536. doi: 10.1111/j.1469-7998.1991.tb03783.x.

BROWN, W.A.B. & CHAPMAN, N.G. (1991b): Age assessment of red deer (Cervus elaphus): from a scoring scheme based on radiographs of developing permanent molariform teeth. – *Journal of Zoology*, **225**/1: 85–97.

BRYANT, J.D. & FROELICH, P.N. (1995): A model of oxygen isotope fractionation in body water of large mammals. – *Geochimica et Cosmochimica Acta*, **59**: 4523–4537. doi: 10.1016/0016-7037(95)00250-4.

BRYANT, J.D., KOCH, P.L., FROELICH, P.N., SHOWERS, W.J. & GENNA, B.J. (1996): Oxygen isotope partitioning between phosphate and carbonate in mammalian apatite. – *Geochimica et Cosmochimica Acta*, **60**/24: 5145–5148. doi: 10.1016/S0016-7037(96)00308-0.

BUCHANAN, B., HAMILTON, M.J. & DAVID KILBY, J. (2019): The small-world topology of Clovis lithic networks. – *Archaeological and Anthropological Sciences*, **11**/7: 3537–3548. doi: 10.1007/s12520-018-0767-7.

BUCKLAND, P.C., AMOROSI, T., BARLOW, L.K., DUGMORE, A.J., MAYEWSKI, P.A., MCGOVERN, T.H., OGILVIE, A.E.J., SADLER, J.P. & SKIDMORE, P. (1996): Bioarchaeological and climatological evidence for the fate of Norse farmers in medieval Greenland. – *Antiquity*, **70**/267: 88–96. doi: 10.1017/S0003598X00082910.

BUNN, H.T. (1981): Archaeological evidence for meat-eating by Plio-Pleistocene hominids from Koobi Fora and Olduvai Gorge. – *Nature*, **291**/5816: 574–577. doi: 10.1038/291574a0.

BUNN, H.T. (1986): Patterns of skeletal representation and hominid subsistence activities at Olduvai Gorge, Tanzania, and Koobi Fora, Kenya. – *Journal of Human Evolution*, **15**/8: 673–690.

BUNN, H.T., BARTRAM, L.E. & KROLL, E.M. (1988): Variability in bone assemblage formation from Hadza hunting, scavenging, and carcass processing. – *Journal of Anthropological Archaeology*, **7**/4: 412–457. doi: 10.1016/0278-4165(88)90004-9.

BURGER, O., HAMILTON, M.J. & WALKER, R. (2005): The prey as patch model: optimal handling of resources with diminishing returns. – *Journal of Archaeological Science*, **32**/8: 1147–1158. doi: 10.1016/j.jas.2005.02.012.

BURKE, A. (2006): Introduction to the special issue: "Multidisciplinary approaches to the study of site function and settlement dynamics in prehistory." – *Journal of Anthropological Archaeology*, **25**/4: 403–407. doi: 10.1016/j.jaa.2006.03.001.

BUTZER, K.W. (1982): Archaeology as human ecology: method and theory for a contextual approach. – (Cambridge University Press).

BUTZER, K.W. (1986): Paleolithic adaptations and settlement in Cantabrian Spain. – *Advances in World Archaeology*, **5**/20: l–252 (Academic New York).

BYERS, D.A. & UGAN, A. (2005): Should we expect large game specialization in the late Pleistocene? An optimal foraging perspective on early Paleoindian prey choice. – *Journal of Archaeological Science*, **32**/11: 1624–1640. doi: 10.1016/j.jas.2005.05.003.

CABRERA-VALDÉS, V. (1984): El yacimiento de la cueva de "El Castillo": Puente Viesgo, Santander. – 485 pp. Madrid (Editorial CSIC-CSIC Press).

CABRERA-VALDÉS, V., MAILLO FERNÁNDEZ, J.M., PIKE-TAY, A., GARRALDA BENAJES, M.D. & BERNALDO DE QUIRÓS, F. (2006): A Cantabrian Perspective of late Neanderthals. – In: When Neanderthals and Modern humans met. – pp. 419–439, Tübingen (Kerns Verlag).

CACHO, C. (1999): El poblamiento de la Meseta durante el Paleolítico Superior. – *Arqueología en Castilla y León, Memorias 8*: 237–244.

CACHO, I., GRIMALT, J.O., CANALS, M., SBAFFI, L., SHACKLETON, N.J., SCHÖNFELD, J. & ZAHN, R. (2001): Variability of the western Mediterranean Sea surface temperature during the last 25,000 years and its connection with the Northern Hemisphere climatic changes. – *Paleoceanography*, **16**/1: 40–52. doi: 10.1029/2000PA000502.

CAHEN, D. (1987): Refitting stone artefacts: why bother. – In: SIEVEKING, A. & NEWCOMER, M.H. (eds): The Human Uses of Flint and Chert: Proceedings of the Fourth International Flint Symposium Held at Brighton Polytechnic 10–15 April 1983. – pp. 1–9, Cambridge (Cambridge University Press).

CAIN, C.R. (2005): Using burned animal bone to look at Middle Stone Age occupation and behavior. – *Journal of Archaeological Science*, **32**/6: 873–884.

CALVO, A. (2012): El yacimiento gravetiense al aire libre de Ametzagaina (Donostia, País Vasco). Los tecnocomplejos líticos del Conjunto Oeste. – *CKQ - Estudios de Cuaternario / Kuaternario Ikasketak / Quaternary Studies*: 15–32.

CALVO, A. & PRIETO, A. (2013): El final del Gravetiense y el comienzo del Solutrense en la Península Ibérica. Un estado de la cuestión acerca de la cronología radiocarbónica en 2012. – *Espacio Tiempo y Forma. Serie I, Prehistoria y Arqueología*, **5**. doi: 10.5944/etf i.5.5377.

CAMARÓS, E., MÜNZEL, S.C., CUETO, M., RIVALS, F. & CONARD, N.J. (2016): The evolution of Paleolithic hominin–carnivore interaction written in teeth: Stories from the Swabian Jura (Germany). – *Journal of Archaeological Science: Reports*, **6**: 798–809 (Elsevier).

CAMPANA, D.V. & CRABTREE, P. (2019): Evidence for skinning and craft activities from the Middle Paleolithic of Shanidar Cave, Iraq. – *Journal of Archaeological Science: Reports*, **25**: 7–14. doi: 10.1016/j.jasrep.2019.03.024.

CANNON, M.D. (2000): Large Mammal Relative Abundance in Pithouse and Pueblo Period Archaeofaunas from Southwestern New Mexico: Resource Depression among the Mimbres-Mogollon? – *Journal of Anthropological Archaeology*, **19**/3: 317–347. doi: 10.1006/jaar.2000.0366.

CANNON, M.D. (2003): A model of central place forager prey choice and an application to faunal remains from the Mimbres Valley, New Mexico. – *Journal of Anthropological Archaeology*, **22**/1: 1–25. doi: 10.1016/S0278-4165(03)00002-3.

CANNON, M.D. (2013): NISP, Bone Fragmentation, and the Measurement of Taxonomic Abundance. – *Journal of Archaeological Method and Theory*, **20**/3: 397–419. doi: 10.1007/s10816-012-9166-z.

CAPALDO, S.D. & BLUMENSCHINE, R.J. (1994): A Quantitative Diagnosis of Notches Made by Hammerstone Percussion and Carnivore Gnawing on Bovid Long Bones. – *American Antiquity*, **59**/04: 724–748. doi: 10.2307/282345.

CARBONELL, E., BERMUDEZ DE CASTRO, J., ARSUAGA, J., DIEZ, J., ROSAS, A., CUENCA-BESCOS, G., SALA, R., MOSQUERA, M. & RODRIGUEZ, X. (1995): Lower Pleistocene hominids and artifacts from Atapuerca-TD6 (Spain). – *Science*, **269**/5225: 826–830. doi: 10.1126/science.7638598.

CARBONELL, E., MOSQUERA, M., RODRÍGUEZ, X.P. & SALA, R. (1996): The First Human Settlement of Europe. – *Journal of Anthropological Research*, **52**/1: 107–114. doi: 10.1086/jar.52.1.3630238.

CARBONELL, E. & RODRÍGUEZ, X.P. (1999): Atapuerca y la evolución biológica y cultural de los humanos. – *Enseñanza de las Ciencias de la Tierra*, **7**/2: 112–120.

CARRANZA, J. (2011): Ciervo–Cervus elaphus Linnaeus, 1758. – *Enciclopedia Virtual de los Vertebrados Españoles.* Retrieved May 27, 2013, from http://vertebradosibericos.org.

CARRETERO, J.M., QUAM, R.M., GÓMEZ-OLIVENCIA, A., CASTILLA, M., RODRÍGUEZ, L. & GARCÍA-GONZÁLEZ, R. (2015): The Magdalenian human remains from El Mirón Cave, Cantabria (Spain). – *Journal of Archaeological Science*, **60**: 10–27. doi: 10.1016/j.jas.2015.03.026.

CARRIÓN, J.S. (2012): Paleoflora y paleovegetación de la Península Ibérica e Islas Baleares: Plioceno-Cuaternario. – Madrid (Ministerio de Economía y Competitividad).

CARRIÓN, J.S., FERNÁNDEZ, S., GONZÁLEZ-SAMPÉRIZ, P., GIL-ROMERA, G., BADAL, E., CARRIÓN-MARCO, Y., LÓPEZ-MERINO, L., LÓPEZ-SÁEZ, J.A., FIERRO, E. & BURJACHS, F. (2010): Expected trends and surprises in the Lateglacial and Holocene vegetation history of the Iberian Peninsula and Balearic Islands. – *Review of Palaeobotany and Palynology*, **162**/3: 458–475. doi: 10.1016/j.revpalbo.2009.12.007.

CARRIÓN, J.S., YLL, E.I., WALKER, M.J., LEGAZ, A.J., CHAÍN, C. & LÓPEZ, A. (2003): Glacial refugia of temperate, Mediterranean and Ibero-North African flora in south-eastern Spain: new evidence from cave pollen at two Neanderthal man sites. – *Global Ecology and Biogeography*, **12**/2: 119–129.

CARRIÓN SANTAFÉ, E. & BAENA PREYSLER, J. (1998): Breves anotaciones sobre la colección Musteriense de la Cueva de Las Monedas (Puente Viesgo, Cantabria), depositada en el Museo Regional de Prehistoria y Arqueología de Santander. – (Universidad Autónoma de Madrid).

CARTAILHAC, É. (1902): Mea culpa d'un sceptique. – *L'Anthropologie*, **13**: 348–354.

CARVALHO, M., PEIREIRA, T. & MANSO, C. (2018): Rabbit exploitation in the Middle Paleolithic at Gruta Nova da Columbeira, Portugal. – *Journal of Archaeological Science: Reports*, **21**: 821–832. doi: 10.1016/j.jasrep.2018.09.003.

CASCALHEIRA, J. & BICHO, N. (2013): Hunter–gatherer ecodynamics and the impact of the Heinrich event 2 in Central and Southern Portugal. – *Quaternary International*, **318**: 117–127. doi: 10.1016/j.quaint.2013.05.039.

CASTANEDO, A.G., GRANDELA, A.M.C., COLLADO, F.S., CUENCA, E.G. & GANCEDO, M.L.S. (2006): El registro arqueológico de la cueva de La Luz: nuevas aportaciones. – *Sautuola: Revista del Instituto de Prehistoria y Arqueología Sautuola*, **12**: 75–88.

CASTAÑOS, J., ZULUAGA, M.C., ORTEGA, L.Á., MURELAGA, X., ALONSO-OLAZABAL, A., ROFES, J. & CASTAÑOS, P. (2014): Carbon and nitrogen stable isotopes of bone collagen of large herbivores from the Late Pleistocene Kiputz IX cave site (Gipuzkoa, north Iberian Peninsula) for palaeoenvironmental reconstruction. – *Quaternary International*, **339–340**: 131–138. doi: 10.1016/j.quaint.2013.10.006.

CASTAÑOS, P. (1980): La Macrofauna de la Cueva de La Paloma (Pleistoceno Terminal de Asturias). – In: La Cueva de La Paloma. Soto de las regueras (Asturias). Excavaciones Arqueológicas en España. – pp. 65–100, (Dirrecion general de bellas Artes, Archivos y Bibliotecas).

CASTAÑOS, P. (1982): Estudio de los micromamíferos del yacimiento prehistórico de >>Cueto de la Mina<<. – In: Cueto de la Mina "(Asturias)". Boletín del Inst. de Estudios Asturianos. – pp. 43–86,.

CASTAÑOS, P. (1986): Los Macromamíferos del Pleistoceno y Holoceno de Vizcaya- Faunas Asociadas a Los Yacimientos Arqueológicos. – Diss.: Lejona (Universidad de País Vasco).

CASTAÑOS, P. (1994): Estudio de los macromamíferos de Laminak II. – *Kobie. Paleoantropología*, **21**/21: 173–187.

CASTAÑOS, P. & ALVAREZ-FERNÁNDEZ, E. (2012): Nuevas aportaciones a las bases de subsistencia de origen animal durante el Gravetiense cantábrico. – In: Pensando el Gravetiense: nuevos datos para la región cantábrica en su contexto peninsular y pirenaico. – pp. 313–329, (Ministerio de Educación, Cultura y Deporte).

CASTAÑOS, P. & CASTAÑOS, J. (2007): Estudio de la fauna del Abrigo del Cuco (Capitulo 2). – In: Muñoz, E., Montes, R.(Eds.), Intervenciones arqueológicas en Castro Urdiales. – pp. 161–170, Castro Urdiales (Concejalía de Medio Ambiente y Patrimonio Arqueológico).

CASTAÑOS, P. & CASTAÑOS, J. (2011): Estrategias de caza en la secuencia prehistórica de Santimamiñe. – In: La cueva de Santimamiñe: revisión y actualización (2004-2006). – pp. 197–206,.

CAVA, A., ELORRIETA, I. & BARANDIARÁN-MAESTU, I. (2009): The Gravettian of Alkerdi cave (Urdax, Navarra): analysis and context of the lithic industry. – *Munibe*, **60**: 51–80.

CERLING, T.E. & HARRIS, J.M. (1999): Carbon isotope fractionation between diet and bioapatite in ungulate mammals and implications for ecological and paleoecological studies. – *Oecologia*, **120**/3: 347–363. doi: 10.1007/s004420050868.

CERLING, T.E., HARRIS, J.M. & LEAKEY, M.G. (1999): Browsing and grazing in elephants: the isotope record of modern and fossil proboscideans. – *Oecologia*, **120**/3: 364–374. doi: 10.1007/s004420050869.

CERNUSAK, L.A., BARBOUR, M.M., ARNDT, S.K., CHEESMAN, A.W., ENGLISH, N.B., FEILD, T.S., HELLIKER, B.R., HOLLOWAY-PHILLIPS, M.M., HOLTUM, J.A.M., KAHMEN, A., MCINERNEY, F.A., MUNKSGAARD, N.C., SIMONIN, K.A., SONG, X., STUART-WILLIAMS, H., WEST, J.B. & FARQUHAR, G.D. (2016): Stable isotopes in leaf water of terrestrial plants: Stable isotopes in leaf water. – *Plant, Cell & Environment*, **39**/5: 1087–1102. doi: 10.1111/pce.12703.

CHARNOV, E. & ORIANS, G.H. (1973): Optimal foraging: some theoretical explorations. – 2006 (https://digitalrepository.unm.edu/biol_fsp/45).

CHARNOV, E.L. (1976): Optimal foraging, the marginal value theorem. – *Theoretical population biology*, **9**/2: 129–136.

CHENERY, C.A., PASHLEY, V., LAMB, A.L., SLOANE, H.J. & EVANS, J.A. (2012): The oxygen isotope relationship between the phosphate and structural carbonate fractions of human bioapatite: Relationship

between phosphate and structural carbonate $\delta^{18}O$ in human enamel. – *Rapid Communications in Mass Spectrometry*, **26**/3: 309–319. doi: 10.1002/rcm.5331.

CHURCH, R.R. & LYMAN, R.L. (2003): Small fragments make small differences in efficiency when rendering grease from fractured artiodactyl bones by boiling. – *Journal of Archaeological Science*, **30**/8: 1077–1084. doi: 10.1016/S0305-4403(03)00010-4.

CHURCHILL, S.E. & SMITH, F.H. (2000): Makers of the early Aurignacian of Europe. – *American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropologists*, **113**/S31: 61–115.

CIOCHON, R.L., PIPERNO, D.R. & THOMPSON, R.G. (1990): Opal Phytoliths Found on the Teeth of the Extinct Ape Gigantopithecus blacki: Implications for Paleodietary Studies. – *Proceedings of the National Academy of Sciences of the United States of America*, **87**/20: 8120–8124.

CLARK, G.A. (1971): The Asturian of Cantabria: Subsistence Base and the Evidence for Post-Pleistocene Climatic Shifts1. – *American Anthropologist*, **73**/5: 1244–1257. doi: 10.1525/aa.1971.73.5.02a00220.

CLARK, G.A. (1975): El hombre y su ambiente a principios del Holoceno en la Región Cantábrica. Los cazadoresrecolectores asturienses. – *Boletín del Instituto de Estudios Asturianos*, **84**/5: 362–87.

CLARK, G.A. (1983): Asturian of Cantabria: Early Holocene Hunter-Gatherers in Northern Spain. – Tucson (University of Arizona Press).

CLARK, G.A. (1986): El nicho alimenticio en el norte de España desde el Paleolítico hasta la romanización. – *Trabajos de Prehistoria*/43: 159–184.

CLARK, G.A. & STRAUS, L.G. (1986): Synthesis and conclusions—part I: Upper Paleolithic and Mesolithic hunter-gatherer subsistence in northern Spain. – In: La Riera Cave: Stone Age Hunter-Gatherer Adaptations in northern Spain. – pp. 351–366, Arizona State University (Tempe).

CLARK, G.A. & YI, S. (1983): Niche-width variation in Cantabrian archaeofaunas: a diachronic study. – In: Animals and archaeology. – pp. 183–208, Oxford.

CLARK, J.G.D. (1952): Prehistoric Europe: The economic basis. – New York.

CLARK, J.G.D. (1953): The groove and splinter technique of working reindeer and red deer antler in Upper Palaeolithic and Early Mesolithic Europe. – *Arch. Prehist. Levantina*, **4**: 57–65.

CLARK, J.G.D. (1970): The mesolithic settlement of Northern Europe: a study of the food-gathering peoples of Northern Europe during the early post-glacial period. – 328 pp. (Greenwood Press).

CLARK, P.U., DYKE, A.S., SHAKUN, J.D., CARLSON, A.E., CLARK, J., WOHLFARTH, B., MITROVICA, J.X., HOSTETLER, S.W. & MCCABE, A.M. (2009): The Last Glacial Maximum. – *Science*, **325**/5941: 710–714. doi: 10.1126/science.1172873.

CLARK, P.U. & MIX, A.C. (2002): Ice sheets and sea level of the Last Glacial Maximum. – *Quaternary Science Reviews*, **21**/1–3: 1–7. doi: 10.1016/S0277-3791(01)00118-4.

CLARK, P.U., MIX, A.C. & BARD, E. (2001): Ice sheets and sea level of the Last Glacial Maximum. – *Eos, Transactions American Geophysical Union*, **82**/22: 241–241. doi: 10.1029/01EO00133.

CLARKE, D. (1973): Archaeology: the loss of innocence. – *Antiquity*, **47**/185: 6–18. doi: 10.1017/S0003598X0003461X.

CLARKE, D.L. (1977): Spatial archaeology. – London (Academic Press).

CLEGHORN, N. & MAREAN, C.W. (2004): Distinguishing selective transport and in situ attrition: a critical review of analytical approaches. – *Journal of Taphonomy*, **2**/1: 43–67.

COHEN, M.N. (1977): The Food Crisis in Prehistory: Overpopulation and the Origins of Agriculture. – New Haven (Yale University Press).

COLLINS, M.J., NIELSEN-MARSH, C.M., HILLER, J., SMITH, C.I., ROBERTS, J.P., PRIGODICH, R.V., WESS, T.J., CSAPO, J., MILLARD, A. & TURNER-WALKER, G. (2002): The survival of organic matter in bone: a review. – *Archaeometry*, **44**/3: 383–394. doi: 10.1111/1475-4754.t01-1-00071.

COLONESE, A. C., MANNINO, M. A., BAR-YOSEF MAYER, D.E., FA, D. A., FINLAYSON, J.C., LUBELL, D. & STINER, M.C. (2011): Marine mollusc exploitation in Mediterranean prehistory: An overview. – *Quaternary International*, **239**/1–2: 86–103. doi: 10.1016/j.quaint.2010.09.001.

CONARD, N.J., KITAGAWA, K., KRÖNNECK, P., BÖHME, M. & MÜNZEL, S.C. (eds) (2013): The Importance of Fish, Fowl and Small Mammals in the Paleolithic Diet of the Smabian Jura, Southwestern Germany. – In: Zooarchaeology and Modern Human Origins. – pp. 173–190, Dordrecht (Springer Netherlands).

CONKEY, M.W., BELTRÁN, A., CLARK, G.A., GONZÁLEZ-ECHEGARAY, J., GUENTHER, M.G., HAHN, J., HAYDEN, B., PADDAYYA, K., STRAUS, L.G. & VALOCH, K. (1980): The Identification of Prehistoric Hunter-Gatherer Aggregation Sites: The Case of Altamira [and Comments and Reply]. – *Current Anthropology*, **21**/5: 609–630.

CONSUEGRA, S., GARCÍA DE LEÁNIZ, C., SERDIO, A., GONZÁLEZ-MORALES, M.R., STRAUS, L.G., KNOX, D. & VERSPOOR, E. (2002): Mitochondrial DNA variation in Pleistocene and modern Atlantic salmon from the Iberian glacial refugium. – *Molecular Ecology*, **11**/10: 2037–2048.

COOPER, S.J.B., IBRAHIM, K.M. & HEWITT, G.M. (1995): Postglacial expansion and genome subdivision in the European grasshopper Chorthippus parallelus. – *Molecular Ecology*, **4**/1: 49–60.

COPLEN, T.B., KENDALL, C. & HOPPLE, J. (1983): Comparison of stable isotope reference samples. – *Nature*, **302**/5905: 236–238. doi: 10.1038/302236a0.

CORCHÓN-RODRÍGUEZ, M.S. (1986): El arte paleolítico cantábrico: contexto y analisis interno. First Edition. – 482 pp. Madrid (Ministerio de Cultura, Dirección General de Bellas Artes y Archivos, Subdirección General de Arqueología y Etnografía).

CORCHÓN-RODRÍGUEZ, M.S. (1995): Reflexiones acerca de la cronología del Magdaleniense cantábrico. Las dataciones 14C de la Cueva de Las Caldas (Asturias, España). – *Zephyrus*, **XLVIII**: 3–19.

CORCHÓN-RODRÍGUEZ, M.S. (1999): Solutrean and Magdalenian of the Western Cantabrian Coast: 14C (Calibrated) Datings and cronological framework. – *Zephyrus*, **52**: 3–32.

CORCHÓN-RODRÍGUEZ, M.S. (2000): Le Tardiglaciaire du Plateau Nord de l'Espagne: modèles d'habitat et stratégies de chasse. – *Anthropologie et Préhistoire*, **111**: 249–265.

CORCHÓN-RODRÍGUEZ, M.S. (2002): El Tardiglaciar y la transición al Postglaciar en la Meseta Norte española: una visión de síntesis(reflexiones acerca de las investigaciones realizadas en los últimos 10 años en el territorio de Castilla-León). – *Zephyrus: Revista de prehistoria y arqueología*/55: 85–142.

CORCHÓN-RODRÍGUEZ, M.S. (2012): Contactos extra-cantábricos en el Magdaleniense medio: nuevos datos de la Cueva Las Caldas. – In: Primera Mesa Redonda" El Paleolítico Superior Cantábrico": celebrada del 26 al 28 de abril de 2007 en San Román de Candamo (Asturias). – pp. 113–128, (Universidad de Cantabria).

CORCHÓN-RODRÍGUEZ, M.S. (2015): El origen del Magdaleniense: una cuestión controvertida. La cueva de Las Caldas y los yacimientos del Nalón (Asturias, Norte de España). – *Munibe*, **66**: 053–075. doi: 10.21630/maa.2015.66.03.

CORCHÓN-RODRÍGUEZ, M.S. (2017): La cueva de las Caldas (Priorio, Oviedo): ocupaciones solutrenses, análisis espaciales y arte parietal. – 441 pp. Salamanca (Ediciones Universidad de Salamanca).

CORCHÓN-RODRÍGUEZ, M.S. & ÁLVAREZ-FERNÁNDEZ, E. (2008): New Evidence of Marine Mammal Remains during the Magdalenian: Data from Las Caldas Cave (Asturias, Spain). – *Munibe*, **59**: 47–99.

CORCHÓN-RODRÍGUEZ, M.S., GARATE-MAIDAGAN, D., VALLADAS, H., RIVERO, O., PONS-BRANCHU, E., ORTEGA MARTÍNEZ, P. & HERNANDO ÁLVAREZ, C. (2014): Back to the point: New datings for la Peña de Candamo Cave Art (Asturias) - De vuelta al punto de partida: nuevas dataciones del arte de la cueva de La Peña de Candamo (Asturias). – *Zephyrvs*, **73**/0: 67. doi: 10.14201/zephyrus2014736781.

CORCHÓN-RODRÍGUEZ, M.S. & HOYOS GÓMEZ, M. (1972): La Cueva de Sofoxó (Las Regueras, Asturias). – *Zephyrus: Revista de prehistoria y arqueología*, **23–24**: 64.

CORCHÓN-RODRÍGUEZ, M.S. & RIVERO, O. (2008): Los rodetes del Magdaleniense Medio cántabro-pirenaico: análisis tecnológico y nuevas evidencias de la cueva de Las Caldas (Asturias, España). – *Zephyrus*, **LXI**: 61–84 (Ediciones Universidad de Salamanca (España)).

CORCHÓN-RODRÍGUEZ, M.S., VALLADAS, H., PÉREZ, J.B., ARNOLD, M., TISNERAT, N. & CACHIER, H. (2009): Datación de las pinturas y revisión del Arte Paleolítico de Cueva Palomera (Ojo Guareña, Burgos, España). – *Zephyrvs*, **49**/0.

CORDAIN, L., MILLER, J.B., EATON, S.B., MANN, N., HOLT, S.H. & SPETH, J.D. (2000): Plant-animal subsistence ratios and macronutrient energy estimations in worldwide hunter-gatherer diets. – *The American journal of clinical nutrition*, **71**/3: 682–692.

COSTAMAGNO, S. (2013): Bone Grease Rendering in Mousterian Contexts: The Case of Noisetier Cave (Fréchet-Aure, Hautes-Pyréné es, France). – In: Zooarchaeology and Modern Human Origins. – pp. 209–225, Dordrecht (Springer Netherlands).

COSTAMAGNO, S., BOURGUIGNON, L., SOULIER, M.-C., MEIGNEN, L., BEAUVAL, C., RENDU, W., MUSSINI, C., MANN, A. & MAUREILLE, B. (2017): Bone retouchers and site function in the Quina Mousterian: the case of Les Pradelles (Marillac-le-France, France). – In: HUTSON, J. (ed.): The Origins of Bone Tool Technologies. – pp. 1–31, Mainz (Verlag des Römisch-Germanischen Zentralmuseums).

COSTAMAGNO, S. & FANO, M.A. (2005): Pratiques cynégétiques et exploitation des ressources animales dans les niveaux du Magdalénien supérieur-final de El Horno (Ramales, Cantabrie, Espagne). – *PALEO. Revue d'archéologie préhistorique*, **17**: 31–56.

COSTAMAGNO, S., GRIGGO, C. & MOURRE, V. (1999): Approche expérimentale d'un problème taphonomique: utilisation de combustible osseux au Paléolithique - Experimental approach to a taphonomic problem: the use of bone as fuel in the Palaeolithic. – *Préhistoire Européene*, **Vol. 13**/13: 167–194.

COSTAMAGNO, S., ROBERT, I., LAROULANDIE, V., MOURRE, V. & THIÉBAUT, C. (2008): Rôle du gypaète barbu (Gypaetus barbatus) dans la constitution de l'assemblage osseux de la grotte du Noisetier (Fréchet-Aure, Hautes-Pyrénées, France). – *Annales de Paléontologie*, **94**/4: 245–265. doi: 10.1016/j.annpal.2008.09.003.

COSTAMAGNO, S., THÉRY-PARISOT, I., BRUGAL, J.-P. & GUIBERT, R. (2005): Taphonomic consequences of the use of bones as fuel. Experimental data and archaeological applications. – In: O'CONNOR, T.P. (ed.): Biosphere to lithosphere: new studies in vertebrate taphonomy. – pp. 51–62, Oxford (Oxbow Books).

COSTAMAGNO, S., THÉRY-PARISOT, I., CASTEL, J.-C. & BRUGAL, J.-P. (2009): Combustible ou non? Analyse multifactorielle et modèles explicatifs sur des ossements brûlés Paléolithiques. – In: THÉRY-PARISOT, I., COSTAMAGNO, S. & HENRY, A. (eds): Fuel Management during the Palaeolithic and Mesolithic Periods. – p. Oxford.

COURTY, M.-A. & VALLVERDU, J. (2001): The microstratigraphic record of abrupt climate changes in cave sediments of the Western Mediterranean. – *Geoarchaeology*, **16**/5: 467–499. doi: 10.1002/gea.1002.

CREMA, E.R., EDINBOROUGH, K., KERIG, T. & SHENNAN, S.J. (2014): An Approximate Bayesian Computation approach for inferring patterns of cultural evolutionary change. – *Journal of Archaeological Science*, **50**: 160–170. doi: 10.1016/j.jas.2014.07.014.

CRISTIANI, E., RADINI, A., BORIĆ, D., ROBSON, H.K., CARICOLA, I., CARRA, M., MUTRI, G., OXILIA, G., ZUPANCICH, A., ŠLAUS, M. & VUJEVIĆ, D. (2018): Dental calculus and isotopes provide direct evidence of fish and plant consumption in Mesolithic Mediterranean. – *Scientific Reports*, **8**/1. doi: 10.1038/s41598-018-26045-9.

CROWLEY, B.E. & WHEATLEY, P.V. (2014): To bleach or not to bleach? Comparing treatment methods for isolating biogenic carbonate. – *Chemical Geology*, **381**: 234–242. doi: 10.1016/j.chemgeo.2014.05.006.

CRUZ-URIBE, K. (1991): Distinguishing hyena from hominid bone accumulations. – *Journal of Field Archaeology*, **18**/4: 467–486.

CUCART-MORA, C., LOZANO, S. & FERNÁNDEZ-LÓPEZ DE PABLO, J. (2018): Bio-cultural interactions and demography during the Middle to Upper Palaeolithic transition in Iberia: An agent-based modelling approach. – *Journal of Archaeological Science*, **89**: 14–24. doi: 10.1016/j.jas.2017.11.001.

CUENCA SOLANA, D. (2013): Utilización de instrumentos de concha para la realización de actividades productivas en las formaciones económico-sociales de cazadores-recolectores-pescadores y primeras sociedades tribales de la fachada atlántica europea. – 445 pp. Santander (PUbliCan Universidad de Cantabria).

CUENCA-BESCÓS, G. & GARCÍA PIMIENTA, J.C. (2012): Chapter 12- Holocene Biostratigraphy and Climatic Change in Cantabria: The Micromammalian Faunas of El Mirón Cave. – In: STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (eds): El Mirón Cave, Cantabrian Spain: The Site and Its Holocene Archaeological Record. – pp. 205–242, Albuquerque (University of New Mexico Press).

CUENCA-BESCÓS, G., MARÍN-ARROYO, A.B., MARTÍNEZ, I., GONZÁLEZ-MORALES, M.R. & STRAUS, L.G. (2012): Relationship between Magdalenian subsistence and environmental change: The mammalian evidence from El Mirón (Spain). – *Quaternary International*, **272–273**: 125–137. doi: 10.1016/j.quaint.2012.04.035.

CUENCA-BESCÓS, G., ROFES, J., LÓPEZ-GARCÍA, J.M., BLAIN, H.-A., DE MARFÁ, R.J., GALINDO-PELLICENA, M.A., BENNÁSAR-SERRA, M.L., MELERO-RUBIO, M., ARSUAGA, J.L., BERMÚDEZ DE CASTRO, J.M. & CARBONELL, E. (2010a): Biochronology of Spanish Quaternary small vertebrate faunas. – *Quaternary International*, **212**/2: 109–119. doi: 10.1016/j.quaint.2009.06.007.

CUENCA-BESCÓS, G., STRAUS, L.G., GARCÍA-PIMIENTA, J.C., GONZÁLEZ-MORALES, M.R. & LÓPEZ-GARCÍA, J.M. (2010b): Late Quaternary small mammal turnover in the Cantabrian Region: The extinction of Pliomys lenki (Rodentia, Mammalia). – *Quaternary International*, **212**/2: 129–136. doi: 10.1016/j.quaint.2009.06.006.

CUENCA-BESCÓS, G., STRAUS, L.G., GONZÁLEZ-MORALES, M.R. & GARCÍA PIMIENTA, J.C. (2008): Paleoclima y paisaje del final del Cuaternario en Cantabria: los pequeños mamíferos de la Cueva del Mirón (Ramales de la victoria). – *Revista Española de Paleontologia*, **23**/1: 91–126.

CUENCA-BESCÓS, G., STRAUS, L.G., GONZÁLEZ-MORALES, M.R. & GARCÍA PIMIENTA, J.C. (2009): The reconstruction of past environments through small mammals: from the Mousterian to the Bronze Age in El Mirón Cave (Cantabria, Spain). – *Journal of Archaeological Science*, **36**/4: 947–955.

DANSGAARD, W. (1964): Stable isotopes in precipitation. – *Tellus A*, **16**/4: 436–468.

DANSGAARD, W., JOHNSEN, S.J., CLAUSEN, H.B., DAHL-JENSEN, D., GUNDESTRUP, N.S., HAMMER, C.U., HVIDBERG, C.S., STEFFENSEN, J.P., SVEINBJÖRNSDOTTIR, A.E., JOUZEL, J. & BOND, G. (1993): Evidence for general instability of past climate from a 250-kyr ice-core record. – *Nature*, **364**/6434: 218–220. doi: 10.1038/364218a0.

DARI, A., PATOU-MATHIS, M., LUMLEY, H. DE, GIACOBINI, G., AOURAGHE, H., VIALOU, D., CABRERA, V., MUSÉUM NATIONAL D'HISTOIRE NATURELLE (PARIS), ÉCOLE DOCTORALE SCIENCES DE LA NATURE ET DE L'HOMME & ÉVOLUTION ET ÉCOLOGIE (PARIS) (2003): Comportements de subsistance pendant la transition Paléolithique moyen - Paléolithique supérieur en Cantabrie à partir de l'étude archéozoologique des restes osseux des grands mammifères de la grotte d'El Castillo (Puente Viesgo, Espagne). – Paris (Muséum national d'histoire naturell).

DAUJEARD, C. & MONCEL, M.-H. (2010): On Neanderthal subsistence strategies and land use: A regional focus on the Rhone Valley area in southeastern France. – *Journal of Anthropological Archaeology*, **29**/3: 368–391.

DAUX, V., LÉCUYER, C., HÉRAN, M.-A., AMIOT, R., SIMON, L., FOUREL, F., MARTINEAU, F., LYNNERUP, N., REYCHLER, H. & ESCARGUEL, G. (2008): Oxygen isotope fractionation between human phosphate and water revisited. – *Journal of Human Evolution*, **55**/6: 1138–1147. doi: 10.1016/j.jhevol.2008.06.006.

DAVIES, W., VALDES, P., ROSS, C. & VAN ANDEL, T. (2003): Chapter 11: The human presence in Europe during the last glacial period III: site clusters, regional climates and resource attractions. – In: Neanderthals and Modern Humans in the European Landscape during the Last Glaciation. – pp. 167–190, Cambridge (McDonald Institute for Archaeological Research).

DAVIS, S. (1995): The Archaeology of Animals. – 224 pp. New Haven and London (Yale University Press).

DAVIS, S. (2002): The mammals and birds from the Gruta do Caldeirão, Portugal. – *revista Portuguesa de Arqueologia*, **5**/2: 29–98.

DAVIS, S., ROBERT, I. & ZILHÃO, J. (2007): Caldeirao cave (Central Portugal)-whose home? Hyaena, man, bearded vulture. – *Courier-Forschungsinstitut Senckenberg*, **259**: 213.

DE JUANA, S. & DOMINGUEZ-RODRIGO, M. (2011): Testing Analogical Taphonomic Signatures In Bone Breaking: A Comparison Between Hammerstone-Broken Equid And Bovid Bones. – *Archaeometry*, **53**: 996–1011. doi: 10.1111/j.1475-4754.2010.00576.x.

DE LA RASILLA VIVES, M. (1989): Secuencia y crono-estratigrafía del solutrense cantábrico. – *Trabajos de Prehistoria*, **46**/0: 35–46. doi: 10.3989/tp.1989.v46.i0.585.

DELAGNES, A. & RENDU, W. (2011): Shifts in Neandertal mobility, technology and subsistence strategies in western France. – *Journal of Archaeological Science*, **38**/8: 1771–1783. doi: 10.1016/j.jas.2011.04.007.

DELGADO HUERTAS, A., IACUMIN, P. & LONGINELLI, A. (1997): A stable isotope study of fossil mammal remains from the Paglicci cave, southern Italy, 13 to 33 ka BP: palaeoclimatological considerations. – *Chemical Geology*, **141**/3–4: 211–223. doi: 10.1016/S0009-2541(97)00066-1.

DELGADO HUERTAS, A., IACUMIN, P., STENNI, B., SÁNCHEZ CHILLÓN, B. & LONGINELLI, A. (1995): Oxygen isotope variations of phosphate in mammalian bone and tooth enamel. – *Geochimica et Cosmochimica Acta*, **59**/20: 4299–4305. doi: 10.1016/0016-7037(95)00286-9.

DEMARCHI, B., PRESSLEE, S., GUTIÉRREZ-ZUGASTI, I., GONZÁLEZ-MORALES, M.R., MARÍN-ARROYO, A.B., STRAUS, L.G. & FISCHER, R. (2019): Birds of prey and humans in prehistoric Europe: A view from El Mirón Cave, Cantabria (Spain). – *Journal of Archaeological Science: Reports*, **24**: 244–252. doi: 10.1016/j.jasrep.2019.01.010.

DENIRO, M.J. & EPSTEIN, S. (1978): Influence of diet on the distribution of carbon isotopes in animals. – *Geochimica et cosmochimica acta*, **42**/5: 495–506.

DENTON, G.H., BROECKER, W.S. & ALLEY, R.B. (2006): The mystery interval 17.5 to 14.5 kyrs ago. – *PAGES news*, **14**/2: 14–16. doi: 10.22498/pages.14.2.14.

D'ERRICO, F. & SÁNCHEZ-GOÑI, M.F. (2003): Neandertal extinction and the millennial scale climatic variability of OIS 3. – *Quaternary Science Reviews*, **22**/8–9: 769–788. doi: 10.1016/S0277-3791(03)00009-X.

DETTMAN, D.L., KOHN, M.J., QUADE, J., RYERSON, F.J., OJHA, T.P. & HAMIDULLAH, S. (2001): Seasonal stable isotope evidence for a strong Asian monsoon throughout the past 10.7 m.y. – *Geology*, **29**/1: 31–34.

DÍAZ, Y. & ASTORQUI, Á. (2012): Nuevos hallazgos de arte parietal y mobiliar en la cueva de La Cullalvera (Ramales de la Victoria, Cantabria) = New rock and portable art finds in La Cullalvera cave (Ramales de la Victoria, Cantabria). – *Zephyrus*, **69**: 191–198.

DISCAMPS, E., JAUBERT, J. & BACHELLERIE, F. (2011): Human choices and environmental constraints: deciphering the variability of large game procurement from Mousterian to Aurignacian times (MIS 5-3) in southwestern France. – *Quaternary Science Reviews*, **30**/19–20: 2755–2775. doi: 10.1016/j.quascirev.2011.06.009.

DJINDJIAN, F. (1988): Improvements in intra-site spatial analysis techniques. – *Computer and quantitative methods in archaeology*, **1**: 95.

DJINDJIAN, F. (2016): Territories and economies of hunter–gatherer groups during the last glacial maximum in Europe. – *Quaternary International*, **412**: 37–43. doi: 10.1016/j.quaint.2015.06.058.

DOBROVOLSKAYA, M., RICHARDS, M.-P. & TRINKAUS, E. (2012): Direct radiocarbon dates for the Mid Upper Paleolithic (eastern Gravettian) burials from Sunghir, Russia. – *Bulletins et mémoires de la Société d'anthropologie de Paris*, **24**/1–2: 96–102.

DOMINGO, L., KOCH, P.L., GRIMES, S.T., MORALES, J. & LÓPEZ-MARTÍNEZ, N. (2012): Isotopic paleoecology of mammals and the Middle Miocene Cooling event in the Madrid Basin (Spain). – *Palaeogeography, Palaeoclimatology, Palaeoecology*, **339–341**: 98–113. doi: 10.1016/j.palaeo.2012.04.026.

DOMINGO, L., PÉREZ-DIOS, P., HERNÁNDEZ FERNÁNDEZ, M., MARTÍN-CHIVELET, J., ORTIZ, J.E. & TORRES, T. (2015): Late Quaternary climatic and environmental conditions of northern Spain: An isotopic approach based on the mammalian record from La Paloma cave. – *Palaeogeography, Palaeoclimatology, Palaeoecology*, **440**: 417–430. doi: 10.1016/j.palaeo.2015.09.017.

DOMINGO, R., MAZO, C. & UTRILLA, P. (2012): Hunting camps and nucleiform endscrapers in the Cantabrian Lower Magdalenian: A lithic microwear analysis. – *Quaternary International*, **272–273**: 105–110. doi: 10.1016/j.quaint.2012.03.027.

DOMÍNGUEZ-RODRIGO, M. (1994): Dinámica trófica, estrategias de consumo y alteraciones óseas en la sabana africana: resumen de un proyecto de investigación etoarqueológico (1991-1993); Trophic dynamics, consumption strategies and bone alterations in the African savanna ecosystem: summary of an etho-archaeological research project (1991-1993). – *Trabajos de Prehistoria*, **51**: 15–37.

DOMÍNGUEZ-RODRIGO, M., DE JUANA, S., GALÁN, A.B. & RODRÍGUEZ, M. (2009): A new protocol to differentiate trampling marks from butchery cut marks. – *Journal of Archaeological Science*, **36**/12: 2643–2654. doi: 10.1016/j.jas.2009.07.017.

DOMÍNGUEZ-RODRIGO, M., PICKERING, T.R. & BUNN, H.T. (2010): Configurational approach to identifying the earliest hominin butchers. – *Proceedings of the National Academy of Sciences of the United States of America*, **107**/49: 20929–34. doi: 10.1073/pnas.1013711107.

DOMÍNGUEZ-RODRIGO, M., PICKERING, T.R., SEMAW, S. & ROGERS, M.J. (2005): Cutmarked bones from Pliocene archaeological sites at Gona, Afar, Ethiopia: implications for the function of the world's oldest stone tools. – *Journal of Human Evolution*, **48**/2: 109–121.

DOMÍNGUEZ-RODRIGO, M., YRAVEDRA, J., ORGANISTA, E., GIDNA, A., FOURVEL, J.-B. & BAQUEDANO, E. (2015): A new methodological approach to the taphonomic study of paleontological and archaeological faunal assemblages: a preliminary case study from Olduvai Gorge (Tanzania). – *Journal of Archaeological Science*, **59**: 35–53. doi: 10.1016/j.jas.2015.04.007.

DOMÍNGUEZ-RODRIGO, M. (1999): Flesh availability and bone modifications in carcasses consumed by lions: palaeoecological relevance in hominid foraging patterns. – *Palaeogeography, Palaeoclimatology, Palaeoecology*, **149**/1: 373–388.

VAN DOMMELEN, P. (2014): Moving On: Archaeological Perspectives on Mobility and Migration. – *World Archaeology*, **46**/4: 477–483. doi: 10.1080/00438243.2014.933359.

DOWDESWELL, J.A. & WHITE, J.W.C. (1995): Greenland Ice Core Records and Rapid Climate Change. – *Philosophical Transactions: Physical Sciences and Engineering*, **352**/1699,.

VON DEN DRIESCH, A. (1976): A guide to the measurements of bones from archaeological sites: as developed by the Institut für Palaeoanatomie, Domestikationsforschung und Geschichte der Tiermedizin of the University of Munich. – Harvard University (Peabody Museum Bulletin 1).

DRUCKER, D.G., BRIDAULT, A., CUPILLARD, C., HUJIC, A. & BOCHERENS, H. (2011): Evolution of habitat and environment of red deer (Cervus elaphus) during the Late-glacial and early Holocene in eastern France (French Jura and the western Alps) using multi-isotope analysis ($\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$, $\delta^{34}S$) of archaeological remains. – *Quaternary International*, **245**/2: 268–278. doi: 10.1016/j.quaint.2011.07.019.

DRUCKER, D.G., BRIDAULT, A., HOBSON, K.A., SZUMA, E. & BOCHERENS, H. (2008): Can carbon-13 in large herbivores reflect the canopy effect in temperate and boreal ecosystems? Evidence from modern and ancient ungulates. – *Palaeogeography, Palaeoclimatology, Palaeoecology*, **266**/1–2: 69–82. doi: 10.1016/j.palaeo.2008.03.020.

DUARTE, C., MAURÍCIO, J., PETTITT, P.B., SOUTO, P., TRINKAUS, E., PLICHT, H. VAN DER & ZILHÃO, J. (1999): The early Upper Paleolithic human skeleton from the Abrigo do Lagar Velho (Portugal) and modern human emergence in Iberia. – *Proceedings of the National Academy of Sciences*, **96**/13: 7604–7609.

DUARTE MATÍAS E., DE LA R.V.M. (2014): La técnica pseudoexcisa en el Badeguliense / Magdaleniense arcaico de Asturias. – *Archivo de Pehisoria Levantina*, **XXX**: 27–55.

DUCASSE, S. (2012): What is left of the Badegoulian "interlude"? New data on cultural evolution in southern France between 23,500 and 20,500 cal. BP. – *Quaternary International*, **272–273**: 150–165. doi: 10.1016/j.quaint.2012.05.018.

DUCASSE, S. (2013): Badegoulien versus Magdalénien : I - Le Badegoulien récent quercinois : état de la recherche, réflexions et questionnements. – In: Modalité d'occupation et exploitation des milieux au Paléolithique dans le Sud-Ouest de la France : l'exemple du Quercy. – pp. 361–378,.

DUPRÈ, M. (1990): Análisis polínico de la cueva de Amalda. – In: La Cueva de Amalda (Zestoa, Pais Vasco). – pp. 49–51, Donostia (Eusko Ikaskuntza).

DUSSELDORP, G.L. (2009): A view to a kill. Investigating Middle Palaeolithic subsistence using an Optimal Foraging perspective. – (Sidestone Press).

ECKER, M., BOCHERENS, H., JULIEN, M.-A., RIVALS, F., RAYNAL, J.-P. & MONCEL, M.-H. (2013): Middle Pleistocene ecology and Neanderthal subsistence: Insights from stable isotope analyses in Payre (Ardèche, southeastern France). – *Journal of Human Evolution*, **65**/4: 363–373. doi: 10.1016/j.jhevol.2013.06.013.

EFREMOV, I.A. (1940): Taphonomy: a new branch of paleontology: Pan-American Geologist, v. 74. – *Pan-American Geologist,*, **74**: 81–93.

EGELAND, C.P., WELCH, K.R. & NICHOLSON, C.M. (2014): Experimental determinations of cutmark orientation and the reconstruction of prehistoric butchery behavior. – *Journal of Archaeological Science*, **49**: 126–133. doi: 10.1016/j.jas.2014.05.007.

EHLERS, J., EHLERS, JÜRGEN, GIBBARD, P.L. & HUGHES, P.D. (2011): Quaternary Glaciations - Extent and Chronology: A Closer Look. – 1128 pp. (Elsevier).

EL ZAATARI, S., GRINE, F.E., UNGAR, P.S. & HUBLIN, J.-J. (2016): Neandertal versus Modern Human Dietary Responses to Climatic Fluctuations. – *PLOS ONE*, **11**/4: e0153277. doi: 10.1371/journal.pone.0153277.

ELLWOOD, B.B., HARROLD, F.B., BENOIST, S.L., STRAUS, L.G., GONZÁLEZ-MORALES, M.R., PETRUSO, K., BICHO, N., ZILHÃO, J. & SOLER, N. (2001): Paleoclimate and intersite correlations from Late Pleistocene/Holocene cave sites: Results from Southern Europe. – *Geoarchaeology*, **16**/4: 433–463. doi: 10.1002/gea.1011.

ENLOE, J.G. (1995): Remontatge en Zooarqueología: tafonomía, economía i societat. – *Cota zero: revista d'arqueologia i ciència*/11: 31–37.

ENLOE, J.G. (1997): Seasonality and Age Structure in Remains of Rangifer tarandus: Magdalenian Hunting Strategy at Verberie. – *Anthropozoologica. Proceedings of the 7th ICAZ conference, Muséum national d'Histoire naturelle*, **25–26**: 95–102.

ENLOE, J.G. (2010): Refitting bones: negative evidence, site structure and social organization. – *Lithic Technology*, **35**/1: 63–71.

ERASO, F. (1983): El yacimiento paleolitico final de Silibranka (Vizcaya). – *Kobie*, **13**: 7–57.

D'ERRICO, F. & BACKWELL, L.R. (2003): Possible evidence of bone tool shaping by Swartkrans early hominids. – *Journal of Archaeological Science*, **30**/12: 1559–1576. doi: 10.1016/S0305-4403(03)00052-9.

D'ERRICO, F. & VANHAEREN, M. (1999): Les méthodes d'analyse de l'art mobilier paléolithique. – *Anthropologie et Préhistoire*, **110**: 31–45.

D'ERRICO, F. & VANHAEREN, M. (2002): Criteria for Identifying Red Deer (Cervus elaphus) Age and Sex from Their Canines. Application to the Study of Upper Palaeolithic and Mesolithic Ornaments. – *Journal of Archaeological Science*, **29**/2: 211–232. doi: 10.1006/jasc.2001.0687.

D'ERRICO, F., ZILHÃO, J., JULIEN, M., BAFFIER, D. & PELEGRIN, J. (1998): Neanderthal Acculturation in Western Europe? A Critical Review of the Evidence and Its Interpretation. – *Current Anthropology*, **39**/S1: S1–S44. doi: 10.1086/204689.

ESRI (2007): Voronoi Maps. – ArcGIS 9.2 Desktop Help: *ArcGIS 9.2 Desktop Help*. Retrieved March 10, 2017, from http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=Voronoi_maps.

ESRI (2009a): Spatial Autocorrelation: Moran's I. – ArcGIS 9.2 Desktop Help: *ArcGIS 9.2 Desktop Help*. Retrieved March 10, 2017, from http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?topicname=how_spatial_autocorrelation:moran's_i_(spatial_statistics)_works.

ESRI (2009b): Cluster and Outlier Analysis: Anselin Local Moran's I. – ArcGIS 9.2 Desktop Help: *ArcGIS 9.2 Desktop Help*. Retrieved March 10, 2017, from http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?topicname=cluster_and_outlier_analysis:anselin_local_moran's_i_(spatial_statistics).

ESTÉVEZ ESCALERA, J. (1980): La Fauna del pleistoceno en Catalan. – Diss.: (University of Barcelona).

ESTÉVEZ ESCALERA, J. & VILA, A. (2006): Una historia de la investigación sobre el Paleolítico en la Península Ibérica. Edición: 1. – 416 pp. Madrid (Sintesis).

EVANS, J.A., TATHAM, S., CHENERY, S.R. & CHENERY, C.A. (2007): Anglo-Saxon animal husbandry techniques revealed though isotope and chemical variations in cattle teeth. – *Applied Geochemistry*, **22**/9: 1994–2005. doi: 10.1016/j.apgeochem.2007.03.059.

EXCAVATORS EL MIRÓN (Unpub.): Excavation documentation:The "pink-sheets" from El Miròn cave (1996-2013). – .

EYNAUD, F., DE ABREU, L., VOELKER, A., SCHÖNFELD, J., SALGUEIRO, E., TURON, J.-L., PENAUD, A., TOUCANNE, S., NAUGHTON, F., SÁNCHEZ-GOÑI, M.F., MALAIZÉ, B. & CACHO, I. (2009): Position of the Polar Front along the western Iberian margin during key cold episodes of the last 45 ka. – *Geochemistry, Geophysics, Geosystems*, **10**/7: n/a–n/a. doi: 10.1029/2009GC002398.

FAITH, J.T. & GORDON, A.D. (2007): Skeletal element abundances in archaeofaunal assemblages: economic utility, sample size, and assessment of carcass transport strategies. – *Journal of Archaeological Science*, **34**/6: 872–882. doi: 10.1016/j.jas.2006.08.007.

FANO, M.A., RIVERO, O. & GARATE-MAIDAGAN, D. (2010): Plaqueta decorada de la cueva de El Horno (Ramales de la Victoria, Cantabria) en su contexto local y regional. – *Munibe*, **61**: 71–88.

FARRAND, W.R. (2012): Sedimentology of el Mirón cave. – In: STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (eds): El Mirón Cave, Cantabrian Spain: The Site and Its Holocene Archaeological Record. – pp. 60–94, Albuquerque (University of New Mexico Press).

FERNÁNDEZ ACEBO, V. (2010): Cueva de La Clotilde: Ejemplo de destrucción del arte rupestre. – *Sautuola*, **XVI–XVII**: 497–511.

FERNANDEZ, H. (2001): Ostéologie comparée des petits ruminants eurasiatiques sauvages et domestiques (genres Rupicapra, Ovis, Capra et Capreolus) : diagnose différentielle du squelette appendiculaire. – Diss.: Muséum d'histoire naturelle Genève (University of Geneva).

FERNANDEZ JALVO, Y., SÁNCHEZ–CHILLÓN, B., ANDREWS, P., FERNÁNDEZ-LÓPEZ, S. & ALCALÁ, L. (2002): Morphological taphonomic transformations of fossil bones in continental environments, and repercussions on their chemical composition. – *Archaeometry*, **44**: 353–361. doi: 10.1111/1475-4754.t01-1-00068.

FERNÁNDEZ REY, A., ADÁN ALVAREZ, G.E., ARBIZU, M. & ARSUAGA, J.L. (2005): Grafismo rupestre paleolítico de la Cueva del Conde (Tuñón, Santo Adriano, Asturias). – *Zephyrus*, **58**: 67–88.

FERNANDEZ VEGA, P., GARCIA DIEZ, M. & HUREL, A. (2010): Las Cavernas de la Region Cantabrica - Histoire et Préhistoire. – 108 pp. Santander (Consejería de Cultura, Turismo y Deporte, Gobierno de Cantabria).

FERNANDEZ-JALVO, Y. & ANDREWS, P. (2016): Atlas of Taphonomic Identifications. – 359 pp. Dordrecht (Springer Netherlands).

FERNÁNDEZ-JALVO, Y. & ANDREWS, P. (2016): Discoloration and Staining. – In: Atlas of Taphonomic Identifications. – pp. 155–166, Dordrecht (Springer Netherlands). doi: 10.1007/978-94-017-7432-1_5.

FERNÁNDEZ-LÓPEZ DE PABLO, J. (2016): The timing of postglacial coastal adaptations in Eastern Iberia: A Bayesian chronological model for the El Collado shell midden (Oliva, Valencia, Spain). – *Quaternary International*, **407**: 94–105. doi: 10.1016/j.quaint.2015.10.077.

FERNÁNDEZ-LÓPEZ DE PABLO, J., GUTIÉRREZ-ROIG, M., GÓMEZ-PUCHE, M., MCLAUGHLIN, R., SILVA, F. & LOZANO, S. (2019): Palaeodemographic modelling supports a population bottleneck during the Pleistocene-Holocene transition in Iberia. – *Nature Communications*, **10**/1: 1872. doi: 10.1038/s41467-019-09833-3.

FERNÁNDEZ-LÓPEZ, S. & FERNÁNDEZ-JALVO, Y. (2002): The limit between biostratinomy and fossildiagenesis. – In: Current Topics on Taphonomy and Fossilization (De Renzi, M.; Pardo Alonso, MV. – pp. 27–37, (Ayuntamiento de Valencia).

FERNÁNDEZ-TRESGUERRES VELASCO, J.A. (2006): El Aziliense de la región cantábrica. – *Zephyrus: Revista de prehistoria y arqueología*, **59**: 163–180.

FERRING, C.R. (1984): Intrasite spatial patterning: Its role in settlement-subsistence systems analysis. – In: Intrasite spatial analysis in archaeology. – pp. 116–126, Cambridge (Cambridge University Press).

FINLAYSON, C., GILES PACHECO, F., RODRÍGUEZ-VIDAL, J., FA, D.A., MARÍA GUTIERREZ LÓPEZ, J., SANTIAGO PÉREZ, A., FINLAYSON, G., ALLUE, E., BAENA PREYSLER, J., CÁCERES, I., CARRIÓN, J.S., FERNÁNDEZ JALVO, Y., GLEED-OWEN, C.P., JIMENEZ ESPEJO, F.J., LÓPEZ, P., ANTONIO LÓPEZ SÁEZ, J., ANTONIO RIQUELME CANTAL, J., SÁNCHEZ MARCO, A., GILES GUZMAN, F., BROWN, K., FUENTES, N., VALARINO, C.A., VILLALPANDO, A., STRINGER, C.B., MARTINEZ RUIZ, F. & SAKAMOTO, T. (2006): Late survival of Neanderthals at the southernmost extreme of Europe. – *Nature*, **443**/7113: 850–853. doi: 10.1038/nature05195.

FISHER, J.L. & VALENTINE, B. (2013): Resource depression, climate change, and mountain sheep in the eastern Great Basin of western North America. – *Archaeological and Anthropological Sciences*, **5**/2: 145–157. doi: 10.1007/s12520-013-0124-9.

FISHER, J.W. (1995): Bone surface modifications in zooarchaeology. – *Journal of Archaeological Method and Theory*, **2**/1: 7–68. doi: 10.1007/BF02228434.

FLADERER, F.A., SALCHER-JEDRASIAK, T.A. & HÄNDEL, M. (2014): Hearth-side bone assemblages within the 27 ka BP Krems-Wachtberg settlement: Fired ribs and the mammoth bone-grease hypothesis. – *Quaternary International*, **351**: 115–133. doi: 10.1016/j.quaint.2012.06.030.

FLANNERY, K.V. (1969): Origins and ecological effects of early domestication in Iran and the Near East. – In: UCKO, PETER J., U., PETER J. & DIMBLEBY, G. W., D., G.W. (eds): The domestication and exploitation of plants and animals. – pp. 73–100, Chicago (Aldine Publisher Company).

FLANNERY, K.V. (1972): Archaeological systems theory and early Mesoamerica. – In: Anthropological archaeology in the Americas. – pp. 222–234, Carbondale (Southern Illinois Univ Press).

FLEMING, K., JOHNSTON, P., ZWARTZ, D., YOKOYAMA, Y., LAMBECK, K. & CHAPPELL, J. (1998): Refining the eustatic sea-level curve since the Last Glacial Maximum using far- and intermediate-field sites. – *Earth and Planetary Science Letters*, **163**/1–4: 327–342. doi: 10.1016/S0012-821X(98)00198-8.

FLETCHER, W.J., SÁNCHEZ GOÑI, M.F., ALLEN, J.R.M., CHEDDADI, R., COMBOURIEU-NEBOUT, N., HUNTLEY, B., LAWSON, I., LONDEIX, L., MAGRI, D., MARGARI, V., MÜLLER, U.C., NAUGHTON, F., NOVENKO, E., ROUCOUX, K. & TZEDAKIS, P.C. (2010): Millennial-scale variability during the last glacial in vegetation records from Europe. – *Quaternary Science Reviews*, **29**/21–22: 2839–2864. doi: 10.1016/j.quascirev.2009.11.015.

FLETCHER, W.J. & SÁNCHEZ-GOÑI, M.F. (2008): Orbital- and sub-orbital-scale climate impacts on vegetation of the western Mediterranean basin over the last 48,000 yr. – *Quaternary Research*, **70**/3: 451–464. doi: 10.1016/j.yqres.2008.07.002.

FLORINETH, D. & SCHLÜCHTER, C. (2000): Alpine evidence for atmospheric circulation patterns in Europe during the Last Glacial Maximum. – *Quaternary Research*, **54**/3: 295–308.

FOLEY, R. (1981): Off-site archaeology and human adaptation in Eastern Africa: an analysis of regional artefact density in the Amboseli, southern Kenya. – Oxford, England (B.A.R.).

FOLEY, R. (1985): Optimality theory in anthropology. – *Man*, **20**/2: 222–242.

FOLKE, C. (2006): Resilience: The emergence of a perspective for social–ecological systems analyses. – *Global Environmental Change*, **16**/3: 253–267. doi: 10.1016/j.gloenvcha.2006.04.002.

FONTANA, L. (2000): La chasse au renne au Paléolithique supérieur dans le sud-ouest de la France: nouvelles hypothèses de travail / Reindeer hunting in the Upper Palaeolithic in south-west France : demography and seasonality. – *Paléo*, **12**/1: 141–164. doi: 10.3406/pal.2000.1600.

FONTES, L.M. (2016a): Economies set in stone? Magdalenian Lithic Technological Organization and Adaptation in Vasco-Cantabrian Spain. – Diss.unpub.: Albuquerque (University of New Mexico).

FONTES, L.M. (2016b): The Initial Magdalenian mosaic: New evidence from Urtiaga cave, Guipúzcoa, Spain. – *Journal of Anthropological Archaeology*, **41**: 109–131. doi: 10.1016/j.jaa.2015.11.006.

FONTES, L.M., STRAUS, L.G. & GONZÁLEZ MORALES, M.R. (2018): Lower Magdalenian lithic raw material provisioning: A diachronic view from El Mirón cave (Ramales de la Victoria, Cantabria, Spain). – *Journal of Archaeological Science: Reports*, **19**: 794–803.

FONTES, L.M., STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2015): Lithic and osseous artifacts from the Lower Magdalenian human burial deposit in El Mirón cave, Cantabria, Spain. – *Journal of Archaeological Science*, **60**: 99–111. doi: 10.1016/j.jas.2015.03.010.

FONTES, L.M., STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2016): Lithic raw material conveyance and hunter-gatherer mobility during the Lower Magdalenian in Cantabria, Spain. – *Quaternary International*, **412**: 66–81. doi: 10.1016/j.quaint.2015.09.017.

FORTEA-PÉREZ, J., RASILLA VIVES, M. DE LA & SANTAMARÍA ÁLVAREZ, D. (2007): Solutrense y Magdaleniense en Asturias. – In: La Preshitoria in Asturias. Un legado artístico único en el mundo. – pp. 389–416, Oviedo (Gobierno del Principado de Asturias).

FOSSE, P. (2012): Bone Modification by Modern Wolf (Canis lupus): A Taphonomic Study From their Natural Feeding Places. – *Journal of taphonomy*, **10**/3: 147–164.

FOURVEL, J.-B. (2012): Hyénidés modernes et fossiles d'Europe et d'Afrique : taphonomie comparée de leurs assemblages osseux. – Diss.: Toulouse (Université Toulouse le Mirail).

FOX, C.L., JUAN, J. & ALBERT, R.M. (1996): Phytolith analysis on dental calculus, enamel surface, and burial soil: information about diet and paleoenvironment. – *American Journal of Physical Anthropology*, **101**/1: 101–113. doi: 10.1002/(SICI)1096-8644(199609)101:1<101::AID-AJPA7>3.0.CO;2-Y.

FOX, C.L., PÉREZ-PÉREZ, A. & JUAN, J. (1994): Dietary Information through the Examination of Plant Phytoliths on the Enamel Surface of Human Dentition. – *Journal of Archaeological Science*, **21**/1: 29–34. doi: 10.1006/jasc.1994.1005.

FREEMAN, L.G. (1964): Mousterian Developments in Cantabrian Spain. – Diss.: University of Chicago.

FREEMAN, L.G. (1973): The Significance of Mammalian Faunas from Paleolithic Occupations in Cantabrian Spain. – *American Antiquity*, **38**/1: 3–44.

FREEMAN, L.G. (1981): The fat of the land: notes on Paleolithic diet in Iberia. – In: Omnivorous Primates. – pp. 104–165, New York (Columbia University Press).

FREEMAN, L.G. & GONZÁLEZ-ECHEGARAY, J. (1967): La Industria Musteriense de la Cueva de la Flecha (Puente Viesgo - Santander). – *Zephyrvs*, **18**: 43–61.

FREEMAN, L.G. & GONZÁLEZ-ECHEGARAY, J. (1984): Magdalenian structures and sanctuary from the cave of El Juyo (Igollo, Cantabria, Spain). – In: Jungpaläolithische Siedlungsstrukturen in Europa. – pp. 39–49, (Verlag Archaeologica Venatoria, Institut für Urgeschichte der Universität Tübingen).

FRENCH, J.C. (2016): Demography and the Palaeolithic Archaeological Record. – *Journal of Archaeological Method and Theory*, **23**/1: 150–199. doi: 10.1007/s10816-014-9237-4.

FREY, H., LLOPIS, A., 2015. Bearded Vulture European Endangered Species Programme (EEP): Guidelines for Feeding Bearded Vultures in Captivity [WWW Document]. Vulture Conservation Foundation. URL *https://www.4vultures.org*

FRICKE, H.C., CLYDE, W.C. & O'NEIL, J.R. (1998): Intra-tooth variations in $\delta^{18}O$ (PO_4) of mammalian tooth enamel as a record of seasonal variations in continental climate variables. – *Geochimica et Cosmochimica Acta*, **62**/11: 1839–1850. doi: 10.1016/S0016-7037(98)00114-8.

FRICKE, H.C. & O'NEIL, J.R. (1996): Inter- and intra-tooth variation in the oxygen isotope composition of mammalian tooth enamel phosphate: implications for palaeoclimatological and palaeobiological research. – *Palaeogeography, Palaeoclimatology, Palaeoecology*, **126**/1–2: 91–99. doi: 10.1016/S0031-0182(96)00072-7.

FU, Q., POSTH, C., HAJDINJAK, M., PETR, M., MALLICK, S. & ET AL. (2016): The genetic history of Ice Age Europe. – *Nature*, **534**/7606: 200–205. doi: 10.1038/nature17993.

FUENTES VIDARTE, C. (1980): Estudio de la fauna de el Pendo (CAPITULO VII). – In: GONZÁLEZ-ECHEGARAY, J. (ed.): El yacimiento de la cueva de El Pendo: Excavaciones (1953-1957). – pp. 215–238, Madrid (CSIC-CSIC Press).

GALÁN, A.B., RODRÍGUEZ, M., DE JUANA, S. & DOMÍNGUEZ-RODRIGO, M. (2009): A new experimental study on percussion marks and notches and their bearing on the interpretation of hammerstone-broken faunal assemblages. – *Journal of Archaeological Science*, **36**/3: 776–784. doi: 10.1016/j.jas.2008.11.003.

GALINDO-PELLICENA, M.Á., UREÑA, I., VALDIOSERA, C. & ARSUAGA, L. (2016): Osteological identification criteria for Capra pyrenaica and Capra hircus validated with DNA. – *Spanish Journal of Paleontology*, **31**/2: 297–304.

GAMBLE, C. (1999): The Palaeolithic Societies of Europe. – 532 pp. (Cambridge University Press).

GAMBLE, C., DAVIES, W., PETTITT, P., HAZELWOOD, L. & RICHARDS, M. (2005): The Archaeological and Genetic Foundations of the European Population during the Late Glacial: Implications for. – *Cambridge Archaeological Journal*, **15**/02: 193–223. doi: 10.1017/S0959774305000107.

GAMBLE, C., DAVIES, W., PETTITT, P. & RICHARDS, M. (2004): Climate change and evolving human diversity in Europe during the last glacial. – *Philosophical Transactions of the Royal Society B: Biological Sciences*, **359**/1442: 243–254. doi: 10.1098/rstb.2003.1396.

GARATE-MAIDAGAN, D. (2010): Las Ciervas punteadas en las cuevas del Paleolítico: una expresión pictórica propia de la cornisa Cantábrica. – Donostia (Aranzadi Zientzia Elkartea).

GARATE-MAIDAGAN, D. (2012): Neandertales y Cromañones - Los primeros habitantes de Bizkaia. – 270 pp. (Diputación Foral de Bizkaia, Bizkaikoa y Arkeologi Museoa).

GARATE-MAIDAGAN, D. (2018): New Insights into the Study of Paleolithic Rock Art: Dismantling the "Basque Country Void." – *Journal of Anthropological Research*, **74**/2: 168–200.

GARATE-MAIDAGAN, D. & BOURRILLON, R. (2010): La grotte ornée d'Etxeberri (Camou-Cihigue, Pyrénées-Atlantiques). Un art audacieux. – *Pleistocene art of the world, Actes du Congrès ifrao, Tarascon-sur-Ariège*: 65–66.

GARATE-MAIDAGAN, D., JIMÉNEZ, J.M. & ORTIZ, J. (2000): The Palaeolithic rock art of Arenaza cave (Galdames, Biscay). – *Kobie*, **24**: 5–64.

GARATE-MAIDAGAN, D., LABARGE, A., RIVERO, O., NORMAND, C. & DARRICAU, J. (2013): The Cave of Isturitz (West Pyrenees, France): One Century of Research in Paleolithic Parietal Art. – *Arts*, **2**/4: 253–272. doi: 10.3390/arts2040253.

GARATE-MAIDAGAN, D. & RIOS-GARAIZAR, J. (eds) (2012): La cueva de Askondo (Mañaria, Bizkaia) : arte parietal y ocupación humana durante la prehistoria. – 141 pp. (Bizkaiko Foru Aldundia).

GARCÍA CARRERO, P. (2013): Selección de dieta de la cabra montés (Capra pyrenaica) en el sureste peninsular. – Master's Thesis: (Universidad de Castilla-La Mancha).

GARCÍA DIEZ, M. & EGUIZABAL TORRE, J. (2007): Los dibujos rojos de estilo paleolítico de la Cueva de La Haza (Ramales de la Victoria, Cantabria): estudio monográfico. – *Munibe*, **58**: 177–222.

GARCÍA DÍEZ, M., GONZÁLEZ-MORALES, M.R. & STRAUS, L.G. (2012): El grafismo rupestre paleolítico de la cueva de El Mirón (Ramales de la Victoria, Cantabria, España): una propuesta para su datación estratigráfica. – *Trabajos de Prehistoria*, **69**/1: 21–36. doi: 10.3989/tp.2012.12077.

GARCIA, R.A., CABEZA, M., RAHBEK, C. & ARAUJO, M.B. (2014): Multiple Dimensions of Climate Change and Their Implications for Biodiversity. – *Science*, **344**/6183: 1247579–1247579. doi: 10.1126/science.1247579.

GARCÍA-ESCÁRZAGA, A. (2019): Paleoclima y aprovechamiento de recursos costeros durante el Mesolítico en la región cantábrica. – Diss.unpub.: Santander (Universidad Cantabria).

GARCÍA-GONZÁLEZ, R., CARRETERO, J.M., RICHARDS, M.P., RODRÍGUEZ, L. & QUAM, R. (2015): Dietary inferences through dental microwear and isotope analyses of the Lower Magdalenian individual from El Mirón Cave (Cantabria, Spain). – *Journal of Archaeological Science*, **60**: 28–38. doi: 10.1016/j.jas.2015.03.020.

GARCÍA-MORENO, A. (2010): Patrones de asentamiento y ocupación del territorio en el Cantábrico Oriental al final del Pleistoceno. Una aproximación mediante SIG. – Santander (Universidad de Cantabria).

GARCÍA-MORENO, A. (2013): To see or to be seen… is that the question? An evaluation of palaeolithic sites' visual presence and their role in social organization. – *Journal of Anthropological Archaeology*, **32**/4: 647–658. doi: 10.1016/j.jaa.2013.03.003.

GARCÍA-MORENO, A., FANO, M.A. & GARATE-MAIDAGAN, D. (2013): Integrating spatial analyses into foraging societies land use strategies. A case study from the Nalón basin (Asturias, North of Spain). – *CAA*.

GARCÍA-MORENO, A., GUTIÉRREZ-ZUGASTI, I. & GONZÁLEZ MORALES, M.R. (2017): Nueva datación radiocarbónica del abrigo de Cubera en la cuenca alta del río Asón (Arredondo, Cantabria). – *NAILOS. Estudios Interdisciplinares de Arqueología*, **4**: 195–207.

GAT, J.R., MOOK, W.G. & MEIJER, H.A. (2001): Environmental isotopes in the hydrological cycle. – *Principles and Applications UNESCO/IAEA Series*, **2**: 63–7.

GAUDZINSKI, S. (2000): On the variability of Middle Palaeolithic procurement tactics: the case of Salzgitter Lebenstedt, northern Germany. – *International Journal of Osteoarchaeology*, **406**/July: 396–406.

GEILING, J.M. (2018): Exploring Human Palaeoeconomic Behavioral Development by Faunal Records: An Overview. – In: Actas de las IX Jornadas de Jóvenes en Investigación Arqueológica - Santander 8-11 Junio 2016. – pp. 353–359, Santander (UNICAN).

GEILING, J.M. & MARÍN-ARROYO, A.B. (2013): Palaeoeconomic Behaviour in Northern Iberia During the Late Glacial Maximum from a Zooarchaeological Perspective. – In: – p. 97, *European Society for the Study of Human Evolution* Vienna.

GEILING, J.M. & MARÍN-ARROYO, A.B. (2015): Spatial distribution analysis of the Lower Magdalenian human burial in El Mirón Cave (Cantabria, Spain). – *Journal of Archaeological Science*, **60**: 47–56. doi: 10.1016/j.jas.2015.03.005.

GEILING, J.M., MARÍN-ARROYO, A.B., STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2018): Deciphering archaeological palimpsests with bone micro-fragments from the Lower Magdalenian of El Mirón cave (Cantabria, Spain). – *Historical Biology*, **30**/6: 730–742. doi: 10.1080/08912963.2017.1385611.

GEILING, J.M., STRAUS, L.G., GONZÁLEZ-MORALES, M.R. & MARÍN-ARROYO, A.B. (2016): A Spatial Distribution Study of Faunal Remains from Two Lower Magdalenian Occupation Levels in El Mirón Cave, Cantabria, Spain. – *Papers from the Institute of Archaeology*, **26**/1, Art. 4: 1–16. doi: 10.5334/pia-477.

GENERAL BATHYMETRIC CHART OF THE OCEANS (2014): GEBCO 2014 Grid – Gridded bathymetry data. – *GEBCO 2019 Gridded Bathymetry Data Download*. Retrieved May 11, 2017, from http://www.gebco.net/data_and_products/gridded_ bathymetry_data/.

GERMONPRÉ, M., SABLIN, M.V., STEVENS, R.E., HEDGES, R.E.M., HOFREITER, M., STILLER, M. & DESPRÉS, V.R. (2009): Fossil dogs and wolves from Palaeolithic sites in Belgium, the Ukraine and Russia: osteometry, ancient DNA and stable isotopes. – *Journal of Archaeological Science*, **36**/2: 473–490. doi: 10.1016/j.jas.2008.09.033.

GIGERENZER, G. & SELTEN, R. (eds) (2002): Bounded Rationality: The Adaptive Toolbox. Reprint edition. – 394 pp. Cambridge, Mass. (MIT Press).

GIGERENZER, G. & TODD, P.M. (1999): Fast and frugal heuristics: The adaptive toolbox. – In: Simple heuristics that make us smart. – pp. 3–43, (Oxford University Press, USA).

GILEAD, I. (2002): Too many notes? virtual recording of artifacts provenance. – In: Virtual archaeology: proceedings of the VAST Euroconference, Arezzo 24-25 November 2000. – pp. 41–44,.

GOBETZ, K.E. & BOZARTH, S.R. (2001): Implications for Late Pleistocene Mastodon Diet from Opal Phytoliths in Tooth Calculus. – *Quaternary Research*, **55**/2: 115–122. doi: 10.1006/qres.2000.2207.

GOBIERNO DE CANTABRIA (2009): Cultura de Cantabria: Cueva de La Estación. – Retrieved April 24, 2019, from https://web.archive.org/web/20091211083538/http://culturadecantabria.es/ficha_patrimonio.asp?idmonumento=11.

GOCHI, E.B. & PASTOR, J.L.A. (2014): La intervención arqueológica en el yacimiento de la cueva de Santa Catalina. – *Kobie*, **4**: 7–24.

GÓMEZ-OLIVENCIA, A., SALA, N., NÚÑEZ-LAHUERTA, C., SANCHIS, A., ARLEGI, M. & RIOS-GARAIZAR, J. (2018): First data of Neandertal bird and carnivore exploitation in the Cantabrian Region (Axlor; Barandiaran excavations; Dima, Biscay, Northern Iberian Peninsula). – *Scientific Reports*, **8**/1: 10551. doi: 10.1038/s41598-018-28377-y.

GONZÁLES-SAINZ, C. & MAIDAGÁN, D.G. (2009): Los grabados y pinturas rupestres de la cueva de El Rincón, en el contexto artístico del desfiladero del río Carranza (Bizkaia-Cantabria). – *Zephyrvs*, **59**: 135–154.

GONZÁLEZ-ECHEGARAY, J. (1971): Apreciaciones cuantitativas sobre el Magdaleniense III de la costa cantábrica. – *Munibe*, **23**/2/3: 323–327.

GONZÁLEZ-ECHEGARAY, J. (2011): Balance sobre el Magdaleniense III de la costa cantábrica. – *Veleia*, **24–25**: 483–492.

GONZÁLEZ-ECHEGARAY, J. & BARANDIARÁN-MAESTU, I. (1981): El Paleolitico Superior de la Cueva del Rascaño (Santander). – 339 pp. Santander (Santilla del Mar (Santander): Centro de Investigacion y Museo de Altamira).

GONZÁLEZ-ECHEGARAY, J. & FREEMAN, L.G. (1978): Vida y muerte en Cueva Morín. – (Institución Cultural de Cantabria, Diputación Provincial).

GONZÁLEZ-ECHEGARAY, J. & FREEMAN, L.G. (1992): Las Excavaciones de la Cueva del Juyo (Cantabria). – *Kobie*, **20**/93: 29–42.

GONZÁLEZ-ECHEGARAY, J., GARCÍA GUINEA, M., BEGINES RAMÍREZ, A. & MADARIAGA DE LA CAMPA, B. (1962): Cueva de La Chora (Santander). – 91 pp. (Ministerio de Cultura, Dirección General de Bellas Artes y Archivos).

GONZÁLEZ-ECHEGARAY, J., GARCÍA-GUINEA, M. & BEGINES, A. (1966): Cueva del Otero. – Madrid (Ministerio de Cultura, Dirección General de Bellas Artes y Archivos).

GONZÁLEZ-ECHEGARAY, J. & PERELLÓ, E.R. I (1953): Hallazgos en la cueva de la Pasiega (Puente Viesgo, Santander). – *Empúries: revista de món clàssic i antiguitat tardana*/15: 43–65.

GONZÁLEZ-MORALES, M.R. (1975): El gravado rupestre paleolítico de la Cueva de las Mestas (Las Regueras, Asturias). – In: – pp. 149–154, *Crónica del XIII Congreso Arqueológico Nacional* Huelva (Seminario de Arqueología).

GONZÁLEZ-MORALES, M.R. (1980): El asturiense y otras culturas locales: la explotación de las áreas litorales de la Región Cantábrica en los tiempos epipaleolíticos. – Diss.: Oviedo (Universidad de Oviedo).

GONZÁLEZ-MORALES, M.R. & STRAUS, L.G. (2000): Parietal engravings in Magdalenian stratigraphic context in El Mirón Cave. – *INORA*, **27**: 1–5.

GONZÁLEZ-MORALES, M.R. & STRAUS, L.G. (2005): The Magdalenian sequence of El Mirón Cave (Cantabria, Spain): an approach to the problems of definition of the Lower Magdalenian in Cantabrian Spain. – *Mémoires de la Société préhistorique française*, **39**: 209–219.

GONZÁLEZ-MORALES, M.R. & STRAUS, L.G. (2009): Extraordinary Early Magdalenian finds from El Mirón Cave, Cantabria (Spain). – *Antiquity*, **83**/320: 267–281. doi: 10.1017/S0003598X00098422.

GONZÁLEZ-MORALES, M.R. & STRAUS, L.G. (2012): Terminal Magdalenian / Azilian at El Mirón Cave (Ramales de la Victoria, Cantabria) and the Río Asón Valley. – In: Ad orientem: del final de paleolítico en el norte de España a las primeras civilizaciones del Oriente Próximo : estudios en homenaje al profesor Juan Antonio Fernández-Tresguerres Velasco. – pp. 189–215, Oviedo (Ediciones de la Universidad de Oviedo).

GONZÁLEZ-MORALES, M.R. & STRAUS, L.G. (2013): La ocupación gravetiense de la cueva de El Mirón (Ramales de la Victoria, Cantabria) y el contexto del arte paleolítico temprano de la cuenca del Asón. – In: DE LAS HERAS, C. (ed.): Pensando el Gravetiense: Nuevos datos para la región cantábrica en su contexto peninsular y pirenaico. – pp. 289–300, Santander (Museo Nacional y Centro de Investigación de Altamira).

GONZÁLEZ-MORALES, M.R. & STRAUS, L.G. (2014a): Cueva del Mirón (Ramales de la Victoria, Cantabria) Excavaciones 1996-1999. – In: Pleistocene and Holocene hunter-gatherers in Iberia and the Gibraltar strait: the current archaeological record. – pp. 121–133, Burgos (Universidad de Burgos).

GONZÁLEZ-MORALES, M.R. & STRAUS, L.G. (2014b): Arte parietal asociado al enterramiento Magdaleniense de la Cueva del Mirón (Ramales de la Victoria, Cantabria). – In: Cien años de arte rupestre paleolítico. – pp. 89-99., Salamanca (Ediciones Universidad).

GONZÁLEZ-MORALES, M.R. & STRAUS, L.G. (2015): Magdalenian-age graphic activity associated with the El Mirón Cave human burial. – *Journal of Archaeological Science*, **60**: 125–133. doi: 10.1016/j.jas.2015.02.025.

GONZÁLEZ-MORALES, M.R., STRAUS, L.G., DIEZ CASTILLO, A.A. & RUIZ COBO, J. (2004): Postglacial Coast & Inland: The Epipaleolithic-Mesolithic-Neolithic transitions in the Vasco-Cantabrian region. – *Munibe*, **65**: 61–78.

GONZÁLEZ-MORALES, M.R., STRAUS, L.G. & MARÍN-ARROYO, A.B. (2006): Los omóplatos decorados magdalenienses de la Cueva del Mirón (Ramales de la Victoria, Cantabria) y su relación con las Cueva del Castillo, Altamira y El Juyo. – *Zona arqueológica*, **1**/7: 483–494.

GONZÁLEZ-PUMARIEGA SOLÍS, M. & PÉREZ, J.F. (2008): Guía del arte rupestre Paleolítico de Asturias. – Gijón (Ménsula).

GONZÁLEZ-PUMARIEGA SOLÍS, M., POLLEDO GONZÁLEZ, M. & MALLO VIESCA, M. (2018): Los grabados parietales de la cueva de Las Mestas (Tahoces, Las Regueras, Asturias). – *NAILOS. Estudios Interdisciplinares de Arqueología*, **5**: 149–170.

GONZÁLEZ-SAINZ, C. (1989): El Magdaleniense Superior-Final de la región cantábrica. – Diss.: Santander (Universidad Cantabria).

GONZÁLEZ-SAINZ, C. (1992): Aproximación al aprovechamiento económico de las poblaciones cantábricas durante el Tardiglacial. – In: Elefantes, ciervos y ovicaprinos : economía y aprovechamiento del medio en la Prehistoria de España y Portugal. – pp. 129–147, (Servicio de Publicaciones).

GONZÁLEZ-SAINZ, C. & GONZÁLEZ-URQUIJO, J.E. (2004): El Magdaleniense reciente en la región Cantábrica - The late Magdalenian in Cantabrian Spain. – In: Las Sociedades del Paleolítico en la Región Cantábrica. – pp. 275–308, (Bizkaiko Foru Aldundia).

GONZÁLEZ-SAINZ, C., MONTES BARQUÍN, R. & MUÑOZ-FERNÁNDEZ, E. (2009): La cueva de Sovilla (San Felices de Buelna, Cantabria). – *Zephyrvs*, **46**/0.

GONZÁLEZ-SAINZ, C., RUIZ-REDONDO, A., GARATE-MAIDAGAN, D. & IRIARTE-AVILÉS, E. (2013): Not only Chauvet: Dating Aurignacian rock art in Altxerri B Cave (northern Spain). – *Journal of Human Evolution*, **65**/4: 457–464. doi: 10.1016/j.jhevol.2013.08.001.

GONZÁLEZ-SAINZ, C. & SAN MIGUEL LLAMOSAS, C. (2001): Las cuevas del desfiladero: arte rupestre paleolítico en el valle del río Carranza (Cantabria-Vizcaya). – 232 pp. Santander (Universidad de Cantabria).

GONZÁLEZ-SAINZ, C., TOCA, R.C. & FUKAZAWA, T. (2003): Arte paleolítico en la región cantábrica: base de datos multimedia Photo VR, DVD-ROM versión Windows. – 204 pp. Santander (Universidad de Cantabria).

GONZÁLEZ-SAINZ, C. & UTRILLA, P. (2005): Problemas actuales en la organización y datación del Magdaleniense de la Región Cantábrica. – In: O Paleolítico: actas do IV Congresso de Arqueologia Peninsular (Faro, 14 a 19 de Setembro de 2004). – pp. 39–48, (Centro de Estudos de Patrimonio, Departamento de Historia, Arqueologia e Patrimonio, Universidade do Algarve).

GONZÁLEZ-SAMPÉRIZ, P., LEROY, S.A.G., CARRIÓN, J.S., FERNÁNDEZ, S., GARCÍA-ANTÓN, M., GIL-GARCÍA, M.J., UZQUIANO, P., VALERO-GARCÉS, B. & FIGUEIRAL, I. (2010): Steppes, savannahs, forests and phytodiversity reservoirs during the Pleistocene in the Iberian Peninsula. – *Review of Palaeobotany and Palynology*, **162**/3: 427–457. doi: 10.1016/j.revpalbo.2010.03.009.

GONZÁLEZ-URQUIJO, J.E., BÁÑEZ, J.J., RIOS-GARAIZAR, J., OURGUIGNON, L., ASTAÑOS, P. & ARRIÑO, A. (2005): Excavaciones recientes en Axlor. Movilidad y planificación de actividades en grupos de neandertales. – In: Neandertales cantábricos, estado de la cuestión: actas de la reunión científica: celebrada en el Museo de Altamira los días 20-22 de octubre de 2004. – p. .

GOOD, S.P. & CAYLOR, K.K. (2011): Climatological determinants of woody cover in Africa. – *Proceedings of the National Academy of Sciences*, **108**/12: 4902–4907. doi: 10.1073/pnas.1013100108.

GOREN-INBAR, N. & ALPERSON-AFIL, N. (2010): The Acheulian site of Gesher Benot Ya'aqov Ancient flames and controlled use of fire. – xxviii, 120 pp. Dordrecht, London (Springer).

GOULD, R.A. & WATSON, P.J. (1982): A dialogue on the meaning and use of analogy in ethnoarchaeological reasoning. – *Journal of Anthropological Archaeology*, **1**/4: 355–381.

GRANADOS, J.E., PÉREZ, J.M., MÁRQUEZ, F.J., SERRANO, E., SORIGUER, R.C. & FANDOS, P. (2001): La cabra montés (Capra pyrenaica, Schinz 1838). – *Galemys*, **13**/1: 3–37.

GRAVEL-MIGUEL, C. & WREN, C.D. (2018): Agent-based least-cost path analysis and the diffusion of Cantabrian Lower Magdalenian engraved scapulae. – *Journal of Archaeological Science*, **99**: 1–9.

GRAYSON, D.K. (1979): On the quantification of vertebrate archaeofaunas. – *Advances in archaeological method and theory*, **2**: 199–237.

GRAYSON, D.K. (1984): Quantitative zooarchaeology: topics in the analysis of archaeological faunas. – 230 pp. (Academic Press).

GRAYSON, D.K. (1989): Bone transport, bone destruction, and reverse utility curves. – *Journal of Archaeological Science*, **16**/6: 643–652. doi: 10.1016/0305-4403(89)90028-9.

GRAYSON, D.K. (2001): The archaeological record of human impacts on animal populations. – *Journal of World Prehistory*, **15**/1: 1–68.

GRAYSON, D.K. & DELPECH, F. (1998): Changing diet breadth in the early Upper Palaeolithic of southwestern France. – *Journal of Archaeological Science*, **25**/11: 1119–1129.

GRAYSON, D.K. & DELPECH, F. (2003): Ungulates and the Middle-to-Upper Paleolithic transition at Grotte XVI (Dordogne, France). – *Journal of Archaeological Science*, **30**/12: 1633–1648. doi: 10.1016/S0305-4403(03)00064-5.

GRAYSON, D.K., DELPECH, F., RIGAUD, J.-P. & SIMEK, J.F. (2001): Explaining the Development of Dietary Dominance by a Single Ungulate Taxon at Grotte XVI, Dordogne, France. – *Journal of Archaeological Science*, **28**/2: 115–125. doi: 10.1006/jasc.2000.0556.

GREEN, R.E., KRAUSE, J., BRIGGS, A.W., MARICIC, T., STENZEL, U., KIRCHER, M., PATTERSON, N., LI, H., ZHAI, W., FRITZ, M.H.Y., HANSEN, N.F., DURAND, E.Y., MALASPINAS, A.S., JENSEN, J.D., MARQUES-BONET, T., ALKAN, C., PRUFER, K., MEYER, M., BURBANO, H.A., GOOD, J.M., SCHULTZ, R., AXIMU-PETRI, A., BUTTHOF, A., HOBER, B., HOFFNER, B., SIEGEMUND, M., WEIHMANN, A., NUSBAUM, C., LANDER, E.S., RUSS, C., NOVOD, N., AFFOURTIT, J., EGHOLM, M., VERNA, C., RUDAN, P., BRAJKOVIC, D., KUCAN, Z., GUSIC, I., DORONICHEV, V.B., GOLOVANOVA, L.V., LALUEZA-FOX, C., DE LA RASILLA, M., FORTEA, J., ROSAS, A., SCHMITZ, R.W., JOHNSON, P.L.F., EICHLER, E.E., FALUSH, D., BIRNEY, E., MULLIKIN, J.C., SLATKIN, M., NIELSEN, R., KELSO, J., LACHMANN, M., REICH, D. & PAABO, S. (2010): A Draft Sequence of the Neandertal Genome. – *Science*, **328**/5979: 710–722. doi: 10.1126/science.1188021.

GREINER, M., RODRÍGUEZ-NAVARRO, A., HEINIG, M.F., MAYER, K., KOCSIS, B., GÖHRING, A., TONCALA, A., GRUPE, G. & SCHMAHL, W.W. (2019): Bone incineration: An experimental study on mineral structure, colour and crystalline state. – *Journal of Archaeological Science: Reports*, **25**: 507–518. doi: 10.1016/j.jasrep.2019.05.009.

GRIMES, V. & PELLEGRINI, M. (2013): A comparison of pretreatment methods for the analysis of phosphate oxygen isotope ratios in bioapatite: Analysis of phosphate oxygen isotope ratios in bioapatite. – *Rapid Communications in Mass Spectrometry*, **27**/3: 375–390. doi: 10.1002/rcm.6463.

GROOTES, P.M., STUIVER, M., WHITE, J.W.C., JOHNSEN, S. & JOUZEL, J. (1993): Comparison of oxygen isotope records from the GISP2 and GRIP Greenland ice cores. – *Nature*, **366**/6455: 552–554. doi: 10.1038/366552a0.

GUAN, Y., GAO, X., WANG, H., CHEN, F., PEI, S., ZHANG, X. & ZHOU, Z. (2011): Spatial analysis of intra-site use at a Late Paleolithic site at Shuidonggou, Northwest China. – *Chinese Science Bulletin*, **56**/32: 3457–3463. doi: 10.1007/s11434-011-4682-x.

GUTHRIE, R.D. (1968): Paleoecology of the Large-Mammal Community in Interior Alaska during the Late Pleistocene. – *The American Midland Naturalist*, **79**/2: 346–363 (University of Notre Dame). doi: 10.2307/2423182.

GUTIÉRREZ-ZUGASTI, I. (2010): La explotación de moluscos y otros recursos litorales en la región cantábrica durante el Pleistoceno final y el Holoceno inicial. – 564 pp. Santander (PUbliCan).

GUTIÉRREZ-ZUGASTI, I. & CUENCA-SOLANA, D. (2015): Ornaments from the Magdalenian burial area in El Mirón Cave (Cantabria, northern Spain). Were they grave goods? – *Journal of Archaeological Science*, **60**: 112–124. doi: 10.1016/j.jas.2015.04.012.

GUTIÉRREZ-ZUGASTI, I., CUENCA-SOLANA, D., COLONESE, A.C. & FERNÁNDEZ-LÓPEZ DE PABLO, J. (2016): Time for the tide. New perspectives on hunter–fisher–gatherer exploitation of intertidal resources in Atlantic Europe and Mediterranean regions. – *Quaternary International*, **407, Part B**: 2–5. doi: 10.1016/j.quaint.2016.04.044.

GUTIÉRREZ-ZUGASTI, I., RIOS-GARAIZAR, J., MARÍN-ARROYO, A.B., RASINES DEL RÍO, P., MAROTO, J., JONES, J.R., BAILEY, G.N. & RICHARDS, M.P. (2018): A chrono-cultural reassessment of the levels VI–XIV from El Cuco rock-shelter: A new sequence for the Late Middle Paleolithic in the Cantabrian region (northern Iberia). – *Quaternary International*, **474**: 44–55. doi: 10.1016/j.quaint.2017.06.059.

HAHN, J. (1991): Erkennen und Bestimmen von Stein- und Knochenartefakten: Einführung in die Artefaktmorphologie. – 314 pp. (Verlag Archaeologica Venatoria).

HAKENBECK, S. (2008): Migration in archaeology: are we nearly there yet. – *Archaeological Review from Cambridge*, **23**/2: 9–26.

HAMES, R.B. & VICKERS, W.T. (1982): Optimal diet breadth theory as a model to explain variability in Amazonian hunting. – *American Ethnologist*, **9**/2: 358–378.

HAMILTON, M.J., LOBO, J., RUPLEY, E., YOUN, H. & WEST, G.B. (2016): The ecological and evolutionary energetics of hunter-gatherer residential mobility. – *Evolutionary Anthropology*, **25**/3: 124–132. doi: 10.1002/evan.21485.

HARDY, K., BLAKENEY, T., COPELAND, L., KIRKHAM, J., WRANGHAM, R. & COLLINS, M. (2009): Starch granules, dental calculus and new perspectives on ancient diet. – *Journal of Archaeological Science*, **36**/2: 248–255. doi: 10.1016/j.jas.2008.09.015.

HARDY, K., BUCKLEY, S. & COPELAND, L. (2018): Pleistocene dental calculus: Recovering information on Paleolithic food items, medicines, paleoenvironment and microbes. – *Evolutionary Anthropology: Issues, News, and Reviews*, **27**/5: 234–246. doi: 10.1002/evan.21718.

HÄRKE, H. (2004): The debate on migration and identity in Europe. – *Antiquity*, **78**/300: 453–456.

HARRIS, E.C. (1989): Principles of archaeological stratigraphy. 2nd edition. – London (Academic Press).

HARRISON, S.P. & SANCHEZ GOÑI, M.F. (2010): Global patterns of vegetation response to millennial-scale variability and rapid climate change during the last glacial period. – *Quaternary Science Reviews*, **29**/21–22: 2957–2980. doi: 10.1016/j.quascirev.2010.07.016.

HARROLD, F.B. (1980): A comparative analysis of Eurasian Palaeolithic burials. – *World Archaeology*, **12**/2: 195–211.

HARROLD, F.B. (1981): New perspectives on the Chatelperronian. – *Empúries: revista de món clàssic i antiguitat tardana*/43: 1–51.

HAWS, J.A. (2012a): Paleolithic socionatural relationships during MIS 3 and 2 in central Portugal. – *Quaternary International*, **264**: 61–77. doi: doi: 10.1016/j.quaint.2011.10.003.

HAWS, J.A. (2012b): Paleolithic socionatural relationships during MIS 3 and 2 in central Portugal. – *Quaternary International*, **264**: 61–77. doi: 10.1016/j.quaint.2011.10.003.

HAYNES, G. (1983a): Frequencies of Spiral and Green-Bone Fractures on Ungulate Limb Bones in Modern Surface Assemblages. – *American Antiquity*, **48**/1: 102–114. doi: 10.2307/279822.

HAYNES, G. (1983b): A Guide for Differentiating Mammalian Carnivore Taxa Responsible for Gnaw Damage to Herbivore Limb Bones. – *Paleobiology*, **9**/2: 164–172.

HEDGES, R.E.M. (2002): Bone diagenesis: an overview of processes. – *Archaeometry*, **44**/3: 319–328. doi: 10.1111/1475-4754.00064.

HEDGES, R.E.M., STEVENS, R.E. & RICHARDS, MICHAEL.P. (2004): Bone as a stable isotope archive for local climatic information. – *Quaternary Science Reviews*, **23**/7–8: 959–965. doi: 10.1016/j.quascirev.2003.06.022.

HEINRICH, H. (1988): Origin and consequences of cyclic ice rafting in the Northeast Atlantic Ocean during the past 130,000 years. – *Quaternary Research*, **29**/2: 142–152. doi: 10.1016/0033-5894(88)90057-9.

HEMMING, S.R. (2004): Heinrich events: Massive late Pleistocene detritus layers of the North Atlantic and their global climate imprint. – *Reviews of Geophysics*, **42**/1: n/a–n/a. doi: 10.1029/2003RG000128.

HENRY, A.G., BROOKS, A.S. & PIPERNO, D.R. (2011): Microfossils in calculus demonstrate consumption of plants and cooked foods in Neanderthal diets (Shanidar III, Iraq; Spy I and II, Belgium). – *Proceedings of the National Academy of Sciences*, **108**/2: 486–491. doi: 10.1073/pnas.1016868108.

HENRY, A.G., BROOKS, A.S. & PIPERNO, D.R. (2014): Plant foods and the dietary ecology of Neanderthals and early modern humans. – *Journal of Human Evolution*, **69**: 44–54. doi: 10.1016/j.jhevol.2013.12.014.

HENRY, A.G. & PIPERNO, D.R. (2008): Using plant microfossils from dental calculus to recover human diet: a case study from Tell al-Raqā'i, Syria. – *Journal of Archaeological Science*, **35**/7: 1943–1950. doi: 10.1016/j.jas.2007.12.005.

HENRY, D. (2012): The palimpsest problem, hearth pattern analysis, and Middle Paleolithic site structure. – *Quaternary International*, **247**: 246–266.

HENRY-GAMBIER, D., VILLOTTE, S., BEAUVAL, C. & GRIMAUD-HERVÉ, D. (2013): Les vestiges humains : un assemblage original. – In: Le Gravettien final de l'abri Pataud (Dordogne, France) Fouilles et études 2005-2009. – pp. 135–176, Oxford (Archaeopress).

DE LAS HERAS, C., BARQUÍN, R.M., CORRUCHAGA, J.A.L., DEL RÍO, P.R. & MONFORTE, P.F. (2007): Dos rodetes paleolíticos procedentes de las cuevas del Linar y Las Aguas, Alfoz de Lloredo (Cantabria). – *Veleia: Revista de prehistoria, historia antigua, arqueología y filología clásicas*/24: 161–174.

DE LAS HERAS, C., LASHERAS, J.A., ARRIZABALAGA, Á. & DE LA RASILLA, M. (eds) (2013): Pensando el Gravetiense: nuevos datos para la región cantábrica en su contexto peninsular y pirenaico. – 619 pp. Santander (Museo Nacional y Centro de Investigación de Altamira).

DE LAS HERAS, C., LASHERAS, J.A., RASINES, P., MONTES, R., FATÁS, P., PRADA, A. & MUÑOZ, E. (2012): Datation et contexte archéologique de la nouvelle omoplate gravée découverte a Altamira. – *L'Art Pléistocène dans le Monde, Bulletin de la Société Préhistorique Ariège-Pyrénées*, **65**: 21.

HERMOSO-BUXÁN, X.L. (Unpub.): Carbon and nitrogen stable isotope analysis of red deer bone from El Mirón cave, Cantabria (Northern Spain). Climatic and environmental reconstructions across the Pleistocene- Holocene transition. – Thesis: (University of Cambridge).

HESSE, B. & WAPNISH, P. (1985): Animal bone archeology: from objectives to analysis. – (Washington, D.C. : Taraxacum).

HEWITT, G. (2000): The genetic legacy of the Quaternary ice ages. – *Nature*, **405**/6789: 907–913.

HEWITT, G.M. (1999): Post-glacial re-colonization of European biota. – *Biological Journal of the Linnean Society*, **68**/1–2: 87–112. doi: 10.1111/j.1095-8312.1999.tb01160.x.

HIETALA, H.J. & LARSON, P.A. (1984): Intrasite spatial analysis in archaeology. – Cambridge (Cambridge University Press).

HIGGS, E.S. & JARMAN, M.R. (1975): Papers in economic prehistory. – Cambridge a.o (Cambridge University Press).

HIGHAM, T., DOUKA, K., WOOD, R., RAMSEY, C.B., BROCK, F., BASELL, L., CAMPS, M., ARRIZABALAGA, A., BAENA, J., BARROSO-RUÍZ, C., BERGMAN, C., BOITARD, C., BOSCATO, P., CAPARRÓS, M., CONARD, N.J., DRAILY, C., FROMENT, A., GALVÁN, B., GAMBASSINI, P., GARCIA-MORENO, A., GRIMALDI, S., HAESAERTS, P., HOLT, B., IRIARTE-CHIAPUSSO, 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**/7514: 306–309. doi: 10.1038/nature13621.

HIGHAM, T., JACOBI, R., BASELL, L., RAMSEY, C.B., CHIOTTI, L. & NESPOULET, R. (2011): Precision dating of the Palaeolithic: a new radiocarbon chronology for the Abri Pataud (France), a key Aurignacian sequence. – *Journal of Human Evolution*, **61**/5: 549–63. doi: 10.1016/j.jhevol.2011.06.005.

HIGHAM, T., JACOBI, R., JULIEN, M., DAVID, F., BASELL, L., WOOD, R., DAVIES, W. & RAMSEY, C.B. (2010): Chronology of the Grotte du Renne (France) and implications for the context of ornaments and human remains within the Chatelperronian. – *Proceedings of the National Academy of Sciences*, **107**/47: 20234–20239. doi: 10.1073/pnas.1007963107.

HIGHAM, T.F.G., JACOBI, R.M. & RAMSEY, C.B. (2006): AMS Radiocarbon Dating of Ancient Bone Using Ultrafiltration. – *Radiocarbon*, **48**/2: 179–195. doi: 10.1017/S0033822200066388.

HILL, M.E. (2007): A Moveable Feast: Variation in Faunal Resource Use among Central and Western North American Paleoindian Sites. – *American Antiquity*, **72**/03: 417–438. doi: 10.2307/40035854.

HILLSON, S. (1990): Teeth. – Cambridge (Cambridge University Press).

HODDER, I. & ORTON, C. (1976): Spatial analysis in archaeology. – Cambridge.

HOFFECKER, J.F. (2009): The spread of modern humans in Europe. – *Proceedings of the National Academy of Sciences*, **106**/38: 16040–16045. doi: 10.1073/pnas.0903446106.

HOLLING, C.S. (1959): The Components of Predation as Revealed by a Study of Small-Mammal Predation of the European Pine Sawfly. – *The Canadian Entomologist*, **91**/05: 293–320. doi: 10.4039/Ent91293-5.

HOLLING, C.S. (2001): Understanding the Complexity of Economic, Ecological, and Social Systems. – *Ecosystems*, **4**/5: 390–405. doi: 10.1007/s10021-001-0101-5.

HOPPE, K.A., STOVER, S.M., PASCOE, J.R. & AMUNDSON, R. (2004): Tooth enamel biomineralization in extant horses: implications for isotopic microsampling. – *Palaeogeography, Palaeoclimatology, Palaeoecology*, **206**/3–4: 355–365. doi: 10.1016/j.palaeo.2004.01.012.

HOYOS GÓMEZ, M. (1995): Paleoclimatología del Tardiglacial en la Cornisa Cantábrica basada en los resultados sedimentológicos de yacimientos arqueológicos kársticos. – In: El final del Paleolítico cantábrico. Universidad de Cantabria, Santander. – pp. 15–75, Santander (Universidad de Cantabria).

HUBBARD, W.J. (2000): Geoarchaeological study of El Mirón Cave, Ramales de la Victoria, Cantabria, Spain. – Unpublished master's thesis: Michigan (University of Michigan).

HUBLIN, J.-J. (2015): The modern human colonization of western Eurasia: when and where? – *Quaternary Science Reviews*, **118**: 194–210. doi: 10.1016/j.quascirev.2014.08.011.

HUGHES, P.D. & WOODWARD, J.C. (2008): Timing of glaciation in the Mediterranean mountains during the last cold stage. – *Journal of Quaternary Science*, **23**/6–7: 575–588. doi: 10.1002/jqs.1212.

IACUMIN, P., BOCHERENS, H., MARIOTTI, A. & LONGINELLI, A. (1996): Oxygen isotope analyses of co-existing carbonate and phosphate in biogenic apatite: a way to monitor diagenetic alteration of bone phosphate? – *Earth and Planetary Science Letters*, **142**/1: 1–6. doi: 10.1016/0012-821X(96)00093-3.

INIZAN, M.-L., REDURON-BALLINGER, M., ROCHE, H., TIXIER, J. & FÉBLOT-AUGUSTINS, J. (eds) (1999): Technology and terminology of knapped stone: followed by a multilingual vocabulary - Arabic, English, French, German, Greek, Italian, Portuguese, Spanish. – 189 pp. Nanterre (CREP).

IRIARTE, E., LOPEZ-HORGUE, M.A., SCHROEDER, S. & CALINE, B. (2012): Interplay between fracturing and hydrothermal fluid flow in the Ason Valley hydrothermal dolomites (Basque-Cantabrian Basin, Spain). – *Geological Society, London, Special Publications*, **370**/1: 207–227. doi: 10.1144/SP370.10.

IRIARTE-CHIAPUSSO, M.J. (2014): El Tardiglaciar en la cueva de Santa Catalina (Lekeitio, Bizkaia). Evaluación del medio vegetal a través del registro polínico. – *Kobie*, **4**/4: 59–74.

IRIARTE-CHIAPUSSO, M.J. (2015): The cave of Bolinkoba (Abadiño, Bizkaia) and its archaeological deposit. Geoarchaeological sequence. A synthesis of the excavation process and of the archaeological collection dag in the successive researches. – In: Bolinkoba (Abadiño) y su yacimiento arqueológico: arqueología de la arqueología para la puesta en valor de su depósito, a la luz de las excavaciones antiguas y recientes. – pp. 173–182, Bilbao (Ser).

IRIARTE-CHIAPUSSO, M.J. & ARRIZABALAGA, Á. (2013): El Gravetiense de Bolinkoba (Bizkaia) a la luz de las excavaciones antiguas y recientes. – In: Pensando el Gravetiense: Nuevos datos para la región cantábrica en su contexto peninsular y pirenáico. – pp. 217–227, Santander (Museo Nacional y Centro de Investigación de Altamira).

IRIARTE-CHIAPUSSO, M.J., ARRIZABALAGA, A. & CUENCA-BESCÓS, G. (2015): The vegetational and climatic contexts of the Lower Magdalenian human burial in El Mirón Cave (Cantabria, Spain): implications related to human behavior. – *Journal of Archaeological Science*, **60**: 66–74. doi: 10.1016/j.jas.2015.02.008.

IRIARTE-CHIAPUSSO, M.J., MUÑOZ-SOBRINO, C., GÓMEZ-ORELLANA, L., HERNÁNDEZ-BELOQUI, B., GARCÍA-MOREIRAS, I., FERNÁNDEZ RODRIGUEZ, C., HEIRI, O., LOTTER, A.F. & RAMIL-REGO, P. (2016): Reviewing the Lateglacial–Holocene transition in NW Iberia: A palaeoecological approach based on the comparison between dissimilar regions. – *Quaternary International*, **403**: 211–236. doi: 10.1016/j.quaint.2015.09.029.

ISAAC, G. (1978): The Food-sharing Behavior of Protohuman Hominids. – *Scientific American*, **238**/4: 90–108. doi: 10.1038/scientificamerican0478-90.

ISAAC, G.L. (1967): Towards the interpretation of occupation debris: some experiments and observations. – *Kroeber Anthropological Society Papers*, **37**/37: 31–57.

IVY-OCHS, S., KERSCHNER, H., REUTHER, A., PREUSSER, F., HEINE, K., MAISCH, M., KUBIK, P.W. & SCHLÜCHTER, C. (2008): Chronology of the last glacial cycle in the European Alps. – *Journal of Quaternary Science*, **23**/6–7: 559–573.

JALUT, G., TURU I MICHELS, V., DEDOUBAT, J.-J., OTTO, T., EZQUERRA, J., FONTUGNE, M., BELET, J.M., BONNET, L., DE CELIS, A.G., REDONDO-VEGA, J.M., VIDAL-ROMANÍ, J.R. & SANTOS, L. (2010): Palaeoenvironmental studies in NW Iberia (Cantabrian range): Vegetation history and synthetic approach of the last deglaciation phases in the western Mediterranean. – *Palaeogeography, Palaeoclimatology, Palaeoecology*, **297**/2: 330–350. doi: 10.1016/j.palaeo.2010.08.012.

JANZEN, A., REID, R.E.B., VASQUEZ, A. & GIFFORD-GONZALEZ, D. (2014): Smaller fragment size facilitates energy-efficient bone grease production. – *Journal of Archaeological Science*, **49**: 518–523. doi: 10.1016/j.jas.2014.06.004.

JAOUEN, K., RICHARDS, M.P., CABEC, A.L., WELKER, F., RENDU, W., HUBLIN, J.-J., SORESSI, M. & TALAMO, S. (2019): Exceptionally high δ15N values in collagen single amino acids confirm Neandertals as high-trophic level carnivores. – *Proceedings of the National Academy of Sciences*, **116**/11: 4928–4933. doi: 10.1073/pnas.1814087116.

JÉQUIER, C., LIVRAGHI, A., ROMANDINI, M. & PERESANI, M. (2018): Same but different: 20,000 years of bone retouchers from Northern Italy. A diachronological approach from Neanderthals to Anatomical Modern Humans. – In: The Origins of Bone Tool Technologies. – pp. 1–17,.

JOCHIM, M. (1987): Late pleistocene refugia in Europe. – In: The Pleistocene Old World. – pp. 317–331, New York (Springer).

JOCHIM, M.A. (1988): Optimal foraging and the division of labor. – *American Anthropologist*, **90**/1: 130–136.

JONES, E.L. (2007): Subsistence change, landscape use, and changing site elevation at the Pleistocene–Holocene transition in the Dordogne of southwestern France. – *Journal of Archaeological Science*, **34**/3: 344–353. doi: 10.1016/j.jas.2006.05.005.

JONES, E.L. (2016): Archaeofaunal Diversity and Broad Spectrum Diets in Late Paleolithic Southwest Europe. – In: JONES, E.L. (ed.): In Search of the Broad Spectrum Revolution in Paleolithic Southwest Europe. – pp. 61–78, Cham (Springer International Publishing). doi: 10.1007/978-3-319-22351-3_5.

JONES, J.R., MARÍN-ARROYO, A.B., STRAUS, L.G. & RICHARDS, M.P. (2020): Adaptability, resilience and environmental buffering in European Refugia during the Late Pleistocene: Insights from La Riera Cave (Asturias, Cantabria, Spain). – *Scientific Reports*, **10**/1: 1217. doi: 10.1038/s41598-020-57715-2.

JONES, J.R., RICHARDS, M.P., READE, H., BERNALDO DE QUIRÓS, F. & MARÍN-ARROYO, A.B. (2019): Multi-Isotope investigations of ungulate bones and teeth from El Castillo and Covalejos caves (Cantabria, Spain): Implications for paleoenvironment reconstructions across the Middle-Upper Palaeolithic transition. – *Journal of Archaeological Science: Reports*, **23**: 1029–1042. doi: 10.1016/j.jasrep.2018.04.014.

JONES, J.R., RICHARDS, M.P., STRAUS, L.G., READE, H., ALTUNA, J., MARIEZKURRENA, K. & MARÍN-ARROYO, A.B. (2018): Changing environments during the Middle-Upper Palaeolithic transition in the eastern Cantabrian Region (Spain): direct evidence from stable isotope studies on ungulate bones. – *Scientific Reports*, **8**/1. doi: 10.1038/s41598-018-32493-0.

JORDÁ-CERDÁ, F. (1963): El Paleolítico Superior cantábrico y sus industrias. – *Saitabi: revista de la Facultat de Geografia i Història*, **13**: 3–22.

JORDÁ-PARDO, J.F., BAENA PREYSLER, J., CARRAL GONZÁLEZ, P., GARCÍA-GUINEA, J., CORRECHER DELGADO, V. & YRAVEDRA, J. (2008): Procesos sedimentarios y diagenéticos en el registro arqueológico del yacimiento Pleistoceno de la Cueva de El Esquilleu (Picos de Europa, Norte de España). – *Cuaternario y geomorfología*, **22**/3–4: 31–46.

JÖRIS, O., STREET, M. & SIROCKO, F. (2009): Siedlungsleere-das Kältemaximum der letzten Kaltzeit. – In: SIROCKO, F. (ed.): Wetter, Klima, Menschheitsentwicklung von der Eiszeit bis ins 21. Jahrhundert. – pp. 83–87, (WBG Darmstadt).

JÖRIS, O., STREET, M. & TURNER, E. (2011): Spatial Analysis at the Magdalenian Site of Gönnersdorf (Central Rhineland, Germany) – an Introduction. – *Site-internal spatial organization of hunter-gatherer societies: Case studies from the European Palaeolithic and Mesolithic*: 53–80.

JUDZIEWICZ, E.J., SORENG, R.J., DAVIDSE, G., PETERSON, P.M., FILGUEIRAS, T.S. & ZULOAGA, F.O. (2000): Catalogue of New World Grasses (Poaceae): I. Subfamilies Anomochlooideae, Bambusoideae, Ehrhartoideae, and Pharoideae. – *Contributions from the United States National Herbarium*, **39**: 1–128.

JULIEN, M.-A., BOCHERENS, H., BURKE, A., DRUCKER, D.G., PATOU-MATHIS, M., KROTOVA, O. & PÉAN, S. (2012): Were European steppe bison migratory? ^{18}O, ^{13}C and Sr intra-tooth isotopic variations applied to a palaeoethological reconstruction. – *Quaternary International*, **271**: 106–119. doi: 10.1016/j.quaint.2012.06.011.

JULIEN, M.-A., RIVALS, F., SERANGELI, J., BOCHERENS, H. & CONARD, N.J. (2015): A new approach for deciphering between single and multiple accumulation events using intra-tooth isotopic variations: Application to the Middle Pleistocene bone bed of Schöningen 13 II-4. – *Journal of Human Evolution*, **89**: 114–128. doi: 10.1016/j.jhevol.2015.02.012.

KAGEYAMA, M., NEBOUT, N.C., SEPULCHRE, P., PEYRON, O., KRINNER, G., RAMSTEIN, G. & CAZET, J.-P. (2005): The Last Glacial Maximum and Heinrich Event 1 in terms of climate and vegetation around the Alboran Sea: a preliminary model-data comparison. – *Comptes Rendus Geoscience*, **337**/10–11: 983–992. doi: 10.1016/j.crte.2005.04.012.

KAHNEMAN, D. & TVERSKY, A. (2012): Prospect Theory: An Analysis of Decision Under Risk. – In: Econometrica. – pp. 263–291, (WORLD SCIENTIFIC). doi: 10.1142/9789814417358_0006.

KAISER, T.M., BRAUNE, C., KALINKA, G. & SCHULZ-KORNAS, E. (2018): Nano-indentation of native phytoliths and dental tissues: implications for herbivore-plant combat and dental wear proxies. – *Evolutionary Systematics*, **2**/1: 55–63. doi: 10.3897/evolsyst.2.22678.

KARKANAS, P., BAR-YOSEF, O., GOLDBERG, P. & WEINER, S. (2000): Diagenesis in Prehistoric Caves: the Use of Minerals that Form In Situ to Assess the Completeness of the Archaeological Record. – *Journal of Archaeological Science*, **27**/10: 915–929. doi: 10.1006/jasc.1999.0506.

KARKANAS, P. & GOLDBERG, P. (2010): 23 - Phosphatic Features. – In: STOOPS, G., MARCELINO, V. & MEES, F. (eds): Interpretation of Micromorphological Features of Soils and Regoliths. – pp. 521–541, Amsterdam (Elsevier). doi: 10.1016/B978-0-444-53156-8.00023-4.

KARR, L.P., OUTRAM, A.K. & HANNUS, L.A. (2010): A chronology of bone marrow and bone grease exploitation at the Mitchell Prehistoric Indian Village. – *Plains Anthropologist*, **55**/215: 215–223.

KARR, L.P., SHORT, A.E.G., ADRIEN HANNUS, L. & OUTRAM, A.K. (2015): A bone grease processing station at the Mitchell Prehistoric Indian Village: Archaeological evidence for the exploitation of bone fats. – *Environmental Archaeology*, **20**/1: 1–12. doi: 10.1179/1749631414Y.0000000035.

KEELEY, L.H. (1988): Lithic economy, style and use: a comparison of three Late Magdalenian sites. – *Lithic Technology*, **17**/1: 19–25.

KELLY, R.L. (1983): Hunter-Gatherer Mobility Strategies. – *Journal of Anthropological Research*, **39**/3: 277–306.

KELLY, R.L. (1992): Mobility/Sedentism: Concepts, Archaeological Measures, and Effects. – *Annual Review of Anthropology*, **21**: 43–66.

KELLY, R.L. (1995): The foraging spectrum: Diversity in hunter-gatherer lifeways. – (Smithsonian Institution Press Washington, DC).

KELSO, N.V. & PATTERSON, T. (2010): Introducing natural earth data-naturalearthdata. com. – *Geographia Technica*, **5**/82–89: 25.

KENT, S. (1991): Chapter 2: The Relationship between Mobility Strategies and Site Structure. – In: KROLL, E.M. & PRICE, T.D. (eds): The Interpretation of Archaeological Spatial Patterning. – pp. 33–59, Boston, MA (Springer US). doi: 10.1007/978-1-4899-2602-9_3.

KINTIGH, K.W. (1990): Intrasite spatial analysis: A commentary on major methods. – *Mathematics and Information Science in Archaeology: A Flexible Framework, Studies in Modern Archaeology*, **3**: 165–200.

KLEIN, R.G. (1982): Age (mortality) profiles as a means of distinguishing hunted species from scavenged ones in Stone Age archeological sites. – *Paleobiology*, **8**/2: 151–158.

KLEIN, R.G. (1989): Why does skeletal part representation differ between smaller and larger bovids at Klasies river mouth and other archeological sites? – *Journal of Archaeological Science*, **16**/4: 363–381. doi: 10.1016/0305-4403(89)90012-5.

KLEIN, R.G. (2008): Out of Africa and the evolution of human behavior. – *Evolutionary Anthropology: Issues, News, and Reviews*, **17**/6: 267–281. doi: 10.1002/evan.20181.

KLEIN, R.G. (2009): The Human Career: Human Biological and Cultural Origins, Third Edition. – 1021 pp. (University of Chicago Press).

KLEIN, R.G. & CRUZ-URIBE, K. (1984): The analysis of animal bones from archeological sites. – Chicago (University of Chicago Press).

KLEIN, R.G. & CRUZ-URIBE, K. (1987): La Fauna de Mamífera del Yacimiento de la Cueva de" El Juyo": Campañas de 1978 y 1979. – In: Excavaciones en la Cueva Del Juyo (ed. by I. Barandiarán, LG Freeman, J. González Echegaray, and RG Klein). – pp. 97–120,.

KLEIN, R.G. & CRUZ-URIBE, K. (1994): The Paleolithic mammalian fauna from the 1.910-14 excavations at El Castillo Cave (Cantabria). – In: Homenaje al Dr. Joaquín González Echegaray. – pp. 141–158, (Dirección General de Bellas Artes y Archivos).

KLEIN, R.G., WOLF, C., FREEMAN, L.G. & ALLWARDEN, K. (1981): The use of dental crown heights for constructing age profiles of red deer and similar species in archaeological samples. – *Journal of Archaeological Science*, **8**/1: 1–31. doi: 10.1016/0305-4403(81)90010-8.

KOCH, P.L. (1998): Isotopic Reconstruction of Past Continental Environments. – *Annual Review of Earth and Planetary Sciences*, **26**/1: 573–613. doi: 10.1146/annurev.earth.26.1.573.

KOCH, P.L., TUROSS, N. & FOGEL, M.L. (1997): The Effects of Sample Treatment and Diagenesis on the Isotopic Integrity of Carbonate in Biogenic Hydroxylapatite. – *Journal of Archaeological Science*, **24**/5: 417–429. doi: 10.1006/jasc.1996.0126.

KOHN, M.J. (1996): Predicting animal $\delta^{18}O$: Accounting for diet and physiological adaptation. – *Geochimica et Cosmochimica Acta*, **60**/23: 4811–4829. doi: 10.1016/S0016-7037(96)00240-2.

KOHN, M.J. (2004): Comment: Tooth Enamel Mineralization in Ungulates: Implications for Recovering a Primary Isotopic Time-Series, by B. H. Passey and T. E. Cerling (2002). – *Geochimica et Cosmochimica Acta*, **68**/2: 403–405. doi: 10.1016/S0016-7037(03)00443-5.

KOHN, M.J. & CERLING, T.E. (2002): Stable isotope compositions of biological apatite. – *Reviews in mineralogy and geochemistry*, **48**/1: 455–488.

KOHN, M.J., SCHOENINGER, M.J. & VALLEY, J.W. (1996): Herbivore tooth oxygen isotope compositions: Effects of diet and physiology. – *Geochimica et Cosmochimica Acta*, **60**/20: 3889–3896. doi: 10.1016/0016-7037(96)00248-7.

KOHN, M.J., SCHOENINGER, M.J. & VALLEY, J.W. (1998): Variability in oxygen isotope compositions of herbivore teeth: reflections of seasonality or developmental physiology? – *Chemical Geology*, **152**/1–2: 97–112. doi: 10.1016/S0009-2541(98)00099-0.

KOON, H.E.C., O'CONNOR, T.P. & COLLINS, M.J. (2010): Sorting the butchered from the boiled. – *Journal of Archaeological Science*, **37**/1: 62–69. doi: 10.1016/j.jas.2009.08.015.

KRUMME, K. (2016): Sustainable Development and Social-Ecological-Technological Systems (SETS): Resilience as a Guiding Principle in the Urban-Industrial Nexus. – *Renewable Energy and Sustainable Development*, **2**/2: 70–90. doi: 10.21622/resd.2016.02.2.070.

KUHN, B.F., BERGER, L.R. & SKINNER, J.D. (2008): Examining criteria for identifying and differentiating fossil faunal assemblages accumulated by hyenas and hominins using extant hyenid accumulations. – *International Journal of Osteoarchaeology*, **35**/August 2008: n/a–n/a. doi: 10.1002/oa.996.

KUNTZ, D., SÉCHER, A., COSTAMAGNO, S., MALLYE, J.-B., PÉTILLON, J.-M., PESCHAUX, C., PUBERT, É., RENDU, W., BOUDADI-MALIGNE, M., LAROULANDIE, V., BARSHAY-SZMIDT, C.C. & LANGLAIS, M. (2015): Le Roc de Marcamps 2 (Prignac-et-Marcamps, Gironde): nouvelles données sur la subsistance et les traditions techniques au début du Magdalénien moyen. – *Bulletin de la Société préhistorique française*, **112**/3: 475–516.

KÜßNER, M. & TERBERGER, T. (2006): Die Fundstelle Gera-Zoitzberg und die Zeit zwischen Gravettien und Magdalénien in Mitteldeutschland. – *Alt-Thüringen*, **39**: 69–120.

LAM, Y.M., CHEN, X., MAREAN, C.W. & FREY, C.J. (1998): Bone density and long bone representation in archaeological faunas: comparing results from CT and photon densitometry. – *Journal of Archaeological Science*, **25**/6: 559–570.

LAM, Y.M., CHEN, X. & PEARSON, O.M. (1999): Intertaxonomic variability in patterns of bone density and the differential representation of bovid, cervid, and equid elements in the archaeological record. – *American Antiquity*, **64**/2: 343–362.

LAM, Y.M. & PEARSON, O.M. (2004): The Fallibility of Bone Density Values and Their Use in Archaeological Analyses. – *Journal of taphonomy*, **2**/1: 99–116.

LAM, Y.M. & PEARSON, O.M. (2005): Bone density studies and the interpretation of the faunal record. – *Evolutionary Anthropology: Issues, News, and Reviews*, **14**/3: 99–108.

LAM, Y.M., PEARSON, O.M., MAREAN, C.W. & CHEN, X. (2003): Bone density studies in zooarchaeology. – *Journal of Archaeological Science*, **30**/12: 1701–1708.

LAMBECK, K. (2001): Sea Level Change Through the Last Glacial Cycle. – *Science*, **292**/5517: 679–686. doi: 10.1126/science.1059549.

LAMBECK, K., ROUBY, H., PURCELL, A., SUN, Y. & SAMBRIDGE, M. (2014): Sea level and global ice volumes from the Last Glacial Maximum to the Holocene. – *Proceedings of the National Academy of Sciences*, **111**/43: 15296–15303. doi: 10.1073/pnas.1411762111.

LAMBECK, K., YOKOYAMA, Y. & PURCELL, T. (2002): Into and out of the Last Glacial Maximum: sea-level change during Oxygen Isotope Stages 3 and 2. – *Quaternary Science Reviews*, **21**/1–3: 343–360. doi: 10.1016/S0277-3791(01)00071-3.

LANGLAIS, M., PÉTILLON, J.-M., DUCASSE, S. & LENOIR, M. (2010): Badegoulien versus Magdalénien: Entre choc culturel et lente transition dans l'Aquitaine paléolithique. – *De Néandertal à l'Homme moderne. L'Aquitaine préhistorique, vingt ans de découvertes (1990-2010)*: 117–129.

LANGLEY, M.C. (2015): Investigating maintenance and discard behaviours for osseous projectile points: A Middle to Late Magdalenian (c. 19,000–14,000 cal. BP) example. – *Journal of Anthropological Archaeology*, **40**: 340–360. doi: 10.1016/j.jaa.2015.10.001.

LANGLEY, M.C., PÉTILLON, J.-M. & CHRISTENSEN, M. (2016): Diversity and Evolution of Osseous Hunting Equipment During the Magdalenian (21,000–14,000 cal BP). – In: LANGLEY, M.C. (ed.): Osseous Projectile Weaponry. – pp. 143–159, Dordrecht (Springer). doi: 10.1007/978-94-024-0899-7_10.

LAROULANDIE, V. (2014): Processing and Use of Avian Ressources during the Late Glacial in the Cave of Santa Catalina. – *Kobie*, **4**: 297–330.

LAVANDERA, P.A. (2006): Ecogeografía de la cabra montés (capra pyrenaica): relación con otros ungulados en simpatría en el centro-sur de la Península Ibérica. – Diss.: (Universidad de Castilla).

LAVILLE, H. (1986): Stratigraphy, sedimentology and chronology of the La Riera cave deposits. – In: STRAUS, L.G. & CLARK, G.A. (eds): La Riera Cave. Stone Age Hunter-Gatherer adaptations in Northern Spain. – pp. 25–55, Arizona State University (Tempe).

LEE, R.B. & DEVORE, I. (eds) (1987): Man the hunter. The first intensive survey of a single, crucial stage of human development - man's once universal hunting way of life. 11th Edition. – 415 pp. New York (de Gruyter).

LEE-THORP, J.A. & VAN DER MERWE, N.J. (1991): Aspects of the chemistry of modern and fossil biological apatites. – *Journal of Archaeological Science*, **18**/3: 343–354. doi: 10.1016/0305-4403(91)90070-6.

LEGGE, A.J. (1978): Archaeozoology—or zooarchaeology. – In: Research problems in zooarchaeology. – pp. 129–132, London (Routledge).

LEONARD, C., VASHRO, L., O'CONNELL, J.F. & HENRY, A.G. (2015): Plant microremains in dental calculus as a record of plant consumption: A test with Twe forager-horticulturalists. – *Journal of Archaeological Science: Reports*, **2**: 449–457. doi: 10.1016/j.jasrep.2015.03.009.

LEROI-GOURHAN, A. (1986): The palynology of La Riera cave. – In: STRAUS, L.G. & CLARK, G.A. (eds): La Riera Cave: Stone age hunter-gatherer adaptations in northern Spain. – pp. 59–64, Arizona State University (Tempe).

LEROI-GOURHAN, A. & BRÉZILLON, M. (1966): L'habitation magdalénienne n° 1 de Pincevent près Monterau (Seine-et-Marne). – *Gallia préhistoire*, **9**/2: 263–385. doi: 10.3406/galip.1966.1264.

LEROI-GOURHAN, ARL. (1966): Analisis polínico de cueva Morín. – In: GONZÁLEZ-ECHEGARAY, J. & FREEMAN, L.G. (eds): Cueva Morín: Excavaciones 1966-1968. – pp. 359–365, Santander (Patronato de las Cuevas Prehistóricas, Museo de Prehistoria).

LEVIN, N.E., CERLING, T.E., PASSEY, B.H., HARRIS, J.M. & EHLERINGER, J.R. (2006): A stable isotope aridity index for terrestrial environments. – *Proceedings of the National Academy of Sciences of the United States of America*, **103**/30: 11201–5. doi: 10.1073/pnas.0604719103.

LIEBERMAN, D.E., BELFER-COHEN, A., HENRY, D.O., KAUFMAN, D., MACKIE, Q., OLSZEWSKI, D.I., ROCEK, T.R., SHEPPARD, P.J., TRINKAUS, E. & VALLA, F.R. (1993): The Rise and Fall of Seasonal Mobility among Hunter-Gatherers: The Case of the Southern Levant [and Comments and Replies]. – *Current Anthropology*, **34**/5: 599–631. doi: 10.1086/204209.

LIEVERSE, A.R. (1999): Diet and the aetiology of dental calculus. – *International Journal of Osteoarchaeology*, **9**/4: 219–232. doi: 10.1002/(SICI)1099-1212(199907/08)9:4<219::AID-OA475>3.0.CO;2-V.

LLORET, M. (1995): Análisis tecnológico de los núcleos de la cueva de la Pila (Magdaleniense Superior: Nivel V y IV. 4). – *Espacio, Tiempo y Forma, Serie I, Prehistoria y Arqueología*, **1**: 11–32.

LLOVERAS, L., MORENO-GARCÍA, M. & NADAL, J. (2012): Feeding the Foxes: An Experimental Study to Assess Their Taphonomic Signature on Leporid Remains: The Taphonomy of Leporid Remains Accumulated by Foxes. – *International Journal of Osteoarchaeology*, **22**/5: 577–590. doi: 10.1002/oa.1280.

LLOVERAS, L., MORENO-GARCÍA, M., NADAL, J. & ZILHÃO, J. (2011): Who brought in the rabbits? Taphonomical analysis of Mousterian and Solutrean leporid accumulations from Gruta do Caldeirão (Tomar, Portugal). – *Journal of Archaeological Science*, **38**/9: 2434–2449. doi: 10.1016/j.jas.2011.05.012.

LLOVERAS, L., NADAL, J., MORENO-GARCÍA, M., THOMAS, R., ANGLADA, J., BAUCELLS, J., MARTORELL, C. & VILASÍS, D. (2014): The role of the Egyptian Vulture (Neophron percnopterus) as a bone accumulator in cliff rock shelters: an analysis of modern bone nest assemblages from North-eastern Iberia. – *Journal of Archaeological Science*, **44**: 76–90. doi: 10.1016/j.jas.2014.01.018.

LONGINELLI, A. (1984): Oxygen isotopes in mammal bone phosphate: A new tool for paleohydrological and paleoclimatological research? – *Geochimica et Cosmochimica Acta*, **48**/2: 385–390. doi: 10.1016/0016-7037(84)90259-X.

LÓPEZ QUINTANA, J.C. (ed) (2011): La cueva de Santimamiñe: revisión y actualización (2004-2006). – 446 pp. Bilbao (Diputación Foral de Bizkaia).

LÓPEZ-GARCÍA, J.M. & CUENCA-BESCÓS, G. (2010): Évolution climatique durant le Pléistocène supérieur en Catalogne (nord-est de l'Espagne) d'après l'étude des micromammifères. – *Quaternaire*, **21**/3: 249–257. doi: 10.4000/quaternaire.5597.

LÓPEZ-GONZÁLEZ, F., GRANDAL-D'ANGLADE, A. & VIDAL-ROMANÍ, J.R. (2006): Deciphering bone depositional sequences in caves through the study of manganese coatings. – *Journal of Archaeological Science*, **33**/5: 707–717. doi: 10.1016/j.jas.2005.10.006.

LUCAS, P.W., CASTEREN, A. VAN, AL-FADHALAH, K., ALMUSALLAM, A.S., HENRY, A.G., MICHAEL, S., WATZKE, J., REED, D.A., DIEKWISCH, T.G.H., STRAIT, D.S. & ATKINS, A.G. (2014): The Role of Dust, Grit and Phytoliths in Tooth Wear. – *Annales Zoologici Fennici*, **51**/1–2: 143–152. doi: 10.5735/086.051.0215.

LUDWIG, P., SHAO, Y., KEHL, M. & WENIGER, G.-C. (2018): The Last Glacial Maximum and Heinrich event I on the Iberian Peninsula: A regional climate modelling study for understanding human settlement patterns. – *Global and Planetary Change*, **170**: 34–47. doi: 10.1016/j.gloplacha.2018.08.006.

LUPO, K.D. (1995): Hadza Bone Assemblages and Hyena Attrition: An Ethnographic Example of the Influence of Cooking and Mode of Discard on the Intensity of Scavenger Ravaging. – *Journal of Anthropological Archaeology*, **14**/3: 288–314. doi: 10.1006/jaar.1995.1015.

LUPO, K.D. (1998): Experimentally derived extraction rates for marrow: Implications for body part exploitation strategies of Plio-Pleistocene hominid scavengers. – *Journal of Archaeological Science*, **25**/7: 657–675.

LUPO, K.D. (2001): Archaeological skeletal part profiles and differential transport: an ethnoarchaeological example from Hadza bone assemblages. – *Journal of Anthropological Archaeology*, **20**/3: 361–378.

LUPO, K.D. (2006): What Explains the Carcass Field Processing and Transport Decisions of Contemporary Hunter-Gatherers? Measures of Economic Anatomy and Zooarchaeological Skeletal Part Representation. – *Journal of Archaeological Method and Theory*, **13**/1: 19–66. doi: 10.1007/s10816-006-9000-6.

LUPO, K.D. & O'CONNELL, J.F. (2002): Cut and tooth mark distributions on large animal bones: ethnoarchaeological data from the Hadza and their implications for current ideas about early human carnivory. – *Journal of Archaeological Science*, **29**/1: 85–109.

LUPO, K.D. & SCHMITT, D.N. (1997): Experiments in bone boiling: Nutritional returns and archaeological reflections: Methods. – *Anthropozoologica*, **25–26**: 137–144.

LUZ, B., CORMIE, A.B. & SCHWARCZ, H.P. (1990): Oxygen isotope variations in phosphate of deer bones. – *Geochimica et Cosmochimica Acta*, **54**/6: 1723–1728. doi: 10.1016/0016-7037(90)90403-8.

LUZ, B., KOLODNY, Y. & HOROWITZ, M. (1984): Fractionation of oxygen isotopes between mammalian bone-phosphate and environmental drinking water. – *Geochimica et Cosmochimica Acta*, **48**/8: 1689–1693. doi: 10.1016/0016-7037(84)90338-7.

LYMAN, R.L. (1984): Bone density and differential survivorship of fossil classes. – *Journal of Anthropological Archaeology*, **3**/4: 259–299. doi: 10.1016/0278-4165(84)90004-7.

LYMAN, R.L. (1985): Bone frequencies: differential transport, in situ destruction, and the MGUI. – *Journal of Archaeological Science*, **12**/3: 221–236.

LYMAN, R.L. (1987): Archaeofaunas and Butchery Studies: A Taphonomic Perspective. – *Advances in Archaeological Method and Theory*, **10**: 249–337.

LYMAN, R.L. (1992): Anatomical considerations of utility curves in zooarchaeology. – *Journal of Archaeological Science*, **19**/1: 7–22.

LYMAN, R.L. (1994): Vertebrate taphonomy. – (Cambridge University Press).

LYMAN, R.L. (2004): The Concept of Equifinality in Taphonomy. – *Journal of Taphonomy*, **2**/1: 15–26.

LYMAN, R.L. (2005): Analyzing cut marks: lessons from artiodactyl remains in the northwestern United States. – *Journal of Archaeological Science*, **32**/12: 1722–1732.

LYMAN, R.L. (2008): Quantitative paleozoology. – (Cambridge University Press).

LYMAN, R.L. (2010): What taphonomy is, what it isn't, and why taphonomists should care about the difference. – *Journal of Taphonomy*, **8**/1: 1–16.

MACARTHUR, R.H. & PIANKA, E.R. (1966): On optimal use of a patchy environment. – *The American Naturalist*, **100**/916: 603–609.

MACHADO, J. & PÉREZ, L. (2016): Temporal frameworks to approach human behavior concealed in Middle Palaeolithic palimpsests: A high-resolution example from El Salt Stratigraphic Unit X (Alicante, Spain). – *Quaternary International*, **417**: 66–81. doi: 10.1016/j.quaint.2015.11.050.

MADRIGAL, T.C. & HOLT, J.Z. (2002): White-tailed deer meat and marrow return rates and their application to eastern woodlands archaeology. – *American Antiquity*, **67**: 745–759.

MAÍLLO-FERNÁNDEZ, J.M. (2014): Cueva Morín (Villanueva de Villaescusa, Cantabria). – In: Los Cazadores Recolectores Del Pleistoceno Y Del Holoceno En Iberia Y El Estrecho de Gibraltar. – pp. 72–78, Burgos (Universidad de Burgos).

MAKAREWICZ, C.A. & PEDERZANI, S. (2017): Oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) isotopic distinction in sequentially sampled tooth enamel of co-localized wild and domesticated caprines: Complications to establishing seasonality and mobility in herbivores. – *Palaeogeography, Palaeoclimatology, Palaeoecology*, **485**: 1–15. doi: 10.1016/j.palaeo.2017.01.010.

MALAINEY, M.E. (2011): A consumer's guide to archaeological science: analytical techniques. – 603 pp. New York (Springer).

MALINSKY-BULLER, A., HOVERS, E. & MARDER, O. (2011): Making time: 'Living floors', 'palimpsests' and site formation processes – A perspective from the open-air Lower Paleolithic site of Revadim Quarry, Israel. – *Journal of Anthropological Archaeology*, **30**/2: 89–101. doi: 10.1016/j.jaa.2010.11.002.

MALLOL, C. & HERNÁNDEZ, C. (2016): Advances in palimpsest dissection. – *Quaternary International*, **417**: 1–2. doi: 10.1016/j.quaint.2016.09.021.

MALLYE, J.-B., THIÉBAUT, C., MOURRE, V., COSTAMAGNO, S., CLAUD, É. & WEISBECKER, P. (2012): The Mousterian bone retouchers of Noisetier Cave: experimentation and identification of marks. – *Journal of Archaeological Science*, **39**/4: 1131–1142. doi: 10.1016/j.jas.2011.12.018.

MANNE, T. (2010): Upper Paleolithic foraging decisions and early economic intensification at Vale Boi, southwestern Portugal. – Diss.: (University of Arizona).

MANNE, T., STINER, M.C. & BICHO, N.F. (2006): Evidence for bone grease rendering during the Upper Paleolithic at Vale Boi (Algarve, Portugal). – *Animais na Pré-História e Arqueologia da Península Ibérica. Actas do IV Congresso de Arqueología Peninsular*, **3**: 145–158.

MAREAN, C.W., ABE, Y., NILSSEN, P.J. & STONE, E.C. (2001): Estimating the minimum number of skeletal elements (MNE) in zooarchaeology: a review and a new image-analysis GIS approach. – *American antiquity*, **66**/2: 333–48.

MAREAN, C.W. & CLEGHORN, N. (2003): Large mammal skeletal element transport: applying foraging theory in a complex taphonomic system. – *Journal of Taphonomy*, **1**/1: 15–42.

MAREAN, C.W. & KIM, S.Y. (1998): Mousterian Large-Mammal Remains from Kobeh Cave Behavioral Implications for Neanderthals and Early Modern Humans 1. – *Current Anthropology*, **39**/S1: S79–S114.

MAREAN, C.W. & SPENCER, L.M. (1991): Impact of Carnivore Ravaging on Zooarchaeological Measures of Element Abundance. – *American Antiquity*, **56**/4: 645–658.

MAREAN, C.W., SPENCER, L.M., BLUMENSCHINE, R.J. & CAPALDO, S.D. (1992): Captive hyaena bone choice and destruction, the schlepp effect and Olduvai archaeofaunas. – *Journal of Archaeological Science*, **19**/1: 101–121.

MARGALIDA, A. (2008): Bearded vultures (Gypaetus barbatus) prefer fatty bones. – *Behavioral Ecology and Sociobiology*, **63**/2: 187–193.

MARIEZKURRENA, K. (2001): Restos de macromamíferos del yacimiento de Zatoya (Navarra). – *Trabajos de arqueología Navarra*, **15**: 101–114.

MARIEZKURRENA, K. & ALTUNA, J. (1983a): Contribución al conocimiento del desarrollo de la dentición y el esqueleto postcraneal de Cervus elaphus. – *Munibe*, **35**: 149–202.

MARIEZKURRENA, K. & ALTUNA, J. (1983b): Biometría y dimorfismo sexual en el esqueleto de Cervus elaphus würmiense, postwürmiense y actual del Cantábrico. – *Munibe*, **35**: 203–246.

MARÍN ARROYO, A.B. (2008): Mobility patterns and control of the Eastern Cantabrian territory during late Last Glacial. – *Trabajos de Prehistoria*, **65**/1: 29–45. doi: 10.3989/tp.2008.v65.i1.134.

MARÍN-ARROYO, A.B. (2003): Análisis arqueozoológico, tafonómico y de distribución espacial de la fauna de mamíferos de la cueva de la Fragua (Santoña, Cantabria). – Master's Thesis: Santander (Universidad de Cantabria).

MARÍN-ARROYO, A.B. (2004): Archaeozoological, taphonomical and spatial distribution analysis of mammalian faunas from la Fragua Cave (Santoña, Cantabria). – *Munibe*, **56**: 19–44.

MARÍN-ARROYO, A.B. (2005a): A GIS System for the archaeozoological and taphonomic study in the Cave of La Fragua (Santoña, Cantabria). – *Complutum*, **16**: 73–87.

MARÍN-ARROYO, A.B. (2005b): Evolución de la fauna de la cueva de La Fragua del Pleistoceno al Holoceno. – : 145–153.

MARÍN-ARROYO, A.B. (2007): La fauna de mamíferos en el Cantábrico Oriental durante el Magdaleniense y Aziliense: Nuevos enfoques y líneas de investigación arqueozoológicas. – Diss.: Santander (Universidad de Cantabria).

MARÍN-ARROYO, A.B. (2008a): Demografía y cambio ambiental. Hipótesis para el cambio económico en el Cantábrico Oriental durante el Tardiglacial/ Demography and environmental change. A model for the economic change in Eastern Cantabria during the Late Glacial. – *Complutum*, **19**/1: 47–66.

MARÍN-ARROYO, A.B. (2008b): El yacimiento paleolítico de la Cueva del Mirón: resultados de la aplicación de nuevas metodologías arqueozoológicas. – .

MARÍN-ARROYO, A.B. (2009a): Economic adaptations during the Late Glacial in northern Spain. A simulation approach. – *Before Farming*, **2**: 1–18.

MARÍN-ARROYO, A.B. (2009b): Exploitation of the Montane Zone of Cantabrian Spain during the Late Glacial: Faunal Evidence from El Mirón Cave. – *Journal of Anthropological Research*: 69–102.

MARÍN-ARROYO, A.B. (2009c): The use of optimal foraging theory to estimate Late Glacial site catchment areas from a central place: The case of eastern Cantabria, Spain. – *Journal of Anthropological Archaeology*, **28**/1: 27–36.

MARÍN-ARROYO, A.B. (2009d): A comparative study of analytic techniques for skeletal part profile interpretation at El Mirón Cave (Cantabria, Spain). – *Archaeofauna*, **18**: 79–98.

MARÍN-ARROYO, A.B. (2009e): Assessing what lies beneath the spatial distribution of a zooarchaeological record: the use of GIS and spatial correlations at el Mirón Cave (Spain). – *Archaeometry*, **51**/3: 506–524.

MARÍN-ARROYO, A.B. (2010): Arqueozoología en el Cantábrico Oriental durante la transición Pleistoceno/Holoceno. La cueva del Mirón. - Archeozoology in the Eastern Cantabrian Region during the Pleistocene/ Holocene transition. El Mirón cave. – 685 pp. Santander (PUbliCan Universidad de Cantabria).

MARÍN-ARROYO, A.B. (2011): Palaeolithic Human Subsistence in Mount Carmel (Israel). A Taphonomic Assessment of Middle and Early Upper Palaeolithic Faunal Remains from Tabun, Skhul and el-Wad. – *International Journal of Osteoarchaeology*, **3**/23: 254–273.

MARÍN-ARROYO, A.B. (2013): Human response to Holocene warming on the Cantabrian Coast (northern Spain): an unexpected outcome. – *Quaternary Science Reviews*, **81**: 1–11. doi: 10.1016/j.quascirev.2013.09.006.

MARÍN-ARROYO, A.B. (2015): Taphonomic study of the human remains from the Magdalenian burial in El Mirón Cave (Cantabria, Spain). – *Journal of Archaeological Science*, **60**: 57–65. doi: 10.1016/j.jas.2015.03.032.

MARÍN-ARROYO, A.B., FOSSE, P. & VIGNE, J.D. (2009): Probable evidences of bone accumulation by Pleistocene bearded vulture at the archaeological site of El Mirón Cave (Spain). – *Journal of Archaeological Science*, **36**/2: 284–296.

MARÍN-ARROYO, A.B. & GEILING, J.M. (2015): Archeozoological study of the macromammal remains stratigraphically associated with the Magdalenian human burial in El Mirón Cave (Cantabria, Spain). – *Journal of Archaeological Science*, **60**/Supplement C: 75–83. doi: 10.1016/j.jas.2015.03.009.

MARÍN-ARROYO, A.B., GEILING, J.M., JONES, J.R., GONZÁLEZ MORALES, M.R., STRAUS, L.G. & RICHARDS, M.P. (2018a): The Middle to Upper Palaeolithic transition at El Mirón Cave (Cantabria, Spain). – *Quaternary International*. doi: 10.1016/j.quaint.2018.06.036.

MARÍN-ARROYO, A.B. & GONZÁLEZ-MORALES, M.R. (2009): Comportamiento económico de los últimos cazadores-recolectores y primeras evidencias de domesticación en el occidente de Asturias. La Cueva de Mazaculos II. – *Trabajos de prehistoria*, **66**/1: 47–74.

MARÍN-ARROYO, A.B., LANDETE RUIZ, M.D., SEVA ROMÁN, R. & LEWIS, M.D. (2014): Manganese coating of the Tabun faunal assemblage: Implications for modern human behaviour in the Levantine Middle Palaeolithic. – *Quaternary International*, **330**: 10–18. doi: 10.1016/j.quaint.2013.07.016.

MARÍN-ARROYO, A.B., LANDETE RUIZ, M.D., VIDAL BERNABEU, G., SEVA ROMÁN, R., GONZÁLEZ-MORALES, M.R. & STRAUS, L.G. (2008): Archaeological implications of human-derived manganese coatings: a study of blackened bones in El Mirón Cave, Cantabrian Spain. – *Journal of Archaeological Science*, **35**/3: 801–813. doi: 10.1016/j.jas.2007.06.007.

MARÍN-ARROYO, A.B. & MARGALIDA, A. (2012): Distinguishing Bearded Vulture Activities within Archaeological Contexts: Identification Guidelines. – *International Journal of Osteoarchaeology*, **22**/5: 563–576. doi: 10.1002/oa.1279.

MARÍN-ARROYO, A.B. & OCIO, D. (2018): Disentangling faunal skeletal profiles. A new probabilistic framework. – *Historical Biology*, **30**/6: 720–729. doi: 10.1080/08912963.2017.1336620.

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. (2018b): Chronological reassessment of the Middle to Upper Paleolithic transition and Early Upper Paleolithic cultures in Cantabrian Spain. – *PLOS ONE*, **13**/4: e0194708. doi: 10.1371/journal.pone.0194708.

MAROTO, J., VAQUERO, M., ARRIZABALAGA, Á., BAENA, J., BAQUEDANO, E., JORDÁ, J., JULIÀ, R., MONTES, R., VAN DER PLICHT, J., RASINES, P. & WOOD, R. (2012): Current issues in late Middle Palaeolithic chronology: New assessments from Northern Iberia. – *Quaternary International*, **247**: 15–25. doi: 10.1016/j.quaint.2011.07.007.

MARQUER, L., OTTO, T., NESPOULET, R. & CHIOTTI, L. (2010): A new approach to study the fuel used in hearths by hunter-gatherers at the Upper Palaeolithic site of Abri Pataud (Dordogne, France). – *Journal of Archaeological Science*, **37**/11: 2735–2746. doi: 10.1016/j.jas.2010.06.009.

MARREIROS, J. & BICHO, N. (2013): Lithic technology variability and human ecodynamics during the Early Gravettian of Southern Iberian Peninsula. – *Quaternary International*, **318**: 90–101. doi: 10.1016/j.quaint.2013.05.008.

MARSHALL, F. & PILGRAM, T. (1993): NISP vs. MNI in Quantification of Body-Part Representation. – *American Antiquity*, **58**/2: 261. doi: 10.2307/281968.

MARTIN, C., BENTALEB, I., KAANDORP, R., IACUMIN, P. & CHATRI, K. (2008): Intra-tooth study of modern rhinoceros enamel $\delta^{18}O$: Is the difference between phosphate and carbonate $\delta^{18}O$ a sound diagenetic test? – *Palaeogeography, Palaeoclimatology, Palaeoecology*, **266**/3–4: 183–189. doi: 10.1016/j.palaeo.2008.03.039.

MARTÍNEZ, L. & RASILLA VIVES, M. DE LA (2013): El Gravetiense en Asturias: revisión y novedades. – In: DE LAS HERAS, C. (ed.): Pensando el Gravetiense: nuevos datos para la región cantábrica en su contexto peninsular y pirenaico. – pp. 291–304, Santander (Museo Nacional y Centro de Investigación de Altamira).

MARTÍNEZ, T. & MARTÍNEZ, E. (2009): Diet of Spanish wild goat, Capra pyrenaica, in spring and summer at the Sierra de Gredos, Spain. – *Mammalia*, **51**/4: 547–558. doi: 10.1515/mamm.1987.51.4.547.

MARTINEZ, T. & OTHERS (2000): Diet selection by Spanish ibex in early summer in Sierra Nevada. – *Acta Theriologica*, **45**/3: 335–346.

MARTRAT, B., GRIMALT, J.O., SHACKLETON, N.J., ABREU, L. DE, HUTTERLI, M.A. & STOCKER, T.F. (2007): Four Climate Cycles of Recurring Deep and Surface Water Destabilizations on the Iberian Margin. – *Science*, **317**/5837: 502–507. doi: 10.1126/science.1139994.

MATEOS CACHORRO, A. (1999): El consumo de grasa en el Paleolítico Superior: implicaciones paleoeconómicas, nutrición y subsistencia. – *Espacio Tiempo y Forma. Serie I, Prehistoria y Arqueología*, **12**/12: 161–184. doi: 10.5944/etfi.12.1999.4684.

MATEOS CACHORRO, A. (2005): Comportamientos de subsistencia y nicho ecológico de los grupos cazadores recolectores del occidente Asturiano en el final del Pleistoceno. – Diss.: Salmanaca (Universidad de Salmanaca).

MCGUIRE, K. & MCDONNELL, J. (2008): Stable Isotope Tracers in Watershed Hydrology. – In: Stable Isotopes in Ecology and Environmental Science. – pp. 334–374, (John Wiley & Sons, Ltd). doi: 10.1002/9780470691854.ch11.

MCKELLAR, J.A. (1983): Correlations and the Explanation of Distributions. – *Arizona Anthropologist*, **4**/0: 2–5.

MEESE, D.A., ALLEY, R.B., FIACCO, R.J., GERMANI, M.S., GOW, GROOTES, ILLYING & MAYEWSKI, P.A. (1994): Preliminary depth-age scale of the GISP2 ice core. – *Special CRREL Report*, **94**/1: 66.

MEIRI, M., LISTER, A.M., HIGHAM, T.F.G., STEWART, J.R., STRAUS, L.G., OBERMAIER, H., GONZÁLEZ-MORALES, M.R., MARÍN-ARROYO, A.B. & BARNES, I. (2013): Late-glacial recolonization and phylogeography of European red deer (*Cervus elaphus* L.). – *Molecular Ecology*, **22**/18: 4711–4722.

MELLARS, P. (2006): A new radiocarbon revolution and the dispersal of modern humans in Eurasia. – *Nature*, **439**/7079: 931–935.

MELLARS, P. (2010): Neanderthal symbolism and ornament manufacture: The bursting of a bubble? – *Proceedings of the National Academy of Sciences*, **107**/47: 20147–20148. doi: 10.1073/pnas.1014588107.

MELLARS, P. & FRENCH, J.C. (2011): Tenfold population increase in western europe at the neandertal–to–modern human transition. – *Science*, **333**/6042: 623–627.

MENÉNDEZ FERNÁNDEZ, M., GARCÍA SÁNCHEZ, E. & QUESADA-LÓPEZ, J.M. (2005): Magdaleniense inferior y territorialidad en la Cueva de La Güelga:(Asturias). – In: O Paleolítico: actas do IV Congresso de Arqueologia Peninsular (Faro, 14 a 19 de Setembro de 2004). – pp. 63–75, Universidade do Algarve (Centro de Estudos de Patrimonio, Departamento de Historia, Arqueologia e Patrimonio, Universidade do Algarve.).

MENGONI GOÑALONS, G. (1988): Análisis de materiales faunísticos de sitios arqueológicos. – *Xama*, **1**: 71–120.

VAN DER MERWE, N.J. & MEDINA, E. (1991): The canopy effect, carbon isotope ratios and foodwebs in amazonia. – *Journal of Archaeological Science*, **18**/3: 249–259. doi: 10.1016/0305-4403(91)90064-V.

METCALFE, D. & JONES, K.T. (1988): A Reconsideration of Animal Body-Part Utility Indices. – *American Antiquity*, **53**/3: 486–504. doi: 10.2307/281213.

MICHEL, V., SHEN, C.-C., WOODHEAD, J., HU, H.-M., WU, C.-C., MOULLÉ, P.-É., KHATIB, S., CAUCHE, D., MONCEL, M.-H., VALENSI, P., CHOU, Y.-M., GALLET, S., ECHASSOUX, A., ORANGE, F. & DE LUMLEY, H. (2017): New dating evidence of the early presence of hominins in Southern Europe. – *Scientific Reports*, **7**/1. doi: 10.1038/s41598-017-10178-4.

MIDDLETON, W.D. & ROVNER, I. (1994): Extraction of Opal Phytoliths from Herbivore Dental Calculus. – *Journal of Archaeological Science*, **21**/4: 469–473. doi: 10.1006/jasc.1994.1046.

MILLER, C.E., CONARD, N.J., GOLDBERG, P. & BERNA, F. (2010): Dumping, sweeping and trampling: experimental micromorphological analysis of anthropogenically modified combustion features. – *Palethnologie*, **2**: 25–37.

MILO, R.G. (1994): Human-animal Interactions in Southern African Prehistory: A Microscopic Study of Bone Damage Signatures. – 552 pp. (University of Chicago).

MILTON, K. (1999): A hypothesis to explain the role of meat-eating in human evolution. – *Evolutionary Anthropology: Issues, News, and Reviews*, **8**/1: 11–21. doi: 10.1002/(SICI)1520-6505(1999)8:1<11::AID-EVAN6>3.0.CO;2-M.

MIX, A.C., BARD, E. & SCHNEIDER, R. (2001): Environmental processes of the ice age: land, oceans, glaciers (EPILOG). – *Quaternary Science Reviews*, **20**/4: 627–657. doi: 10.1016/S0277-3791(00)00145-1.

MOÇO, G., SERRANO, E., GUERREIRO, M., FERREIRA, A.F., PETRUCCI-FONSECA, F., MAIA, M.J., SORIGUER, R.C. & PÉREZ, J.M. (2013): Seasonal dietary shifts and selection of Iberian wild goat Capra pyrenaica Schinz, 1838 in Peneda-Gerês National Park (Portugal). – *Galemys*, **25**: 12–27.

MODOLO, M. & ROSELL, J. (2017): Reconstructing occupational models: Bone refits in Level I of Abric Romaní. – *Quaternary International*, **435**: 180–194. doi: 10.1016/j.quaint.2015.12.098.

MONAHAN, C.M. (1998): The Hadza carcass transport debate revisited and its archaeological implications. – *Journal of Archaeological Science*, **25**/5: 405–424.

MONTES BARQUÍN, R., MUÑOZ FERNÁNDEZ, E. & MORLOTE EXPÓSITO, J.M. (2002): Los grabados rupestres paleolíticos de la cueva de La Luz (Ramales de la Victoria, Cantabria). – *Nivel cero: revista del grupo arqueológico Attica*, **10**: 23–32.

MONTES BARQUÍN, R., MUÑOZ FERNÁNDEZ, E., MORLOTE EXPÓSITO, J.M., SANTAMARÍA SANTAMARÍA, S. & GÓMEZ LAGUNA, A.J. (2015): El conjunto rupestre de la Cueva de Cudón (Miengo, Cantabria) y otros conjuntos análogos del centro de la Región Cantábrica: ¿Evidencias de aniconismo en el arte rupestre paleolítico? – In: COLLADO GIRALDO, H. (ed.): Symbols in the landscape: rock art and its context : XIX International rock art conference, IFRAO 2015. – pp. 167–198,.

MONTES, R., LASHERAS, J.A., MUÑOZ, E., DE LAS HERAS, C. & FATÁS, P. (eds) (2009): Proyecto de investigación "Los tiempos de Altamira" Actuaciones arqueológicas en las cuevas de Cualventi, El Linar y Las Aguas (Alfoz de Lloredo, Cantabria, España). – 850 pp. Santilla del Mar (Santander) (Museo Nacional y Centro de Investigación de Altamira).

MORALES-MUÑIZ, A. (1990): Arqueozoología teórica: usos y abusos reflejados en la interpretación de las asociaciones de fauna de yacimientos antrópicos. – *Trabajos de Prehistoria*, **47**/0: 251–290. doi: 10.3989/tp.1990.v47.i0.562.

MORALES-MUÑIZ, A. (2002): 35 years of Archaeozoology in Spain: a critical review. – *Archaeofauna*/11: 103–112.

MORENO, A., GONZÁLEZ-SAMPÉRIZ, P., MORELLÓN, M., VALERO-GARCÉS, B.L. & FLETCHER, W.J. (2012): Northern Iberian abrupt climate change dynamics during the last glacial cycle: A view from lacustrine sediments. – *Quaternary Science Reviews*, **36**: 139–153. doi: 10.1016/j.quascirev.2010.06.031.

MORENO, A., STOLL, H., JIMÉNEZ-SÁNCHEZ, M., CACHO, I., VALERO-GARCÉS, B., ITO, E. & EDWARDS, R.L. (2010): A speleothem record of glacial (25–11.6 kyr BP) rapid climatic changes from northern Iberian Peninsula. – *Global and Planetary Change*, **71**/3: 218–231.

MORENO, R. & MORALES, A. (1987): Análisisde la malacofauna recuperada en la Cueva de Tito Bustillo (Ribadesella, Asturias). – *Boletín del Real Instituto de Estudios Asturianos*, **123**: 662–688.

MORIN, E. (2010): Taphonomic implicatons of the use of bone as fuel. – In: The taphonomy of burned organic residues and combustion features in archaeological contexts (proceedings of the round table, Valbonne, May 27-29 2008, CEPAM). – pp. 209–217,.

MORIN, E. (2012): Reassessing paleolithic subsistence : the Neandertal and modern human foragers of Saint-Césaire. – New York (Cambridge University Press).

MORIN, E., MEIER, J.S., GUENNOUNI, K.E., MOIGNE, A.-M., LEBRETON, V., RUSCH, L., VALENSI, P., CONOLLY, J. & COCHARD, D. (2019): New evidence of broader diets for archaic Homo populations in the northwestern Mediterranean. – *Science advances*, **5**/3: 1–11.

MORIN, E. & READY, E. (2013): Foraging Goals and Transport Decisions in Western Europe during the Paleolithic and Early Holocene. – In: Zooarchaeology and Modern Human Origins: Human Hunting Behavior 227 during the Later Pleistocene. – pp. 227–269, Dordrecht (Springer).

MORIN, E., READY, E., BOILEAU, A., BEAUVAL, C. & COUMONT, M.-P. (2017): Problems of Identification and Quantification in Archaeozoological Analysis, Part II: Presentation of an Alternative Counting Method. – *Journal of Archaeological Method and Theory*, **24**/3: 938–973. doi: 10.1007/s10816-016-9301-3.

MORIN, E. & SOULIER, M.-C. (2017): New criteria for the archaeological identification of bone grease processing. – *American Antiquity*, **82**/1: 96–122.

MORIN, E., TSANOVA, T., SIRAKOV, N., RENDU, W., MALLYE, J.-B. & LÉVÊQUE, F. (2005): Bone refits in stratified deposits: testing the chronological grain at Saint-Césaire. – *Journal of Archaeological Science*, **32**/7: 1083–1098. doi: 10.1016/j.jas.2005.02.009.

MORONI, A., BOSCATO, P. & RONCHITELLI, A. (2013): What roots for the Uluzzian? Modern behaviour in Central-Southern Italy and hypotheses on AMH dispersal routes. – *Quaternary International*, **316**: 27–44. doi: 10.1016/j.quaint.2012.10.051.

MOURE-ROMANILLO, J.A. & GONZÁLEZ-MORALES, M.R. (1988): El contexto del arte parietal. La tecnología de los artistas en la cueva de Tito Bustillo (Asturias). – *Trabajos de Prehistoria*, **45**: 19–49.

MOURE-ROMANILLO, J.A. & GONZÁLEZ-MORALES, M.R. (1992): Radiocarbon dating of a decorated area in the Fuente del Salin cave in Spain - Datation C14 d'une zone decoree de la grotte Fuente del Salin en Espagne. – *INORA - International Newsletter on Rock Art*/3: 1–2.

MOURE-ROMANILLO, J.A., GONZÁLEZ-SAINZ, C., BERNALDO DE QUIRÓS, F. & CABRERA-VALDÉS, V. (1996): Dataciones absolutas de pigmentos en cuevas cantábricas: Altamira, El Castillo, Chimeneas y Las Monedas. – In: "El hombre fosil" 80 años después : volumen conmemorativo del 50 aniversario de la muerte de Hugo Obermaier. – pp. 295–324, Santander (Universidad de Cantabria).

MOZOTA-HOLGUERAS, M. (2012): El hueso como materia prima: el utillaje óseo del final del Musteriense en el sector central del norte de la Península Ibérica. – Diss.: Santander (Universidad de Cantabria).

MOZOTA-HOLGUERAS, M. (2014): Los útiles óseos "poco elaborados" en el Paleolítico inferior y medio y su continuidad en el Paleolítico superior. Una revisión historiográfica. – *Complutum*, **25**/1. doi: 10.5209/rev_CMPL.2014.v25.n1.45353.

MÜLLER, W., LEESCH, D., BULLINGER, J., CATTIN, M.-I. & PLUMETTAZ, N. (2006): Chasse, habitats et rythme des déplacements: réflexions à partir des campements magdaléniens de Champréveyres et Monruz (Neuchâtel, Suisse). – *Bulletin de la Société préhistorique française*: 741–752.

MUÑOZ FERNANDEZ, E. & MONTES BARQUIN, R. (2007): Arqueologia y arte rupestre paleolitico en las cavidades de El Cuco o Sobera y La Lastrilla. – 278 pp. Ajuntamiento de Castro Urdiales (Concejalia de Medioambiente y Patrimonio arqueologico).

MUÑOZ, M., SANCHEZ GOÑI, M.F. & UGARTE, F.M. (1990): El entorno geo-ambiental del yacimiento arqueológico de Kurtzia. – *Munibe*, **41**: 107–115.

MUÑOZ-SOBRINO, C., RAMIL-REGO, P. & GÓMEZ-ORELLANA, L. (2007): Late Würm and early Holocene in the mountains of northwest Iberia: biostratigraphy, chronology and tree colonization. – *Vegetation History and Archaeobotany*, **16**/4: 223–240. doi: 10.1007/s00334-006-0083-5.

MUÑOZ-SOBRINO, C., RAMIL-REGO, P. & GUITIÁN, M.A.R. (2001): Vegetation in the mountains of northwest Iberia during the last glacial-interglacial transition. – *Vegetation History and Archaeobotany*, **10**/1: 7–21.

MUNRO, N. (2009): Epipaleolithic subsistence intensification in the southern Levant: the faunal evidence. – In: The Evolution of Hominin Diets. – pp. 141–155, (Springer).

MUNRO, N., BAROZ, G., DAYAN, T., BROUGHTON, J., UGAN, A., DAVIS, S., HAYDEN, B., JONES, E., LYMAN, R.L. & VALLA, F. (2004): Zooarchaeological measures of hunting pressure and occupation intensity in the Natufian: implications for agricultural origins. – *Current Anthropology*, **45**/S4: S5–S34.

MUNRO, N.D. & BAR-OZ, G. (2004): Debating issues of equifinality in ungulate skeletal part studies. – *Journal of Taphonomy*, **2**/1: 1–13.

MUNRO, N.D. & BAR-OZ, G. (2005): Gazelle bone fat processing in the Levantine Epipalaeolithic. – *Journal of Archaeological Science*, **32**/2: 223–239.

MÜNZEL, S.C. & CONARD, N.J. (2004): Change and continuity in subsistence during the Middle and Upper Palaeolithic in the Ach Valley of Swabia (south-west Germany). – *International Journal of Osteoarchaeology*, **14**/3–4: 225–243.

MUTTONI, G., SCARDIA, G. & KENT, D.V. (2013): A critique of evidence for human occupation of Europe older than the Jaramillo subchron (~1 Ma): Comment on 'The oldest human fossil in Europe from Orce (Spain)' by. – *Journal of Human Evolution*, **65**/6: 746–749. doi: 10.1016/j.jhevol.2013.08.005.

MUTTONI, G., SCARDIA, G., KENT, D.V., MORSIANI, E., TREMOLADA, F., CREMASCHI, M. & PERETTO, C. (2011): First dated human occupation of Italy at ~0.85Ma during the late Early Pleistocene climate transition. – *Earth and Planetary Science Letters*, **307**/3–4: 241–252. doi: 10.1016/j.epsl.2011.05.025.

NAKAZAWA, Y. (2007): Hearth-centered spatial organization: a comparative approach to the study of palimpsests in late Upper Paleolithic sites in Hokkaido (Japan) and Cantabria (Spain). – Diss.unpub.: Albuquerque (University of New Mexico).

NAKAZAWA, Y., STRAUS, L.G., GONZÁLEZ-MORALES, M.R., SOLANA, D.C. & SAIZ, J.C. (2009): On stone-boiling technology in the Upper Paleolithic: behavioral implications from an Early Magdalenian hearth in El Mirón Cave, Cantabria, Spain. – *Journal of Archaeological Science*, **36**/3: 684–693. doi: 10.1016/j.jas.2008.10.015.

NAP, R.C. & HAZEWINKEL, H.A.W. (1994): Growth and skeletal development in the dog in relation to nutrition; a review. – *Veterinary Quarterly*, **16**/1: 50–59. doi: 10.1080/01652176.1994.9694417.

NAUDINOT, N. & KELLY, R.L. (2017): Climate change and archaeology. – *Quaternary International*, **428**: 1–2. doi: 10.1016/j.quaint.2016.02.026.

NAUGHTON, F., SÁNCHEZ-GOÑI, M.-F., DESPRAT, S., TURON, J.-L., DUPRAT, J., MALAIZÉ, B., JOLI, C., CORTIJO, E., DRAGO, T. & FREITAS, M.C. (2007): Present-day and past (last 25 000 years) marine pollen signal off western Iberia. – *Marine Micropaleontology*, **62**/2: 91–114. doi: 10.1016/j.marmicro.2006.07.006.

NAUGHTON, F., SÁNCHEZ-GOÑI, M.-F., KAGEYAMA, M., BARD, E., DUPRAT, J., CORTIJO, E., DESPRAT, S., MALAIZÉ, B., JOLY, C. & ROSTEK, F. (2009): Wet to dry climatic trend in north-western Iberia within Heinrich events. – *Earth and Planetary Science Letters*, **284**/3: 329–342.

NGRIP DATING GROUP (2008): IGBP PAGES/World Data Center for Paleoclimatology Data Contribution Series # 2008-034. – *Greenland Ice Core Chronology 2005 (GICC05) 60,000 Year, 20 Year Resolution*. Retrieved from ftp://ftp.ncdc.noaa.gov/pub/data/paleo/icecore/greenland/summit/ngrip/gicc05-60ka-20yr.txt.

NICHOLS, L. (2014): Social desire paths: a new theoretical concept to increase the usability of social science research in society. – *Theory and Society*, **43**/6: 647–665. doi: 10.1007/s11186-014-9234-3.

NICKEL, R., SCHUMMER, A. & SEIFERLE, E. (1992): Lehrbuch der Anatomie der Haustiere. – 539 pp. (Paul Parey).

NIGST, P.R., HAESAERTS, P., DAMBLON, F., FRANK-FELLNER, C., MALLOL, C., VIOLA, B., GÖTZINGER, M., NIVEN, L., TRNKA, G. & HUBLIN, J.-J. (2014): Early modern human settlement of Europe north of the Alps occurred 43,500 years ago in a cold steppe-type environment. – *Proceedings of the National Academy of Sciences*, **111**/40: 14394–14399. doi: 10.1073/pnas.1412201111.

NILSSEN, P.J. (2000): An actualistic butchery study in South Africa and its implications for reconstructing hominid strategies of carcass acquisition and butchery in the Upper Pleistocene and Plio-Pleistocene. – Diss.: Capetown (University of Capetown).

NIVEN, L. (2006): The Palaeolithic occupation of Vogelherd Cave : implications for the subsistence behavior of late Neanderthals and early modern humans. – 312 pp. Tübingen (Kerns).

NODDLE, B. (1974): Ages of epiphyseal closure in feral and domestic goats and ages of dental eruption. – *Journal of Archaeological Science*, **1**/2: 195–204. doi: 10.1016/0305-4403(74)90042-9.

NOE-NYGAARD, N. (1977): Butchering and marrow fracturing as a taphonomic factor in archaeological deposits. – *Paleobiology*, **3**: 218–237.

NOE-NYGAARD, N. (1989): Man-made trace fossils on bones. – *Human Evolution*, **4**/6: 461–491.

NORMAND, C., GOUTAS, N., LACARRIÈRE, J. & SIMONET, A. (2013): El Gravetiense de la cueva de Isturitz: nuevas investigaciones, nuevos datos. – In: Pensando el Gravetiense: Nuevos datos para la región cantábrica en su contexto peninsular y pirenáico. – pp. 161–183, Santander (Museo Nacional y Centro de Investigación de Altamira).

NORSTRÖM, E., GUSTAVSSON, R., MOLIN, F. & GUMMESSON, S. (2019): Micro-fossil analysis of Mesolithic human dental calculus, Motala, Sweden - Indications of health status and paleo-diet. – *Journal of Archaeological Science: Reports*, **26**: 101866. doi: 10.1016/j.jasrep.2019.05.031.

NUIN CABELLO, J. & PRIETO PRAT, M. (1997): Los utensilios de caza en Legintxiki (Navarra). – *Isturitz. Cuadernos de Prehistoria y Arqueología*, **7**: 95–130.

OBERMAIER, H. (1924): Fossil man in Spain. – London (Greenwood Pub Group).

OCHOA, B. & GARCÍA-DIEZ, M. (2015): Chronology of western Pyrenean Paleolithic cave art: A critical examination. – *Quaternary International*, **364**: 272–282. doi: 10.1016/j.quaint.2014.07.015.

O'CONNELL, J.F. (1995): Ethnoarchaeology needs a general theory of behavior. – *Journal of Archaeological Research*, **3**/3: 205–255. doi: 10.1007/BF02231450.

O'CONNELL, J.F., HAWKES, K. & BLURTON JONES, N. (1990): Reanalysis of large mammal body part transport among the Hadza. – *Journal of Archaeological Science*, **17**/3: 301–316.

O'CONNELL, J.F., HAWKES, K. & JONES, N.B. (1988): Hadza Hunting, Butchering, and Bone Transport and Their Archaeological Implications. – *Journal of Anthropological Research*, **44**/2: 113–161.

O'CONNELL, J.F., HAWKES, K. & JONES, N.B. (1991): Chapter 3: Distribution of refuse-producing activities at Hadza residential base camps. – In: The Interpretation of Archaeological Spatial Patterning. – pp. 61–76, New York (Springer).

O'CONNOR (2000): The Archaeology of Animal Bones. – 214 pp. Texas (Sutton).

O'CONNOR, T. (2005): Biosphere to Lithosphere: new studies in vertebrate taphonomy. – 161 pp. Oxford (Oxbow Books).

OLALDE, I., MALLICK, S., PATTERSON, N., ROHLAND, N., VILLALBA-MOUCO, V., SILVA, M., DULIAS, K., EDWARDS, C.J., GANDINI, F., PALA, M., SOARES, P., FERRANDO-BERNAL, M., ADAMSKI, N., BROOMANDKHOSHBACHT, N., CHERONET, O., CULLETON, B.J., FERNANDES, D., LAWSON, A.M., MAH, M., OPPENHEIMER, J., STEWARDSON, K., ZHANG, Z., ARENAS, J.M.J., MOYANO, I.J.T., SALAZAR-GARCÍA, D.C., CASTANYER, P., SANTOS, M., TREMOLEDA, J., LOZANO, M., BORJA, P.G., FERNÁNDEZ-ERASO, J., MUJIKA-ALUSTIZA, J.A., BARROSO, C., BERMÚDEZ, F.J., MÍNGUEZ, E.V., BURCH, J., COROMINA, N., VIVÓ, D., CEBRIÀ, A., FULLOLA, J.M., GARCÍA-PUCHOL, O., MORALES, J.I., OMS, F.X., MAJÓ, T., VERGÈS, J.M., DÍAZ-CARVAJAL, A., OLLICH-CASTANYER, I., LÓPEZ-CACHERO, F.J., SILVA, A.M., ALONSO-FERNÁNDEZ, C., CASTRO, G.D. DE, ECHEVARRÍA, J.J., MORENO-MÁRQUEZ, A., BERLANGA, G.P., RAMOS-GARCÍA, P., RAMOS-MUÑOZ, J., VILA, E.V., ARZO, G.A., ARROYO, Á.E., LILLIOS, K.T., MACK, J., VELASCO-VÁZQUEZ, J., WATERMAN, A., ENRICH, L.B. DE L., SÁNCHEZ, M.B., AGUSTÍ, B., CODINA, F., PRADO, G. DE, ESTALRRICH, A., FLORES, Á.F., FINLAYSON, C., FINLAYSON, G., FINLAYSON, S., GILES-GUZMÁN, F., ROSAS, A., GONZÁLEZ, V.B., ATIÉNZAR, G.G., PÉREZ, M.S.H., LLANOS, A., MARCO, Y.C., BENEYTO, I.C., LÓPEZ-SERRANO, D., TORMO, M.S., VALERA, A.C., BLASCO, C., LIESAU, C., RÍOS, P., DAURA, J., MICHÓ, M.J. DE P., DIEZ-CASTILLO, A.A., FERNÁNDEZ, R.F., FARRÉ, J.F., GARRIDO-PENA, R., GONÇALVES, V.S., GUERRA-DOCE, E., HERRERO-CORRAL, A.M., JUAN-CABANILLES, J., LÓPEZ-REYES, D., MCCLURE, S.B., PÉREZ, M.M., FOIX, A.O., BORRÀS, M.S., SOUSA, A.C., ENCINAS, J.M.V., KENNETT, D.J., RICHARDS, M.B., ALT, K.W., HAAK, W., PINHASI, R., LALUEZA-FOX, C. & REICH, D. (2019): The genomic history of the Iberian Peninsula over the past 8000 years. – *Science*, **363**/6432: 1230–1234. doi: 10.1126/science.aav4040.

OLSEN, S.L. & OLSEN, J.W. (1981): A Comment on Nomenclature in Faunal Studies. – *American Antiquity*, **46**/01: 192–194. doi: 10.2307/280000.

OLSEN, S.L. & SHIPMAN, P. (1988): Surface Modification Butchery on Bone : Trampling versus. – *Journal of Archaeological Science*, **15**: 535–553.

ONTAÑÓN-PEREDO, R. & ARIAS-CABAL, P. (2012): Decorated plaquettes from Magdalenian habitation floors in the Lower Gallery at La Garma (Cantabria, Spain). – In: L'art pléistocène dans le monde / Pleistocene art of the world / Arte pleistoceno en el mundo, Actes du Congrès IFRAO, Tarascon-sur-Ariège, septembre 2010, Symposium « Art mobilier pléistocène ». N° spécial de Préhistoire, Art et Sociétés. – pp. 1393–1410,.

ORON, M. & GOREN-INBAR, N. (2014): Mousterian intra-site spatial patterning at Quneitra, Golan Heights. – *Quaternary International*, **331**: 186–202. doi: 10.1016/j.quaint.2013.04.013.

ORSCHIEDT, J. (2013): Bodies, bits and pieces: Burials from the Magdalenian and the Late Palaeolithic. – In: Pleistocene foragers: Their culture and environment. – pp. 117–132, Mettman (Neanderthal Museum).

ORTEA, J. (1986): The malacology of La Riera cave. – In: STRAUS, L.G. & CLARK, G.A. (eds): La Riera cave. Stone Age hunter—gatherer adaptations in northern Spain. – pp. 289–313, Arizona State University (Tempe).

ORTON, C. (2000): Sampling in archaeology. – 261 pp. (Cambridge University Press).

ORTON, C. (2004): Point pattern analysis revisited. – *Archeologia e Calcolatori*, **15**: 299–315.

OUTRAM, A.K. (1997): Economic anatomy, element abundance and optimality: A new way of examining hunters' bone transportation choices. – In: Archaeological Sciences '97: Proceedings of the

conference held at the University of Durham, 2nd-4th September. – pp. 117–126, Oxford (Archaeopress).

OUTRAM, A.K. (1998): The identification and Palaeoeconomic context of prehistoric bone marrow and grease exploitation. – Diss.: Durham (University of Durham).

OUTRAM, A.K. (1999): A comparison of paleo-eskimo and medieval Norse bone fat exploitation in western Greenland. – *Arctic Anthropology*, **36**/1–2: 103–117.

OUTRAM, A.K. (2001): A New Approach to Identifying Bone Marrow and Grease Exploitation: Why the "Indeterminate" Fragments should not be Ignored. – *Journal of Archaeological Science*, **28**/4: 401–410. doi: 10.1006/jasc.2000.0619.

OUTRAM, A.K. (2002): "Bone Fracture and Within-bone Nutrients: an Experimentally Based Method for Investigating Levels of Marrow" Extraction [in] Consuming Passions and Patterns of Consumption. – In: MIRACLE, P.T. & MILNER, N. (eds): Consuming Passions and Patterns of Consumption. – pp. 51–63, McDonald Institute for Archaeological Research (Cambridge).

OUTRAM, A.K. (2003): Comparing Levels of Subsistence Stress amongst Norse Settlers in Iceland and Greenland using Levels of Bone Fat Exploitation as an Indicator. – *Environmental Archaeology*, **8**/2: 119–128. doi: 10.1179/env.2003.8.2.119.

OUTRAM, A.K. (2004a): Applied models and indices vs. high-resolution, observed data: Detailed fracture and fragmentation analyses for the investigation of skeletal part abundance patterns. – *Journal of Taphonomy*, **2**/3: 167–184.

OUTRAM, A.K. (2004b): Identifying dietary stress in marginal environments: bone fats, optimal foraging theory and the seasonal round. – *Colonisation, migration and marginal areas: A zooarchaeological approach*: 74–85.

PÄÄBO, S. (2015): The diverse origins of the human gene pool. – *Nature Reviews Genetics*, **16**/6: 313–314. doi: 10.1038/nrg3954.

PALES, L. & LAMBERT, C. (1971): Atlas ostéologique pour servir à l'identification des mammifères du quaternaire: Herbivores. – 177 pp. Paris (Éditions du Centre national de la recherche scientifique).

PARKINGTON, J. (2001): Presidential Address: Mobility, Seasonality and Southern African Hunter-Gatherers. – *The South African Archaeological Bulletin*, **56**/173/174: 1. doi: 10.2307/3889023.

PARKINGTON, J. (2013): Rounded but not reworked?: Spatial patterning in the stone tool assemblage from Dunefield midden. – *The South African Archaeological Bulletin*, **68**/198: 211–216.

PASSEY, B.H. & CERLING, T.E. (2002): Tooth enamel mineralization in ungulates: implications for recovering a primary isotopic time-series. – *Geochimica et Cosmochimica Acta*, **66**/18: 3225–3234. doi: 10.1016/S0016-7037(02)00933-X.

PASSEY, B.H. & CERLING, T.E. (2004): Response to the comment by M. J. Kohn on "Tooth Enamel Mineralization in Ungulates: Implications for Recovering a Primary Isotopic Time-Series," by B. H. Passey and T. E. Cerling (2002). – *Geochimica et Cosmochimica Acta*, **68**/2: 407–409. doi: 10.1016/S0016-7037(03)00446-0.

PATOU-MATHIS, M. (2000): Neanderthal subsistence behaviours in Europe. – *International Journal of Osteoarchaeology*, **10**/5: 379–395.

PEDERZANI, S. & BRITTON, K. (2019): Oxygen isotopes in bioarchaeology: Principles and applications, challenges and opportunities. – *Earth-Science Reviews*, **188**: 77–107. doi: 10.1016/j.earscirev.2018.11.005.

PEDERZANI, S., SNOECK, C., WACKER, U. & BRITTON, K. (2020): Anion exchange resin and slow precipitation preclude the need for pretreatments in silver phosphate preparation for oxygen isotope analysis of bioapatites. – *Chemical Geology*, **534**: 119455. doi: 10.1016/j.chemgeo.2019.119455.

PELLEGRINI, M., LEE-THORP, J.A. & DONAHUE, R.E. (2011): Exploring the variation of the δ^{18}Op and $\delta 1^{8}$Oc relationship in enamel increments. – *Palaeogeography, Palaeoclimatology, Palaeoecology*, **310**/1–2: 71–83. doi: 10.1016/j.palaeo.2011.02.023.

DE LA PEÑA, P. (2013): The palaeoclimatic record for the Gravettian in the Iberian Peninsula. – In: Pleistocene foragers on the Iberian Peninsula: their culture and environment: Festschrift in honour of Gerd-Christian Weniger for his sixtieth birthday. – pp. 183–200, Mettman (Neanderthal Museum).

PEÑA-CHOCARRO, L., ZAPATA, L., GAZÓLAZ, J.G., GONZÁLEZ-MORALES, M.R., SESMA, J.S. & STRAUS, L.G. (2005a): The spread of agriculture in northern Iberia: new archaeobotanical data from El Mirón cave (Cantabria) and the open-air site of Los Cascajos (Navarra). – *Vegetation History and Archaeobotany*, **14**/4: 268–278. doi: 10.1007/s00334-005-0078-7.

PEÑA-CHOCARRO, L., ZAPATA, L., IRIARTE-CHIAPUSSO, M.J., GONZÁLEZ-MORALES, M.R. & STRAUS, L.G. (2005b): The oldest agriculture in northern Atlantic Spain: new evidence from El Mirón Cave (Ramales de la Victoria, Cantabria). – *Journal of Archaeological Science*, **32**/4: 579–587. doi: 10.1016/j.jas.2004.12.001.

PEÑALVER, X., SAN JOSÉ, S. & MUJIKA-ALUSTIZA, J.A. (eds) (2017): La Cueva de Praileaitz I (Deba, Gipuzkoa, Euskal Herria): intervención arqueológica 2000-2009. – 542 pp. San Sebastian (Sociedad de Ciencias Aranzadi).

PÉREZ, J.M., GRANADOS, J.E., SORIGUER, R.C., FANDOS, P., MÁRQUEZ, F.J. & CRAMPE, J.P. (2002): Distribution, status and conservation problems of the Spanish Ibex, Capra pyrenaica (Mammalia: Artiodactyla). – *Mammal Review*, **32**/1: 26–39. doi: 10.1046/j.1365-2907.2002.00097.x.

PÉREZ-BARBERÍA, F.J., GARCÍA-GONZÁLEZ, R. & PALACIOS, B. (2004): Rupicapra pyrenaica Bonaparte, 1845. – In: Enciclopedia Virtual de los Vertebrados Españoles. – pp. 1–64, Madrid (Museo Nacional de Ciencias Naturales).

PEREZ-BARBERIA, F.J. & MUTUBERRIA, G. (1996): Teeth eruption pattern in Cantabrian chamois Rupicapra pyrenaica parva. – *Acta Theriologica*, **41**: 217–222.

PÉREZ-RIPOLL, M. (1988): Estudio de la secuencia del desgaste de los molares de la «Capra pyrenaica» de yacimientos prehistóricos. – *Archivo de Prehistoria levantina*, **18**: 83–127.

PÉREZ-RIPOLL, M. (1992): Marcas de carnicería, fracturas intencionadas y mordeduras de carnívoros: en huesos prehistóricos del mediterráneo español. – 270 pp. Alicante (Instituto de Cultura "Juan Gil-Albert").

PÉREZ-RIPOLL, M. & LÓPEZ-GILA, M.D.L. (2012): Taphonomic study of the large and medium mammals from the post-Paleolithic occupations in El Mirón Cave. – In: El Mirón Cave, Cantabrian Spain : the site and its Holocene archaeological record. – pp. 262–287, Albuquerque (University of New Mexico Press).

PÉTILLON, J.-M. (2014): Life on the shore of the Bay of Biscay in the Late Upper Paleolithic: towards a new paradigm / Vivre au bord du golfe de Gascogne au Paléolithique supérieur récent: vers un nouveau paradigme. – In: Archéologie des chasseurs-cueilleurs maritimes. De la fonction des habitats à l'organisation de l'espace littoral/Archaeology of maritime hunter-gatherers. From settlement function to the organization of the coastal zone. – pp. 23–36, Paris (Société préhistorique française).

PÉTILLON, J.-M. & DUCASSE, S. (2012): From flakes to grooves: A technical shift in antlerworking during the last glacial maximum in southwest France. – *Journal of Human Evolution*, **62**/4: 435–465. doi: 10.1016/j.jhevol.2011.12.005.

PÉTILLON, J.-M., PLISSON, H. & CATTELAIN, P. (2016): Thirty Years of Experimental Research on the Breakage Patterns of Stone Age Osseous Points. Overview, Methodological Problems and Current Perspectives. – In: IOVITA, R. & SANO, K. (eds): Multidisciplinary Approaches to the Study of Stone Age Weaponry. – pp. 47–63, Dordrecht (Springer). doi: 10.1007/978-94-017-7602-8_4.

PETIT, R.J., BREWER, S. & BORDÁCS, S. (2002): Identification of refugia and post-glacial colonisation routes of European white oaks based on chloroplast DNA and fossil pollen evidence. – *Forest Ecology and Management*, **156**/1–3: 49–74. doi: 10.1016/S0378-1127(01)00634-X.

PETTITT, P. (2011): The Palaeolithic Origins of Human Burial. – 320 pp. New York (Routledge).

PEYRON, O., GUIOT, J., CHEDDADI, R., TARASOV, P., REILLE, M., DE BEAULIEU, J.-L., BOTTEMA, S. & ANDRIEU, V. (1998): Climatic reconstruction in Europe for 18,000 yr BP from pollen data. – *Quaternary research*, **49**/2: 183–196.

PFRETZSCHNER, H.-U. & TÜTKEN, T. (2011): Rolling bones – Taphonomy of Jurassic dinosaur bones inferred from diagenetic microcracks and mineral infillings. – *Palaeogeography, Palaeoclimatology, Palaeoecology*, **310**/1–2: 117–123. doi: 10.1016/j.palaeo.2011.01.026.

PHOCA-COSMETATOU, N. (2004): Site function and the 'ibex-site phenomenon': myth or reality? – *Oxford Journal of Archaeology*, **23**/3: 217–242. doi: 10.1111/j.1468-0092.2004.t01-1-00210.x.

PICKERING, T.R. (2002): Reconsideration of criteria for differentiating faunal assemblages accumulated by hyenas and hominids. – *International Journal of Osteoarchaeology*, **12**/2: 127–141. doi: 10.1002/oa.594.

PICKERING, T.R. & EGELAND, C.P. (2006): Experimental patterns of hammerstone percussion damage on bones: implications for inferences of carcass processing by humans. – *Journal of Archaeological Science*, **33**/4: 459–469. doi: 10.1016/j.jas.2005.09.001.

PICKERING, T.R., MAREAN, C.W. & DOMÍNGUEZ-RODRIGO, M. (2003): Importance of limb bone shaft fragments in zooarchaeology: a response to "On in situ attrition and vertebrate body part profiles" (2002), by M.C. Stiner. – *Journal of Archaeological Science*, **30**/11: 1469–1482. doi: 10.1016/S0305-4403(03)00042-6.

PINTO-LLONA, A.C., CLARK, G., KARKANAS, P., SKINNER, A.R., ANDREWS, P., REED, K., MILLER, A., ROSADO, R.M. & 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*, **63**: 45–79.

PIPERNO, D.R. (2006): Phytoliths: A Comprehensive Guide for Archaeologists and Paleoecologists. – 249 pp. (Rowman Altamira).

POKINES, J.T. (1998a): The Paleoecology of Lower Magdalenian Cantabrian Spain. – 189 pp. Oxford (BAR Publishing).

POKINES, J.T. (1998b): Experimental Replication and Use of Cantabrian Lower Magdalenian Antler Projectile Points. – *Journal of Archaeological Science*, **25**/9: 875–886. doi: 10.1006/jasc.1997.0269.

POKINES, J.T. (2000): When the cat's away: Micromammalian indicators of human seasonality in the Cantabrian Lower Magdalenian. – *Archaeozoologia*, **11**/1–2: 15–31.

POSTH, C., RENAUD, G., MITTNIK, A., DRUCKER, D.G., ROUGIER, H., CUPILLARD, C., VALENTIN, F., THEVENET, C., FURTWÄNGLER, A., WIßING, C., FRANCKEN, M., MALINA, M., BOLUS, M., LARI, M., GIGLI, E., CAPECCHI, G., CREVECOEUR, I., BEAUVAL, C., FLAS, D., GERMONPRÉ, M., VAN DER PLICHT, J., COTTIAUX, R., GÉLY, B., RONCHITELLI, A., WEHRBERGER, K., GRIGORESCU, D., SVOBODA, J., SEMAL, P., CARAMELLI, D., BOCHERENS, H., HARVATI, K., CONARD, N.J., HAAK, W., POWELL, A. & KRAUSE, J. (2016): Pleistocene Mitochondrial Genomes Suggest a Single Major Dispersal of Non-Africans and a Late Glacial Population Turnover in Europe. – *Current Biology*, **26**/6: 827–833. doi: 10.1016/j.cub.2016.01.037.

POTTS, R. & SHIPMAN, P. (1981): Cutmarks made by stone tools on bones from Olduvai Gorge, Tanzania. – *Nature*, **291**/5816: 577.

POWER, R.C., SALAZAR-GARCÍA, D.C., STRAUS, L.G., GONZÁLEZ-MORALES, M.R. & HENRY, A.G. (2015): Microremains from El Mirón Cave human dental calculus suggest a mixed plant–animal subsistence economy during the Magdalenian in Northern Iberia. – *Journal of Archaeological Science*, **60**: 39–46. doi: 10.1016/j.jas.2015.04.003.

PREMO, L.S. & HUBLIN, J.-J. (2009): Culture, population structure, and low genetic diversity in Pleistocene hominins. – *Proceedings of the National Academy of Sciences*, **106**/1: 33–37. doi: 10.1073/pnas.0809194105.

PRICE, T.D., BLITZ, J., BURTON, J. & EZZO, J.A. (1992): Diagenesis in prehistoric bone: Problems and solutions. – *Journal of Archaeological Science*, **19**/5: 513–529. doi: 10.1016/0305-4403(92)90026-Y.

PROVAN, J. & BENNETT, K.D. (2008): Phylogeographic insights into cryptic glacial refugia. – *Trends in Ecology & Evolution*, **23**/10: 564–571. doi: 10.1016/j.tree.2008.06.010.

PRUMMEL, W. (1987a): Atlas for identification of foetal skeletal elements of Cattle, Horse, Sheep and Pig. Part 1. – *Archaeozoologia*, **I**/1: 23–30.

PRUMMEL, W. (1987b): Atlas for identification of foetal skeletal elements of Cattle, Horse, Sheep and Pig. Part 2. – *Archaeozoologia*, **I**/2: 11–41.

PRUMMEL, W. (1988): Atlas for identification of foetal skeletal elements of Cattle, Horse, Sheep and Pig. Part 3. – *Archaeozoologia*, **II**/1,2: 13–26.

PRUMMEL, W. & FRISCH, H.-J. (1986): A Guide for the Distinction of Species, Sex and Body Side in Bones of Sheep and Goat. – *Journal of Archaeological Science*, **13**: 567–577.

QUESADA-LÓPEZ, J.M. (1995): Las estrategias de caza durante el Paleolitico Superior cantábrico. El caso del oriente asturiano. – *Complutum*, **6**: 79–103.

QUESADA-LÓPEZ, J.M. (1997a): Modelos de asentamiento y estrategias de subsistencia en el Paleolítico Superior Cantábrico. – Diss.unpub.: Madrid (Universidad Complutense de Madrid).

QUESADA-LÓPEZ, J.M. (1997b): Los cazadores-recolectores cantábricos del Inter Laugerie Lacaux. – *Complutum*, **8**/8: 7–32.

QUESADA-LÓPEZ, J.M. (1997c): La caza en el Solutrense cantábrico: una nueva perspectiva. – *Zephyrus: Revista de prehistoria y arqueología*, **50**: 3–36.

QUESADA-LÓPEZ, J.M. (2006): Faunas del Auriñaciense y Gravetiense cantábrico: Asturias y Santander: revisión crítica y periodización. – *Zona arqueológica*/7: 407–420.

QUESADA-LÓPEZ, J.M., ÁLVAREZ, G.E.A. & SÁNCHEZ, E.G. (2001): Cueva Oscura de Ania (Las Regueras, Asturias): Contribución al conocimiento del Aziliense antiguo cantábrico. – *Complutum*/12: 9–32.

RADINI, A., NIKITA, E., BUCKLEY, S., COPELAND, L. & HARDY, K. (2017): Beyond food: The multiple pathways for inclusion of materials into ancient dental calculus. – *American Journal of Physical Anthropology*, **162**/S63: 71–83. doi: 10.1002/ajpa.23147.

RAMIL-REGO, P. (2005): Cambio climático y dinámica temporal del paisaje y de los hábitats en las ecorregiones del NW de la Península Ibérica durante el Pleistoceno superior-- Climatic change and temporal dynamics of the landscape and the habitats in the ecoregions from NW Iberia during the Upper Pleistocene. – *Munibe*, **57**: 537–551.

RAMIL-REGO, P., MUÑOZ-SOBRINO, C., RODRÍGUEZ-GUITIÁN, M. & GÓMEZ-ORELLANA, L. (1998): Differences in the vegetation of the North Iberian Peninsula during the last 16,000 years. – *Plant Ecology*, **138**/1: 41–62.

RANDOLPH-QUINNEY, P.S., BACKWELL, L.R., BERGER, L.R., HAWKS, J., DIRKS, P.H.G.M., ROBERTS, E.M., NHAURO, G. & KRAMERS, J. (2016): Response to Thackeray (2016) – The possibility of lichen growth on bones of Homo naledi: Were they exposed to light? – *South African Journal of Science*, **112**/9/10: 1–5. doi: 10.17159/sajs.2016/a0177.

RASILLA-VIVES, M. DE LA & SANTAMARÍA-ÁLVAREZ, D. (2006): El Gravetiense del Abrigo de Cueto de la Mina (Posada de Llanes, Asturias). – In: Miscelánea en homenaje a Victoria Cabrera. – pp. 422–439,.

RASILLA-VIVES, M. DE LA & STRAUS, L.G. (2004): El poblamiento en la región Cantábrica en torno al Último Máximo Glacial: Gravetiense y Solutrense. – *Las Sociedades del Paleolítico en la Región Cantábrica*, **8**: 209–242.

RASMUSSEN, S.O., ANDERSEN, K.K., SVENSSON, A.M., STEFFENSEN, J.P., VINTHER, B.M., CLAUSEN, H.B., SIGGAARD-ANDERSEN, M.-L., JOHNSEN, S.J., LARSEN, L.B., DAHL-JENSEN, D., BIGLER, M., RÖTHLISBERGER, R., FISCHER, H., GOTO-AZUMA, K., HANSSON, M.E. & RUTH, U. (2006): A new Greenland ice core chronology for the last glacial termination. – *Journal of Geophysical Research*, **111**/D6. doi: 10.1029/2005JD006079.

RAYNAL, J.-P., MONCEL, M.-H., FERNANDES, P., BINDON, P., DAUJEAURD, C., FIORE, I., SANTAGATA, C., BEUX, L.-L., GUADELLI, J.-L., LE PAPE, J.-M. & OTHERS (2013): Land-use strategies, related tool-kits and social organization of lower and middle palaeolithic groups in the South-East of the Massif Central, France= Strategien der Landschaftsnutzung, Geräteinventare und soziale Organisation von alt-und mittelpaläolithischen Gruppen im sudwestfranzösischen Zentralmassif. – *Quartär: Internationales Jahrbuch zur Eiszeitalter-und Steinzeitforschung*, **60**: 29–59.

READE, H., O'CONNELL, T.C., BARKER, G. & STEVENS, R.E. (2016): Pleistocene and Holocene palaeoclimates in the Gebel Akhdar (Libya) estimated using herbivore tooth enamel oxygen isotope compositions. – *Quaternary International*, **404**/B: 150–162. doi: 10.1016/j.quaint.2015.10.009.

READE, H., STEVENS, R.E., BARKER, G. & O'CONNELL, T.C. (2015): Tooth enamel sampling strategies for stable isotope analysis: Potential problems in cross-method data comparisons. – *Chemical Geology*, **404**: 126–135. doi: 10.1016/j.chemgeo.2015.03.026.

REDMAN, C.L. & KINZIG, A.P. (2003): Resilience of Past Landscapes: Resilience Theory, Society, and the Longue Durée. – *Conservation Ecology*, **7**/1: 1–19. doi: 10.5751/ES-00510-070114.

REIMER, P.J., BARD, E., BAYLISS, A., BECK, J.W., BLACKWELL, P.G., RAMSEY, C.B., GROOTES, P.M., GUILDERSON, T.P., HAFLIDASON, H., HAJDAS, I., HATTÉ, C., HEATON, T.J., HOFFMANN, D.L., HOGG, A.G., HUGHEN, K.A., KAISER, K.F., KROMER, B., MANNING, S.W., NIU, M., REIMER, R.W., RICHARDS, D.A., SCOTT, E.M., SOUTHON, J.R., STAFF, R.A., TURNEY, C.S.M. & PLICHT, J. VAN DER (2013): IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0–50,000 Years cal BP. – *Radiocarbon*, **55**/4: 1869–1887. doi: 10.2458/azu_js_rc.55.16947.

REITZ, E.J. & WING, E.S. (2008): Zooarchaeology. – Cambridge; New York (Cambridge University Press).

RENDU, W., BEAUVAL, C., CREVECOEUR, I., BAYLE, P., BALZEAU, A., BISMUTH, T., BOURGUIGNON, L., DELFOUR, G., FAIVRE, J.-P., LACRAMPE-CUYAUBÈRE, F., TAVORMINA, C., TODISCO, D., TURQ, A. & MAUREILLE, B. (2014): Evidence supporting an intentional Neandertal burial at La Chapelle-aux-Saints. – *Proceedings of the National Academy of Sciences*, **111**/1: 81–86. doi: 10.1073/pnas.1316780110.

RENDU, W., RENOU, S., SOULIER, M.-C., RIGAUD, S., ROUSSEL, M. & SORESSI, M. (2019): Subsistence strategy changes during the Middle to Upper Paleolithic transition reveals specific adaptations of Human Populations to their environment. – *Scientific Reports*, **9**/1: 15817. doi: 10.1038/s41598-019-50647-6.

RICHARDS, M.P., PETTITT, P.B., STINER, M.C. & TRINKAUS, E. (2001): Stable isotope evidence for increasing dietary breadth in the European mid-Upper Paleolithic. – *Proceedings of the National Academy of Sciences*, **98**/11: 6528–6532.

RICHARDS, M.P., PETTITT, P.B., TRINKAUS, E., SMITH, F.H., PAUNOVIĆ, M. & KARAVANIĆ, I. (2000): Neanderthal diet at Vindija and Neanderthal predation: the evidence from stable isotopes. – *Proceedings of the National Academy of Sciences of the United States of America*, **97**/13: 7663–6. doi: 10.1073/pnas.120178997.

RIEL-SALVATORE, J. & BARTON, C.M. (2004): Late Pleistocene Technology, Economic Behavior, and Land-Use Dynamics in Southern Italy. – *American Antiquity*, **69**/2: 257. doi: 10.2307/4128419.

RIEL-SALVATORE, J. & GRAVEL-MIGUEL, C. (2013): Upper Paleolithic mortuary practices in Eurasia: A critical look at the burial record. – In: The Oxford Handbook of the Archaeology of Death and Burial. – pp. 303–346, Oxford (Oxford University Press).

RIEL-SALVATORE, J. & NEGRINO, F. (2018): Human adaptations to climatic change in Liguria across the Middle–Upper Paleolithic transition. – *Journal of Quaternary Science*, **33**/3: 313–322. doi: 10.1002/jqs.3005.

RINCÓN VILA, R. (1975): Notas sobre los grabados de la Cueva de "La Lastrilla" (Castro Urdiales - Santander). – *Sautuola: Revista del Instituto de Prehistoria y Arqueología Sautuola*, **1**: 49–51.

RIOS-GARAIZAR, J. (2007): Industria lítica y sociedad en la Transición del Paleolítico Medio al Superior en torno al Golfo de Bizkaia. – 561 pp. Santander (PUbliCan Universidad de Cantabria).

RIOS-GARAIZAR, J. (2012): El yacimiento chatelperroniense al aire libre de Aranbaltza (Barrika, Euskadi). – *Munibe*, **63**: 81–92.

RIOS-GARAIZAR, J. (2016): Early Middle Palaeolithic occupations at Ventalaperra cave (Cantabrian Region, Northern Iberian Peninsula). – *Journal of Lithic Studies*, **3**/1. doi: 10.2218/jls.v3i1.1287.

RIOS-GARAIZAR, J. (2017): A new chronological and technological synthesis for Late Middle Paleolithic of the Eastern Cantabrian Region. – *Quaternary International*, **433**: 50–63. doi: 10.1016/j.quaint.2016.02.020.

RIOS-GARAIZAR, J., ARRIZABALAGA, A. & VILLALUENGA, A. (2012): Hunting camps during the Chatelperronian in the Iberian Peninsula: Labeko Koba and Ekain (Peninsular Basque country) -- Haltes de chasse du Châtelperronien de la Péninsule Ibérique : Labeko Koba et Ekain (Pays Basque Péninsulaire). – *L'Anthropologie*, **116**/4: 532–549. doi: 10.1016/j.anthro.2012.10.001.

RIOS-GARAIZAR, J., FERNÁNDEZ, J.M. & DE LA PEÑA, P. (2013): El final del Auriñaciense y el comienzo del Gravetiense en la región cantábrica: una visión tecno-tipológica. – In: Pensando el Gravetiense: nuevos datos para la Región Cantábrica en su contexto. – pp. 369–382, Santander (Museo Nacional de Ciencias Naturales).

RIOS-GARAIZAR, J., GARATE-MAIDAGAN, D., GÓMEZ-OLIVENCIA, A., IRIARTE-AVILÉS, E., ARANBURU-ARTANO, A., ARCEREDILLO-ALONSO, D., GARCÍA-MORENO, A., IRIARTE-CHIAPUSSO, M.J., MORENO, J. & MURELAGA, X. (2011):

The Lower to Middle Palaeolithic transition in northern Iberia: new data from Arlanpe Cave. – *Antiquity*, **85**/329.

RIOS-GARAIZAR, J. & GARCÍA-MORENO, A. (eds) (2015): Middle Paleolithic Mobility Patterns and Settlement System Variability in the Eastern Cantabrian Region (Iberian Peninsula): A GIS-Based Resource Patching Model. – In: Settlement dynamics of the Middle Paleolithic and Middle Stone Age. – p. Tübingen (Kerns).

RIPOLL LÓPEZ, S. & RIPOLL-PERELLÓ, E. (1990): Gravetiense y Solutrense en la Península Ibérica. – *Espacio Tiempo y Forma. Serie I, Prehistoria y Arqueología*, **3**: 55–70.

RISSETTO, J.D. (2005): Using Lithic Procurement Strategies to Define Magdalenian Hunter-Gatherer Mobility Patterns in the Asón Valley of Eastern Cantabria, Spain. – In: O Paleolítico: Actas Do IV Congresso de Arqueologia Peninsular (Faro, 14 a 19 de Setembro de 2004). – pp. 481–492, (Centro de Estudos de Patrimonio, Departamento de Historia, Arqueologia e …).

RISSETTO, J.D. (2009): Late Pleistocene hunter -gatherer mobility patterns and lithic exploitation in eastern Cantabria (Spain). – Diss.: Albuquerque (University of New Mexico).

RIVALS, F., JULIEN, M.-A., KUITEMS, M., VAN KOLFSCHOTEN, T., SERANGELI, J., DRUCKER, D.G., BOCHERENS, H. & CONARD, N.J. (2015): Investigation of equid paleodiet from Schöningen 13 II-4 through dental wear and isotopic analyses: Archaeological implications. – *Journal of Human Evolution*, **89**: 129–137. doi: 10.1016/j.jhevol.2014.04.002.

RIVERO, O. (2010): La Movilidad de los grupos humanos del Magdaleniense en la Región Cantábrica y los Pirineos: Una visión a través del arte. – Diss.: Salamanca (Universidad de Salamanca).

RIVERO, O., GARATE-MAIDAGAN, D., SALAZAR, S. & INTXAURBE, I. (2019): The Cantabrian Lower Magdalenian striated hinds on scapulae: Towards a new definition of a graphic morphotype. – *Quaternary International*, **506**: 69–79. doi: 10.1016/j.quaint.2019.01.037.

ROBERT, I. & VIGNE, J.-D. (2002): Bearded Vulture Gypaetus barbatus contributions to the constitution of two different bone assemblages: Modern reference data and an archaeological example in Corsica. – *Acta zoologica cracoviensia*, **45**/special issue: 319–329.

ROBERTS, P., FERNANDES, R., CRAIG, O.E., LARSEN, T., LUCQUIN, A., SWIFT, J. & ZECH, J. (2018): Calling all archaeologists: guidelines for terminology, methodology, data handling, and reporting when undertaking and reviewing stable isotope applications in archaeology. – *Rapid Communications in Mass Spectrometry*, **32**/5: 361–372. doi: 10.1002/rcm.8044.

ROBERTS, S.J., SMITH, C.I., MILLARD, A. & COLLINS, M.J. (2002): The taphonomy of cooked bone: Characterizing boiling and its physico-chemical effects. – *Archaeometry*, **44**/3: 485–494. doi: 10.1111/1475-4754.t01-1-00080.

RODRÍGUEZ ASENSIO, J.A. (1992): La cueva de Trescalabres (Posada de LLanes, Asturias) y sus pinturas rupestres. – In: Excavaciones arqueológicas en Asturias 1987-90. – pp. 81–87, (Gobierno del Principado de Asturias).

RODRÍGUEZ ASENSIO, J.A. & BARRERA LOGARES, J.M. (2013): La Lluera II (San Juan de Priorio, Oviedo, Asturias, España): Estudio integral de un santuario complementario solutrense. – *Espacio Tiempo y Forma. Serie I, Prehistoria y Arqueología*/5.

RODRÍGUEZ ASENSIO, J.A., BARRERA LOGARES, J.M. & AGUILAR HUERGO, E. (2013): Cueva de La Lluera I (San Juan de Priorio, Oviedo, Asturias, España): Estratigrafía Solutrense = La Lluera I cave (San Juan de Priorio,

Oviedo, Asturias, Spain): Solutrean stratigraphy. – *Espacio Tiempo y Forma. Serie I, Prehistoria y Arqueología*, **5**: 235–248. doi: 10.5944/etf i.5.9319.

RODRÍGUEZ-SÁNCHEZ, F., HAMPE, A., JORDANO, P. & ARROYO, J. (2010): Past tree range dynamics in the Iberian Peninsula inferred through phylogeography and palaeodistribution modelling: A review. – *Review of Palaeobotany and Palynology*, **162**/3: 507–521. doi: 10.1016/j.revpalbo.2010.03.008.

ROEBROEKS, W. & KOLFSCHOTEN, T. VAN (1994): The earliest occupation of Europe: a short chronology. – *Antiquity*, **68**/260: 489–503. doi: 10.1017/S0003598X00047001.

ROEBROEKS, W. & SORESSI, M. (2016): Neandertals revised. – *Proceedings of the National Academy of Sciences*, **113**/23: 6372–6379. doi: 10.1073/pnas.1521269113.

ROFES, J., GARCIA-IBAIBARRIAGA, N., AGUIRRE, M., MARTÍNEZ-GARCÍA, B., ORTEGA, L., ZULUAGA, M.C., BAILON, S., ALONSO-OLAZABAL, A., CASTAÑOS, J. & MURELAGA, X. (2015): Combining Small-Vertebrate, Marine and Stable-Isotope Data to Reconstruct Past Environments. – *Scientific Reports*, **5**/1: 1–12 (Nature Publishing Group). doi: 10.1038/srep14219.

ROGERS, A.R. (2000a): On the Value of Soft Bones in Faunal Analysis. – *Journal of Archaeological Science*, **27**/7: 635–639. doi: 10.1006/jasc.1999.0494.

ROGERS, A.R. (2000b): On Equifinality in Faunal Analysis. – *American Antiquity*, **65**/4: 709–723. doi: 10.2307/2694423.

ROMANDINI, M., CRISTIANI, E. & PERESANI, M. (2015): A retouched bone shaft from the Late Mousterian at Fumane cave (Italy). Technological, experimental and micro-wear analysis. – *Comptes Rendus Palevol*, **14**/1: 63–72. doi: 10.1016/j.crpv.2014.08.001.

ROMERO, A.J., DÍEZ, J.C., RODRÍGUEZ, L. & ARCEREDILLO, D. (2015): Anthropic fractures and human tooth marks: An experimental approach to non-technological human action on avian long bones. – *Quaternary International*, **421**: 219–227. doi: 10.1016/j.quaint.2015.10.005.

ROPER, D.C. (1979): The method and theory of site catchment analysis: a review. – *Advances in archaeological method and theory*, **2**: 119–140.

ROWLAND, J.C. (2006): Inter-and intra-tooth isotopic variation in mammalian tooth enamel from western Israel: Implications for paleoenvironmental and paleoclimate change over the past 350 kyr. – Master's Thesis: Arizona (University of Arizona).

ROYER, A., DAUX, V., FOUREL, F. & LÉCUYER, C. (2017): Carbon, nitrogen and oxygen isotope fractionation during food cooking: Implications for the interpretation of the fossil human record: ROYER ET AL . – *American Journal of Physical Anthropology*, **163**/4: 759–771. doi: 10.1002/ajpa.23246.

RUIZ IDARRAGA, R. (1990): The Aurignacian-Perigordian complex in the Basque Country. – *Munibe*, **42**: 23–32.

RUIZ-REDONDO, A. (2014): Entre el Cantábrico y los Pirineos: El conjunto de Altxerri en el contexto de la actividad gráfica magdaleniense. – 315 pp. Santander (Nadir Ediciones).

SALA, N. & ARSUAGA, J.L. (2018): Regarding beasts and humans: A review of taphonomic works with living carnivores. – *Quaternary International*, **466**: 131–140. doi: 10.1016/j.quaint.2016.03.011.

SALADIÉ, P., RODRÍGUEZ-HIDALGO, A., DÍEZ, C., MARTÍN-RODRÍGUEZ, P. & CARBONELL, E. (2013): Range of bone modifications by human chewing. – *Journal of Archaeological Science*, **40**/1: 380–397. doi: 10.1016/j.jas.2012.08.002.

SANCHEZ, V.F.V. & THAM, T.E.R. (2014): Malacofauna de la Cueva de Santa Catalina. – *Kobie*, **4**: 119–150.

SÁNCHEZ-GOÑI, M.-F. & HARRISON, S.P. (2010): Millennial-scale climate variability and vegetation changes during the Last Glacial: Concepts and terminology. – *Quaternary Science Reviews*, **29**/21–22: 2823–2827. doi: 10.1016/j.quascirev.2009.11.014.

SÁNCHEZ-GOÑI, M.-F., LANDAIS, A., FLETCHER, W.J., NAUGHTON, F., DESPRAT, S. & DUPRAT, J. (2008): Contrasting impacts of Dansgaard–Oeschger events over a western European latitudinal transect modulated by orbital parameters. – *Quaternary Science Reviews*, **27**/11–12: 1136–1151. doi: 10.1016/j.quascirev.2008.03.003.

SÁNCHEZ-GOÑI, M.-F., TURON, J.-L., EYNAUD, F. & GENDREAU, S. (2000): European Climatic Response to Millennial-Scale Changes in the Atmosphere–Ocean System during the Last Glacial Period. – *Quaternary Research*, **54**/3: 394–403. doi: 10.1006/qres.2000.2176.

SANCHIS, A., REAL, C., SAUQUÉ, V., NÚÑEZ-LAHUERTA, C., ÉGÜEZ, N., TORMO, C., PÉREZ RIPOLL, M., CARRIÓN MARCO, Y., DUARTE, E. & DE LA RASILLA, M. (2019): Neanderthal and carnivore activities at Llonin Cave, Asturias, northern Iberian Peninsula: Faunal study of Mousterian levels (MIS 3). – *Comptes Rendus Palevol*, **18**/1: 113–141. doi: 10.1016/j.crpv.2018.06.001.

SANCHIS, A., REAL MARGALEF, C., MORALES PÉREZ, J.V., PÉREZ-RIPOL, M., TORMO CUÑAT, C., CARRIÓN MARCO, Y., PÉREZ JORDÁ, G., RIBERA GÓMEZ, A., BOLUFER MARQUÉS, J. & VILLAVERDE BONILLA, V. (2014): Towards the identification of a new taphonomic agent: An analysis of bone accumulations obtained from modern Egyptian vulture (Neophron percnopterus) nests. – *Quaternary International*, **330**: 136–149. doi: 10.1016/j.quaint.2013.10.047.

SANDGATHE, D.M., DIBBLE, H.L., GOLDBERG, P. & MCPHERRON, S.P. (2011): The Roc de Marsal Neandertal child: A reassessment of its status as a deliberate burial. – *Journal of Human Evolution*, **61**/3: 243–253. doi: 10.1016/j.jhevol.2011.04.003.

SANGUINO, J. & MONTES, R. (2005): Nuevos datos para el conocimiento del Paleolítico Medio en el centro de la Región Cantábrica: la Cueva de Covalejos (Piélagos, Cantabria). – *Neandertales Cantábricos. Estado de la cuestión*, **20**: 489–504.

SANTAMARÍA-ÁLVAREZ, D. (2012): La transición del Paleolítico medio al superior en Asturias. El abrigo de La Viña (Oviedo, Asturias) y la cueva de El Sidrón (Borines, Piloña). – .

SANTUCCI, F., EMERSON, B.C. & HEWITT, G.M. (1998): Mitochondrial DNA phylogeography of European hedgehogs. – *Molecular Ecology*, **7**/9: 1163–1172.

SARRIÓN MONTAÑANA, I. (1988): Notas sobre una morfología diferenciada en los restos óseos de la "Capra pyrenaica" y "Capra hircus." – *Archivo de prehistoria levantina*/18: 129–134.

SAUQUÉ, V., SANCHIS, A. & MADURELL-MALAPEIRA, J. (2018): Late Pleistocene leopards as a bone accumulator: taphonomic results from S'Espasa cave and other Iberian key sites. – *Historical Biology*, **30**/6: 821–834. doi: 10.1080/08912963.2017.1343313.

SAUTUOLA, M.S. DE (1880): Breves apuntes sobre algunos objetos prehistóricos de la provincia de Santander. – 5–27 pp. Real Academia de la Historia (Blanca).

SAUVET, G. (2015): Histoire de chasseurs. Chronique des temps paléolithiques. – In: Cien años de arte rupestre paleolítico. – pp. 15–30, Salamanca (Ediciones Universidad de Salamanca).

SAUVET, G. (2019): The lifeworld of hunter-gatherers and the concepts of territory. – *Quaternary International*, **503**: 191–199.

SAUVET, G., FORTEA, J., FRITZ, C. & TOSELLO, G. (2008): Echanges culturels entre groupes humains paléolithiques entre 20.000 et 12.000 BP. – *Bulletin de la Société Préhistorique Ariège-Pyrénées*, **LXIII**: 73–92.

SCHIFFER, M.B. (1976): Behavioral archaeology. – 222 pp. New York (Academic Press).

SCHIFFER, M.B. (1983a): Forward to McKellar Paper. – *Arizona Anthropologist*, **4**: 1–1.

SCHIFFER, M.B. (1983b): Toward the Identification of Formation Processes. – *American Antiquity*, **48**/4: 675. doi: 10.2307/279771.

SCHIFFER, M.B. (1996): Formation Processes of the Archaeological Record. Originally published: Albuquerque, NM 1987. – 448 pp. Salt Lake City (University of Utah Press).

SCHIFFER, M.B. (1999): Behavioral Archaeology: Some Clarifications. – *American Antiquity*, **64**/01: 166–168. doi: 10.2307/2694352.

SCHIFFER, M.B. & SKIBO, J.M. (1987): Theory and Experiment in the Study of Technological Change. – *Current Anthropology*, **28**/5: 595–622. doi: 10.1086/203601.

SCHIFFER, M.B., SKIBO, J.M., GRIFFITTS, J.L., HOLLENBACK, K.L. & LONGACRE, W.A. (2001): Behavioral Archaeology and the Study of Technology. – *American Antiquity*, **66**/4: 729. doi: 10.2307/2694186.

SCHMID, E. (1972): Atlas of animal bones: for prehistorians, archaeologists and quaternary geologists = Knochenatlas : für Prähistoriker, Archäologen und Quartärgeologen. – 156 pp. Amsterdam-London-New York (Elsevier).

SCHMIDT, I. (2015): Beyond Solutrean Point Types: Technological Organization and Behavioral Implications. – *Journal of Anthropological Research*, **71**/4: 493–508. doi: 10.3998/jar.0521004.0071.402.

SCHMIDT, I., BRADTMÖLLER, M., KEHL, M., PASTOORS, A., TAFELMAIER, Y., WENINGER, B. & WENIGER, G.-C. (2012): Rapid climate change and variability of settlement patterns in Iberia during the Late Pleistocene. – *Quaternary International*, **274**: 179–204. doi: 10.1016/j.quaint.2012.01.018.

SCHMIDT, I. & ZIMMERMANN, A. (2019): Population dynamics and socio-spatial organization of the Aurignacian: Scalable quantitative demographic data for western and central Europe. – *PloS one*, **14**/2: 1–20.

SCHOVILLE, B.J. & OTÁROLA-CASTILLO, E. (2014): A model of hunter-gatherer skeletal element transport: The effect of prey body size, carriers, and distance. – *Journal of Human Evolution*, **73**: 1–14. doi: 10.1016/j.jhevol.2014.06.004.

SCHWENDLER, R.H. (2012): Diversity in social organization across Magdalenian Western Europe ca. 17–12,000 BP. – *Quaternary International*, **272–273**: 333–353. doi: 10.1016/j.quaint.2012.03.054.

SEPULCHRE, P., RAMSTEIN, G., KAGEYAMA, M., VANHAEREN, M., KRINNER, G., SÁNCHEZ-GOÑI, M.-F. & D'ERRICO, F. (2007): H4 abrupt event and late Neanderthal presence in Iberia. – *Earth and Planetary Science Letters*, **258**/1–2: 283–292. doi: 10.1016/j.epsl.2007.03.041.

SERRANO, E., GÁLLEGO, L. & PÉREZ, J.M. (2004): Ossification of the appendicular skeleton in the Spanish Ibex Capra pyrenaica Schinz, 1838 (Artiodactyla: Bovidae), with regard to determination of age. – *Anatomia, Histologia, Embryologia*, **33**/1: 33–37. doi: 10.1111/j.1439-0264.2004.00506.x.

SERRANO, ENRIQUE, GÓMEZ-LENDE, M., GONZÁLEZ-AMUCHASTEGUI, M.J., GONZÁLEZ-GARCÍA, M., GONZÁLEZ-TRUEBA, J.J., PELLITERO, R. & RICO, I. (2015): Glacial chronology, environmental changes and implications for human occupation during the upper Pleistocene in the eastern Cantabrian Mountains. – *Quaternary International*, **364**: 22–34. doi: 10.1016/j.quaint.2014.09.039.

SERRANO, E., GÓMEZ-LENDE, M., PELLITERO-ONDICOL, R. & TRUEBA, J.J.G. (2015): Deglaciation in the Cantabrian Mountains: pattern and evolution. – *Cuadernos de Investigación Geográfica*, **41**/2: 389–408. doi: 10.18172/cig.2716.

SERRANO, E., GONZÁLEZ-TRUEBA, J.J. & GONZÁLEZ-GARCÍA, M. (2012): Mountain glaciation and paleoclimate reconstruction in the Picos de Europa (Iberian Peninsula, SW Europe). – *Quaternary Research*, **78**/02: 303–314. doi: 10.1016/j.yqres.2012.05.016.

SERRANO, E., GONZÁLEZ-TRUEBA, J.J., PELLITERO, R., GONZÁLEZ-GARCÍA, M. & GÓMEZ-LENDE, M. (2013): Quaternary glacial evolution in the Central Cantabrian Mountains (Northern Spain). – *Geomorphology*, **196**: 65–82. doi: 10.1016/j.geomorph.2012.05.001.

SERRANO, E., PEREZ, J.M., CHRISTIANSEN, P. & GALLEGO, L. (2006): Sex-Difference in The Ossification Rate of The Appendicular Skeleton in Capra pyrenaica Schinz, 1838, and Its Utility in The Sex Identification of Long Bones. – *Anatomia, Histologia, Embryologia: Journal of Veterinary Medicine Series C*, **35**/2: 69–75. doi: 10.1111/j.1439-0264.2005.00638.x.

SEVA ROMÁN, R., BIETE BAÑÓN, C. & LANDETE RUIZ, M.D. (2015): Analysis of the red ochre of the El Mirón burial (Ramales de la Victoria, Cantabria, Spain). – *Journal of Archaeological Science*, **60**: 84–98. doi: 10.1016/j.jas.2015.03.033.

SEVA ROMÁN, R., LANDETE RUIZ, M.D. & BIETE BAÑÓN, C. (Unpub.): Estudio geoquímico de los huesos del Nivel 17 de la cueva de El Mirón: informe analítico 2018. – Unidad de Arqueometría. Servicios Técnicos de Investigación Universidad de Alicante.

SEVA ROMÁN, R., LANDETE RUIZ, M.D., JUAN-JUAN, J., BIETE BAÑÓN, C., STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2019): Sources of the ochres associated with the Lower Magdalenian "Red Lady" human burial and rock art in El Mirón Cave (Cantabria, Spain). – *Journal of Archaeological Science: Reports*, **23**: 265–280. doi: 10.1016/j.jasrep.2018.10.024.

SHACKLETON, N.J. (1987): Oxygen isotopes, ice volume and sea level. – *Quaternary Science Reviews*, **6**/3–4: 183–190. doi: 10.1016/0277-3791(87)90003-5.

SHACKLETON, N.J., HALL, M.A. & VINCENT, E. (2000): Phase relationships between millennial-scale events 64,000–24,000 years ago. – *Paleoceanography*, **15**/6: 565–569. doi: 10.1029/2000PA000513.

SHAHACK-GROSS, R., BAR-YOSEF, O. & WEINER, S. (1997): Black-Coloured Bones in Hayonim Cave, Israel: Differentiating Between Burning and Oxide Staining. – *Journal of Archaeological Science*, **24**/5: 439–446. doi: 10.1006/jasc.1996.0128.

SHEA, J.J. (2008): Transitions or turnovers? Climatically-forced extinctions of Homo sapiens and Neanderthals in the east Mediterranean Levant. – *Quaternary Science Reviews*, **27**/23–24: 2253–2270. doi: 10.1016/j.quascirev.2008.08.015.

SHENNAN, S., DOWNEY, S.S., TIMPSON, A., EDINBOROUGH, K., COLLEDGE, S., KERIG, T., MANNING, K. & THOMAS, M.G. (2013): Regional population collapse followed initial agriculture booms in mid-Holocene Europe. – *Nature Communications*, **4**/1: 1–8. doi: 10.1038/ncomms3486.

SHIPMAN, P. (1981): Applications of Scanning Electron Microscopy to Taphonomic Problems. – *Annals of the New York Academy of Sciences*, **376**/1: 357–385. doi: 10.1111/j.1749-6632.1981.tb28179.x.

SHIPMAN, P., FOSTER, G. & SCHOENINGER, M. (1984): Burnt bones and teeth: an experimental study of color, morphology, crystal structure and shrinkage. – *Journal of Archaeological Science*, **11**/4: 307–325. doi: 10.1016/0305-4403(84)90013-X.

SHIPMAN, P. & ROSE, J. (1983): Early hominid hunting, butchering, and carcass-processing behaviors: approaches to the fossil record. – *Journal of anthropological Archaeology*, **2**/1: 57–98.

SIDDALL, M., ROHLING, E.J., THOMPSON, W.G. & WAELBROECK, C. (2008): Marine isotope stage 3 sea level fluctuations: Data synthesis and new outlook. – *Reviews of Geophysics*, **46**/4. doi: 10.1029/2007RG000226.

SIEVEKING, A. (1987): Engraved Magdalenian plaquettes: a regional and stylistic analysis of stone, bone and antler plaquettes from Upper Palaeolithic sites in France and Cantabric Spain. – Oxford (Archaeopress).

SILVA, F. & STEELE, J. (2014): New methods for reconstructing geographical effects on dispersal rates and routes from large-scale radiocarbon databases. – *Journal of Archaeological Science*, **52**: 609–620. doi: 10.1016/j.jas.2014.04.021.

SILVER, I.A. (1980): La determinación de la edad en los animales domésticos. – *Ciencia en arqueología*: 289–308.

SILVERMAN, B.W. (1986): Density Estimation for Statistics and Data Analysis. – 22 pp. London (CRC Press).

SIMON, U., HÄNDEL, M., EINWÖGERER, T. & NEUGEBAUER-MARESCH, C. (2014): The archaeological record of the Gravettian open air site Krems-Wachtberg. – *Quaternary International*, **351**: 5–13. doi: 10.1016/j.quaint.2013.08.009.

SIMONET, G. (2010): The concept of adaptation : interdisciplinary scope and involvement in climate change. – *S.A.P.I.EN.S. Surveys and Perspectives Integrating Environment and Society*, **3**/1: 1–10.

SIMPSON, E.H. (1949): Measurement of Diversity. – *Nature*, **163**: 688–688.

SMITH, E.A., BETTINGER, R.L., BISHOP, C.A., BLUNDELL, V., CASHDAN, E., CASIMIR, M.J., CHRISTENSON, A.L., COX, B., DYSON-HUDSON, R., HAYDEN, B., RICHERSON, P.J., ROTH, E.A., SIMMS, S.R. & STINI, W.A. (1983): Anthropological Applications of Optimal Foraging Theory: A Critical Review [and Comments and Reply]. – *Current Anthropology*, **24**/5: 625–651. doi: 10.1086/203066.

SMITH, P. (2003): Matienzo Caving Expedition Archaeology. – Retrieved April 24, 2019, from http://matienzocaves.org.uk/archaeol.htm.

SNOECK, C. & PELLEGRINI, M. (2015): Comparing bioapatite carbonate pre-treatments for isotopic measurements: Part 1—Impact on structure and chemical composition. – *Chemical Geology*, **417**: 394–403. doi: 10.1016/j.chemgeo.2015.10.004.

SOLARI, A., OLIVERA, D., GORDILLO, I., BOSCH, P., FETTER, G., LARA, V.H. & NOVELO, O. (2013): Cooked Bones? Method and Practice for Identifying Bones Treated at Low Temperature. – *International Journal of Osteoarchaeology*, **25**/4: 426–440. doi: 10.1002/oa.2311.

SOMMER, R.S., ZACHOS, F.E., STREET, M., JÖRIS, O., SKOG, A. & BENECKE, N. (2008): Late Quaternary distribution dynamics and phylogeography of the red deer (Cervus elaphus) in Europe. – *Quaternary Science Reviews*, **27**/7–8: 714–733.

SORENG, R.J., PETERSON, P.M., ROMASCHENKO, K., DAVIDSE, G., TEISHER, J.K., CLARK, L.G., BARBERÁ, P., GILLESPIE, L.J. & ZULOAGA, F.O. (2017): A worldwide phylogenetic classification of the Poaceae (Gramineae) II: An update and a comparison of two 2015 classifications. – *Journal of Systematics and Evolution*, **55**/4: 259–290.

SOTO, E. (1984): Restos faunísticos de la cueva del Buxu (Oviedo). – *Boletín del Real Instituto de Estudios Asturianos BIDEA*, **38**/112: 803–810.

SOULIER, M.-C. & COSTAMAGNO, S. (2017): Let the cutmarks speak! Experimental butchery to reconstruct carcass processing. – *Journal of Archaeological Science: Reports*, **11**/C: 782–802. doi: 10.1016/j.jasrep.2016.12.033.

SPETH, J.D. (2004): Hunting Pressure, Subsistence Intensification, and Demographic Change in the Levantine Late Middle Paleolithic. – In: Human Paleoecology in the Levantine Corridor. – pp. 149–166, Oxford (Oxbow Books).

SPETH, J.D. & DAVIS, D.D. (1976): Seasonal Variability in Early Hominid Predation. – *Science*, **192**/4238: 441–445. doi: 10.1126/science.192.4238.441.

STEELE, T.E. (2002): Red deer: their ecology and how they were hunted by Late Pleistocene hominids in western Europe. – Diss.: (Stanford University).

STEVENS, R.E., HERMOSO-BUXÁN, X.L., MARÍN-ARROYO, A.B., GONZÁLEZ-MORALES, M.R. & STRAUS, L.G. (2014): Investigation of Late Pleistocene and Early Holocene palaeoenvironmental change at El Mirón cave (Cantabria, Spain): Insights from carbon and nitrogen isotope analyses of red deer. – *Palaeogeography, Palaeoclimatology, Palaeoecology*, **414**: 46–60.

STEWARD, J. (1955): Theory of Culture Change. The Methodology of Multilinear Evolution. – *American Antiquity*, **22**/2Part1: 195–196. doi: 10.2307/276830.

STEWART, B.A. (2010): Modifications on the bovid bone assemblage from Dunefield Midden, South Africa: stage one of a multivariate taphonomic analysis. – *Azania: Archaeological Research in Africa*, **45**/3: 238–275. doi: 10.1080/0067270X.2010.491951.

STEWART, J.R. & STRINGER, C.B. (2012): Human Evolution Out of Africa: The Role of Refugia and Climate Change. – *Science*, **335**/6074: 1317–1321. doi: 10.1126/science.1215627.

STINER, M.C. (1990): The use of mortality patterns in archaeological studies of hominid predatory adaptations. – *Journal of anthropological archaeology*, **9**/4: 305–351.

STINER, M.C. (1991): Food procurement and transport by human and non-human predators. – *Journal of Archaeological Science*, **18**/4: 455–482. doi: 10.1016/0305-4403(91)90038-Q.

STINER, M.C. (1994): Honor among thieves: A zooarchaeological study of Neandertal ecology. – 447 pp. Princeton (Princeton University Press).

STINER, M.C. (2001): Thirty years on the "Broad Spectrum Revolution" and paleolithic demography. – *Proceedings of the National Academy of Sciences*, **98**/13: 6993–6996. doi: 10.1073/pnas.121176198.

STINER, M.C. (2002a): Zooarchaeological evidence for resource intensification in Algarve, southern Portugal. – *Promontoria, Revista do Departamento de Historia, Arqueologia e Patrimonio da Universidade do Algarve*, **1**: 23–58.

STINER, M.C. (2002b): On in situ Attrition and Vertebrate Body Part Profiles. – *Journal of Archaeological Science*, **29**/9: 979–991. doi: 10.1006/jasc.2001.0798.

STINER, M.C. (2004): A Comparison of Photon Densitometry and Computed Tomography Parameters of Bone Density in Ungulate Body Part Profiles. – *Journal of Taphonomy*, **2**: 117–146.

STINER, M.C. (2008): Small Animal Exploitation and its Relation to Hunting, Scavenging, and Gathering in the Italian Mousterian. – *Archeological Papers of the American Anthropological Association*, **4**/1: 107–125. doi: 10.1525/ap3a.1993.4.1.107.

STINER, M.C., BARKAI, R. & GOPHER, A. (2009): Cooperative hunting and meat sharing 400–200 kya at Qesem Cave, Israel. – *Proceedings of the National Academy of Sciences of the United States of America*, **106**/32: 13207–13212. doi: 10.1073/pnas.0900564106.

STINER, M.C., BAR-YOSEF, O. & BELFER-COHEN, A. (2005): The Faunas of Hayonim Cave, Israel: A 200,000-year Record of Paleolithic Diet, Demography, and Society. – 353 pp. Cambridge (Peabody Museum Press).

STINER, M.C., BEAVER, J.E., MUNRO, N.D. & SUROVELL, T.A. (2008): Modeling Paleolithic Predator-Prey Dynamics and the Effects of Hunting Pressure on Prey 'Choice.' – In: BOCQUET-APPEL, J.-P. (ed.): Recent Advances in Palaeodemography. – pp. 143–178, Dordrecht (Springer). doi: 10.1007/978-1-4020-6424-1_6.

STINER, M.C., KUHN, S.L., WEINER, S. & BAR-YOSEF, O. (1995): Differential burning, recrystallization, and fragmentation of archaeological bone. – *Journal of Archaeological Science*, **22**/2: 223–237.

STINER, M.C. & MUNRO, N.D. (2002): Approaches to Prehistoric Diet Breadth, Demography, and Prey Ranking Systems in Time and Space. – *Journal of Archaeological Method and Theory*, **9**/2: 181–214.

STINER, M.C., MUNRO, N.D. & SUROVELL, T.A. (2000): The Tortoise and the Hare: Small-Game Use, the Broad-Spectrum Revolution, and Paleolithic Demography. – *Current Anthropology*, **41**/1: 39–79. doi: 10.1086/300102.

STINER, M.C., MUNRO, N.D., SUROVELL, T.A., TCHERNOV, E. & BAR-YOSEF, O. (1999): Paleolithic Population Growth Pulses Evidenced by Small Animal Exploitation. – *Science*, **283**/5399: 190–194. doi: 10.1126/science.283.5399.190.

STRAUS, L.G. (1974): Posible atribución al solutrense del yacimiento de La Pasiega (Puente Viesgo, Santander). – *Ampurias: revista de arqueología, prehistoria y etnografía*, **36**: 217–224.

STRAUS, L.G. (1975a): Solutrense o magdaleniense inferior cantábrico?: significado de la diferencia. – *Boletín del Instituto de Estudios Asturianos*, **29**/86: 782–800.

STRAUS, L.G. (1975b): A study of the Solutrean in Vasco-Cantabrian Spain. – Diss.: (University of Chicago).

STRAUS, L.G. (1976): Análisis arqueológico de la fauna paleolítica del norte de la Peninsula Ibérica. – *Munibe*, **28**: 277–285.

STRAUS, L.G. (1977a): Of deerslayers and mountain men: Paleolithic faunal exploitation in Cantabrian Spain. – In: BINFORD, L.R. (ed.): For Theory Building in Archaeology. – pp. 41–76, New York (Academic Press).

STRAUS, L.G. (1977b): Thoughts on Solutrean Concave Base Point Distribution. – *Lithic Technology*, **6**/3: 32–35. doi: 10.1080/01977261.1977.11754437.

STRAUS, L.G. (1979a): Caves: a palaeoanthropological resource. – *World Archaeology*, **10**/3: 331–339.

STRAUS, L.G. (1979b): Cantabria and Vascongadas, 21,000–17,000 BP: toward a Solutrean settlement pattern. – *Munibe*, **34**: 195–202.

STRAUS, L.G. (1980): The role of raw materials in lithic assemblage variability. – *Lithic technology*, **9**/3: 68–72.

STRAUS, L.G. (1981a): On Maritime Huntergatherers: A View from Cantabrian Spain. – *Munibe*, **33**: 171–173.

STRAUS, L.G. (1981b): On the habitat and diet of Cervus elaphus. – *Munibe*, **33**/3–4: 175–182.

STRAUS, L.G. (1982): Carnivores and cave sites in Cantabrian Spain. – *Journal of Anthropological Research*, **38**/1: 75–96.

STRAUS, L.G. (1983): El solutrense vasco-cantábrico, una nueva perspectiva. – Madrid (Ministerio de cultura, Dirección general de bellas artes y archivos).

STRAUS, L.G. (1986a): Once more into the breach: Solutrean chronology. – *Munibe*, **38**: 35–8.

STRAUS, L.G. (1986b): An overview of the La Riera chronology. – In: La Riera Cave: Stone Age Hunter-Gatherer Adaptations in Northern Spain. – pp. 19–23, Arizona State University (Tempe).

STRAUS, L.G. (1986c): Late Würm adaptive systems in Cantabrian Spain: The case of eastern Asturias. – *Journal of Anthropological Archaeology*, **5**/4: 330–368. doi: 10.1016/0278-4165(86)90016-4.

STRAUS, L.G. (1987): Upper paleolithic ibex hunting in southwest Europe. – *Journal of Archaeological Science*, **14**/2: 163–178. doi: 10.1016/0305-4403(87)90004-5.

STRAUS, L.G. (1990a): The Last Glacial Maximum in Cantabrian Spain: The Solutrean. – In: The World at 18,000 BP. – pp. 89–108, London (Unwin Hyman).

STRAUS, L.G. (1990b): Underground Archaeology: Perspectives on Caves and Rockshelters. – *Archaeological Method and Theory*, **2**: 255–304.

STRAUS, L.G. (1990c): Human occupation of Euskalerria during the last Glacial Maximum: the Basque Solutrean. – *Munibe*, **42**/42: 33–40.

STRAUS, L.G. (1991a): Southwestern Europe at the last glacial maximum. – *Current Anthropology*, **32**/2: 189–199.

STRAUS, L.G. (1991b): Human Geography of the Late Upper Paleolithic in Western Europe: Present State of the Question. – *Journal of Anthropological Research*, **47**/2: 259–278. doi: 10.1086/jar.47.2.3630328.

STRAUS, L.G. (1992): Iberia before the Iberians: the Stone Age prehistory of Cantabrian Spain. – 360 pp. Albuquerque (University of New Mexico Press).

STRAUS, L.G. (1996): The Archaeology of the Pleistocene—Holocene Transition in Southwest Europe. – In: STRAUS, L.G., ERIKSEN, B.V., ERLANDSON, J.M. & YESNER, D.R. (eds): Humans at the End of the Ice Age: The Archaeology of the Pleistocene—Holocene Transition. – pp. 83–99, Boston (Springer). doi: 10.1007/978-1-4613-1145-4_5.

STRAUS, L.G. (2000): A quarter-century of research on the Solutrean of Vasco-Cantabria, Iberia and beyond. – *Journal of Anthropological Research*, **56**/1: 39–58.

STRAUS, L.G. (2005): The upper paleolithic of Cantabrian Spain. – *Evolutionary Anthropology: Issues, News, and Reviews*, **14**/4: 145–158.

STRAUS, L.G. (2006): Of stones and bones: Interpreting site function in the Upper Paleolithic and Mesolithic of Western Europe. – *Journal of Anthropological Archaeology*, **25**/4: 500–509. doi: 10.1016/j.jaa.2006.03.004.

STRAUS, L.G. (2008): Palimpsest, assemblages, phases & facies: the conundrum of taxonomic generalization from particular archaeological cases. – In: Proceedings of the XV World Congress (Lisbon, 4-9 September 2006). – pp. 215–222, Oxford (Archaeopress).

STRAUS, L.G. (2012a): The emergence of modern-like forager capacities & behaviors in Africa and Europe: Abrupt or gradual, biological or demographic? – *Quaternary International*, **247**: 350–357. doi: 10.1016/j.quaint.2010.10.002.

STRAUS, L.G. (2012b): The Magdalenian occupations of the Cantabrian Cordillera (No.Spain): the view from El Miron Cave, 18.5-12 cal BP. – *Quaternary International*, **279–280**: 472. doi: 10.1016/j.quaint.2012.08.1586.

STRAUS, L.G. (2013a): Iberian Archaeofaunas and Hominin Subsistence during Marine Isotope Stages 4 and 3. – In: CLARK, J.L. & SPETH, J.D. (eds): Zooarchaeology and Modern Human Origins. – pp. 97–128, Dordrecht (Springer Netherlands).

STRAUS, L.G. (2013b): After the Deep Freeze: Confronting "Magdalenian" Realities in Cantabrian Spain And Beyond. – *Journal of Archaeological Method and Theory*, **20**/2: 236–255. doi: 10.1007/s10816-012-9152-5.

STRAUS, L.G. (2013c): El Solutrense: 40 Años de Reflexiones por un Arqueologo Norteamericano. – *Espacio Tiempo y Forma.*, **5**: 27–36. doi: 10.5944/etf i.5.4768.

STRAUS, L.G. (2015): The Human Occupation of Southwestern Europe during the Last Glacial Maximum: Solutrean Cultural Adaptations in France and Iberia. – *Journal of Anthropological Research*, **71**/4: 465–492. doi: 10.3998/jar.0521004.0071.401.

STRAUS, L.G. (2016): Humans confront the Last Glacial Maximum in Western Europe: Reflections on the Solutrean weaponry phenomenon in the broader contexts of technological change and cultural adaptation. – *Quaternary International*, **425**: 62–68. doi: 10.1016/j.quaint.2016.01.059.

STRAUS, L.G. (2018): The Upper Paleolithic of Iberia - El Paleolítico Superior de la península ibérica. – *Trabajos de Prehistoria*, **75**/1: 9. doi: 10.3989/tp.2018.12202.

STRAUS, L.G. (2019): Just how dense on the Cantabrian landscape were Solutrean people? current speculations. – In: Human Adaptations to the Last Glacial Maximum: The Solutrean and its Neighbors. – pp. 1–25, (Cambridge Scholars Publishing).

STRAUS, L.G., BERNALDO DE QUIRÓS, F., CABRERA-VALDÉS, V. & CLARK, G.A. (1978): Solutrean Chronology & Lithic Variability in Vasco-Cantabrian Spain. – *Zephyrvs*, **28**: 109–112.

STRAUS, L.G., BICHO, N. & WINEGARDNER, A.C. (2000a): Mapping the Upper Paleolithic regions of Iberia. – *Journal of Iberian Archaeology*, **2**: 7–42.

STRAUS, L.G., BICHO, N. & WINEGARDNER, A.C. (2000b): The Upper Palaeolithic settlement of Iberia: first-generation maps. – *Antiquity*, **74**/285: 553–566. doi: 10.1017/S0003598X00059913.

STRAUS, L.G. & CLARK, G.A. (eds) (1986): La Riera Cave: Stone age hunter-gatherer adaptations in northern Spain. – Arizona State University (Tempe).

STRAUS, L.G. & CLARK, G.A. (2000): La grotte de la Riera (Asturies) et la question du Solutréen cantabrique (et ibérique). – *Bulletin de la Société préhistorique française*, **97**/1: 129–132.

STRAUS, L.G., FONTES, L.M., DOMINGO, R. & GONZÁLEZ-MORALES, M.R. (2016): Cores, Core-scrapers, and Bladelet Production during the Lower Magdalenian Occupations of El Mirón Cave, Cantabrian Spain. – *Lithic Technology*, **41**/3: 212–235. doi: 10.1080/01977261.2016.1175547.

STRAUS, L.G., GEILING, J.M. & GONZÁLEZ-MORALES, M.R. (2018): The Lower Magdalenian Osseous Industry from Level 17 in El Mirón Cave (Ramales De La Victoria, Cantabria): A Preliminary Overview. – *Zephyrvs*, **81**/0: 15–30. doi: 10.14201/zephyrus2018811530.

STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2003): El Miron Cave and the 14C Chronology of Cantabrian Spain. – *Radiocarbon*, **45**/1: 41–58.

STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2007a): Further Radiocarbon Dates for the Upper Paleolithic of El Mirón Cave (Ramales de la Victoria, Cantabria, Spain). – *Radiocarbon*, **49**/3: 1205–1214.

STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2007b): Early Tardiglacial human uses of El Mirón Cave (Cantabria, Spain). – *BAR International Series*, **1655**: 83–94.

STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2009): A preliminary description of Solutrean occupations in El Mirón cave (Ramales de la Victoria, Cantabria). – *Munibe*, **60**: 117–137.

STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2010): The Radiocarbon Chronology of El Mirón Cave (Cantabria, Spain): New Dates for the Initial Magdalenian Occupations. – *Radiocarbon*, **52**/1: 33–39.

STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2012a): The Magdalenian settlement of the Cantabrian region (Northern Spain): The view from El Miron Cave. – *Quaternary International*, **272–273**: 111–124.

STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2012b): Conclusions: Preliminary overview and focus on the post-paleolithic occupations of El Mirón cave. – In: El Mirón Cave, Cantabrian Spain: The Site and Its Holocene Archaeological Record. – pp. 426–441, Albuquerque (University of New Mexico Press).

STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2012c): 10: Neolithic, Chalcolithic, and Bronze Age Plant Remains from El Mirón Cave: Evidence on the First Farming Communities in the Cantabrian Region. – In: El Mirón Cave, Cantabrian Spain: The Site and Its Holocene Archaeological Record. – pp. 148–173, Albuquerque (University of New Mexico Press).

STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (eds) (2012d): El Mirón Cave, Cantabrian Spain: The Site and Its Holocene Archaeological Record. – 472 pp. Albuquerque (University of New Mexico Press).

STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2016): El Mirón Cave (Ramales, Cantabria, Spain) Date List V: Middle Paleolithic and Lower Magdalenian. – *Radiocarbon*, **58**/4: 943–945. doi: 10.1017/RDC.2016.84.

STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2018a): A possible structure in the Lower Magdalenian horizon of El Mirón Cave (Cantabria, Spain). – In: Amici Magistro et Collegae suo Ioanni Christopho Kozłowski Dedicant. – p. Krakow (Jagiellon University/Alter).

STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2018b): New Dates for the Solutrean and Magdalenian of Cantabrian Spain: El Miron and La Riera Caves. – *Radiocarbon*, **60**/03: 1013–1016. doi: 10.1017/RDC.2018.14.

STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2019): The Upper Paleolithic sequence in el Mirón Cave (Ramales de la Victoria, Cantabria, Spain): An overview. – *Journal of Archaeological Science: Reports*, **27**: 101998. doi: 10.1016/j.jasrep.2019.101998.

STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2020): The Magdalenian sequence of El Mirón Cave (Ramales de la Victoria, Cantabria) in the context of Northern Spain and the broader Franco-Cantabrian Region. – In: STRAUS, L.G. & LANGLAIS, M. (eds): Magdalenian chrono-stratigraphic correlations and cultural connections between Cantabrian Spain and Southwest France...and beyond. SESSION XVII-2 DU XVIIIE CONGRÈS DE L'UISPP. – pp. 185–203, Paris.

STRAUS, L.G., GONZÁLEZ-MORALES, M.R. & CARRETERO, J.M. (2011): Lower Magdalenian secondary human burial in El Mirón Cave, Cantabria, Spain. – *Antiquity*, **85**: 1151–1164.

STRAUS, L.G., GONZÁLEZ-MORALES, M.R. & CARRETERO, J.M. (2015a): The red lady of El Mirón Cave: Lower Magdalenian human burial in Cantabrian Spain. – *Journal of Archaeological Science*, **60**.

STRAUS, L.G., GONZÁLEZ-MORALES, M.R. & CUENCA-SOLANA, D. (2015b): The Magdalenian human burial of El Mirón Cave (Ramales de la Victoria, Cantabria, Spain): introduction, background, discovery and context. – *Journal of Archaeological Science*, **60**: 1–9. doi: 10.1016/j.jas.2015.02.018.

STRAUS, L.G., GONZÁLEZ-MORALES, M.R. & FANO, M.Á. (2006): The Upper Paleolithic record in the Asón river basin, eastern Cantabria (Spain): research & publications, 2000-2005. – In: NOIRET, P. (ed.): Le Paléolithique supérieur européen. Bilan quinquennal 1996-2001. – pp. 117–128, Liège (Université de Liège).

STRAUS, L.G., GONZÁLEZ-MORALES, M.R., FARRAND, W.R. & HUBBARD, W.J. (2001): Sedimentological and stratigraphic observations in El Mirón, a late Quaternary cave site in the Cantabrian Cordillera, Northern Spain. – *Geoarchaeology*, **16**/5: 603–630. doi: 10.1002/gea.1012.

STRAUS, L.G., GONZÁLEZ-MORALES, M.R. & FONTES, L.M. (2014): Conjuntos de artefactos del Magdaleniense inicial en la Cueva de El Mirón (Ramales de la Victoria, Cantabria, España): un informe preliminar. – *Zephyrvs*, **73**: 65. doi: 10.14201/zephyrus2014734565.

STRAUS, L.G., GONZÁLEZ-MORALES, M.R., GUTIÉRREZ-ZUGASTI, I. & IRIARTE-CHIAPUSSO, M.J. (2011): Further Solutrean evidence in El Mirón Cave (Ramales de la Victoria, Cantabria). – *Munibe*, **62**: 117–133.

STRAUS, L.G., GONZÁLEZ-MORALES, M.R., HIGHAM, T., RICHARDS, M. & TALAMO, S. (2015c): Radiocarbon Dating the Late Upper Paleolithic of Cantabrian Spain: El Mirón Cave Date List IV. – *Radiocarbon*, **57**/1: 183–188. doi: 10.2458/azu_rc.57.18109.

STRAUS, L.G., GONZÁLEZ-MORALES, M.R., MARÍN-ARROYO, A.B. & FONTES, L.M. (2015d): Magdalenian settlement-subsistence systems in Cantabrian Spain: contributions from El Mirón Cave. – In: BUENO RAMIREZ, P. & BAHN, P.G. (eds): Prehistoric Art as Prehistoric Culture Studies in Honour of Professor Rodrigo de Balbín-Berhmann. – pp. 111–112, Oxford (Archaeopress).

STRAUS, L.G., GONZÁLEZ-MORALES, M.R., MARÍN-ARROYO, A.B. & IRIARTE-CHIAPUSSO, M.J. (2013): The human occupations of el Mirón cave (Ramales de la Victoria, Cantabria, Spain) during the Last Glacial Maximum/ Solutrean period. – *Espacio Tiempo y Forma. Serie I, Prehistoria y Arqueología*, **5**: 413–426.

STRAUS, L.G., GONZÁLEZ-MORALES, M.R., MARTÍNEZ, M.Á.F. & GARCÍA-GELABERT, M.P. (2002): Last Glacial Human Settlement in Eastern Cantabria (Northern Spain). – *Journal of Archaeological Science*, **29**/12: 1403–1414. doi: 10.1006/jasc.2001.0800.

STRAUS, L.G., GONZÁLEZ-MORALES, M.R. & STEWART, E.B. (2008): Early Magdalenian Variability: New Evidence from El Mirón Cave, Cantabria, Spain. – *Journal of Field Archaeology*, **33**/2: 197–218.

STREET, M. & TERBERGER, T. (1999): The last Pleniglacial and the human settlement of central Europe: new information from the Rhineland site of Wiesbaden-Igstadt. – *Antiquity*, **73**/280: 259–272.

SUÁREZ REVILLA, R. (2019): Identificación de cambios climáticos abruptos durante la transición Pleistoceno-Holoceno en la región cantábrica y su impacto en las sociedades humanas. - Identification of abrupt climate changes during Pleistocene-Holocene transition in the Cantabrian region and its impact over human populations. – Diss.unpub.: Santander (Universidad Cantabria).

SUROVELL, T.A. (2000): Early Paleoindian Women, Children, Mobility, and Fertility. – *American Antiquity*, **65**/3: 493–508. doi: 10.2307/2694532.

SVENSSON, A., ANDERSEN, K.K., BIGLER, M., CLAUSEN, H.B., DAHL-JENSEN, D., DAVIES, S.M., JOHNSEN, S.J., MUSCHELER, R., PARRENIN, F., RASMUSSEN, S.O., RÖTHLISBERGER, R., SEIERSTAD, I., STEFFENSEN, J.P. & VINTHER, B.M. (2008): A 60 000 year Greenland stratigraphic ice core chronology. – *Climate of the Past*, **4**/1: 47–57.

SVENSSON, A., ANDERSEN, K.K., BIGLER, M., CLAUSEN, H.B., DAHL-JENSEN, D., DAVIES, S.M., JOHNSEN, S.J., MUSCHELER, R., RASMUSSEN, S.O., RÖTHLISBERGER, R., PEDER STEFFENSEN, J. & VINTHER, BO.M. (2006): The Greenland Ice Core Chronology 2005, 15–42 ka. Part 2: comparison to other records. – *Quaternary Science Reviews*, **25**/23–24: 3258–3267. doi: 10.1016/j.quascirev.2006.08.003.

SVOBODA, J.A. (2008): The Upper Paleolithic burial area at Předmostí: ritual and taphonomy. – *Journal of Human Evolution*, **54**/1: 15–33.

TABERLET, P. & BOUVET, J. (1994): Mitochondrial DNA polymorphism, phylogeography, and conservation genetics of the brown bear Ursus arctos in Europe. – *Proc. R. Soc. Lond. B*, **255**/1344: 195–200.

TALLER, A. (2014): Das Magdalénien des Hohle Fels. Chronologische Stellung, Lithische Technologie und Funktion der Rückenmesser. – (Kerns Verlag).

TAPIA, J., ÁLVAREZ-FERNÁNDEZ, E., CUETO, M., PORTERO, R., BÉCARES, J. & JORDÁ-PARDO, J.F. (2018): Bone industry of the Lower Magdalenian in Cantabrian Spain: The square-section antler points of El Cierro Cave. – *Quaternary International*, **472**: 13–22. doi: 10.1016/j.quaint.2017.10.029.

TAPIA, J., ARRIZABALAGA, Á., IRIATE, M.J. & CALVO, A. (2009): El campamento gravetiense de Ametzagaina (Donostia, País Vasco). Un avance a su estudio arqueológico. – *Munibe*, **60**: 99–115.

TARTAR, E. (2012a): Réflexion autour de la fonction des retouchoirs en os de l'Aurignacien ancien. – *Bulletin de la Société préhistorique française*, **109**/1: 69–83. doi: 10.3406/bspf.2012.14143.

TARTAR, E. (2012b): The recognition of a new type of bone tools in Early Aurignacian assemblages: implications for understanding the appearance of osseous technology in Europe. – *Journal of Archaeological Science*, **39**/7: 2348–2360. doi: 10.1016/j.jas.2012.02.003.

TAYLOR, W.W. (1948): A study of archeology. Memoir of The American Anthropological Association, **69**: – 256 pp. (Southern Illinois University).

TEBO, B.M., BARGAR, J.R., CLEMENT, B.G., DICK, G.J., MURRAY, K.J., PARKER, D., VERITY, R. & WEBB, S.M. (2004): Biogenic manganese oxides: Properties and Mechanisms of Formation. – *Annual Review of Earth and Planetary Sciences*, **32**/1: 287–328. doi: 10.1146/annurev.earth.32.101802.120213.

TEBO, B.M., JOHNSON, H.A., MCCARTHY, J.K. & TEMPLETON, A.S. (2005): Geomicrobiology of manganese(II) oxidation. – *Trends in Microbiology*, **13**/9: 421–428. doi: 10.1016/j.tim.2005.07.009.

TEIXEIRA, J.C. & COOPER, A. (2019): Using hominin introgression to trace modern human dispersals. – *Proceedings of the National Academy of Sciences*, **116**/31: 15327–15332. doi: 10.1073/pnas.1904824116.

TEJERO, J.-M. (2016): Spanish Aurignacian Projectile Points: An Example of the First European Paleolithic Hunting Weapons in Osseous Materials. – In: LANGLEY, M.C. (ed.): Osseous Projectile Weaponry. – pp. 55–69, Dordrecht (Springer). doi: 10.1007/978-94-024-0899-7_5.

TEJERO, J.-M., CHRISTENSEN, M. & BODU, P. (2012): Red deer antler technology and early modern humans in Southeast Europe: an experimental study. – *Journal of Archaeological Science*, **39**/2: 332–346. doi: 10.1016/j.jas.2011.09.018.

THACKER, P. (2000): The relevance of regional analysis for Upper Paleolithic archaeology: a case study from Portugal. – In: PRICE, H. & PETERKIN, G. (eds): Regional Approaches to Adaptation in Late Pleistocene Western Europe. – pp. 25–45, Oxford (BAR Publishing).

THÉRY-PARISOT, I. (2002): Fuel Management (Bone and Wood) During the Lower Aurignacian in the Pataud Rock Shelter (Lower Palaeolithic, Les Eyzies de Tayac, Dordogne, France). Contribution of Experimentation. – *Journal of Archaeological Science*, **29**/12: 1415–1421. doi: 10.1006/jasc.2001.0781.

THÉRY-PARISOT, I., COSTAMAGNO, S., BRUGAL, J.-P., FOSSE, P. & GUILBERT, R. (2005): The use of bone as fuel during the palaeolithic, experimental study of bone combustible properties. – In: MULVILLE, J., OUTRAM, A.K. & ICAZ (eds): The zooarchaeology of fats, oils, milk and dairying. – pp. 50–59, Oxford (Oxbow).

TORNERO, C., AGUILERA, M., FERRIO, J.P., ARCUSA, H., MORENO-GARCÍA, M., GARCIA-REIG, S. & ROJO-GUERRA, M. (2018): Vertical sheep mobility along the altitudinal gradient through stable isotope analyses in tooth molar bioapatite, meteoric water and pastures: A reference from the Ebro valley to the Central Pyrenees. – *Quaternary International*, **484**: 94–106. doi: 10.1016/j.quaint.2016.11.042.

TORNERO, C., BĂLĂŞESCU, A., UGHETTO-MONFRIN, J., VOINEA, V. & BALASSE, M. (2013): Seasonality and season of birth in early Eneolithic sheep from Cheia (Romania): methodological advances and implications for animal economy. – *Journal of Archaeological Science*, **40**/11: 4039–4055. doi: 10.1016/j.jas.2013.05.013.

TORO-MOYANO, I., MARTÍNEZ-NAVARRO, B., AGUSTÍ, J., SOUDAY, C., BERMÚDEZ DE CASTRO, J.M., MARTINÓN-TORRES, M., FAJARDO, B., DUVAL, M., FALGUÈRES, C., OMS, O., PARÉS, J.M., ANADÓN, P., JULIÀ, R., GARCÍA-AGUILAR, J.M., MOIGNE, A.-M., ESPIGARES, M.P., ROS-MONTOYA, S. & PALMQVIST, P. (2013): The oldest human fossil in Europe, from Orce (Spain). – *Journal of Human Evolution*, **65**/1: 1–9. doi: 10.1016/j.jhevol.2013.01.012.

TORRES, T.D., ORTIZ, J.E., GRÜN, R., EGGINS, S., VALLADAS, H., MERCIER, N., TISNÉRAT-LABORDE, N., JULIÀ, R., SOLER, V. & MARTÍNEZ, E. (2010): Dating of the hominid (Homo neanderthalensis) remains accumulation from El Sidrón Cave (Piloña, Asturias, North Spain): an example of a multi-methodological approach to the dating of Upper Pleistocene sites. – *Archaeometry*, **52**/4: 680–705.

TRINKAUS, E., BAILEY, S., DAVIS, S. & ZILHÃO, J. (2011): Magdalenian Human Remains from the Galeria da Cisterna (Almonda karstic system, Torres Novas, Portugal). – In: O Arqueólogo português. – pp. 395–413, Lisboa (Imprensa Nacional-Casa da Moeda).

TÜTKEN, T. (2003): Die Bedeutung der Knochenfrühdiagenese für die Erhaltungsfähigkeit in vivo erworbener Element- und Isotopenzusammensetzungen in fossilen Knochen. – Diss.: (University of Tübingen).

TÜTKEN, T., KNIPPER, C. & ALT, K.W. (2008): Mobilität und Migration im archäologischen Kontext: Informationspotential von Multi-Element-Isotopenanalysen (Sr, Pb, O). – In: Kulturwandel in Mitteleuropa. Langobarden, Awaren, Slawen. – pp. 13–42, Bonn (Dr.Rudolf Habelt GmbH).

TÜTKEN, T., VENNEMANN, T.W., JANZ, H. & HEIZMANN, E.P.J. (2006): Palaeoenvironment and palaeoclimate of the Middle Miocene lake in the Steinheim basin, SW Germany: A reconstruction from C, O, and Sr isotopes of fossil remains. – *Palaeogeography, Palaeoclimatology, Palaeoecology*, **241**/3–4: 457–491. doi: 10.1016/j.palaeo.2006.04.007.

TZEDAKIS, P.C., HUGHEN, K.A., CACHO, I. & HARVATI, K. (2007): Placing late Neanderthals in a climatic context. – *Nature*, **449**/7159: 206–208.

UERPMANN, H.-P. (1973): Animal bone finds and economic archaeology: A critical study of 'osteo-archaeological' method. – *World Archaeology*, **4**/3: 307–322. doi: 10.1080/00438243.1973.9979541.

UERPMANN, H.-P. (1978): Metrical analysis of faunal remains from the Middle East. – In: Approaches to faunal analysis in the Middle East. – pp. 41–45, Cambridge (Peabody Museum Bulletin 2).

ULLAH, I.I., DUFFY, P.R. & BANNING, E.B. (2015): Modernizing Spatial Micro-Refuse Analysis: New Methods for Collecting, Analyzing, and Interpreting the Spatial Patterning of Micro-Refuse from House-Floor Contexts. – *Journal of Archaeological Method and Theory*, **22**/4: 1238–1262. doi: 10.1007/s10816-014-9223-x.

UNNIKRISHNA, P.V., MCDONNELL, J.J. & KENDALL, C. (2002): Isotope variations in a Sierra Nevada snowpack and their relation to meltwater. – *Journal of Hydrology*, **260**/1–4: 38–57. doi: 10.1016/S0022-1694(01)00596-0.

UTRILLA, P. (1981): El Magdaleniense inferior y medio en la costa cantábrica. – 334 pp. Santander (Ministerio de Cultura, Dirección General de Bellas Artes, Archivos y Bibliotecas).

UTRILLA, P. (1984): Reflexiones sobre el origen del Magdaleniense. – *Zephyrus*, **37**: 87–97.

UTRILLA, P. (1994): Campamentos-base, cazaderos y santuarios: algunos ejemplos del paleolítico peninsular. – In: Homenaje al Dr. Joaquín González Echegaray. – pp. 97–114, Madrid (Dirección General de Bellas Artes y Archivos).

UTRILLA, P. (1996): La sistematización del Magdaleniense cantábrico: una revisión histórica de los datos. – In: MOURE-ROMANILLO, J.A. (ed.): "El hombre fósil" 80 años después - Homenaje a Hugo Obermaier. – pp. 211–248, Santander (Universidad de Cantabria).

UTRILLA, P. (2004): Evolución histórica de las sociedades cantábricas durante el Tardiglacial: El Magdaleniense inicial, inferior y medio (16.500-13.000 BP). – *Kobie*, **8**: 243–274.

UTRILLA, P., DOMINGO, R., MONTES, L., MAZO, C., RODANÉS, J.M., BLASCO, F. & ALDAY, A. (2012): The Ebro Basin in NE Spain: A crossroads during the Magdalenian. – *Quaternary International*, **272–273**: 88–104. doi: 10.1016/j.quaint.2012.04.024.

UTRILLA, P., MAZO, C., SOPENA, M.C., MARTÍNEZ-BEA, M. & DOMINGO, R. (2009): A palaeolithic map from 13,660 calBP: engraved stone blocks from the Late Magdalenian in Abauntz Cave (Navarra, Spain). – *Journal of Human Evolution*, **57**/2: 99–111. doi: 10.1016/j.jhevol.2009.05.005.

UZQUIANO, P. (2006): Balance de los estudios antracoanalíticos efectuados en la cueva de El Castillo (1984-2001). Dinámica de vegetación y comportamiento humano en torno a los fuegos domésticos de las ocupaciones del Musteriense y del Auriñaciense de transición. – In: Miscelánea en homenaje a Victoria Cabrera. – pp. 132–143, Madrid (Museo Arqueológico Regional).

UZQUIANO, P. (2008): Domestic fires and vegetation cover among Neanderthalians and Anatomically Modern Human groups (> 53 to 30 Kyrs BP) in the Cantabrian Region (Cantabria, Northern Spain). – In: Charcoal from the Past: Cultural and Palaeoenvironmental implications. – pp. 273–285, Oxford (Archaeopress).

VALENSI, P., CRÉGUT-BONNOURE, E., MARGARIT, X. & DEFLEUR, A. (2011): Découverte exceptionnelle d'un nid de Gypaète barbu (Gypaetus barbatus) en Provence : cas de l'abri protohistorique de la Baume du Houx (Plan d'Aups, Var, France). – *Comptes Rendus Palevol*, **10**/1: 49–59. doi: 10.1016/j.crpv.2010.12.001.

VALLADAS, H., CACHIER, H., MAURICE, P., QUIROST, F.B. DE, CLOTTES, J., VALDÉS, V.C., UZQUIANO, P. & ARNOLD, M. (1992): Direct radiocarbon dates for prehistoric paintings at the Altamira, El Castillo and Niaux caves. – *Nature*, **357**/6373: 68. doi: 10.1038/357068a0.

VALLADAS, H., GENTY, D., KALTNECKER, E., QUILES, A., TISNÉRAT-LABORDE, N., ARNOLD, M., DELQUÉ-KOLIČ, E., MOREAU, C., BAFFIER, D., MERLE, J.J.C., CLOTTES, J., GIRARD, M., MONNEY, J., MONTES, R., SAINZ, C., SANCHIDRIAN, J.L. & SIMONNET, R. (2013): Dating French and Spanish Prehistoric Decorated Caves in Their Archaeological Contexts. – *Radiocarbon*, **55**/2–3: 1422–1431.

VALLADAS, H., TISNÉRAT-LABORDE, N., CACHIER, H., ARNOLD, M., BERNALDO DE QUIRÓS, F., CABRERA-VALDÉS, V., CLOTTES, J., COURTIN, J., FORTEA-PÉREZ, J.J., GONZÁLES-SAINZ, C. & MOURE-ROMANILLO, J.A. (2001): Radiocarbon AMS Dates for Paleolithic Cave Paintings. – *Radiocarbon*, **43**/2B: 977–986. doi: 10.1017/S0033822200041643.

VAN ANDEL, T.H. & TZEDAKIS, P.C. (1996): Palaeolithic landscapes of Europe and environs, 150,000-25,000 years ago: An overview. – *Quaternary Science Reviews*, **15**/5: 481–500. doi: 10.1016/0277-3791(96)00028-5.

VANHAEREN, M. & D'ERRICO, F. (2017): Les incisives de bouquetin perforées de Praileaitz I (Deba, Gipuzkoa). Analyse archéozoologique et technologique. – In: La Cueva de Praileaitz I (Deba, Gipuzkoa, Euskal Herria) : intervención arqueológica 2000-2009. – pp. 485–492,.

VANHAEREN, M. & D'ERRICO, F. (2005): Grave goods from the Saint-Germain-la-Rivière burial: Evidence for social inequality in the Upper Palaeolithic. – *Journal of Anthropological Archaeology*, **24**/2: 117–134. doi: 10.1016/j.jaa.2005.01.001.

VAQUERO, M. & PASTÓ, I. (2001): The Definition of Spatial Units in Middle Palaeolithic Sites: The Hearth-Related Assemblages. – *Journal of Archaeological Science*, **28**/11: 1209–1220. doi: 10.1006/jasc.2001.0656.

VEGA DEL SELLA, C. (1916): Paleolítico de Cueto de la Mina. – Madrid (Museo Nacional de Ciencias Naturales).

VENKATARAMAN, V.V., KRAFT, T.S., DOMINY, N.J. & ENDICOTT, K.M. (2017): Hunter-gatherer residential mobility and the marginal value of rainforest patches. – *Proceedings of the National Academy of Sciences of the United States of America*, **114**/12: 3097–3102. doi: 10.1073/pnas.1617542114.

VERHEUL, J., ZICKEL, M., BECKER, D. & WILLMES, C. (2015): LGM major inland waters of Europe - GIS dataset. – (CRC806-Database). doi: 10.5880/SFB806.14.

VIGAL, C.R. & MACHORDOM, A. (1985): Tooth eruption and replacement in the Spanish wild goat. – *Acta theriologica*, **30**/19: 305–320.

VILLA, P. (1982): Conjoinable pieces and site formation processes. – *American Antiquity*, **47**/2: 276–290.

VILLA, P., CASTEL, J.-C., BEAUVAL, C., BOURDILLAT, V. & GOLDBERG, P. (2004): Human and carnivore sites in the European Middle and Upper Paleolithic: Similarities and differences in bone modification and fragmentation. – *Revue de Paléobiologie*, **23**/2: 705–730.

VILLA, P. & MAHIEU, E. (1991): Breakage patterns of human long bones. – *Journal of Human Evolution*, **21**/1: 27–48. doi: 10.1016/0047-2484(91)90034-S.

VILLA, P., POLLAROLO, L., CONFORTI, J., MARRA, F., BIAGIONI, C., DEGANO, I., LUCEJKO, J.J., TOZZI, C., PENNACCHIONI, M., ZANCHETTA, G., NICOSIA, C., MARTINI, M., SIBILIA, E. & PANZERI, L. (2018): From Neandertals to modern humans: New data on the Uluzzian. – *PLOS ONE*, **13**/5: e0196786. doi: 10.1371/journal.pone.0196786.

VILLA, P. & ROEBROEKS, W. (2014): Neandertal Demise: An Archaeological Analysis of the Modern Human Superiority Complex. – *PLoS ONE*, **9**/4: e96424. doi: 10.1371/journal.pone.0096424.

VILLALBA-MOUCO, V., VAN DE LOOSDRECHT, M.S., POSTH, C., MORA, R., MARTÍNEZ-MORENO, J., ROJO-GUERRA, M., SALAZAR-GARCÍA, D.C., ROYO-GUILLÉN, J.I., KUNST, M. & ROUGIER, H. (2019): Survival of Late Pleistocene hunter-gatherer ancestry in the Iberian Peninsula. – *Current Biology*, **29**/7: 1169–1177.

VILLALUENGA, A. (2013): La evaluación de los úrsidos en medios kárstico s de la Cornisa Cantábrica." Estudio tafonómico de conjuntos arqueológicos y paleontológicos del Pleistoceno superior y Holoceno. – Diss.: Vitoria-Gasteiz (Universidad de País Vasco).

VILLARET, J.C., BON, R. & RIVET, A. (1997): Sexual Segregation of Habitat by the Alpine Ibex in the French Alps. – *Journal of Mammalogy*, **78**/4: 1273–1281. doi: 10.2307/1383070.

VINCENS, A., GARCIN, Y. & BUCHET, G. (2007): Influence of rainfall seasonality on African lowland vegetation during the Late Quaternary: pollen evidence from Lake Masoko, Tanzania. – *Journal of Biogeography*, **34**/7: 1274–1288. doi: 10.1111/j.1365-2699.2007.01698.x.

VITA-FINZI, C. & HIGGS, E.S. (1970): In: Prehistoric Economy in the Mount Carmel Area of Palestine: Site Catchment Analysis. – pp. 1–37, Cambridge (University Press).

WAGUESPACK, N.M. & SUROVELL, T.A. (2003): Clovis Hunting Strategies, or How to Make out on Plentiful Resources. – *American Antiquity*, **68**/02: 333–352. doi: 10.2307/3557083.

WANG, Y., KROMHOUT, E., ZHANG, C., XU, Y., PARKER, W., DENG, T. & QIU, Z. (2008): Stable isotopic variations in modern herbivore tooth enamel, plants and water on the Tibetan Plateau: Implications for paleoclimate and paleoelevation reconstructions. – *Palaeogeography, Palaeoclimatology, Palaeoecology*, **260**/3–4: 359–374. doi: 10.1016/j.palaeo.2007.11.012.

WATSON, J.P. (1979): The estimation of the relative frequencies of mammalian species: Khirokitia 1972. – *Journal of Archaeological Science*, **6**/2: 127–137.

WEIGELT, J. (1989): Recent Vertebrate Carcasses and Their Paleobiological Implications. – 204 pp. (University of Chicago Press).

WEINSTOCK, J. (2000): Osteometry as a Source of Refined Demographic Information: Sex-Ratios of Reindeer, Hunting Strategies, and Herd Control in the Late Glacial site of Stellmoor, Northern Germany. – *Journal of Archaeological Science*, **27**/12: 1187–1195. doi: 10.1006/jasc.1999.0542.

WEINSTOCK, J. (2015): 17. Environment, Body Size and Sexual Dimorphism in Late Glacial Reindeer. – *Recent Advances in Ageing and Sexing Animal Bones*, **9**: 247.

WELKER, F., HAJDINJAK, M., TALAMO, S., JAOUEN, K., DANNEMANN, M., DAVID, F., JULIEN, M., MEYER, M., KELSO, J., BARNES, I., BRACE, S., KAMMINGA, P., FISCHER, R., KESSLER, B.M., STEWART, J.R., PÄÄBO, S., COLLINS, M.J. & HUBLIN, J.-J. (2016): Palaeoproteomic evidence identifies archaic hominins associated with the Châtelperronian at the Grotte du Renne. – *Proceedings of the National Academy of Sciences*, **113**/40: 11162–11167. doi: 10.1073/pnas.1605834113.

WENIGER, G.-C. (1982): Wildbeuter und ihre Umwelt. Ein Beitrag zum Magdalénien Südwestdeutschlands aus ökologischer und ethno-archäologischer Sicht. – 229 pp. Tübingen (Archaeologica Venatoria).

WENINGER, B. & JÖRIS, O. (2008): A 14C age calibration curve for the last 60 ka: the Greenland-Hulu U/Th timescale and its impact on understanding the Middle to Upper Paleolithic transition in Western Eurasia. – *Journal of Human Evolution*, **55**/5: 772–781. doi: 10.1016/j.jhevol.2008.08.017.

WERLEN, B. (1993): Society, Action and Space: An Alternative Human Geography. – 270 pp. London ; New York (Routledge).

WHALLON, R. (1984): Unconstrained clustering for the analysis of spatial distributions in archaeology. – In: HIETALA, H.J. & LARSON, P.A. (eds): Intrasite spatial analysis in archaeology. – pp. 242–277, (Cambridge University Press).

WHALLON, R. (2011): An introduction to information and its role in hunter-gatherer bands. – In: Information and its role in hunter-gatherer bands. – pp. 1–28, (Cotsen Institute of Archaeology Press at UCLA).

WHITE, L.A. (1959): The evolution of culture: the development of civilization to the fall of Rome. – 378 pp. London ; New York (Routledge).

WHITE, T.E. (1953): A method for calculating the dietary percentages of various food animals utilised by aboriginal peoples. – *American Antiquity*, **18**: 386–98.

WIDGA, C., WALKER, J.D. & STOCKLI, L.D. (2010): Middle Holocene Bison diet and mobility in the eastern Great Plains (USA) based on $\delta\,^{13}C$, $\delta\,^{18}O$, and $^{87}Sr/^{86}Sr$ analyses of tooth enamel carbonate. – *Quaternary Research*, **73**/03: 449–463. doi: 10.1016/j.yqres.2009.12.001.

WIDLOK, T., AUFGEBAUER, A., BRADTMÖLLER, M., DIKAU, R., HOFFMANN, T., KRETSCHMER, I., PANAGIOTOPOULOS, K., PASTOORS, A., PETERS, R., SCHÄBITZ, F., SCHLUMMER, M., SOLICH, M., WAGNER, B., WENIGER, G.-C. & ZIMMERMANN, A. (2012): Towards a theoretical framework for analyzing integrated socio-environmental systems. – *Quaternary International*, **274**: 259–272. doi: 10.1016/j.quaint.2012.01.020.

WILKINSON, K. & STEVENS, C. (2003): Environmental archaeology: approaches, techniques & applications. – 320 pp. London (Tempus).

WILLMES, C., BECKER, D., BROCKS, S., HÜTT, C. & BARETH, G. (2017): High Resolution Köppen-Geiger Classifications of Paleoclimate Simulations. – *Transactions in GIS*, **21**/1: 57–73 (Wiley Online Library).

WILLMES, M., BATAILLE, C.P., JAMES, H.F., MOFFAT, I., MCMORROW, L., KINSLEY, L., ARMSTRONG, R.A., EGGINS, S. & GRÜN, R. (2018): Mapping of bioavailable strontium isotope ratios in France for archaeological provenance studies. – *Applied Geochemistry*, **90**: 75–86. doi: 10.1016/j.apgeochem.2017.12.025.

WINTERHALDER, B. (1981): Optimal foraging strategies and hunter-gatherer research in anthropology: Theory and models. – In: Hunter-gatherer foraging strategies: Ethnographic and archaeological analyses. – pp. 13–36, (University of California Press).

WINTERHALDER, B., BAILLARGEON, W. & CAPPELLETTO, F. (1988): The population ecology of hunter-gatherers and their prey. – *Journal of Anthropological Archaeology*, **7**/4: 289–328.

WINTERHALDER, B. & SMITH, E.A. (2000): Analyzing adaptive strategies: Human behavioral ecology at twenty-five. – *Evolutionary Anthropology Issues News and Reviews*, **9**/2: 51–72.

WOLSAN, M. (1982): A comparative analysis of the ribs of ungulates for archaeozoological purposes. – *Acta Zoologica Cracoviensia*, **26**/1 (1-7).

WOLVERTON, S. (2002): NISP: MNE and% whole in analysis of prehistoric carcass exploitation. – *North American Archaeologist*, **23**/2: 85–100.

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. – *Quaternary International*, **474**: 56–70. doi: 10.1016/j.quaint.2016.03.005.

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. – *Journal of Human Evolution*, **69**: 91–109. doi: 10.1016/j.jhevol.2013.12.017.

WYNN, T., OVERMANN, K.A. & COOLIDGE, F.L. (2016): The false dichotomy: a refutation of the Neandertal indistinguishability claim. – *Journal of Anthropological Sciences*, **94**: 1–22.

YELLEN, J.E. (1991): Small mammals: !Kung San utilization and the production of faunal assemblages. – *Journal of Anthropological Archaeology*, **10**/1: 1–26. doi: 10.1016/0278-4165(91)90019-T.

YESNER, D.R., AYRES, W.S., CARLSON, D.L., DAVIS, R.S., DEWAR, R., MORALES, M.R.G., HASSAN, F.A., HAYDEN, B., LISCHKA, J.J. & SHEETS, P.D. (1980): Maritime hunter-gatherers: ecology and prehistory [and comments and reply]. – *Current anthropology*, **21**/6: 727–750.

YRAVEDRA, J. (2002): Especialización o Diversificación: Una nueva propuesta para el Solutrense y el Magdaleniense Cantábrico. – *Munibe*, **54**: 3–20.

YRAVEDRA, J. (2005): Patrones de aprovechamiento de recursos animales en el Pleistoceno Superior de la Península Ibérica: estudio tafonómico y zooarqueológico de los yacimientos del Esquilleu, Amalda, Cueva Ambrosio y la Peña de Estebanvela. – Diss.: Madrid (Universidad Nacional de Educación a Distancia).

YRAVEDRA, J. (2010): Zooarqueología y tafonomía del yacimiento de Hornos de la Peña (San Felices de Buelna, Cantabria). – *Complutum*, **21**/1: 69–86.

YRAVEDRA, J. (2013): New Contributions on Subsistence Practices during the Middle-Upper Paleolithic in Northern Spain. – In: Zooarchaeology and Modern Human Origins. – pp. 77–95, Dordrecht (Springer).

YRAVEDRA, J. & CASTANEDO, A.G. (2010): Estudio zooarqueológico y tafonómico del yacimiento del Otero (Secadura, Voto, Cantabria). – *Espacio, tiempo y forma. Serie I, Prehistoria y arqueología*, **3**: 21–38.

YRAVEDRA, J., GÓMEZ-CASTANEDO, A., ARAMENDI, J., MONTES BARQUÍN, R. & SANGUINO GONZÁLEZ, J. (2016): Neanderthal and Homo sapiens subsistence strategies in the Cantabrian region of northern Spain. – *Archaeological and Anthropological Sciences*, **8**/4: 779–803.

YRAVEDRA, J., GÓMEZ-CASTANEDO, A. & MUÑOZ, E. (2010): Estrategias de subsistencia en el yacimiento paleolítico del Ruso (Igollo de Camargo, Cantabría, España). – *Espacio, tiempo y forma. Serie I, Prehistoria y arqueología*/3: 39–58.

ZAZZO, A., BALASSE, M. & PATTERSON, W.P. (2005): High-resolution $\delta^{13}C$ intratooth profiles in bovine enamel: Implications for mineralization pattern and isotopic attenuation. – *Geochimica et Cosmochimica Acta*, **69**/14: 3631–3642. doi: 10.1016/j.gca.2005.02.031.

ZAZZO, A., BENDREY, R., VELLA, D., MOLONEY, A.P., MONAHAN, F.J. & SCHMIDT, O. (2012): A refined sampling strategy for intra-tooth stable isotope analysis of mammalian enamel. – *Geochimica et Cosmochimica Acta*, **84**: 1–13. doi: 10.1016/j.gca.2012.01.012.

ZILHAO, J. (2006): Chronostratigraphy of the Middle-to-Upper Paleolithic transition in the Iberian Peninsula. – *Pyrenae*, **37**/1: 7–84.

ZILHÃO, J., ANGELUCCI, D.E., BADAL-GARCÍA, E., D'ERRICO, F., DANIEL, F., DAYET, L., DOUKA, K., HIGHAM, T.F.G., MARTÍNEZ-SÁNCHEZ, M.J., MONTES-BERNÁRDEZ, R., MURCIA-MASCARÓS, S., PÉREZ-SIRVENT, C., ROLDÁN-GARCÍA, C., VANHAEREN, M., VILLAVERDE, V., WOOD, R. & ZAPATA, J. (2010): Symbolic use of marine shells

and mineral pigments by Iberian Neandertals. – *Proceedings of the National Academy of Sciences*, **107**/3: 1023–1028. doi: 10.1073/pnas.0914088107.

ZILHÃO, J., D'ERRICO, F., BORDES, J.-G., LENOBLE, A., TEXIER, J.-P. & RIGAUD, J.-P. (2006): Analysis of Aurignacian interstratification at the Châtelperronian-type site and implications for the behavioral modernity of Neandertals. – *Proceedings of the National Academy of Sciences*, **103**/33: 12643–12648. doi: 10.1073/pnas.0605128103.

ZILHÃO, J. & TRINKAUS, E. (2002): Portrait of the artist as a child the gravettian human skeleton from the Abrigo do Lagar Vehlo and its archaeological context. – 616 pp. Lisboa (Instituto português de arqueologia).

ZURRO, D. (2010): Ni carne ni pescado (consumo de recursos vegetales en la Prehistoria): Análisis de la variabilidad de los conjuntos fitolitológicos en contextos cazadores-recolectores. – Diss.: Barcelona (Universidad Autonoma de Barcelona).

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Appendix A El Mirón C14 records used for chronological model

Chronological modeling of El Mirón materials are based on following radiocarbon dates (**Appendix Table A.1**). They were previously published (STRAUS & GONZÁLEZ-MORALES 2003, 2007, 2010, 2016, 2018; STRAUS ET AL. 2015c).

Appendix Table A.1: Radiocarbon (C14) dates relevant to the faunal material under study from El Mirón Cave (see references in text). Cultural periods: LMP= Late Middle Paleolithic, EUP= Early Upper Paleolithic (Gravettian), SOL= Solutrean, IM=Initial Magdalenian and LM=Lower Magdalenian. Methods: Conventional, Accelerator Mass Spectrometry (AMS), or AMS with using an Ultrafiltration protocol (UF AMS).

Area	Square	Level	Spit	Period	C14 Age	1SD	Material	Lab Number	Method	Year
Cabin	J4	11.1		AZ/UM	11 205	55	Bone Collagen	OxA-22088	AMS	2010
Trench	P6a	306	11	AZ/UM	11 650	50	Bone Collagen	GX-24468	AMS	1998
Cabin	I3	11.1	25	AZ/UM	11 720	140	Bone Collagen	GX-23391	Conventional	1997
Cabin	J3a	11		AZ	11 785	55	Bone Collagen	OxA-22087	AMS	2010
Corral	T8d	102.1	3	AZ/UM	11 950	70	Bone Collagen	GX-23417	AMS	1997
Trench	P6d	308	16	UM	12 350	180	Charcoal	GX-28210	AMS	2001
Corral	U-V	106	sev.	UM?	12 460	180	Bone Collagen	GX-32382	Conventional	2006
Cabin	J2c	12	12	UM	12 970	70	Charcoal	GX-22132	AMS	1996
Corral	W7c	105	7	MM	13 490	40	Bone Collagen	UGAMS-9286	AMS	2011
Corral	V8d	108	4	MM	13 660	70	Bone Collagen	GX-22703	AMS	1996
Corral	U7	108	10	MM	13 710	160	Bone Collagen	GX-32381	?	2006
Corral	V8d	115	19	LM	13 800	840	Bone Collagen	GX-23394	Conventional.	2001
Corral	V7a	104	4	MM	14 120	35	Tooth Collagen	UGAMS-15261	AMS	2013
Cabin	H-J	14	sev.	MM	14 600	190	Bone Collagen	GX-32383	Conventional	2006
Inner Cave	Inner Trench	VIII	10	MM	14 620	80	Charcoal	GX-22347	AMS	1996
Corral	V8d	108	5	MM	14 710	160	Bone Collagen	GX-23397	Conventional	1997
Corral	U8b	110	18	LM	14 760	70	Bone Collagen	OxA-22091	AMS	2010
Corral	U8b	110	18	LM	14 795	75	Bone Collagen	OxA-22092	AMS	2010
Corral	T10	108"	8	MM	14 850	60	Charcoal	GX-27114	AMS	2000
Cabin	J4c	13		MM	14 930	70	Bone Collagen	OxA-22089	AMS	2010
Cabin	I3a	15	43	LM	15 010	260	Bone Collagen	GX-23392	Conventional	1997
Burial	X7d	503,1	5	LM	15 120	40	Charcoal	UGAMS-7799	AMS	2010
Cabin	I3a	16	44	LM	15 180	100	Bone Collagen	GX-23415	AMS	1997
Cabin	I3d	15	43	LM	15 220	300	Bone Collagen	GX-23393	Conventional	1997
Corral	V8d	116	20	LM	15 220	100	Bone Collagen	GX-23416	AMS	2000
Cabin	H3d	17	79	LM	15 370	80	Charcoal	GX-32654	AMS	2006
Corral	T8B	112	26	LM	15 430	75	Bone Collagen	OxA-22090	AMS	2001
Cabin	J3	17	39	LM	15 450	160	Bone Collagen	GX-27115	Conventional	2000
Corral	U10	118	38	IM	15 460	190	Charcoal	GX-31933	Extended Count	1999
Burial	X7d	504	7	LM	15 460	40	Human Bone	M-14585	AMS	2010
Cabin	J3d	17	32	LM	15 470	240	Bone Collagen	GX-24466	Conventional	1998
Corral	U7a	111	20	LM	15 530	230	Bone Collagen	GX-24469	Conventional	1997
Cabin	H3b	17	74	LM	15 610	90	Bone Collagen	OxA-22093	AMS	2010
Burial	X6	505	4	LM	15 670	40	Charcoal	UGAMS-15183	AMS	2013
Cabin	J2c	17	20	LM	15 700	190	Charcoal	GX-25853	Extended Count	1999
Burial	X7d	504	7	LM	15 740	40	Bone Collagen	UGAMS-7217	AMS	2011
Trench	P6	312	25	LM	15 850	170	Bone Collagen	GX-31932	Conventional	2005
Cabin	J2c	21	38	IM	16 050	40	Charcoal	UGAMS-3364r	AMS	2007
Cabin	J2b+d	18	35	IM	16 080	40	Bone Collagen	UGAMS-3366r	AMS	2007
Corral	V8d	110	8	LM	16 130	250	Bone Collagen	GX-23396	Conventional	1997
Corral	U9c	119,2	52	IM	16 320	160	Bone Collagen	GX-32656	Conventional.	1998
Corral	V8d	111	14	LM	16 370	190	Bone Collagen	GX-23395	Conventional	1998
Corral	T10c	114	17	LM	16 460	50	Bone Collagen	GX-28209	AMS	2001
Corral	W8	110		LM	16 520	25	Bone Collagen	UGAMS-10628	AMS	2011
Cabin	J2b	19	36	IM	16 600	40	Bone Collagen	UGAMS-3365r	AMS	2007
Niche A	Ramp			LM	16 600	90	Bone Collagen	GX-30398	AMS	2003
Corral	V8a-c	119	28	IM	16 960	80	Charcoal	GX-25858	AMS	1999

Corral	V8a-d	117	24	IM	17 050	60	Charcoal	GX-25857	AMS	2000
Corral	U10	119	41	IM	17 230	40	Bone Collagen	UGAMS-15182	AMS	1998
Corral	U10	117	Base	IM	17 240	40	Bone Collagen	UGAMS-15180	AMS	1999
Trench	P6	313	29	Sol?	17 400	270	Bone Collagen	GX-31194	Conventional	2004
Corral	V7b	116"	26	LM	17 400	80	Charcoal	GX-29439	AMS	2000
Corral	U10	119,2	Base	IM	17 620	40	Bone Collagen	UGAMS-15181	AMS	1998
Corral	V9	121	3	Sol	18 390	300	Bone Collagen	GX-32655	Ext. Count	2006
Corral	W10d	126	5	Sol	18 950	350	Bone Collagen	GX-24471	Conventional	1998
Corral	W10d	125	4	Sol	18 980	360	Bone Collagen	GX-24470	Conventional	1998
Corral	V10a	127	15	Sol	19 230	50	Charcoal	UGAMS-7216	AMS	2010
Corral	X10	128	20	EUP	27 580	210	Charcoal	GX-27113	AMS	2000
Corral	X10	130	36	MP	41 280	1.120	Charcoal	GX-27112	AMS	2000
Corral	X10	130	26	MP	48 200	3.300	Bone Collagen	OxA-33516	UF AMS	2016
Corral	X10	130	34	MP	>45 900		Bone Collagen	OxA-33515	UF AMS	2016
Corral	W10a	127	8	Sol	20.440	50	Bone Collagen	UGAMS-29099	AMS	2018
Corral	V10a	122	7	Sol	17.990	50	Bone Collagen	UGAMS-31471	AMS	2018
Corral	U7b	115	27	LM	16.750	45	Bone Collagen	UGAMS-31472	AMS	2018

Appendix B Faunal materials studied from El Mirón Cave

The faunal data analyzed have following spatial origin in the El Mirón Cave Vestibule as summarized in the next table (Appendix Table B.1).

Appendix Table B.1: El Mirón levels, squares and spits included within this faunal analysis.

Cultural period	Level	Square (spit number)
Late Middle Paleolithic	130	W10 (18-27)
		X10 (25-36)
Early Upper Paleolithic	129	W10 (16,17)
		X10 (22-24)
	128	V10 (16,17)
		W10 (11-15)
		X10 (14-21)
Solutrean	127	X10 (13)
		V10 (15)
	126	V10 (12-14)
	125	U10 (60)
		V10 (11)
	124	U10 (58,59)
		V10 (9,10)
	123	V10 (8)
	122	U10 (54-57)
		V10 (7)
	121	V9 (4,5)
		V10 (4-6)
	120	U10 (55)
Initial Magdalenian	18-21	J2 (33-38)
Lower Magdalenian	15-17	H1 (35-43, 45, 51)
		H2 (40-47, 49-51, 56,57, 61)
		H3 (57-64, 67-69, 74,75, 79,80)
		H4 (50-57, 60, 64, 70-72)
		I2 (25-30, 33, 38, 39)
		I3 (43-49, 51-54, 60, 64)
		I4 (50-57, 59-61, 67,68, 73)
		J2 (15-20, 23,24, 31)
		J3 (25-32, 35-38, 48,49, 52,53)
		J4 (54-62, 65-67, 76, 80)
	504	W7 (5,6,7)
		X5 (5,6)
		X6 (11,12,13)
		X7 (5,5.1,6,7)
		Y5 (7,8)
		Y6 (12,13)
		Y7 (4)

Faunal materials were studied in sub-samples from Levels 15 and 16 (Samples 1-5) and Level 17 (Samples 17-6, 17-8, 17-10 and 17-12), each Level 17 sub-sample is a c. 5cm thick unit (Appendix Table B.2) and according to excavation procedure individual spit numbers for each subsample vary for each square (Appendix Table B.3).

Appendix Table B.2: Upper and Lower excavation depth boundaries for including spits into each study unit.

Sample unit	1	2	3	4	5	6	7	8	9	10	11	12	13
Z-max	15.85	15.80	15.75	15.70	15.65	15.60	15.55	15.50	15.45	15.40	15.35	15.30	15.25
Z-min	15.80	15.75	15.70	15.65	15.60	15.55	15.50	15.45	15.40	15.35	15.30	15.25	15.20

Appendix Table B.3: Studied (✔) and unstudied (✗) units from the Lower Magdalenian sequence in El Mirón cave Levels 15,16 and 17.

Level	Unit	Stu	H1	H2	H3	H4	I2	I3	I4	J2	J3	J4
15	1	✔					25	43		15		
15	2	✔	35,36	40,41			26	44		16	25,26	54
15/16	3	✔	37	42	57,58	50	27	45	50	16	27	55
15/16	4	✔	38	43	59, 60	51,52,53	28	46	51,52	17	28,29	56,57
16	5	✔	39,40	44,45	61,62	54,55,56	29	47	53,54,55	18	30,31	58
17	6	✔	41,42,43	46,47	63,64	57	30	48,49	56,57	19,20	32	(59,60),61, 62
17	7	✗	44	48	65,66	58,59	31,32	50	58	21,22	33,34	63,64
17	8	✔	45	49,50,51	67,68,69	60	33	51,52,53,54	59,60,61	23,24	35,36,37, 38	65,66,67
17	9	✗	46,47,48, 49,50	52,53, 54,55	70,71, 72,73	61,62,63	34,35, 36,37	55,56,57, 58,59	62,63,64, 65,66	25,26,27, 28,29,30	39,40,41,42, 43,44,45,46,47	68,69,70,71, 72,73,74,75
17	10	✔	51	56,57	74,75	64	38,39	60	67,68	31	48,49	76
17	11	✗	52,53	58,59,60	76,77,78	65,66,67, 68,69	40,41,42	61,62,63	69,70, 71,72	32	50,51	77,78,79
17	12	✔		61	79,80	70,71,72		64	73		52,53	80
17	13	✗			81	73,74,75		66	74,75,76, 77,78			81,82

Appendix C Archeozoological and taphonomic data by levels

This archeozoological and taphonomic appendix includes the detailed presentation of each El Mirón faunal assemblage from which the information in Chapter 4 is derived. The following descriptions includes number of studied specimen, NISP counts, MNE and MNI calculations, seasonal occupation estimation, and basic taphonomic analyses for all faunal remains for this present study; all data are organized and described by levels and species. Large quantities of datasets are summarized within tables, but details are highlighted within the text, for example the bone part and landmark that were used to estimate MNE/MNI data or what ageing or sexing indications were found to attribute bones to age classes such as fetal, neonate, infantile or juvenile. The osseous artifacts identified during the present faunal study mainly originate from general bags and were not recognized before, are quantitatively mentioned, thus augmenting the information on the range of human activities performed at the site.

Note that table entries marked with a star "*" are excluded for total MNE calculations, as only the highest value was chosen between maxillae and upper teeth as well as between mandibles and lower teeth for MNE counts.

Appendix C.1 Late Middle Paleolithic (Corral Area)

The oldest occupations so far at El Mirón were found in a deep sondage at the Vestibule Rear of the cave. Level 130 was excavated in two squares W10 (18-27) and X10 (25-36). Despite the late Middle Paleolithic attribution of few artifacts, two radiocarbon dates on bones are beyond the radiocarbon limit (48.2 and >45.9 uncal BP) and the one on charcoal dates to 41.3 uncal BP, placing the deposits at the end of the Middle Paleolithic occupations in Cantabria.

Level 130- Quantification

The faunal spectra were quantified in Level 130 as follows (Appendix Table C.1.1).

Appendix Table C.1.1: Faunal quantification, Level 130.

Species	NR	Weight	MNE	MNI
Equus ferus	2	8.6	1	1
Capra pyrenaica	54	142	34	3
Rupicapra rupicapra	10	38.3	10	2
Cervus elaphus	15	38.9	8	2
Canis lupus	3	1.7	1	1
Ursus arctos	3	10	1	1
Lepus sp.	6	4.1	6	2
Birds	69	14.1		
Fish	5	0.7		
Leporids/Birds	104	7.9		
M Ungulate	20	27.7		
M-L Size	11	38.4		
S Size	1	0.3		
Indeterminate	2694	612.9		
Total	**2997**	**945.6**	**63**	**12**

Equus ferus (Boddaert, 1785)

Two lower incisors were identified from horse; both are from the left side, presumably from the same mandible. Both are heavily digested indicating that a non-human biological agent was likely accumulating this remains. The digestion marks look really similar to bearded vulture activities (MARÍN-ARROYO 2010).

Capra pyrenaica (Schinz, 1838)

Lower teeth (dP3, dP4 and dI1) were identified from an infantile animal as well as from a juvenile and adult. Three upper M3s: two rights with different wear stages and one left were found. A distal radius fragment is unfused, indicating an animal less than 33 months old. An Ulna is represented by a proximal unfused epiphysis that belongs to an ibex of an age under 24 months. Two different carpals were identified, one is very small and has a porous structure probably from a juvenile animal and another comes from an adult. A porous tarsal bone might belong to a juvenile. Proximal phalanges have been found in unfused (<11 months) and fused (>15 months) stages. Four medial phalanges are unfused indicating at least one animal less than nine months of age. See Appendix Table C.1.2.

Appendix Table C.1.2**: Spanish ibex remains, Level 130.**

Capra pyrenaica (Lev 130)	NISP	MNE				MNI			
Element	All	All	inf	juv	adu	All	inf	juv	adu
Viscerocranium	2	1				1			
Upper teeth	4	3			1	1			1
Lower teeth	8	2	1	1	1	1	1	1	1
Scapula	1	1				1			
Radius	1	1		1		1		1	
Ulna	1	1		1		1		1	
Carpal unit	2	2		1	1	1		1	1
Metacarpus	1	1				1			
Pelvis	1	1				1			
Femur	1	1				1			
Patella	1	1				1			
Talus	1	1				1			
Tarsal unit	1	1		1		1		1	
Metapodial	3					1			
Phalanx prox.	8	5	1		1	1	1		1
Phalanx med.	11	7	2	1	4	1	1	1	1
Phalanx dist.	3	3				1			
Sesamoid	4	2				1			
Total	54	34	4	6	8	3	1	1	1

Rupicapra rupicapra (Linnaeus, 1758)

The lower teeth from chamois are four incisors: two right and left, which have fully developed roots and the two left ones are heavily worn. The tibia fragments are all include the landmark of the *foramen nutritium* that is present twice from the right side and once from the left, thus standing for a minimum of two animals. See Appendix Table C.1.3.

Appendix Table C.1.3: Chamois remains, Level 130.

Rupicapra rupicapra (Level 130)	NISP	MNE		MNI	
Element	All	All	adu	All	adu
Lower teeth	4	4	2	1	1
Femur	1	1		1	
Tibia	3	3	3	2	2
Phalanx dist.	2	2		1	
Total	10	10	1	2	2

Cervus elaphus (Linnaeus, 1758)

One lower milk tooth represents an infantile individual. The metapodial fragments origin from minimum one adult individual. One distal phalanx is porous and has small size, therefore, probably comes from a juvenile (or younger) animal. See Appendix Table C.1.4.

Appendix Table C.1.4: Red deer remains, Level 130.

Cervus elaphus (Lev 130)	NISP	MNE			MNI		
Element	All	All	juv	adu	All	juv	adu
Antler	3	1			1		
Lower teeth	1	1	1		1	1	
Rib	1				1		
Metacarpus	1	1		1	1		1
Metatarsus	2	1		1	1		1
Metapodial	3				1		
Phalanx med.	1	1			1		
Phalanx dist.	2	2	1		1	1	
Sesamoid	1	1			1		
Total	15	8	1	1	2	1	1

Canis lupus (Linnaeus, 1758)

A dP4 was identified with open roots that shows the beginning of wear from an infantile wolf. An upper I1 is also present from a wolf. One sesamoid was identified as coming from a wolf.

Ursus arctos (Linnaeus, 1758)

A complete and slightly worn lower M1 from a brown bear, an incisor and a hyoid were identified in the faunal materials of Level 130.

Lepus sp. (Linnaeus, 1758)

A distal humerus epiphysis is found unfused, hence from a young animal. A fused proximal femur was found. Two acetabulum fragments were found, one fused and one unfused, representing, therefore, an adult and a young animal, respectively. A lumbar vertebra was also found unfused. See Appendix Table C.1.5.

Appendix Table C.1.5: Lagomorph remains, Level 130.

Lepus spec. (Lev 130)	NISP	MNE			MNI		
Bone	All	All	juv	adu	All	juv	adu
Lower teeth	1	1			1		

Lumbar vert.	1	1	1		1	1	
Humerus	1	1	1		1	1	
Pelvis	2	2	1	1	1	1	1
Femur	1	1			1		
Total	6	6	1	1	2	1	1

Bird remains

Bird remains have been identified 69 times from the general bags, the species was not determinate further.

Fish remains

Five remains were identified from fish vertebrae.

Anatomically identified by size classes

A high number of long bone shafts and spongy, cancellous bone fragments were recognized, but not possible to be identified on a species level. Especially the spongy bones might represent those elements from the main prey species, which are more prone to crumbling due to higher porosity and fragility and, thus, more easily destroyed during trampling, sediment pressure, or (water) screening after being excavated.

Two porously structured bones, thus possibly young, were identified among these items classified by size classes; these are a rib fragment and a long bone shaft. See Appendix Table C.1.6.

Appendix Table C.1.6: Faunal remains by size classes, Level 130. *=NR.

Size classes (Level 130)	M Ungulate	M-L Size	S Size	Leporids/Birds	Indeterminate
Element	NISP	NISP	NISP	NISP	NISP
Cranium	2	1			
Teeth					1
Hyoid	1				
Cervical vert.	1	1			
Thoracic vert.	1				
Rib	1	2			
Lumbar vert.	1	1			
Sacral vert.	1				
Humerus		1			
Ulna	1				
Pelvis	2				
Femur		1			
Tibia	1	1			
Calcaneus	1				
Tarsals	2				
Sesamoid	1		1		
Long bone shaft	4	3		104	428
Spongy bone					1989*
Indeterminate					1*
Total	20	11	1	104	2419

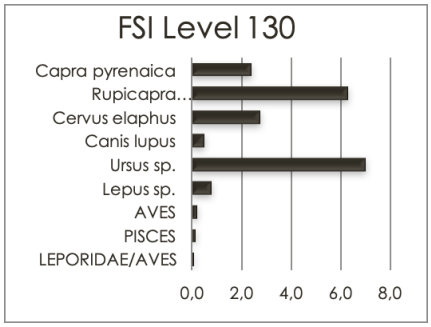
Seasonality

From ibex dentition, it was possible to determine *Capra pyrenaica* age following the methodology of Pérez-Ripoll (1988), thus, a young ibex between 6-12 months would indicate a winter-spring death.

Level 130- Taphonomy

Faunal preservation

Fragment size varies among the species, with generally larger fragments from chamois, red deer and Spanish ibex. The smallest fragments come from wolf and hare that were possible to identify to species level (Appendix Figure C.1.1).



Appendix Figure C.1.1: Fragments Size Index (FSI) variation among species, Level 130.

Mainly only foot bones are entirely preserved, while most of the other remains are fragmented. Complete bones from Spanish ibex include two carpals, a patella and a talus. The complete foot bones are phalanges and sesamoids from chamois, red deer other animals of small to medium sized classes.

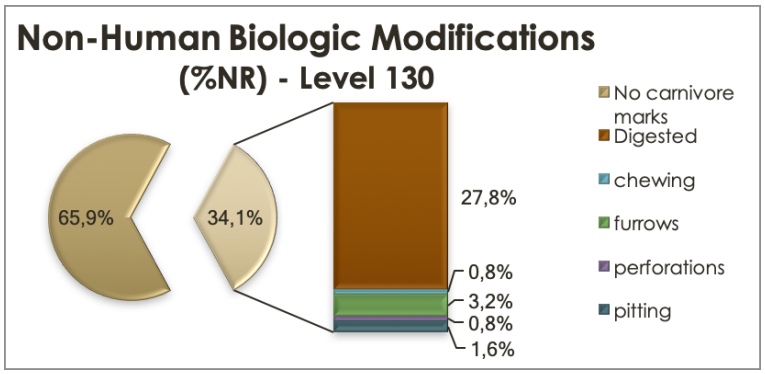
Breakage pattern. The fracture pattern of the studied faunal remains shows more recent fractures than green and dry fractures (Appendix Table C.1.7). Most breakage profiles, however, were classified as indeterminate, followed by green fractures.

Appendix Table C.1.7: Breakage pattern, Level 130.

Breakage- profile	NISP	%NISP
Green fracture	21	21.9
Green and dry fracture	1	1.0
Recent fracture	5	5.2
Indeterminate	69	71.9
Total	**96**	**100**

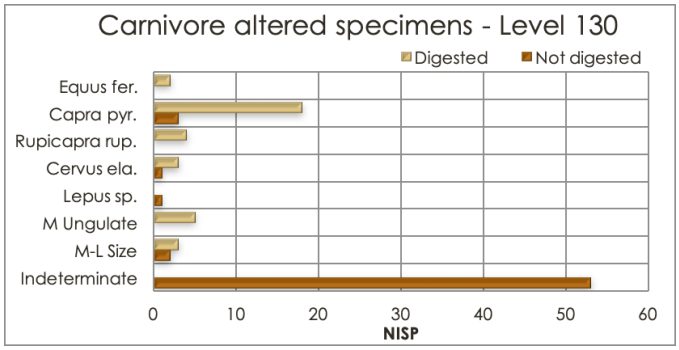
Non-Human Biological Agents

One third of the whole assemblage of Level 130 contains carnivore marks (Appendix_Figure C.1.2), which are dominated by digestion marks. Digested bones include the following elements: cranial parts, horn, teeth, cervical vertebrae, long bone, ulna, metapodial, tarsal, phalanges and sesamoid. Furrows that might imply carnivores were competing for bones dominate the other bite marks. Chewing, perforations and pitting marks suggest the prey bones have been transported and eaten in this area.



Appendix_Figure C.1.2: Type of carnivore activities registered, Level 130.

Most of the carnivore modifications were observed on indeterminate fragments and on ibex bones. It is worth mentioning that eight of the twelve ibex phalanges, sesamoids and teeth show digestion marks very similar to what is found resulting from bearded vulture action (MARÍN-ARROYO 2010). Ibex shows a high rate of digestion marks compared to the other species, followed by chamois, red deer and horse (Appendix Figure C.1.3:). Carnivore and anthropogenic marks were found often on bones or teeth of the same species; only horse shows solely carnivore marks in form of two digested teeth and bear only human modifications.



Appendix Figure C.1.3: Species (NR) containing carnivore modifications, Level 130.

Human activities

Level 130 has generally low frequencies of anthropogenic modifications (Appendix Table C.1.8). Bone flakes (38%) comprise the best presented direct evidence of human activities associated with bone cracking activities. A few of each, cut marks and impacts, were identified as anthropogenic alterations, which imply rather very short or infrequent human visits during the period of the deposit of this level. Burnt bone remains (52%) give an indirect evidence of human activities during the accumulation of this level. Sometimes were multiple anthropogenic modifications observed on the same bone, for example one deer metatarsal showed cut marks as well as impact marks. Twenty-seven items (21 of them bone flakes) with anthropogenic marks were found in square X10 in ten different spits and four in three spits of square W10.

Appendix Table C.1.8: Number of specimen with anthropogenic modifications, Level 130.

Species	Cut Marks	Impacts	Flakes	Burning
Capra pyrenaica	1	1		
Rupicapra rupicapra		1		
Cervus elaphus	1	1		
M Ungulate	1		2	
M-L Size		1		
Indeterminate			24	36
Total	**3**	**4**	**24**	**36**

Human-carnivore interactions

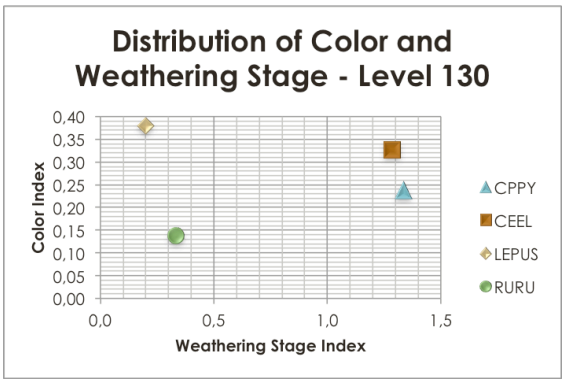
Only eight (1.1%NR) anthropogenic modifications have been found among the faunal remains of the late Middle Paleolithic Level 130 (Appendix Table C.1.9). About 3.2%NR of the investigated bones show carnivore marks that imply carnivores might had played a greater role (than humans) during the accumulation of this cave deposit. Overlaps of anthropogenic and carnivore marks one the same bone was not identified and about 95.8% do not show biological modifications marks.

Appendix Table C.1.9: Number of faunal remains with anthropogenic vs. carnivore marks, Level 130.

Species	Anthropogenic	Carnivore
Equus ferus		**2**
Capra pyrenaica	2	**21**
Rupicapra rupicapra	1	**4**
Cervus elaphus	1	**4**
Lepus sp.		**1**
M Ungulate	3	**5**
M-L Size	1	**5**
Indeterminate	24	**53**
Total	**32**	**95**

Post-depositional modifications

According to diagenetic observations based on the relationship of the weathering stage and the color of bones, red deer and Spanish ibex remains are grouped closer together than hare and chamois bones (Appendix Figure C.1.4). It implies that red deer and ibex are more heavily weathered than the other bones. Chamois remains show a less advanced stage of staining than the other species. Possible variation in the different degree of weathering and coloration among species can origin in whether unlike fragment sizes, varied accumulation contexts or other factors.



Appendix Figure C.1.4: Color and Weathering Index, Level 130.

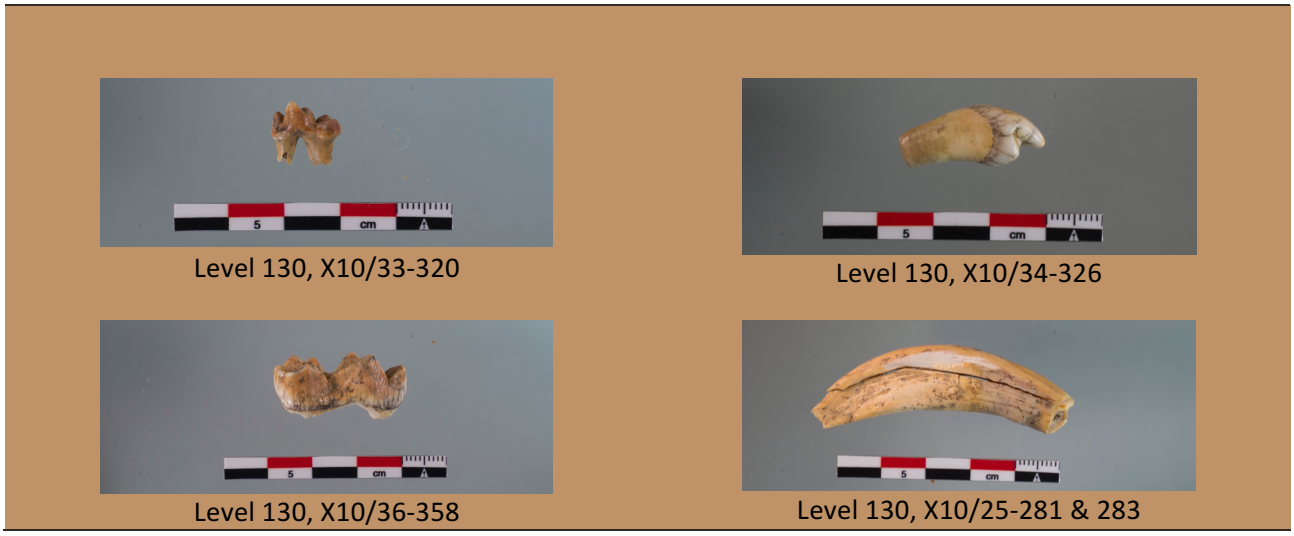
Level 130 - Summary

The main species presented in Level 130 is Spanish ibex, with smaller representations of red deer and chamois. Ibex is dominated by young animals. An infantile milk molar from a wolf implies a den. Ibex was presumably abundant in the surroundings of the mountain terrain of El Mirón cave and young animals were preferentially hunted to feed the puppies. Chamois bones were found digested.

The other type of carnivore modifications found in Level 130 correspond to small carnivores according to the small pits and perforations found on hare and bird bones. An animal of fox size or young wolfs could have been the accumulation agent for them.

Human actions seem to be very sporadically, only a short hunting camp visit is implied by the few cut and impact marks on bones.

Selected materials show diagenetic preservation of the faunal assemblage from Level 130 (Appendix Figure C.1.5) .



Appendix Figure C.1.5: Examples of the faunal material from Level 130.

Appendix C.2 Early Upper Paleolithic – Gravettian (Corral Area)

Early Upper Paleolithic occupations at El Mirón are so far only attested at the Vestibule Rear of the cave. Those remains were excavated in a total of three squares, by Level 129 in squares W10 (16,17)/X10 (22-24) and in Level 128 by squares V10 (16,17)/W10 (11-15)/X10 (14-21). Level 128 was radiocarbon dated to 27.6 uncal BP and is culturally associated to Gravettian occupations. Level 129 was described as sterile at the first place, but the faunal remains show few anthropological modification patterns similar to Level 128, possible indicating similar accumulation contexts.

Level 129- Quantification

The faunal spectra were quantified in Level 129 as follows (Appendix Table C.2.1).

Appendix Table C.2.1: Faunal quantification, Level 129.

Species	NR	Weight	MNE	MNI
Capra pyrenaica	26	82.7	20	2
Rupicapra rupicapra	1	2.3	1	1
Cervus elaphus	8	19.4	7	2
Lepus sp.	15	9.7	14	2
Birds	27	8.6	2	1
Fish	1	0.1		
Leporids/Birds	41	3.3		
M Ungulate	6	7.9		
<XS Size	1	0.1		
M-L Size	6	16.1		
Indeterminate	1083	268.3		
Total	**1215**	**418.5**	**44**	**8**

Capra pyrenaica (Schinz, 1838)

The lower molars (M1 and M2) just started to be worn and represent a juvenile animal that died of an age of 16-18 months (autumn death). The mandible fragment is porous and also belongs to a young individual. Proximal and medial phalanges represent both, juvenile and adult animals. See Appendix Table C.2.2.

Appendix Table C.2.2: Spanish ibex remains, Level 129.

Capra pyrenaica (Lev 129)	NISP	MNE			MNI		
Element	All	All	juv	adu	All	juv	adu
Mandible	1	1	1		1		
Lower teeth	2	1	1		1	1	
Lumbar vert.	1	1			1		
Ulna	2	2			1		
Ulna-Radius	1				1		
Femur	2	1			1		
Calcaneus	1	1			1		
Tarsal unit	1	1			1		
Metatarsal	1	1			1		
Phalanx prox..	2	2	1	1	2	1	1
Phalanx med.	6	5	1		1	1	
Phalanx dist.	6	4	2	2	2	1	1
Total	26	20	3	3	2	1	1

Rupicapra rupicapra (Linnaeus, 1758)

Chamois was identified on only one lower right M3 in an unworn stage, thus being adult individual.

Cervus elaphus (Linnaeus, 1758)

A humerus fragment identified by the landmark of the *Tuberositas teres major* belongs to an adult individual; it shows carnivore marks over anthropogenic modification of the bone surface. One third phalanx is porous and is from a fetal animal. See Appendix Table C.2.3.

Appendix Table C.2.3: Red deer remains, Level 129.

Cervus elaphus (Lev 129)	NISP	MNE			MNI		
Element	All	All	fet	adu	All	fet	adu
Humerus	1	1		1	1		1
Metatarsus	1	1			1		
Phalanx dist.	2	2	1	1	1	1	1
Phalanx atro.	1	1			1		
Sesamoid	3	2			1		
Total	8	7	1	1	2	1	1

Lepus sp. (Linnaeus, 1758)

Three proximal ulna shaft fragments belong to minimum two adults and one young animal. A right and a left distal tibia shaft with metaphysis fragments are unfused coming presumably from one young animal. A minimum of two adult individuals is presented by two left calcanei and a young animal by another left one. See Appendix Table C.2.4.

Appendix Table C.2.4: Lagomorph remains, Level 129.

Lepus spec. (Lev 129)	NISP	MNE			MNI		
Element	All	All	juv	adu	All	juv	adu
Viscocranium/Maxilla	1	1			1		
Indet. vert.	1	1			1		
Scapula	1	1			1		
Ulna	3	3	1	2	3	1	2
Pelvis	2	2			1		
Patella	1	1			1		
Tibia	2	2	2		1	1	
Calcaneus	3	3	1	2	1	1	2
Total	14	14	1	1	2	1	1

Bird remains

Just a few bird remains were identified coming from a distal femur shaft (6 cm, 2 g) and a scapula fragment (2 cm, 0.4 g).

Anatomically identified by size classes

The medial phalange of a medium -size artiodactyl is in a not fully developed stage coming from an infantile or younger animal. From the medium to large size animal also come a long bone and humerus or femur shaft

fragment with a porous bone structure. Two unfused bones were found: a tiny vertebra and a metapodial that is longitudinally fusing between the digits both represent a fetal animal. See Appendix Table C.2.5.

Appendix Table C.2.5: Faunal remains by size classes, Level 129. *=NR.

Size classes (Level 129)	M Ungulate	M-L Size	<XS Size	Leporids/Birds	Indeterminate
Element	NISP	NISP	NISP	NISP	NISP
Lower teeth	1				
Rib	2	1	1		
Lumbar vert.	1				
Indet. vert.		1			
Metapodial		1			
Phalanx med.	1				
Phalanx dist.		1			
Humerus-Femur		1			
Long bone shaft		1		41	87
Spongy bone					815*
Indeterminate	1				1*
Total	6	6	1	41	903

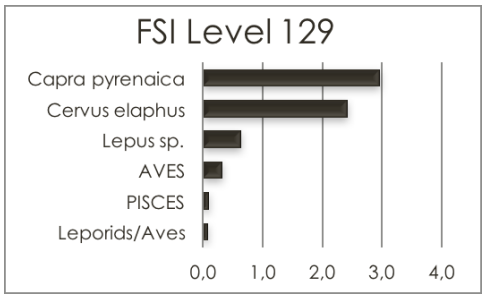
Seasonality

At least one ibex, between 16-18 months old, were recovered indicating a possible autumn death.

Level 129- Taphonomy

Faunal preservation

Spanish ibex has the largest fragment size index (Appendix Figure C.2.1 :) of identified specimen, closely followed by red deer. Bird and hare remains are smaller, presumably due to the naturally smaller size of these species.



Appendix Figure C.2.1 : Fragments Size Index (FSI) variation among species in Level 129.

Mainly feet bones (Nr=6) are entirely preserved, while most of the faunal remains are fragmented. Complete bones from Spanish ibex are a tarsal bone, a medial and distal phalanx. From red deer are completely preserved three sesamoids and one atrophic phalanx. Hare is represented also by whole bones identified as one patella and one calcaneus.

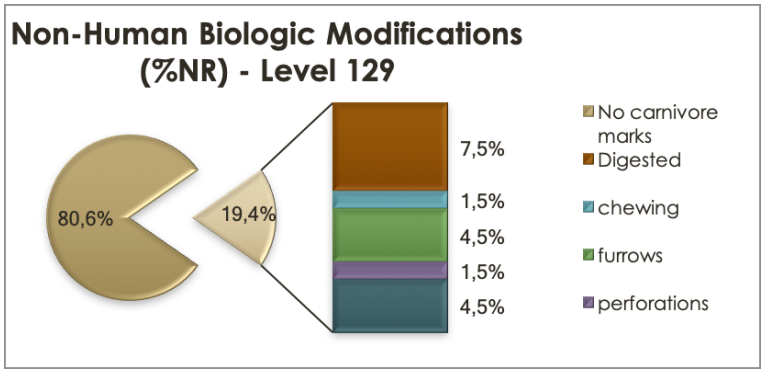
Breakage pattern. The fracture pattern of the studied faunal remains shows mostly indeterminate fractures. The second most breakage profiles, however, were classified as green. See Appendix Table C.2.6.

Appendix Table C.2.6: Breakage pattern, Level 129.

Breakage- profile	NISP	%NISP
Green fracture	13	22.4
Green and dry fracture	1	1.7
Recent fracture	6	10.3
Indeterminate	38	65.5
Total	**58**	**100**

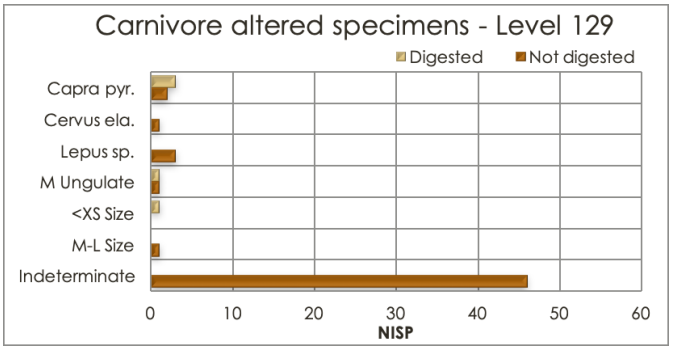
Non-Human Biological Agents

The amount of carnivore marks has decreased in Level 129 (19.4%) compared to Level 130 (34.1%), where bite marks surpass the number of digestion marks. Digestion marks were found on a tooth, three phalanges and a rib head. Furrowing and pitting activities dominated the eight registered bite marks (Appendix Figure C.2.2). Bite marks are located on axial, tarsal, pelvic, long and feet bones.



Appendix Figure C.2.2: Type of carnivore activities registered, Level 129.

Spanish ibex is the species represented that contains the most carnivore marks, followed by hare and red deer (Appendix Figure C.2.3). The few specimens from hare show carnivore marks, but no anthropogenic marks, therewith, carnivores seemed to be the mostly likely accumulation agent for this species within Level 129.



Appendix Figure C.2.3: Prey species that contain carnivore modifications, Level 129.

Human activities

Level 129 has similar to Level 130 generally low frequencies of anthropogenic modifications. The cut marks (6% of anthropogenic marks) were found three times on long bones Appendix Figure C.2.4: Level 129, X10/269. and ones on a rib fragment. Impacts (10% of anthropogenic marks) were found on long bones and phalanges. Further evidence of human activities within this level are given by bone flakes (48%) and burnt remains (36%). Bones showing anthropogenic modifications origin from the square X10- spit 22/23 (NR=21 bones) and from the square W10- spit 16/17 (NR=24 bones). See Appendix Table C.2.7.



Appendix Figure C.2.4: Level 129, X10/269.

Appendix Table C.2.7: Number of specimen with anthropogenic modifications, Level 129.

Species	Cut Marks	Impacts	Flakes	Burning
Capra pyrenaica	1	5		
Cervus elaphus		1		
M Ungulate	1			
M-L Size	1			
Indeterminate	2		34	26
Total	**4**	**7**	**34**	**26**

Human-carnivore interactions

Level 129 yielded 3.6% bones with anthropogenic and 4.8% with carnivore marks (Appendix Table C.2.8). Overlaps of anthropogenic and carnivore marks on the same bone were identified in an adult red deer right humerus shaft with a green spiral fracture, the first occurring as a direct hammer impact with visible striking platform and followed by furrow marks from a medium-size carnivore. Most of the bones 91.5%, however, do not show modification marks.

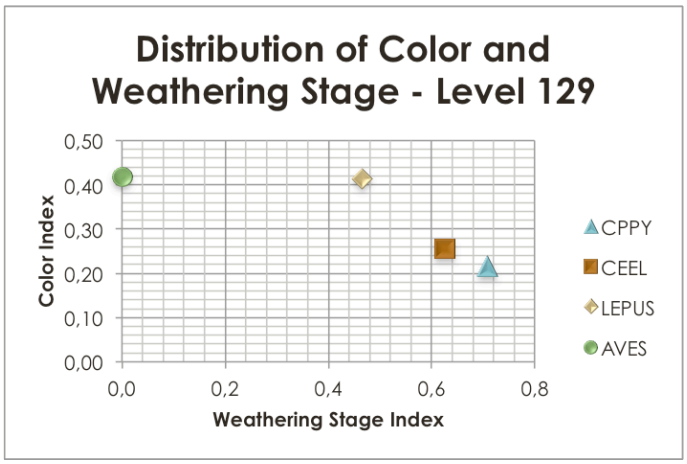
Appendix Table C.2.8: Number of faunal remains with anthropogenic vs. carnivore marks, Level 129.

Species	Anthropogenic	Carnivorous	Both
Capra pyrenaica	5	5	
Cervus elaphus			**1**
Lepus sp.		3	
M Ungulate	2	2	
<XS Size		1	
M-L Size	1	1	
Indeterminate	36	46	
Total	**44**	**58**	**1**

Post-depositional modifications

Diagenetically it seems that red deer and Spanish ibex are related closer together than hare and bird, but this might be due to the different bone sizes of the animals and consequently different bone structure, which leaves colorations and weathering processes with less ability to modify them or to indicate different

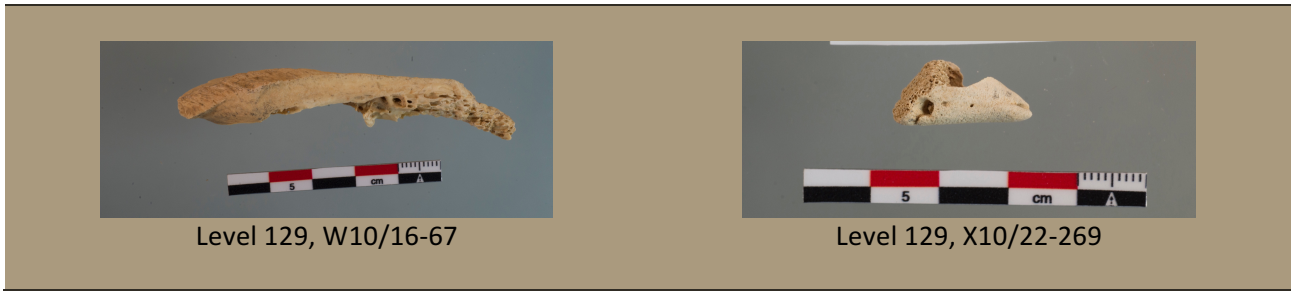
accumulation contexts, for example a carnivore's accumulation versus a human accumulation. See Appendix Figure C.2.5.



Appendix Figure C.2.5: Color and Weathering Index, Level 129.

Level 129 – Summary

The preservation of the faunal assemblage of Level 129 is good (Appendix Figure C.2.6) with well-preserved bone surfaces allowing identification of modifications of animals. The high percentage of carnivore marks, mainly on ibex, are dominated by digestion marks indicating higher activity of larger carnivores. Small carnivores accumulated leporids due to bite mark sizes. The low frequency of anthropogenic activities, evidence is given by few cut marks, bone flakes and impacts on bones and burnt remains, is limited to square X10 and W10. A few bones show an overlap of modification marks, which indicate that carnivores had access to prey animals after humans. The evidence of human modifications on faunal remains increase slightly compared to the underlying Level 130, which is especially interesting as this layer was described by the excavators as archaeologically sterile (due to the lack of lithics). The evidence of these human activities, however, likely represent the earliest remains of the more intensive human occupation from the overlying Level 128.



Appendix Figure C.2.6: Faunal material from Level 129.

Level 128 - Quantification

In total were identified 5 465 bone and 67 tooth fragments (Appendix Table C.2.9). Level 128 (and the few human modified faunal remains from Level 129) might be contributed to the Gravettian period, because of its C14 date and it does have a few banal artifacts, including a blade.

Appendix Table C.2.9: Faunal quantification, Level 128.

Species	NR	Weight	MNE	MNI
Mammuthus primigenius	1	0.5	/	/
Capra pyrenaica	86	175.9	40	3
Rupicapra rupicapra	10	19.7	7	1
Cervus elaphus	44	269.3	28	3
Canis lupus	2	5.6	1	1
Panthera pardus	1	47.6	1	1
Lepus sp.	64	39.1	49	6
Birds	117	27.4	2	1
Fish	4	0.3		
Leporids/Birds	708	66.6		
S Ungulate	4	7.4		
M-L Ungulate	21	40.8		
S Carnivore	1	0.1		
<XS Size	3	1.9		
M-L Size	30	92		
Indeterminate	4435	1302.8		
Total	**5531**	**2096.1**	**128**	**16**

Mammuthus primigenius (Blumenbach, 1799)

In Level 128 there was the only small piece of an ivory fragment identified in El Mirón cave until today. It is a fragment of 2cm size and 0.5mg in weight.

Capra pyrenaica (Schinz, 1838)

Four heavily worn teeth with massive roots represent a minimum of one adult. A minimum of one juvenile animal is represented by two lower milk teeth (dI2 and dP4). The other teeth represent a minimum of one adult. One unfused proximal epiphysis is from femur. A proximal humerus was in the process of fusing. The unfused distal metacarpal and metatarsal epiphyses together with two unfused distal shaft metapodial fragments indicate a minimum of one animal under 2 years. A distal metapodial fragment that is fusing points to a spring death and represents another animal of 23-26 month of age. The patella is a porous bone from a young individual. Two tibiae were recognized in both a fused and an unfused state. The second phalanx is identified in both states, fused and unfused, younger than 9 months and older than 13 months, respectively. The third phalanx gives a MNE of 4 fused, adult and 1 unfused ones. See Appendix Table C.2.10.

Appendix Table C.2.10: Spanish ibex remains, Level 128.

Capra pyrenaica (Level 128)	NISP	MNE				MNI			
Element	All	All	neo	juv	adu	All	neo	juv	adu
Horn	1	1				1			
Viscerocranium/Maxilla	1	1				1			
Upper teeth	4	2		1	1	2		1	1
Mandible	2	1				1			
Lower teeth	14	2		1	1	2		1	1
Hyoid	1	1				1			
Rib	3	1				1			
Lumbar vert.	1	1				1			
Humerus	1	1				1			
Radius	2	1				1			
Ulna	2	1				1			
Ulna-Radius	1					1			
Metacarpus	1	1		1		1		1	
Pelvis	1	1				1			
Femur	2	2		1		1		1	
Patella	1	1		1		1		1	
Tibia	6	2		1	1	1		1	1
Tarsal unit	3	2				1			
Metatarsi	1	1		1		1		1	
Metapodia	3	2	1	1		2	1	1	
Phalanx prox.	3	3				1			
Phalanx med.	7	5		1	4	1		1	1
Phalanx dist.	5	5		1	4	1		1	1
Sesamoid	4	2				1			
Total	70	40	1	10	11	3		1	1

Rupicapra rupicapra (Linnaeus, 1758)

A lower complete incisor was identified. The distal humerus fragment is fused and completely developed as well as the phalanges, all presumably belonging to an adult individual. See Appendix Table C.2.11.

Appendix Table C.2.11: Chamois remains, Level 128.

Rupicapra rupicapra (Level 128)	NISP	MNE		MNI	
Element	All	All	adu	All	adu
Lower teeth	1	1		1	
Humerus	2	1	1	1	1
Ulna	1	1		1	
Tibia	1	1		1	
Phalanx med.	1	1	1	1	1
Phalanx dist.	2	2	1	1	1
Total	8	7	1	1	1

Cervus elaphus (Linnaeus, 1758)

All of the lower teeth identified might belong to minimum one juvenile individual dI3, I1 and I3, which are unworn or only show the begin of the wear and have little root growth. A mandibular fragment represents an adult individual. Three of the seven third phalanges are fully grown and belong to minimum of one adult animal, but the other four almost complete elements have porous structure and are small in size coming from minimum one fetal deer. A radius and ulna metaphysis confirm also the presence of a fetal animal within this level. See Appendix Table C.2.12.

Appendix Table C.2.12: Red deer remains, Level 128.

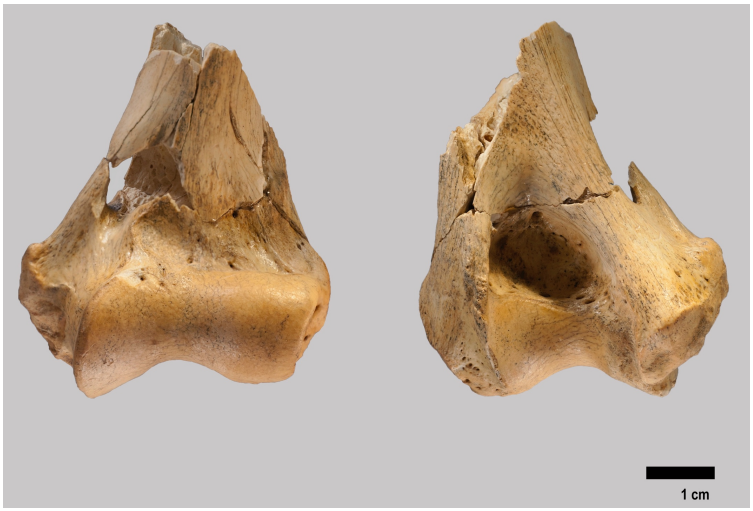
Cervus elaphus (Level 128)	NISP	MNE				MNI			
Element	All	All	inf	juv	adu	All	inf	juv	adu
Cranium	1	1			1	1			1
Viscerocranium/ Maxilla	1	1		1		1		1	
Upper teeth	1	1				1			
Mandibule	1	1			1	1			1
Lower teeth	3	1		1		1		1	
Humerus	3	1				1			
Radius	4	2	1		1	2	1		1
Ulna	3	3	1		2	2	1		1
Ulna/Radius	2								
Carpal unit	1	1				1			
Metacarpus	2	1				1			
Pelvis	1	1				1			
Femur	2	1		1		1		1	
Tibia	1	1				1			
Metatarsus	2	1		1		1		1	
Phalanx prox.	1	1				1			
Phalanx med.	2	2				1			
Phalanx dist.	7	7	4		3	2	1		1
Phalanx atro.	1	1				1			
Long bone	1					1			
Total	40	28	6	4	8	3	1	1	1

Canis lupus (Linnaeus, 1758)

One complete, left *os carpale secundum* was identified belonging to a wolf. Presumably from a young wolf comes a femur fragment with *foramen nutritium*.

Panthera pardus (Linnaeus, 1758)

One of the very few large carnivore findings in El Mirón cave (Appendix Figure C.2.7) is a left distal humerus fragment of 8cm length and 47.6g of weight from an adult male leopard according to measurements (in mm): Maximum length: 77.46; Distal Width: 61.45; Distal Thickness: 38; Distal Width of the articular face: 42.72. Medial foramen is present (ALTUNA 1972; ALTUNA & MARIEZKURRENA 1984; MARÍN-ARROYO ET AL. 2018a, Fig.3). No human modification marks were observed on this bone, and an alternating human-carnivore cave use is inferred. Transport of body elements and hiding in cave sites are common eating habits of this leopard species (SAUQUÉ ET AL. 2014). The Cantabrian region was an Upper Paleolithic refugium for leopards, where they went on to survive until the Mesolithic (SAUQUÉ & CUENCA-BESCÓS 2013).



Appendix Figure C.2.7: Distal humerus, *Panthera pardus*. activities registered in Level 128, X10-253. Photograph by L. Agudo.

Lepus sp. (Linnaeus, 1758)

Six scapula fragments are represented by the glenoid cavity, representing therefore six elements and a minimum of one adult as well as two young hares. Four unfused proximal epiphyses are present, two of each side. Three right femur fragments represent a minimum of two juvenile, while two of them are unfused distal parts. Three distal parts of the tibia were identified, with two of them a metaphysis and one epiphyses, representing minimum two animals. Six calcanei are identified of which four are complete; one is from a young animal and another presumably from an adult one. Five of the calcanei are from the right side, therefore each of them representing an individual. See Appendix Table C.2.13.

Appendix Table C.2.13: Lagomorph remains, Level 128.

Lepus spec. (Level 128)	NISP	MNE			MNI		
Element	All	All	juv	adu	All	juv	adu
Viscocranium/Maxilla	3	2			1		
Mandible	2	2			1		
Teeth	2	2			1		
Lumbar vert.	3	3			1		
Sacral vert.	1	1			1		
Indet. vert.	4	4	1		1		
Scapula	6	6	2	1	3	2	1
Humerus	8	4	4		2	2	
Ulna	3	3	1		1	1	
Pelvis	5	4	3		1	2	
Femur	3	2	2		1	2	

Tibia	3	2	2		1	1	
Talus	1	1			1		
Calcaneus	6	6	1	5	5	1	4
Tarsal unit	3	3			1		
Metatarsus	3	3			1		
Phalanx prox.	1	1	1		1	1	
Long bone	2				1		
Total	59	49	17	6	6	2	4

Bird remains

Two bird bones have been identified in this level, which are the *Processus coracoideus* from a scapula and the proximal part of a third phalanx (a claw).

Anatomically identified by size classes

The sacral bone of a medium –size artiodactyl was found in a fusing stage. Also, were identified within this size class a porous distal medial phalange and a long bone shaft. See Appendix Table C.2.14.

Appendix Table C.2.14: Faunal remains by size classes, Level 128. *=NR.

Size classes (Level 128)	L Ungul.	M Ungul.	M-L Size	S Ungul.	S Car.	<XS Size	Leporids/ Birds	Indeter-minate
Element	NISP	NISP	NISP	NISP	NISP	NISP	NISP	NISP
Cranium		2	2			1		
Viscerocra.			1					
Lower teeth					1			
Cervical vert.			3	2		1		
Rib		4	1					
Lumbar vert.		1						
Sacral vert.		1						
Indet. vert.	1	4	1					
Scapula		1						
Humerus		1						
Radius						1		
Ulna-Radius		1						
Patella				1				
Tarsals				1				
Metapodial		1						
Phalanx med.		2						
Phalanx dist.			1					
Long bone shaft		3	18				708	495
Spongy bone								3205*
Indeterminate			3					3*
Total	1	21	30	4	1	3	708	3703

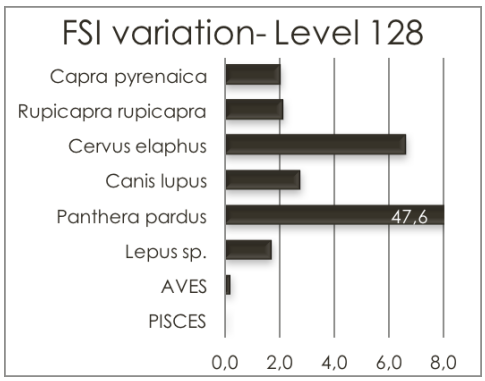
Seasonality

In Level 128 three individuals with ages between 18-24 months, 24-30 and >36 months were identified, which could correspond to winter/early spring, summer-autumn and late spring deaths, respectively. In addition, an infantile red deer corresponds to an individual of around 2-3 months, which might indicate an end spring-early summer occupation as is often attested at the cave during the Upper Magdalenian. Also in the same level, 50% of the leporid remains are unfused indicating the presence of younger individuals.

Level 128- Taphonomy

Faunal preservation

The panther remains identified appear to have the largest size fragments similar to which were classified as red deer. Spanish ibex, chamois and wolf remains cluster together around the fragment size of 2-3g (Appendix Figure C.2.8:), being generally larger than leporid remains.



Appendix Figure C.2.8: Fragments Size Index (FSI) variation among species in Level 128.

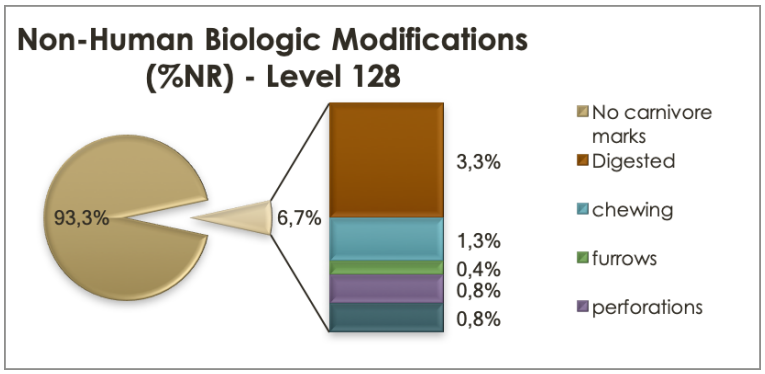
In Level 128 contain the body parts of the lower hind and feet the most complete bones. Complete bones identified from Spanish Ibex are one knee bone, two tarsals, three sesamoids, one proximal phalanx and two distal phalanges. Red deer entire bones preserved are one carpal and two distal phalanges. A complete carpal bone was identified from wolf. Complete hare bones are the following: four calcanei, two tarsals, two metatarsals and one proximal phalanx. Chamois bones were found completely from one medial and one distal phalanx. One complete tarsal and knee bone come from a small ungulate.

Breakage pattern. The fracture pattern of the studied faunal remains shows more green fractures than recent or green and dry fractures. Most breakage profiles, however, were classified as indeterminate. See Appendix Table C.2.15.

Appendix Table C.2.15: Breakage pattern, Level 128.

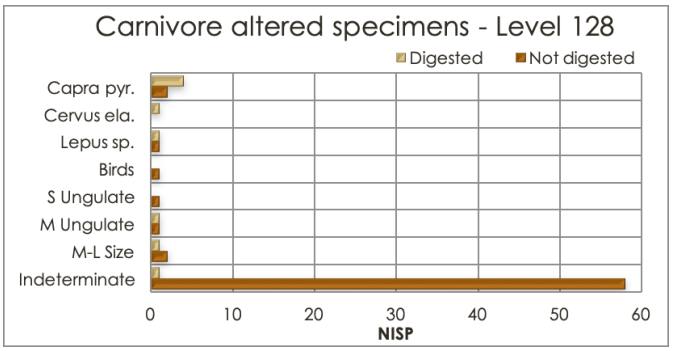
Breakage- profile	NISP	%NISP
Green fracture	66	34.4
Green and dry fracture	6	3.1
Recent fracture	20	10.4
Indeterminate	100	52.1
Total	**192**	**100**

Carnivore marks were identified on fifteen faunal remains, which represents low carnivore activities within this level (Appendix Figure C.2.9:). Digested bones include teeth, tarsal bones, phalanges, a metapodial and a vertebra. The seven bite marks identified are dominated by chewing marks. Bite marks are located on long bones, knee bone, calcanei and phalanges. Square X10 shows two concentrations of carnivore marks, one in the spit 15-17 with seven and another in spit 20-21 with five carnivore modifications.



Appendix Figure C.2.9: Carnivore activities registered in Level 128.

Most carnivore modifications were found on ibex bones (Appendix Figure C.2.10:), while two teeth, one metapodial and one phalanx show digestion marks. The hare calcaneus has chewing and digestion carnivore marks, indicating a non-human accumulation.



Appendix Figure C.2.10: List of species that contain carnivore modifications in Level 128.

Level 128 shows an increased number of bones with anthropogenic modifications vis a vis the underlying levels. Cut marks are located on long bones, a rib and a phalanx. Impact marks are found generally on long bones and phalanges, despite one an ibex mandible diastema. Most of the anthropogenically modified bones were found in square X10 in spit 14; there are cut marks on ten bones and impact marks on nine. Two completely black, burnt bones were identified; both are indeterminate fragments from a medium- to large-

size animal. The carbonized bones come from square V10 spit 16 and W10 spit 11. The type of anthropogenic modifications diversifies within this part of the stratigraphy of El Mirón cave as potential bone tools are recognized for the first time; there is a possible bone retoucheur and bone flakes (debris) were also recognized. See Appendix Table C.2.16.

Appendix Table C.2.16: Number of specimen with anthropogenic modifications in Level 128.

Species	Cut marks	Impacts	Burning	Artifact
Mammuthus primigenius	1			
Capra pyrenaica	7	10		
Rupicapra rupicapra	1	1		
Cervus elaphus	6	11		
Canis lupus		1		
M Ungulate	1	2		1
M-L Size	6	4	1	1
Indeterminate	1		1	
Total	**23**	**29**	**2**	**2**

Human-carnivore interactions

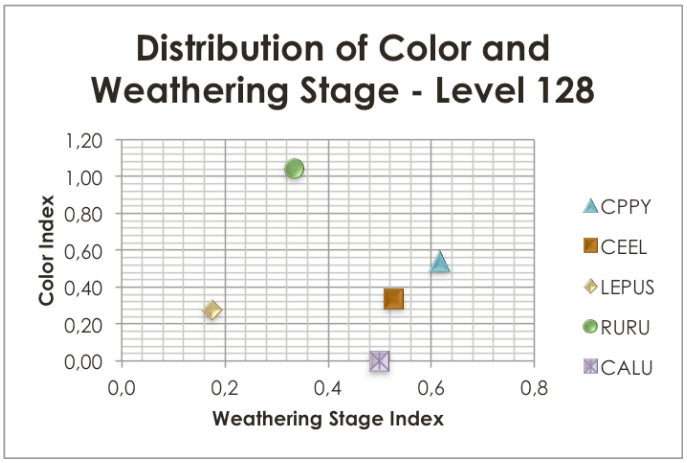
The relative frequency of anthropogenic modifications (5.0%) among the individually registered bones in Level 128 is just slightly higher than in Level 129, but the carnivore marks are generally less common (1.3%). One longitudinally fractured tibia shaft fragment from ibex contains a simple-short, skewed cut mark and superficial pits from a carnivore. Most of the bones (93.7%), though, do not show modification marks. See Appendix Table C.2.17.

Appendix Table C.2.17: Anthropogenic vs. carnivore marks on bones and teeth, Level 128.

Species	Anthropogenic	Carnivorous	Both
Mammuthus primigenius	1		
Capra pyrenaica	22	5	**1**
Rupicapra rupicapra	1	1	
Cervus elaphus	12		
Canis lupus	1		
Lepus sp.		2	
Birds		1	
S-M Ungulate	3	3	
M-L Size	13	3	
Indeterminate	222	59	
Total	**275**	**74**	**1**

Post-depositional modifications

In Level 128 shows Spanish ibex the most advanced weathering stage, closely followed by red deer and wolf and with distance follow chamois and hare. Nonetheless, hare remains display a more similar color index to red deer an ibex. See Appendix Figure C.2.11.



Appendix Figure C.2.11: Color and Weathering Index, Level 128.

Level 128 – Summary

During the occupations of the early Upper Paleolithic Level 128, carnivore activities were still high, but human presence in the cave intensify. The type of anthropogenic modifications diversifies within this part of the stratigraphy of El Mirón cave including bone cavity opening tasks, but human activity stays very sporadic. Modifications representing still alternating cave use of both agents as their concentration was found in different excavation depths (spits). Although only a few specimens evidence their presence, large carnivores are represented by wolf and leopard. The prey species ibex is represented by adult and juvenile individuals, chamois only by adult, red deer by young and adult individuals. Smaller animals are present by leporids and bird remains, due to bite marks possible the result of carnivore prey transport and consumption at the cave. Selected items represent the diagenetic preservation of the faunal assemblage from Level 128 as shown in following photographs (Appendix Figure C.2.12). Diagenetic alterations seemed to have affected red deer, ibex and wolf more similarly compared to the other species, maybe due to related accumulation context.



Appendix Figure C.2.12: Examples from Level 128 faunal material.

Appendix C.3 Solutrean (Corral Area)

Faunal analysis was done on Solutrean levels excavated in the Vestibule Rear (Corral Area) of the cave. There are multiple occupations, beginning with the lowest Level 127 and ending with Level 120, dating between 20.4 and 18.4 uncal BP.

Level 127 - Quantification

In total were registered 1 522 bones and 73 teeth within Level 127, excavated in the two squares X10 (13) and V10 (15). The faunal spectra were quantified in Level 127 as follows (**Appendix Table A.1**).

Appendix Table C.3.1: Faunal quantification, Level 127.

Species	NR	Weight	MNE	MNI
Capra pyrenaica	25	40.7	5	2
Cervus elaphus	21	70.3	6	3
Leporids	6	2.8	6	2
Birds	31	9.8	2	(2)
S Ungulate	1	0.6		
M Ungulate	4	9.2		
M-L Size	4	25.8		
Indeterminate	1503	998		
Total	**1595**	**1157.2**	**19**	**7**

Capra pyrenaica (Schinz, 1838)

The identified teeth are heavily worn and belong to an old individual, next to an milk tooth. Distal phalanx fragments are unfused so that they represent presumably a juvenile. See Appendix Table C.3.2.

Appendix Table C.3.2: Ibex remains, Level 127.

Capra pyrenaica (Level 127)	NISP	MNE			MNI		
Element	All	All	juv	adu	All	juv	adu
Horn	2	1			1		
Upper teeth	2	1		1	1		1
Lower teeth	4	2	1	1	1	1	1
Hyoid	1	1			1		
Ulna	2	1			1		
Carpal unit	2	1			1		
Metatarsus	1	1			1		
Phalanx prox.	2	1			1		
Phalanx dist.	5	3	2		1	1	
Sesamoid	4	1			1		
Total	25	12	3	2	2	1	1

Cervus elaphus (Linnaeus, 1758)

Three proximal joint calcaneus fragments represent minimum two left ones. Two lower incisors were found in different wear stages, one was categorized as juvenile, because it shows just the first stages of tooth wear and the other is completely worn. A distal phalanx comes from an infantile, it is in the fusing stage that occur at an age of about 1 month in spring-early summer. See Appendix Table C.3.3.

Appendix Table C.3.3: Red deer remains, Level 127.

Cervus elaphus (Level 127)	NISP	MNE				MNI			
Element	All	All	inf	juv	adu	All	inf	juv	adu
Antler	1					1			
Upper teeth	1	1				1			
Mandible	1	1				1			
Lower teeth	3	2		1	1	2		1	1
Cervical vert.	2	2				1			
Tibia	1	1				1			
Calcaneus	3	2				1			
Metatarsus	2	1			1	1			1
Metapodial	1	1				1			
Phalanx prox.	1	1				1			
Phalanx med.	1	1				1			
Phalanx dist.	2	2	1			1	1		
Sesamoid	2	2				1			
Total	21	17	1	1	2	3	1	1	1

Lagomorph remains

A scapula and pelvic fragment and a complete, juvenile calcaneus were identified from *Lepus spec*. Three lagomorph remains, a femur, tibia and talus, are apparently from one animal and possibly represent an European rabbit.

Bird remains

Two right, proximal humeri and one distal one was identified coming from bird, one of the latter carries carnivore puncture marks. Six other long bone and 22 other fragments were also identified from bird.

Anatomically identified by size classes

Two long bone shaft fragments, a humerus or femur shaft and an indeterminate compact bone with spongy structure fragment are categorized as coming from a medium to large-size animal and a hyoid from a small sized ungulate. From indeterminate medium sized ungulates were found: a cranium, two long bones and one indeterminate vertebra. The taxonomically indeterminate specimen, presumably from medium sized ungulate, include 29 fetal/neonate bones. See Appendix Table C.3.4.

Appendix Table C.3.4: Faunal remains by size classes, Level 127. *=NR.

Size classes (Level 127)	M Ungulate	M-L Size	S Ungulate	Indeterminate
Element	NISP	NISP	NISP	NISP
Cranium	1			
Teeth				63
Hyoid			1	
Rib				33
Sternum				3
Indet. vert.	1			16
Humerus-Femur		1		
Long bone	2	2		252
Spongy bone				904*
Indeterminate		1		232*
Total	4	4	1	1503

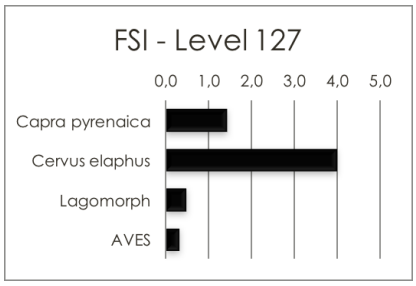
Seasonality

Bird remains have calcite concretions within the bones indicating they are just before or during the time of laying eggs, presumably spring- summer time (SERJEANTSON 1998, 2009). Ungulate fetal bones indicating a death of the mother animals during gestation period in winter-spring.

Level 127 - Taphonomy

Faunal preservation

The largest size fragments belong to red deer (Appendix Figure C.3.1). Ibex, lagomorph and bird remains are much smaller.



Appendix Figure C.3.1: Fragment Size Index (FSI) variation among species in Level 127.

Level 127 only contains two complete bones: a proximal sesamoid and a distal phalange, plus two complete teeth (one incisor and one lower M3) from Spanish ibex.

Appendix Table C.3.5 summarized the observed breakage pattern. The identified species show a mainly green breakage pattern, although the sample size is quite small in Level 127.

Appendix Table C.3.5: Breakage pattern, Level 127 (only bones identified taxonomically or in animal size classes).

Breakage- profile	NISP	%NISP
Green fracture	161	73.9
Green and dry fracture	1	0.5
Indeterminate	56	25.7
Total	**218**	**100**

Non-Human Biological Agents

Carnivore marks were presented on 15 specimens, which in particular included ibex carpal bone with digestion marks and bird and ibex distal phalanx with punctures and gnawing marks.

Human activities

In Level 127, specimens found carried in 10.4%NR cases anthropogenically and in 0.9%NR cases carnivorous modification marks. While mostly red deer bones show anthropogenic marks, some ibex and bird bones contain carnivore marks.

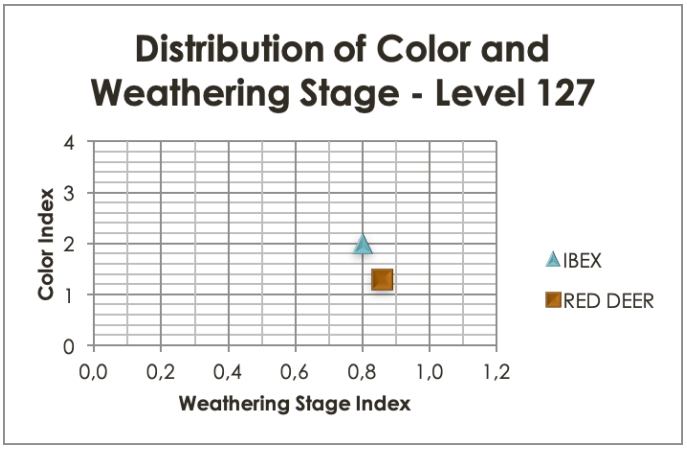
Level 127 shows a similar number of specimen with cut marks and impact marks (Appendix Table C.3.6). Cut marks are located on the atlas, calcaneus, metatarsal and long bones. Impact marks were found on a cervical vertebra, calcaneus, metapodial and long bones. All anthropogenic modification marks were found in square X10 spit 13 and 15.

Appendix Table C.3.6: Number of specimen with anthropogenic modifications in Level 127.

Species	Cut Marks	Impacts
Capra pyrenaica		1
Cervus elaphus	4	4
M-L Size	3	1
Total	**7**	**6**

Post-depositional modifications

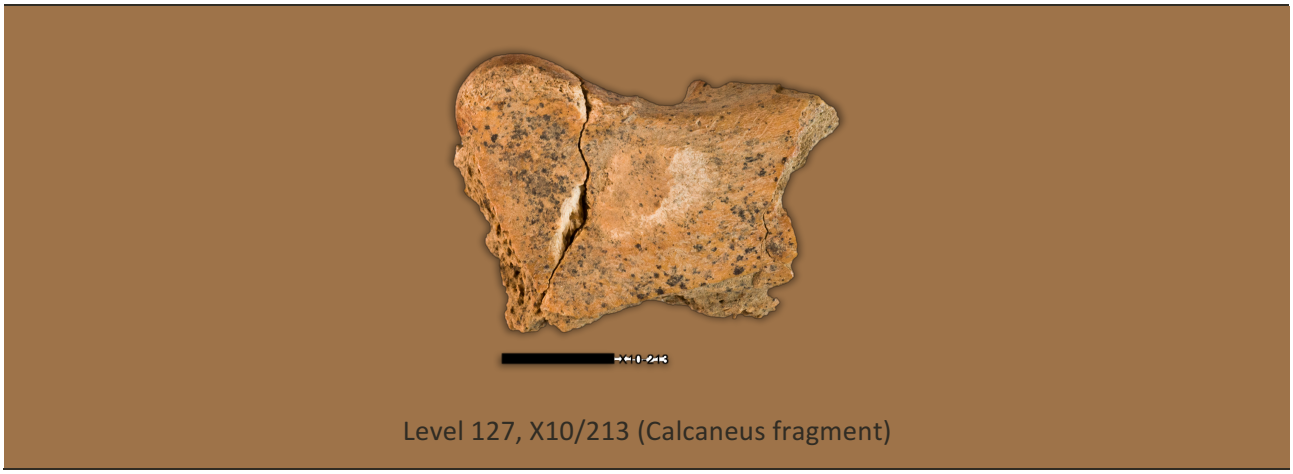
In Level 127 shows ibex only a slightly higher color index (meaning darker) than red deer, but both are generally similar in plotted post-depositional modifications, the low variability may be due to the small sample size or similar accumulation context.



Appendix Figure C.3.2: Color and Weathering Index, Level 127.

Level 127 – Summary

Minimum one adult red deer and ibex complemented by one juveniles of each ungulate species, two leporids and two birds were present in Level 127 fauna. Carnivore marks were found on ibex and bird remains. Leporid and bird remains were accumulated during warm season and ungulate fetal and infantile bones at the end of the cold season (spring-early summer), possible the result of small carnivore visitors to the cave. Cut marks concentrate on red deer adult bones indicating very short human visits to the cave possible for preparing red deer body parts for further transport. Defleshing and disarticulation marks were found (see Appendix Figure C.3.3), for example, on calcaneus representing Binford's cut marks pattern TC1 (BINFORD 1981). Diagenetic alterations are low with few manganese dendrites and good preservation similar to previous levels.



Level 127, X10/213 (Calcaneus fragment)

Appendix Figure C.3.3: Overview faunal material of Level 127.

Level 126 - Quantification

The total faunal remains registered are 946 bones and 36 teeth within Level 126, excavated in one square V10 (12-14). See **Appendix Table C.3.7**.

Appendix Table C.3.7**: Faunal quantification, Level 126.**

Species	NR	Weight	MNE	MNI
Capra pyrenaica	8	26.1	8	3
Rupicapra rupicapra	9	5.4	7	1
Cervus elaphus	14	43.9	5	2
Felis sp.	1	0.2	1	1
Birds	12	3	2	1
S Ungulate	9	13.9		
M Ungulate	5	6		
Indeterminate	924	650.4		
Total	**982**	**748.9**	**23**	**8**

Capra pyrenaica (Schinz, 1838)

Three lower, right M3 and I3 are heavily worn and belong to at least three adult individuals. Phalanx fragments are fused so that they also represent presumably an adult. See Appendix Table C.3.8.

Appendix Table C.3.8: Spanish ibex remains, Level 126.

Capra pyrenaica **(Level 126)**	NISP	MNE		MNI	
Element	All	All	adu	All	adu
Upper teeth	1	1		1	
Lower teeth	3	3	3	3	3
Phalanx med.	1	1		1	
Phalanx dist.	3	3		1	
Total	**8**	**8**	**3**	**3**	**3**

Rupicapra rupicapra (Linnaeus, 1758)

Every identified bone from chamois represent not more than one element and, thus, one individual is inferred.See Appendix Table C.3.9.

Appendix Table C.3.9: Chamois remains, Level 126.

***Rupicapra rupicapra* (Level 126)**	**NISP**	**MNE**	**MNI**
Element	All	All	All
Hyoid	1	1	1
Cervical vert.	1	1	1
Radius	1	1	1
Ulna	2	1	1
Metatarsus	1	1	1
Phalanx prox.	1	1	1
Phalanx med.	2	1	1
Total	**9**	**7**	**1**

Cervus elaphus (Linnaeus, 1758)

The massive root and the fully worn stage of a red deer incisor reveal minimum one adult or older individual. On the other hand, is a ramus fragment from a mandible porous in its structure in belong to a juvenile animal. See Appendix Table C.3.10.

Appendix Table C.3.10: Red deer remains, Level 126.

***Cervus elaphus* (Level 126)**	**NISP**	**MNE**			**MNI**		
Element	All	All	juv	adu	All	juv	adu
Antler	1				1		
Mandible	1	1	1		2	1	
Lower teeth	1			1	1		1
Cervical vert.	1				1		
Rib	1				1		
Humerus	1	1			1		
Carpal unit	1	1			1		
Femur	1	1			1		
Tibia	1	1			1		
Metatarsus	1				1		
Metapodial	1				1		
Phalanx dist.	1				1		
Sesamoid	2				1		
Total	**14**	**5**	**1**	**1**	**2**	**1**	**1**

Felis sp. (Linnaeus, 1758)

One proximal epiphyses, femur head, unfused was identified from *Felis* species.

Bird remains

One humerus were identified and many other long bone shaft fragments coming from bird.

Anatomically identified by size classes

From indeterminate medium sized ungulates were found: a cranium, a rib, a calcaneus and a distal part of a proximal phalanx. Different bones were identified from small ungulates, such are a cervical and thoracic vertebra, a proximal femur, two tarsal bones, a metapodial, a proximal and distal phalanx (from an infantile) and a sesamoid. Further vertebra, sternal, rib, long bone, teeth fragments and 22 fetal/neonate bones coming from indeterminate species. See Appendix Table C.3.11.

Appendix Table C.3.11: Faunal remains by size classes, Level 126. *=NR.

Size classes (Level 126)	M Ungulate	S Ungulate	Indeterminate
Bone	NISP	NISP	NISP
Cranium	1		
Teeth			31
Cervical vert.		1	
Thoracic vert.		1	
Rib	2		17
Sternum			4
Indet. vert.			11
Femur		1	
Calcaneus	1		
Tarsal unit		2	
Metapodia		1	
Phalanx prox.	1	1	
Phalanx dist.		1	
Sesamoid		1	
Long bone			127
Spongy bone			646*
Indeterminate			88*
Total	5	9	924

Seasonality

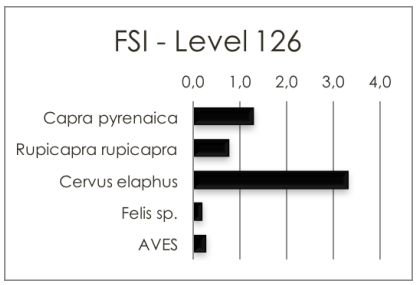
Ungulate fetal bones indicating a death of the mother animals during gestation period in winter-spring.

Level 126 - Taphonomy

Faunal preservation

Level 126 only contains a few complete bones: a complete M3 and distal phalanx from ibex, a complete incisor, *carpale secundum et tertium* and sesamoid from red deer as well as a tarsal and sesamoid from a small ungulate.

The largest size fragments belong to red deer, ibex and chamois fragments are one third smaller and bird and Felis sp. remains are the smallest.



Appendix Figure C.3.4: Fragment Size Index (FSI) variation among species, Level 126.

Appendix Table C.3.12 summarized the observed breakage pattern. The fracture pattern in Level 126 is dominated by indeterminate fractures although the sample size is quite small. When it was possible to determine the fracture type, they were fresh fractures.

Appendix Table C.3.12: Breakage pattern, Level 126 (only bones identified taxonomically or in animal size classes).

Breakage- profile	NISP	%NISP
Green fracture	53	54.6
Indeterminate	44	45.4
Total	**97**	**100**

Non-Human Biological Agents

Carnivore marks are represented on ten bones, all of which are digestion marks, some on chamois phalanges. These bones are coming form square V10, spits 12,13 and 14. The digestion pattern is very similar and might mirror bearded vulture activities.

Human activities

The general preservation of bones is good within Level 126, where it was possible to identify cut marks (3%) and impact marks (21%) as direct human activities. Cut marks are located on a cranium fragment (square V10, spit 12) and a small ungulate thoracic vertebra along the spinal process, this bone has also burning marks (V10, spit 14). Burnt bones were found in square V10, spit 12, 13 and 14. Bone flakes are coming from square V10, spit 12 and 14.

Human-carnivore interactions

In Level 126 were anthropogenically modified specimens found on ibex, red deer and small/medium ungulate remains. Carnivore activities are mainly recognized on chamois and indeterminate bone fragments. See Appendix Table C.3.13.

Appendix Table C.3.13: Number of specimen with anthropogenic vs. carnivore modifications from Level 126.

Species	Anthropogenic	Carnivore
Capra pyrenaica	1	
Rupicapra rupicapra		2
Cervus elaphus	2	1
S Ungulate	4	
M Ungulate	1	
Indeterminate	46	8
Total:65 (100%NR)	**54 (83.1%NR)**	**11 (16.9%NR)**

Level 126 – Summary

Level 126 is a rather small assemblage. Three adult ibex, chamois, and one red deer. Carnivore digestion marks on chamois, possible bearded vulture, but a small felid was also identified, which however is not responsible for the digestion marks. Red deer and ibex were transported to the cave, butchered and long bones were cracked open by humans and possible consumption as burning marks indicate roasting activities.

Level 125 - Quantification

In total were identified 4850 bones and 91 teeth within Level 125, excavated in the two squares U10 (60) and V10 (11). See Appendix Table C.3.14.

Appendix Table C.3.14: Faunal quantification, Level 125.

Species	NR	Weight	MNE	MNI
Capra pyrenaica	97	99.9	55	4
Rupicapra rupicapra	5	11.8	4	2
Cervus elaphus	68	115.6	36	4
Lepus sp.	1	0.1	1	1
Birds	4	0.5	2	1
Amphibia	1	0.1	1	1
Fish	1	0.1	1	1
S Ungulate	10	4.1		
M Ungulate	62	30.4		
L Ungulate	3	7.2		
S Carnivore (fox size)	1	1.5		
S-M Size	14	23.5		
M-L Size	4	10.5		
Indeterminate	4671	1782.6		
Total	**4942**	**2087.9**	**100**	**14**

Capra pyrenaica (Schinz, 1838)

Spanish ibex upper and lower teeth represented adult animals, despite one complete lower dP4 (HC= 7,49mm) from a juvenile. A porous mandible has a size of a neonate. A distal metapodial epiphyseal is unfused and from a juvenile animal not older than two years. See Appendix Table C.3.15.

Appendix Table C.3.15: Spanish ibex remains, Level 125.

Capra pyrenaica (Level 125)	NISP	MNE					MNI				
Bone	All	All	fet	neo	juv	adu	All	fet	inf	juv	adu
Horn	5	1					1				
Cranium	1	1					1				
Upper teeth	5	2			1	1	2			1	1
Mandible	7	3		1		2	2		1		1
Lower teeth	11	4			2	2	2			1	1
Thoracic vert.	2	2					1				
Rib	1	1					1				
Lumbar vert.	1	1					1				
Caudal vert.	1	1					1				
Indet. vert.	1	1					1				
Humerus	1	1					1				
Radius	3	1					1				
Ulna	1	1					1				
Carpal unit	2	2					1				
Pelvis	1	1					1				
Femur	8	2			1	1	2			1	1
Tibia	1	1					1				

Calcaneus	1	1					1				
Tarsal unit	1	1					1				
Metacarpus	2	1					1				
Metapodia	2	2			1	1	2			1	1
Phalanx prox.	19	7			4	3	2			1	1
Phalanx med.	12	10				1	1				1
Phalanx dist.	5	5	1			4	2	1			1
Sesamoid	2	2					1				
Long bone	1						1				
Total	97	55	1	1	9	15	4	1	1	1	1

Rupicapra rupicapra (Linnaeus, 1758)

Two calcaneus fragments represented include each an articulating phase, one proximal and one distal. A carpus radial fragment is complete, but porous in its structure presumably comes from a young animal. See Appendix Table C.3.16.

Appendix Table C.3.16: Chamois remains, Level 125.

Rupicapra rupicapra (Level 125)	NISP	MNE			MNI		
Element	All	All	juv	adu	All	juv	adu
Upper teeth	1	1		1	1		1
Carpal unit	1	1	1		1	1	
Tibia	1	1		1	1		1
Calcaneus	2	1			1		
Total	5	4	1	2	2	1	1

Cervus elaphus (Linnaeus, 1758)

A lower I3 is an unworn deciduous tooth from an infantile individual. A porous metacarpal shaft fragment belongs to a young animal. See Appendix Table C.3.17.

Appendix Table C.3.17: Red deer remains, Level 125.

Cervus elaphus (Level 125)	NISP	MNE					MNI				
Element	All	All	fet	inf	juv	adu	All	fet	inf	juv	adu
Antler	11	1					1				
Upper teeth	2	2		1		1	1		1		1
Mandible	4	2			1	1	1			1	1
Lower teeth	5	3		2		1	1		1		1
Hyoid	1	1					1				
Rib	1	1					1				
Caudal vert.	1	1					1				
Humerus	4	1				1	1				1
Radius	3	1			1		1			1	
Ulna	1	1					1				
Femur	8	2			1	1	1			1	1
Patella	1	1					1				
Tibia	1	1					1				

Talus	1	1					1				
Calcaneus	1	1					1				
Tarsal unit	1	1					1				
Metacarpus	7	2			1	1	1			1	1
Metatarsus	2	1			1		1			1	
Metapodial	1	1					1				
Meta. atro.	1	1					1				
Phalanx prox.	2	2					1				
Phalanx dist.	3	2	1				1	1			
Phalanx atro.	4	4					1				
Sesamoid	1	1					1				
Long bone	1	1					1				
Total	68	36	1	3	5	6	4	1	1	1	1

Lagomorph remains

A vertebra fragment with an articulating phase and fragments of the arch was identified coming from a leporid.

Bird remains

Three shaft fragments belong to a long bone from a bird according to its distinctive trabecular structure. The distal articulating phase from a proximal phalanx of a large sized bird (possibly vulture) was identified. See Appendix Figure C.3.8- mid photograph, where the bird phalanx shows sawing marks.

Amphibian remains

A pelvis fragment presumably represents a frog or toad.

Fish remains

A vertebra fragment was identified as coming from a fish.

Anatomically identified by size classes

Two femur fragments present a small- to medium- size animal, while one of them belongs to a fetal individual. One long bone from a small- to medium -size animal fragment is fusing. One tibia fragment from a small carnivore was identified. See Appendix Table C.3.18.

Appendix Table C.3.18: Faunal remains by size classes, Level 125. *=NR.

Size classes (Level 125)	L Ungulate	M Ungulate	M-L Size	S-M Size	S Ungulate	Indeterminate
Bone	NISP	NISP	NISP	NISP	NISP	NISP
Cranium		6		1		
Viscerocranium		2				
Mandible		1				
Teeth						66
Hyoid				1		
Cervical vert.		4				
Thoracic vert.	1	1		1	1	
Rib		2		1		56
Sternum		1				2

Lumbar vert.		3		1		
Caudal vert.				1		
Indet. vert.		2				48
Scapula		1				
Humerus		1	1			
Radius					1	
Ulna		2				
Pelvis		3				
Femur		1		2	1	
Patella						
Tibia		3			2	
Metapodial				1		
Meta. atro.						
Phalanx prox.					1	
Phalanx med.					1	
Sesamoid				1	1	
Humerus-Femur		2				
Long bone	1	27	2	3	1	355
Flat bone		1		1		
Irregular bone	1		1			
Spongy bone						3607*
Indeterminate					1	
Total	3	63	4	14	10	4134

Seasonality

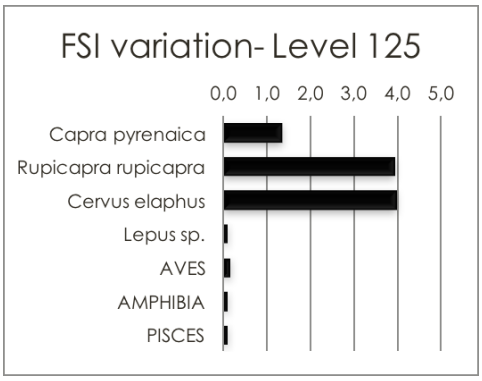
A complete lower left dP4 from Spanish ibex shows the beginning of root absorption just before displacement of the tooth, which occur root with 18-20 months of age, resampling the second autumn-winter of the animal.

Level 125 - Taphonomy

Faunal preservation

In Level 125 there are three complete teeth: one upper P3, a lower dP4 from Spanish ibex and a lower I3 from red deer. A complete carpal bone from chamois is preserved. The other complete bones are all feet bones, including two atrophic phalanges from red deer and two sesamoids.

The fragments that were identified as coming from red deer are the largest ones in size. Despite its smaller body size, the chamois remains are larger than the ibex ones in Level 125.



Appendix Figure C.3.5: Fragment Size Index (FSI) variation among species in Level 125.

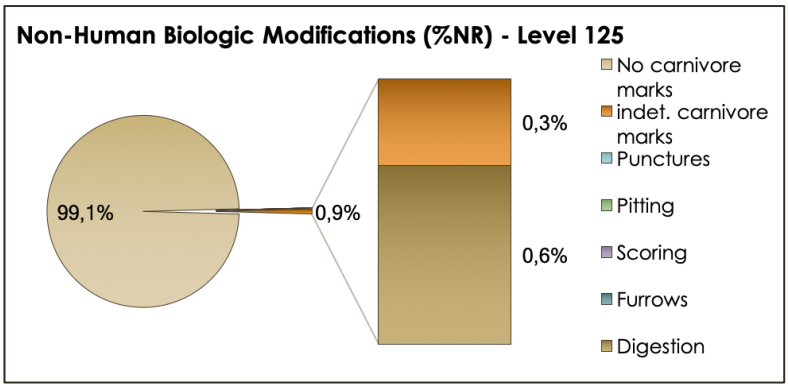
Appendix Table C.3.19 summarized the observed breakage pattern. The faunal assemblage from Level 125 is dominated by green fractures, which are followed by recent fractures. This taphonomic pattern implies good preservation conditions within the sediments and a highly biostratinomic modified bone assemblage.

Appendix Table C.3.19: Breakage pattern, Level 125 (only bones identified taxonomically or in animal size classes).

Breakage- profile	NISP	%NISP
Green fracture	324	69.1
Green and dry fracture	5	1.1
Dry fracture	3	0.6
Green and recent	2	0.4
Recent fracture	11	2.3
Indeterminate	124	26.4
Total	**469**	**100**

Non-Human Biological Agents

Three carnivore-digested feet elements were found in Level 125, which were an atrophic and distal phalanx from red deer and a proximal phalanx from Spanish ibex. The digestion marks seem to be similar to what is characteristic of bearded vulture activity, but generally the sample includes few carnivore marks (0.9%NR) of indeterminate origin. Digested bones were found in square U10 spit 60 and V10 spit 11.



Appendix Figure C.3.6: Carnivore activities observed in Level 125.

Human activities

This level is the second one to yield bone artifacts within the stratigraphic sequence from El Mirón cave. Cut marks are located on cranial and mandible bones, vertebrae, femur, tibia, ulna, long bone fragments, phalanges and on antler as they represent intentional working of this raw material (Appendix Table C.3.20). Impact marks are found generally on the same elements as the cut marks despite the antler remains. One long bone fragment from a medium to large sized animal shows the first level of burning marks that might imply rather roasting and consumption than being used as fuel. In summary, these anthropogenic marks are all identified in spit 60 in square U10. Level 125 represents a rather short human occupation with evidence of carcass processing activities and roasting.

Appendix Table C.3.20: Number of specimen with anthropogenic modifications in Level 125.

Species	Cut marks	Impacts	Burning
Capra pyrenaica	5	5	
Cervus elaphus	4	5	
Birds	1		
S Ungulate	1		
M Ungulate	9	2	
L Ungulate	1	1	
S-M Size	4	3	
M-L Size	2	1	2
Indeterminate	1	224	250
Total	28	241	252

Human-carnivore interactions

The percentual amount of direct anthropogenic modifications (87.2%) among the individually registered bones presumably implies short, but human dominated activities as the carnivore influence on the assemblage seems to be low (Appendix Table C.3.21).

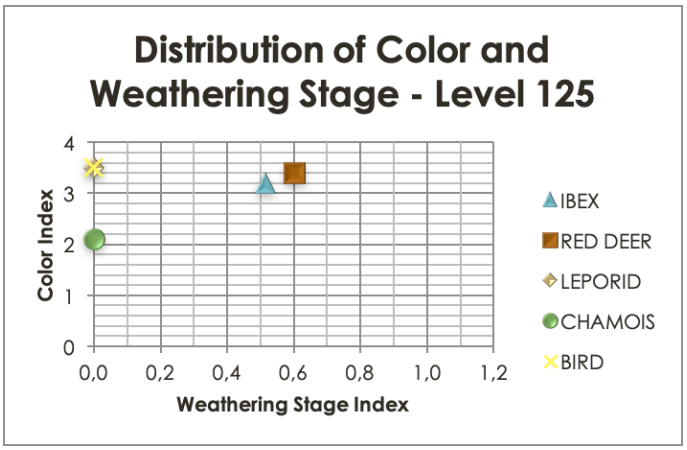
Appendix Table C.3.21: Anthropogenic vs. carnivore marks on bones and teeth from Level 125.

Species	Anthropogenic	Carnivore
Capra pyrenaica	21	2
Cervus elaphus	20	2
Birds	1	
S Ungulate	2	
M Ungulate	15	1
L Ungulate	1	
S-M Size	5	
M-L Size	4	
Indeterminate	225	38
Total: 337 (100%)	294 (87.2%)	43 (12.8%)

Post-depositional modifications

Red deer and Spanish ibex show very similar weathering and color patterns within Level 125 as hare and bird bones do, but without weathering marks. Chamois bones show a distinctive lower color index compared to the other species identified. Considering that they represent a MNI of one juvenile, it might be implied that somehow different accumulations or conservation conditions worked for these bones, for example might

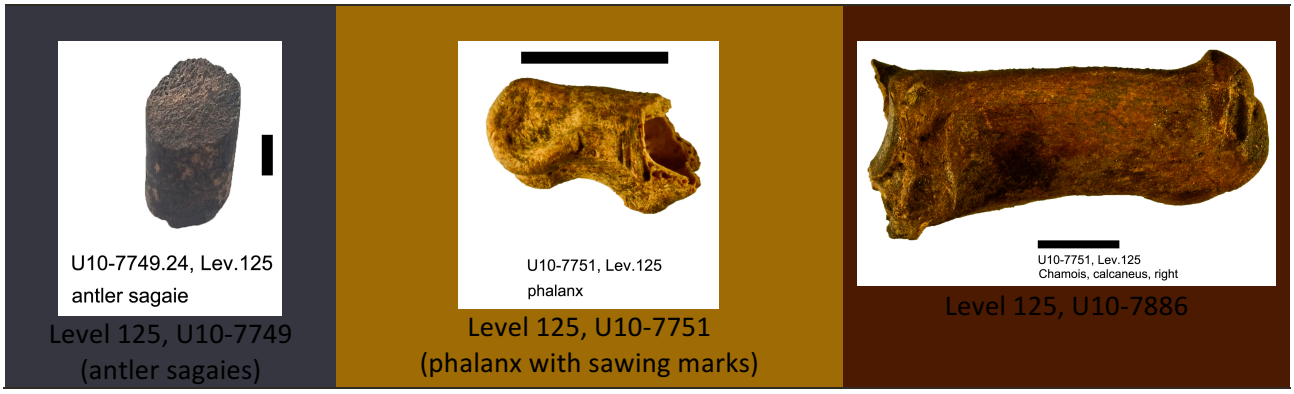
diagenetic processes act differently to the bone structure of a young individual or the accumulation context was time-shifted.



Appendix Figure C.3.7: Color and Weathering Index, Level 125.

Level 125 - Summary

The minimum number of individuals in Level 125 increase remarkable with four red deer four ibex, and two chamois, but mainly due to higher incorporation of young animals, and not necessarily in biomass. The very few carnivore marks found seem to be the results of limited vulture presence at site due to their pattern of digestion. There cave occupation might be interrupted as a possible vulture phalanx show human sawing marks on the lateral bone shaft. Level 125 represents a rather short human occupation with evidence of carcass processing activities and roasting, as well as antler working and possible production of antler weaponry as round sectioned antler sagaies fragments were found, Appendix Figure C.3.8- left. Similar color index of red deer, ibex, leporids and bird could speak for a rather contemporary accumulation of animal remnants and the general diagenetic preservation of the faunal assemblage is good.



Appendix Figure C.3.8: Overview faunal material of Level 125.

Level 124 - Quantification

In total were identified 3575bones and 75 teeth within Level 124, excavated in the two squares U10 (58,59) and V10 (9,10). See Appendix Table C.3.22.

Appendix Table C.3.22: Faunal quantification, Level 124.

Species	NISP	Weight	MNE	MNI
Equus ferus	1	4.9	1	1
Capra pyrenaica	59	112.6	28	4
Rupicapra rupicapra	10	11.4	10	3
Cervus elaphus	59	105	29	3
Lepus sp.	3	3.5	3	1
Birds	2	0.8	2	1
S Ungulate	19	10.8		
M Ungulate	58	74.1		
L Ungulate	3	9.7		
S-M Size	15	39.4		
M-L Size	5	23.6		
Indeterminate	3416	1235.1		
Total	**3650**	**1630.9**	**73**	**13**

Equus ferus (Boddaert, 1785)

A metapodial shaft fragment from a horse was found.

Capra pyrenaica (Schinz, 1838)

One upper P2 and M2 as well as one lower P2 with massive roots indicate an adult individual. The Ulna fragment found is a porous bone and probably belongs to a young animal. Some fully-grown metapodial fragments have been identified, next to two very porous one presumably coming from a fetal (or neonate) baby Spanish ibex. The proximal epiphysis of the first and second phalanx identified is not fused from a juvenile animal. At least an older animal is present by a fused second phalanx and a further developed third phalanx. See Appendix Table C.3.23.

Appendix Table C.3.23: Spanish ibex remains, Level 124.

Capra pyrenaica (Level 124)	NISP	MNE					MNI				
Bone	**All**	**All**	fet	neo	juv	adu	**All**	fet	inf	juv	adu
Horn	**1**										
Cranium	**1**										
Upper teeth	**6**	**2**				2	**1**				1
Mandible	**3**	**2**					**1**				
Lower teeth	**5**	**1**				1	**1**				1
Teeth	**1**	**1**					**1**				
Cervical vert.	**1**	**1**					**1**				
Rib	**2**	**1**					**1**				
Humerus	**2**	**1**					**1**				
Radius	**7**	**2**				1	**1**				1
Ulna	**1**	**1**			1		**1**			1	
Carpal unit	**2**	**2**					**1**				
Femur	**4**	**1**					**1**				
Tibia	**1**	**1**					**1**				
Calcaneus	**1**	**1**					**1**				
Tarsal unit	**1**	**1**					**1**				
Metacarpus	**3**	**2**	1			1	**2**	1			1

Metapodial	**2**		1					1				
Phalanx prox.	**4**	**1**			1		**1**				1	
Phalanx med.	**3**	**2**		1	1	1	**2**		1		1	1
Phalanx dist.	**6**	**4**			1	1	**1**				1	1
Sesamoid	**1**	**1**					**1**					
Long bone	**1**											
Total	**59**	**28**	2	1	4	7	**4**	1	1		1	1

Rupicapra rupicapra (Linnaeus, 1758)

One upper milk molar dP3 were identified showing beginning use wear indicating therefore an infantile individual. One lower I1 is heavily worn and has a massive root representing an adult or old individual. A complete lower I3 is unworn, but already contains a root, meaning this tooth might origin from a juvenile. Also from a juvenile is a proximal phalanx in a fusing stage present. A medial phalanx is fused, but digested in a way similar of which is characteristic of vulture activity. Two distal phalanges are also present. See Appendix Table C.3.24.

Appendix Table C.3.24: Chamois remains, Level 124.

Rupicapra rupicapra (Level 124)	NISP	MNE				MNI			
Element	All	All	inf	juv	adu	All	inf	juv	adu
Upper teeth	1	1	1			1	1		
Lower teeth	2	2			1	1			1
Radius	1	1				1			
Carpal unit	1	1				1			
Tarsals unit	1	1				1			
Phalanx prox.	1	1		1		1		1	
Phalanx med.	1	1				1			
Phalanx dist.	2	2				1			
Total	10	10	1	1	1	3	1	1	1

Cervus elaphus (Linnaeus, 1758)

The proximal and medial phalanges are fused, meaning one individual was at least over 20 months. The other specimen, however, represent an infant individual (upper dP2, lower dI2) and two small, porous third phalanges are from a minimum of one fetal animal. See Appendix Table C.3.25.

Appendix Table C.3.25: Red deer remains, Level 124.

Cervus elaphus (Level 124)	NISP	MNE				MNI			
Element	All	All	fet	inf	adu	All	fet	inf	adu
Antler	5								
Upper teeth	2	1		1		1		1	
Mandible	1	1				1			
Lower teeth	3	3		1	2	1		1	1
Cervical vert.	2	1			1	1			1
Rib	2	1				1			
Lumbar vert.	1	1				1			
Humerus	2	1				1			
Radius	4	1				1			
Carpal unit	1	1				1			

Femur	5	1			1	1				1
Tibia	3	1			1	1				1
Calcaneus	1	1				1				
Tarsal unit	2	1				1				
Metacarpus	3	1				1				
Metatarsus	6	1		1		1			1	
Metapodial	1			1					1	
Phalanx prox.	4	2				1				
Phalanx med.	1	1				1				
Phalanx dist.	3	2	2			1	1			
Phalanx atro.	3	3				1				
Sesamoid	4	4				1				
Total	59	29	2	4	5	3	1	1	1	

Lagomorph remains

A pelvis fragment from *Lepus sp.* was identified including parts of the illium, ischium and acetabulum and two long bone fragments.

Bird remains

A humerus and a rib from a bird has been identified.

Anatomically identified by size classes

Three long bone metaphysis from medium sized ungulate are unfused and indicate young animals and another small shaft fragment belong to a neonate. A tibia shaft fragment with the nutritional canal is from a small ungulate fetal animal. Two unfused vertebrae coming come from small to medium sized ungulate. See Appendix Table C.3.26.

Appendix Table C.3.26: Faunal remains by size classes, Level 124. *=NR.

Size classes (Level 124)	L Ungulate	M Ungulate	M-L Size	S-M Size	S Ungulate	Indeterminate
Bone	NISP	NISP	NISP	NISP	NISP	NISP
Cranium		11				
Mandible				1		
Teeth						55
Cervical vert.		2				
Thoracic vert.				1		
Rib	2	5	1	1	1	39
Lumbar vert.		2	1	2		
Caudal vert.				1		
Indet. vert.		4		2		52
Scapula		1				
Humerus		1				
Radius		1				
Pelvis		1				
Femur		2			4	
Patella					1	
Tibia		2			2	1
Calcaneus					1	
Tarsal unit				1	1	

Metatarsus				1	1	
Metapodial		2			1	
Phalanx prox.		1			1	
Phalanx dist.					2	
Sesamoid					2	
Humerus-Femur		1		1		
Long bone	1	20	2	4	2	322
Flat bone		1	1			
Spongy bone						2568
Indeterminate		1				379*
Total	3	58	5	15	19	3416

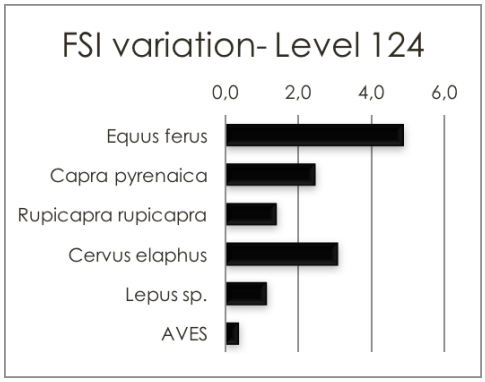
Level 124 - Seasonality

Red deer was killed in winter-spring and ibex during summer-autumn.

Level 124 - Taphonomy

Faunal preservation

The fragment size recognized seem to correlate with animal size; thus, the largest fragments come from the largest animals and the smallest fragments from the smallest animals. Spanish ibex remains are larger than in the other levels.



Appendix Figure C.3.9: Fragment Size Index (FSI) variation among species in Level 124.

Level 124 contains 18 complete skeletal elements and the body parts of the head and feet as the most complete bones preserved. Complete teeth identified from Spanish ibex are one upper P2, M2, and a lower P2, from chamois are two lower incisor and a milk incisor (dI2) from red deer. Complete bones recognized from ibex are two carpals, one phalanx and sesamoid. Chamois only represent a complete phalanx bone and red deer one tarsal, one phalanx and two sesamoids.

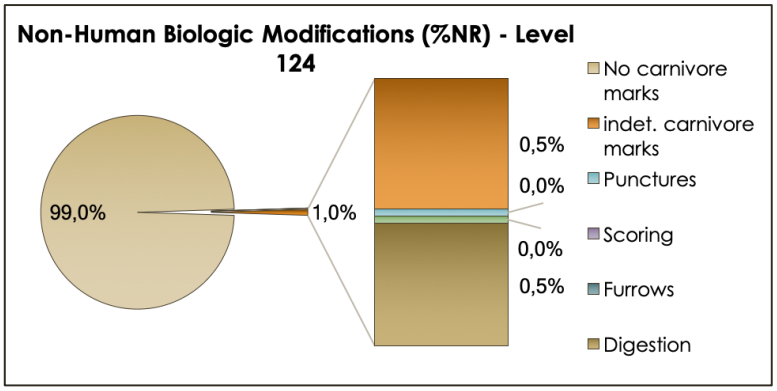
Appendix Table C.3.27 summarized the observed breakage pattern. Green fractures dominate the breakage pattern, next to indeterminate ones, of the studied faunal remains from Level 124 and indicate there with high biostratinomic activities involved into the accumulation processes of this assemblage that cracked bones open when they were still fresh.

Appendix Table C.3.27: Breakage pattern, Level 124 (only bones identified taxonomically or in animal size classes).

Breakage- profile	NISP	%NISP
Green fracture	299	72.6
Green and dry fracture	1	0.2
Green fracture, two phases	1	0.2
Dry fracture	4	1.0
Recent fracture	6	1.5
Indeterminate	101	24.5
Total	**412**	**100**

Non-Human Biological Agents

Carnivore marks are sparsely represented; most bones show digestions marks. One of the digested bones is a distal phalanx from chamois that shows not much digestion marks on the articulating face, which seems to be similar to bearded vulture activities described as digestion code 34 in Marín-Arroyo (2010: p. 415). The other one is a digested knee bone from a small ungulate. On a hare bone were found several cut marks but also pitting form a small carnivore. A cervical vertebra from red deer shows punctures. These carnivore marks are found in square U10 in spit 58/59 and V10 spit 9/10.



Appendix Figure C.3.10: Carnivore activities observed in Level 124.

Human activities

Level 124 anthropogenic modifications show more impact than cut marks (Appendix Table C.3.28). Cut marks are located on all body parts with 71% on long bones. Cut marked elements are located in square U10 in spit 58 (62.5%) and 59 (37.5%) and concentrate in subsquares B (37.5%) and C (29.2%). Regularly were found direct impact notches (N=30) among the open cracked bones, which are located in square U10 in spit 58 (56.2%) and in spit 59 (43,8%) and these dominate in the same subsquares B and C. Burning and artifacts are far more seldom present, with five items per category. The first category shows three gradations of burning: reddish- roasted (20%), partially (60%) and complete carbonized (20%). The carbonized bones were found in square U10, spit 58 in subsquare C and the roasted one in subsquare B in the same spit and square. Bone artifacts comprise two bone flakes (square U10-B, spit 58 and 59), two points (an antler *sagaie* in U10-B-spit 59 and a bone point in U10-D-spit 59) and the above -mentioned roasted bone show some kind of use-wear as tools used for some not yet specified activity/ies.

Appendix Table C.3.28: Number of specimen with anthropogenic modifications in Level 124.

Species	Cut Marks	Impacts	Burning
Capra pyrenaica	14	9	1
Rupicapra rupicapra	2	1	
Cervus elaphus	6	6	3
Lepus sp.	1		
S Ungulate	1	3	2
M Ungulate	9	5	
L Ungulate		2	
S-M Size	5	5	
M-L Size		1	1
Indeterminate	1	206	130
Total	**39**	**238**	**137**

Human-carnivore interactions

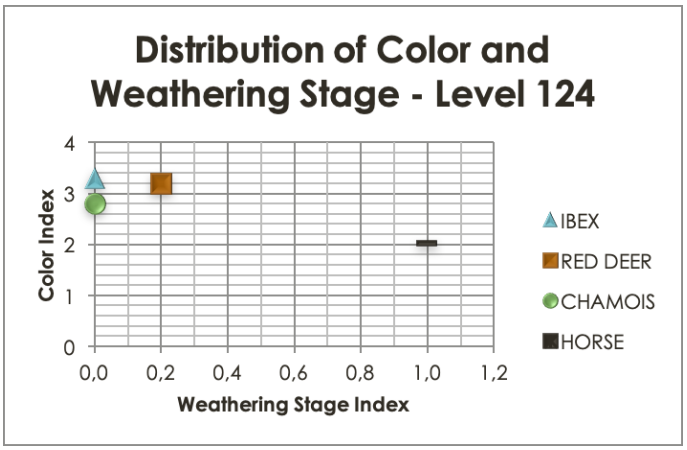
Anthropogenic modifications identified on bones were found in 88.8% of the studied fauna, indicating a clear trend towards a human-made accumulation of the animal remains found in Level 124 (Appendix Table C.3.29). Carnivore activities are only registered for 11.2% of the bones and also 0.6% of the assemblage shows an overlap of marks of both possible accumulation agents with human access occurring first. Most of the bones, though, do not show direct modification marks.

Appendix Table C.3.29: Anthropogenic vs. carnivore modifications on specimen from Level 124.

Species	Anthropogenic	Carnivore	Both
Capra pyrenaica	21	1	
Rupicapra rupicapra	3	1	
Cervus elaphus	15	1	1
Lepus sp.			1
S Ungulate	7	1	
M Ungulate	13		
L Ungulate	2		
S-M Size	7		
M-L Size	2		
Indeterminate	207	31	
Total: 316 (100%)	**277 (88.8%)**	**35 (11.2%)**	**2 (0.6%)**

Post-depositional modifications

In Level 124 the most represented species are Spanish ibex, red deer and chamois, with a quite similar diagenetic pattern of low weathering stages and advanced degrees of manganese coating phenomena. The horse is of set apart by its characteristic of a slightly more advanced weathering stage and lower degree of coating, which might be explained with this is the only bone identified compared to the other indices representing average values of more bones. Together these bones really present the taphonomic profile of an undisturbed assemblage.



Appendix Figure C.3.11: Color and Weathering Index, Level 124.

Level 124 – Summary

Overview photographs (**Appendix Figure C.1.5**) show diagenetic preservation of the faunal assemblage from Level 124.



Appendix Figure C.3.12: Overview faunal material of Level 130.

Level 123 - Quantification

In Level 123 were in total identified 377 bone fragments and only 4 teeth. The level has a relatively low density and was only excavated in one square V10(8), which was for some further statistical analysis not sufficient and were therefore excluded. The number of faunal remains are summarized in Appendix Table C.3.30.

Appendix Table C.3.30: Faunal quantification, Level 123.

Species	NISP	Weight (gram)	MNE	MNI
Capra pyrenaica	12	9.9	10	1
Rupicapra rupicapra	2		2	1
Cervus elaphus	7	9.6	3	1
Vulpes vulpes	1	0.2	1	1
S Ungulate	2	0.2		
M Ungulate	13	2.6		
Indeterminate	344	110.7		
Total	**381**	**133.2**	**16**	**4**

Capra pyrenaica (Schinz, 1838)

One lower P4 with massive roots indicate one adult individual and other fragments are fully grown. See Appendix Table C.3.31.

Appendix Table C.3.31: Spanish ibex remains, Level 123.

Capra pyrenaica (Level 123)	NISP	MNE		MNI	
Element	All	All	adu	All	adu
Lower teeth	2	1	1	1	1
Rib	1	1		1	
Humerus	1	1		1	
Carpal unit	1	1		1	
Metacarpus	1	1		1	
Phalanx prox.	3	2		1	
Phalanx med.	1	1		1	
Sesamoid	2	2		1	
Total	12	10	1	1	1

Rupicapra rupicapra (Linnaeus, 1758)

One lower M1 from a young animal and a humerus shaft with a nutritional canal was identified from chamois.

Cervus elaphus (Linnaeus, 1758)

The proximal and medial phalanges are fused, meaning one individual was at least over 20 months. The other specimen, however, represent an infant individual (upper dP2, lower dI2) and two small, porous third phalanges are from a minimum of one fetal animal. See Appendix Table C.3.32.

Appendix Table C.3.32: Red deer remains, Level 123.

Cervus elaphus (Level 123)	NISP	MNE	MNI
Bone	All	All	All
Antler	1		
Femur	2	1	1
Tibia	1	1	1
Metatarsus	3	1	1
Total	7	3	1

Vulpes vulpes (Linnaeus, 1758)

One complete, left carpal from a fox was identified.

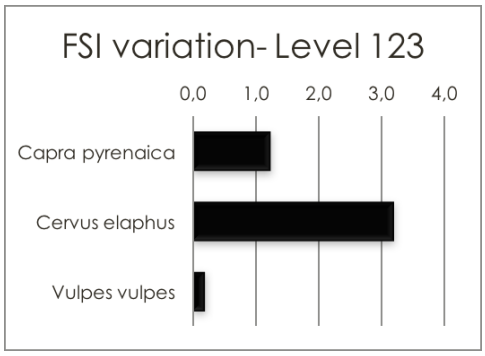
Anatomically identified by size classes

From medium sized ungulates were identified a humerus shaft, a epistropheus, two ribs and nine long bone fragments. A hyoid and another long bone fragment were found from a small sized ungulate. Elements from an indeterminate species are one tooth, 18 long bone shafts, six vertebrae, nine ribs, one sternum, 286 spongy bones and 23 indeterminate fragments.

Level 123 - Taphonomy

Faunal preservation

Level 123 contains complete skeletal elements from an ibex carpal bone, two ibex sesamoids and one fox carpal bone. Red deer remains seem to have a similar fragmentation degree than in previous levels such are older than Level 124, but ibex remains are smaller. Breakage pattern. Level 123 is a small sample, but including green fractures (50% and indeterminate the other 50%) when determinable that indicate biological agents were involved into the accumulation processes of this assemblage.



Appendix Figure C.3.13: Fragment Size Index (FSI) variation among species in Level 124.

Human activities

Level 123 anthropogenic modifications are generally sparse (Appendix Table C.3.33), but dominant. Anthropogenic modifications are located on ibex, chamois, red deer, medium sized ungulates and indeterminate specimen. Carnivore marks on bones have not been identified within Level 123.

Appendix Table C.3.33: Number of specimen with anthropogenic modifications in Level 123.

Species	Cut marks	Impacts	Burning
Cervus elaphus			1
M Ungulate	1		
Indeterminate		15	8
Total	**1**	**15**	**9**

Diagenetic alterations are also limited, with bones showing no or only the first weathering stage (W1).

Level 123 – Summary

Level 123 is a small sample possible itself the fillings of a hearth ((STRAUS ET AL. 2013)), however shows it the typical prey species red deer, ibex, and chamois accompanied with fox remains. Cut marks indicate human being mainly involved in the accumulation, in absence of carnivore marks.

Level 122 – Quantification

Level 122 is a comparable rich faunal assemblage with fragments of 6261 bones and 112 teeth, excavated in the two squares U10 (54-57) and V10 (7). See Appendix Table C.3.34.

Appendix Table C.3.34: Faunal quantification, Level 122.

Species	NISP	Weight	MNE	MNI
Bos/Bison	2	7.2	1	1
Capra pyrenaica	107	280.1	58	5
Rupicapra rupicapra	19	7.8	10	2
Cervus elaphus	106	580	54	3
Birds	3	1	3	1
Fish	2	0.1	1	1
S Ungulate	23	16		
M Ungulate	40	36		
L Ungulate	3	15.7		
XS Size	1	0.9		
S-M Size	23	44.8		
M-L Size	81	305.8		
Indeterminate	5961	2640.8		
Total	**6371**	**3936.2**	**127**	**13**

Bos/Bison

A cervical vertebra was identified from a Bison.

Capra pyrenaica (Schinz, 1838)

Two right upper P2, one P4 and one M1 are fully or heavily worn, all indicating minimum two old/mature individuals. Among the lower teeth were found a complete right milk tooth dP4 (crown height= 9,24mm) as well as a heavily worn P3, indicating minimum of one juvenile and one adult animal. A thoracic vertebra was identified in an unfused stage. Minima of a right and a left humerus were registered, while a fused distal part of this bone indicates an animal of late juvenile or older age. Two proximal femur epiphyses are unfused (fusing at 23-84 months). The distal tibia is represented in a fused (1x) as well as in an unfused (3x) stage, which indicate animals over 24 months and with less than 19 months, respectively. Tarsal bones comprise two fetal ones (one right and left) and two right *t.centroquartale*, which indicate together a minimum of three animals. A distal phalange was identified coming from a fetal individual. See Appendix Table C.3.35.

Appendix Table C.3.35: Spanish ibex remains, Level 122.

Capra pyrenaica (Level 122)	NISP	MNE				MNI			
Element	All	All	fet	juv	adu	All	fet	juv	adu
Upper teeth	7	3		1	2	3		1	2
Mandible	3	2*				1			
Lower teeth	11	3		1	2	2		1	1
Teeth	1								
Cervical vert.	2	1				1			
Thoracic vert.	2	1				1			
Rib	2	1				1			
Humerus	6	2				1			
Radius	3	2*				1			
Ulna-Radius	2	2				1			
Carpal unit	3	3				1			
Pelvis	3	1				1			
Femur	5	2				1			

Tibia	9	4		3	1	3		2	1
Talus	1	1				1			
Calcaneus	1	1				1			
Tarsal unit	6	4	2			3	1		
Metacarpus	3	1				1			
Metatarsus	3	2				1			
Metapodia	3	1				1			
Phalanx prox.	12	9				2			
Phalanx med.	7	4		1		1			
Phalanx dist.	2	2	1			1	1		
Sesamoid	9	9				1			
Humerus-Femur	1	1							
Total	107	58	3	6	5	5	1	2	2

Rupicapra rupicapra (Linnaeus, 1758)

Chamois is represented by a complete *carpale ulnare* and two complete fetal third phalanges. See Appendix Table C.3.36.

Appendix Table C.3.36: Chamois remains, Level 122.

Rupicapra rupicapra (Level 122)	NISP	MNE			MNI		
Element	All	All	fet	adu	All	fet	adu
Lower teeth	4	1		1	1		1
Hyoid	1	1			1		
Cervical vert.	1	1			1		
Carpal unit	1	1			1		
Tibia	2	1		1	1		1
Tarsal unit	3						
Phalanx prox.	2	2	1		1	1	
Phalanx dist.	3	3	2		1	1	
Phalanx indet.	1				1		
Sesamoid	1				1		
Total	19	10	2	1	2	1	1

Cervus elaphus (Linnaeus, 1758)

An upper left P2 and molar (*min 1 mature) as well as a lower left molar showing massive roots with secondary dentin formed and advanced abrasions without enamel inside the occlusal face indicating a mature individual. Two metapodial fragments, having a porous bone structure, evidence at least one younger animal and a distal epiphysis is unfused (fusing with 26-29 months). A first phalanx is unfused (fusing with 17-20 months) and another third phalanx is porous from a young individual (greatest length= 31.97mm). See Appendix Table C.3.37.

Appendix Table C.3.37: Red deer remains, Level 122.

Cervus elaphus (Level 122)	NISP	MNE				MNI			
Element	All	All	inf	juv	adu	All	inf	juv	adu
Antler	10								
Cranium	2	1				1			
Upper teeth	4	1			1	1			1
Mandible	1	1				1			
Lower teeth	1	1			1	1			1
Cervical vert.	1	1				1			
Indet. vert.	1	1				1			
Humerus	6	2			1	1			1
Radius	5	1				1			
Ulna	1	1				1			
Carpal unit	2	1				1			
Pelvis	1	1							
Femur	10	2			1	1			1
Tibia	8	2			1	1			1
Metacarpus	2	2			1	1			
Metatarsus	8	2		1	1	2		1	1
Metapodial	9	2	1	1		1		1	
Meta. atro.	1	1				1			
Phalanx prox.	9	5		2	1	2		1	1
Phalanx med.	1	1				1			
Phalanx dist.	6	3	2	1		2	1	1	
Phalanx atro.	11	11				1			
Phalanx indet.	1								
Sesamoid	2	2				1			
Humerus-Femur	2								
Long bone	1								
Total	106	45	3	5	8	3	1	1	1

Bird remains

One proximal shaft of a femur, one long bone shaft and one complete distal phalange of a bird was registered in the faunal database for Level 122.

Fish remains

Two vertebrae were classified as fish within this study unit.

Anatomically identified by size classes

Two unfused long bone fragments were identified, an epiphysis and a shaft, and three unfused vertebrae among the medium to large sized animal category. Within this category was also found a very porous-structured humerus or femur shaft (diameter: 7.34 x 6.99 mm) that originated from a fetal animal. Another unfused vertebra as well as a porous rib fragment was classified as coming from a small- to medium- size mammal. One unfused indeterminate long bone epiphysis fragment is unfused. See Appendix Table C.3.38.

Appendix Table C.3.38: Faunal remains by size classes, Level 122. *=NR.

Size classes (Level 122)	L Ungulate	M Ungulate	M-L Size	S-M Size	S Ungulate	Indeterminate
Bone	NISP	NISP	NISP	NISP	NISP	NISP
Cranium			4	1		
Mandible			1			
Teeth						84
Cervical vert.		3	2			
Thoracic vert.		1	1	3	2	
Rib	1	3	5	3		53
Lumbar vert.			1	1		
Indet. vert.		1	6	1		79
Scapula					1	
Humerus			2			
Radius			2			
Ulna			1			
Pelvis	1	2	1			
Femur		1			1	1
Patella						
Tibia		1			1	
Calcaneus		1				
Tarsal unit					1	
Metapodial		2			9	1
Meta. atro.						
Phalanx prox.			1		1	
Sesamoid					5	
Humerus-Femur			1			
Long bone	1	25	46	14	2	1961
Flat bone			1			3
Irregular bone			1			3
Spongy bone						3300*
Indeterminate			5			477*
Total	3	40	81	23	23	5962

Seasonality

The fetal bones found in this level indicate winter-spring kills and occupation of the site, which is accompanied by a juvenile ibex died in summer.

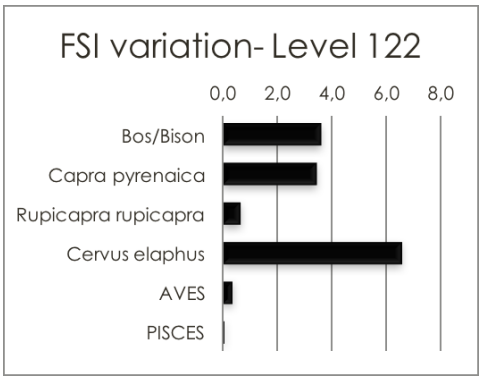
Level 122 - Taphonomy

Faunal preservation

Feet bones are the most frequent complete bones identified within Level 122 from 34 complete skeletal elements. Spanish ibex contains as complete elements two upper P2 and one lower dP4, P3 and M1 as well as two carpals, one talus, one calcaneus, two tarsals, two phalanges and five sesamoids. Complete elements from chamois are one carpal and two distal phalanges. Following red deer remains were preserved completely: one upper P2, molar and canine, one carpal, four phalanges, three atrophic phalanges and one sesamoid. I also identified a complete phalanx from a bird.

The red deer remains identified appear to have the largest sized fragments followed by large bovid and caprine bones in Level 122. All the other species show much smaller fragments. Macro-mammal bone fragments are generally larger compared with the older levels, despite chamois remains.

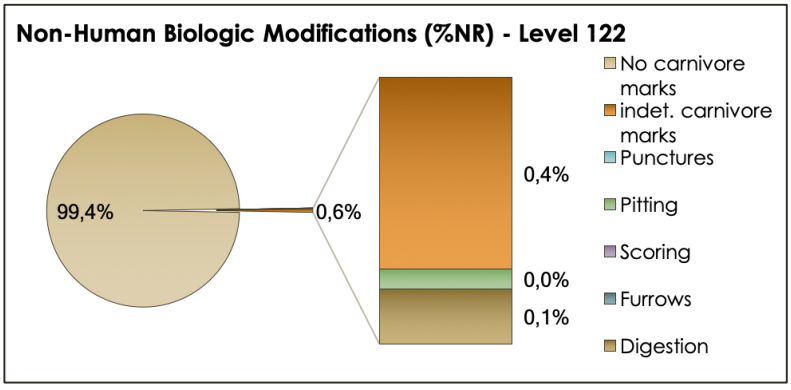
Breakage pattern. With over 80% dominate the green fractures the faunal assemblage from Level 122 and indicate with 2.3% of dry fractures that sediment movements or pressure possibly did not disturb the original accumulation context.



Appendix Figure C.3.14: Fragment Size Index (FSI) variation among species in Level 122.

Non-Human Biological Agents

Carnivore marks were identified on a 39 faunal remains (from total NR of 6382 = 0.6%NR), which represents low carnivore activity within this level (Appendix Figure C.3.15). One red deer distal phalanx as well as one rib and an irregular bone fragment categorized in size classes shows gnawing through pitting and 36 bones are digested. Digestion marks are found on red deer and ibex phalanges and chamois bones, representing vulture activities. The observed carnivore marks seem to be randomly distributed within the excavated part of Level 122.



Appendix Figure C.3.15: Carnivore activities observed in Level 122.

Human activities

Level 122 shows an increased number of bones with anthropogenic modifications (Appendix Table C.3.39). Cut marks were found on all body parts comprising 67.4% on long bones that represent defleshing, disarticulation and periosteal removal activities. They were found in square U10, spit 54 (46.5%), in spit 56 (39.5%) and spit 57 (14%). Bone marrow cracking involved half of the human activities registered, as

suggested by the high amount of impact marks found on the bones. Impact marks were found on all body parts, even on the mandible and cervical vertebrae. They seem to be concentrated in in square U10, and in spit 54 (48%) and then in spits 56 (32,5%) and 57 (19.5%). Seven bones were found completely carbonized, five partially carbonized and two are reddish roasted. Most of these burnt bones are located in subsquare C in spit 54 and 56 in square U10. Following bone artifacts were registered by this present faunal study: nine bone flakes, two point fragments (antler sagaies), three worked antlers and seven used bones; they are additional to previous identified osseous tools published by Straus et al. (2011, 2013). Those bone artifacts in general don't really show a pattern in their distribution, although the bone flakes seem to be heavily concentrated in the subsquare D of square U10, used bones in C and D and antler fabricants in B and D.

Appendix Table C.3.39: Number of specimen with anthropogenic modifications in Level 122.

Species	Cut Marks	Impacts	Burning
Bos/Bison		2	
Capra pyrenaica	9	18	4
Rupicapra rupicapra	1		
Cervus elaphus	18	26	4
M Ungulate	10	5	1
L Ungulate		1	
S-M Size	2	6	1
M-L Size	12	19	3
Indeterminate	3	283	141
Total	**55**	**360**	**154**

Human-carnivore interactions

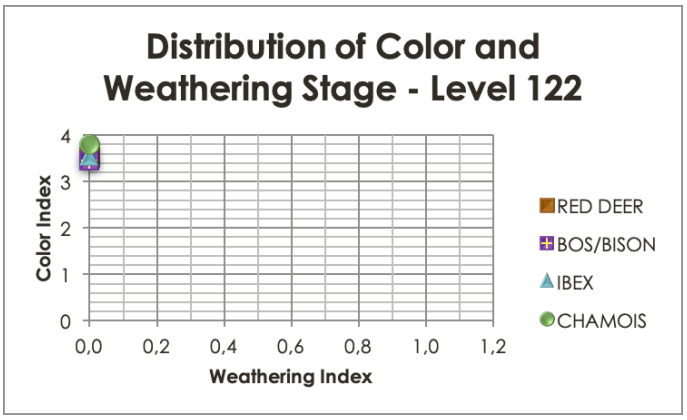
Direct anthropogenic modifications were identified in 37.4% of the faunal remains in Level 122, but carnivore influence on this accumulation seem to be low. Most of the anthropogenic modifications were found on red deer and Spanish ibex specimen. Small carnivore bite marks were found on a burnt bone. Most of the bones (60.4%), though, do not show direct modification marks. See Appendix Table C.3.40. Carnivore marks overlay human alterations, indicating that they had access to preyed animal after humans, possible scavenging animal leftovers after human abandonment of the cave.

Appendix Table C.3.40: Anthropogenic vs. carnivore modifications on specimen from Level 122.

Species	Anthropogenic	Carnivore	Both
Bos/Bison	2		
Capra pyrenaica	26	3	
Rupicapra rupicapra	3	4	
Cervus elaphus	40	2	
M Ungulate	17		
L Ungulate	1	1	
S Size	7		
S-M Size	7		
M-L Size	29		1
Indeterminate	286	28	
Total: 456 (100%)	**418 (91.7%)**	**38 (8.3%)**	**1 (0.2%)**

Post-depositional modifications

In Level 122 is remarkable for the absence of weathering processes and a generally high color index indicating a dominance of bones in colors brown to black (Appendix Figure C.3.16). The large bovid bones show the lightest color, and then ibex group together and the darkest coloration is displayed by chamois bones.



Appendix Figure C.3.16: Color and Weathering Index, Level 122.

Level 122 – Summary

Human activities shown a wide variety in Level 122 by cut marks on long bones that represent defleshing, disarticulation and periosteal removal activities. All these human actions of bone cracking for marrow and fire use seemed to concentrate in square U10 as density is their highest. Carnivore possible scavenged on prey leftovers from human, and their marks are low and overlay human alterations, indicating that they had access to preyed animal after humans, possible scavenging animal leftovers after human cave abandonments. Post-diagenetic alterations are low, with good preservation, no weathering, and very similar dark coloration of bones and teeth (Appendix Figure C.3.17) within the faunal assemblage of Level 122.



Appendix Figure C.3.17: Overview faunal material of Level 130.

Level 121 – Quantification

Level 121 contained 17 275 bone remains and 95 teeth, as summarized by species in Appendix Table C.3.41.

Level 121 was excavated in the two squares V9 (4,5) and V10 (4-6).

Appendix Table C.3.41: Faunal quantification, Level 121.

Species	NISP	Weight	MNE	MNI
Capra pyrenaica	77	142.4	34	4
Rupicapra rupicapra	22	45.2	17	3
Cervus elaphus	107	541.4	35	4
Lepus sp.	1	0.5	1	1
Birds	4	0.8	1	1
Fish	1	0.1	1	1
S Ungulate	14	8.4		
M Ungulate	54	65.2		
L Ungulate	6	66.6		
S Size	1	0.1		
S-M Size	4	6.1		
M-L Size	59	196.1		
Indeterminate	17 020	5 191.48		
Total	**17 370**	**6 264.38**	**89**	**14**

Capra pyrenaica (Schinz, 1838)

Fourteen teeth and 63 bones have been identified from Spanish ibex within the Solutrean Level 121. One upper premolar is heavily worn, while on another one light wear traces just indicate the start of use, together they represent an old Juvenile and a quite old Adult. A complete lower milk molar dP4, in stage AS8 where root absorption already started, indicate also an old juvenile individual. Two lower incisors represent a minimum of one old individual with advanced dental wear and massive roots. In humerus fragments the *Fossa olecrani* was counted three times; one grown up left and one right and a fetal left one. Two proximal right metacarpal articular surfaces indicate two individuals. One proximal phalange identified is fused and indicate an animal that was juvenile or older. Proximal femur epiphysis corresponds to an animal of a very wide age range of 23-84 months (NODDLE 1974). See Appendix Table C.3.42.

Appendix Table C.3.42: Spanish ibex remains, Level 121.

Capra pyrenaica (Level 121)	NISP	MNE					MNI				
Element	All	All	fet	inf	juv	adu	All	foe	inf	juv	adu
Cranium	1	1				1	1				1
Upper teeth	5	2			1	1	2			1	1
Mandible	3	1		1			1		1		
Lower teeth	9	3			2	1	2			1	1
Hyoid	1	1					1				
Rib	2	1					1				
Lumbar vert.	1	1					1				
Humerus	8	3	1				1	1			
Radius	5	2				2	1				1
Ulna	1	1					1				
Carpal unit	5	1					1				
Femur	8	2					1				
Tibia	6	2					1				
Calcaneus	1	1			1		1			1	
Metacarpus	3	2		1			1		1		
Metatarsus	2	1					1				

Metapodial	5		1					1			
Phalanx prox.	2	2					1				
Phalanx med.	3	3		1			1		1		
Phalanx dist.	3	3		1			1		1		
Humerus-Femur	2										
Long bone	1	1									
Total	77	34	2	4	4	5	4	1	1	1	1

Rupicapra rupicapra (Linnaeus, 1758)

Two lower right M1 were identified with different abrasion degrees (AS8 and AS12), and two additional right M3 indicate a minimum of two adults. The adult pelvis fragment was identified as a pelvis with birthing marks representing a female animal. See Appendix Table C.3.43.

Appendix Table C.3.43: Chamois remains, Level 121.

Rupicapra rupicapra (Level 121)	NISP	MNE			MNI		
Element	all	all	inf	adu	all	inf	adu
Maxilla	2	2	1		1	1	
Upper teeth	1	1			1		
Mandible	1	1			1		
Lower teeth	6	3	1	2	2	1	2
Ulna	1	1			1		
Pelvis	2	1		1	1		1
Tarsal unit	2	1			1		
Phalanx prox.	2	2			1		
Phalanx dist.	2	2			1		
Sesamoid	3	3			1		
Total	22	17	2	3	3	1	2

Cervus elaphus (Linnaeus, 1758)

I identified the right nutritional canal from the tibia twice, which thus represent a minimum of two animals. Two dP2 originate from young individuals; a right germen without root is unworn from an infantile and a left other is heavily worn and shows an advanced root absorption indicating an animal that died in a period of time just before milk tooth replacement. Both lower dI3 and I3 are just slightly worn indicating a young infantile (or neonate) as well as a young adult that just changed teeth (I3 eruption between the 25-26 month of life). A proximal femur unfused represents an animal less than three years old. Two distal unfused metapodial fragments indicate a juvenile-subadult age (under 26 months ~2 years). Another two metapodial (one metacarpal and one metatarsal) porous bone shafts indicate also a young animal. One unfused phalange indicates an infantile animal. See Appendix Table C.3.44.

Appendix Table C.3.44: Red deer remains, Level121.

Cervus elaphus (Lev 121)	NISP	MNE				MNI			
Element	**NISP**	**all**	infantile	juvenile	adult	**all**	infantile	juvenile	adult
Antler	**25**								
Maxilla	**1**	**1**		1		**1**		1	
Upper teeth	**5**	**3**	2		1	**2**	1		1
Lower teeth	**2**	**2**	1		1	**2**	1		1
Lumbar vert.	**1**	**1**				**1**			
Humerus	**6**	**3**				**1**			
Radius	**2**	**1**				**1**			
Ulna	**3**	**3**			3	**2**			2
Ulna-Radius	**1**	**1**				**1**			
Femur	**9**	**3**		1	2	**1**		1	1
Tibia	**18**	**4**			4	**2**			2
Metacarpus	**3**	**2**		1	1	**2**		1	1
Metatarsus	**12**	**2**		1	1	**2**		1	1
Metapodial	**4**					**1**			
Meta. atro.	**2**	**2**				**1**			
Phalanx prox.	**1**	**1**				**1**			
Phalanx med.	**1**	**1**				**1**			
Phalanx dist.	**2**	**1**				**1**			
Phalanx atro.	**2**	**1**				**1**			
Phalanx indet.	**1**	**1**	1			**1**	1		
Sesamoid	**2**	**2**							
Humerus-Femur	**1**								
Radius-Tibia	**2**								
Long bone	**1**								
	107	**35**	**4**	**4**	**13**	**4**	1	1	2

Lagomorph remains

A calcaneus from a lagomorph was identified.

Bird remains

A small-size bird tarsometatarsal with a total weight of 0.3 g for the complete bone and 5 cm length was identified. Another long bone shaft was identified as also coming from a bird.

Fish remains

A vertebra from a fish was identified.

Anatomically identified by size classes

One unfused indeterminate phalange shaft comes from an infantile and one small vertebra from a fetal individual of a medium-size ungulate. Three unfused vertebrae fragment were classified as medium- to large-size mammal. A proximal and medial phalange was found in an unfused stage from an infantile small to medium sized animal. One rib and 39 other fragments of indeterminate size class are very tiny, porous and come from minimum one fetal animal. See Appendix Table C.3.45.

Appendix Table C.3.45: Faunal remains by size classes, Level 121. *=NR.

Size classes (Level 121)	L Ungulate	M Ungulate	S Ungulate	M-L Size	S-M Size	S Size	Indeterminate
Bone	NISP	NISP	NISP	NISP	NISP	NISP	NR
Cranium		1					
Mandible				2			
Lower teeth						1	
Teeth							66
Cervical vert.				1			
Thoracic vert.			1	1	1		
Rib		4		5			123
Sternum							4
Lumbar vert.				4			
Caudal vert.				1			
Indet. vert.		2		6			113
Humerus		2	1				
Pelvis		1		1			
Femur		1					
Tibia			2				
Metatarsus		1					
Metapodial			6				
Phalanx prox.		5	2		1		
Phalanx med.					1		
Phalanx indet.		1					
Sesamoid		2	1				
Humerus-Femur		3			1		
Radius-Tibia		2					
Long bone (shaft)	6	28		35			707
Flat bone		1					
Spongy bone							14784
Indeterminate				3			1223*
Total	6	54	13	59	4	1	17020

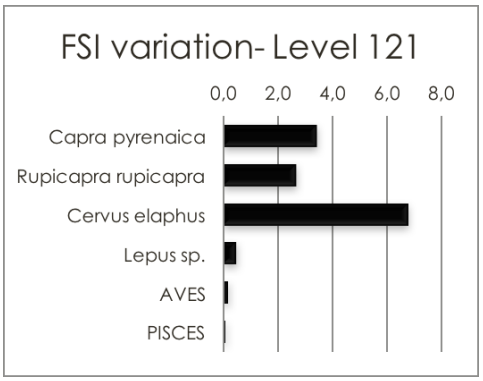
Level 121 – Seasonality

Autumn-winter occupations are identified by a juvenile (18-20 months autumn, winter) and an infantile ibex (<9 months – summer-autumn-winter).

Level 121 - Taphonomy

Faunal preservation

The red deer remains identified appear to have the largest sized fragments. Spanish ibex and chamois remains cluster together around the fragment size of 3g (Appendix Figure C.3.18). Lagomorph, bird and fish remains are generally small with less than 1g.



Appendix Figure C.3.18: Fragment Size Index (FSI) variation among species in Level 121.

In Level 121 complete teeth dominate compared to the bones among the 19 complete skeletal elemetns. From Spanish ibex were identified a upper dP4 and P2, a lower dp4, dC, P2 and two incisors. A lower M3 is complete from chamois. An upper dP2 and C as well as a lower dI3 and I3 were registered from red deer. Four carpals are also classified as ibex, one tarsometarso from a bird, ab atrophic phalanx from red deer and a first phalanx from a small- to medium –size mammal. See Appendix Table C.3.46.

Appendix Table C.3.46: Number of complete Bones preserved, Level 121.

Species	TEETH	UP FRONT	META	FEET
Capra pyrenaica	7	4		
Rupicapra rupicapra	1			
Cervus elaphus	4			1
Bird			1	
S-M Size				1
Total	**12**	**4**	**1**	**2**

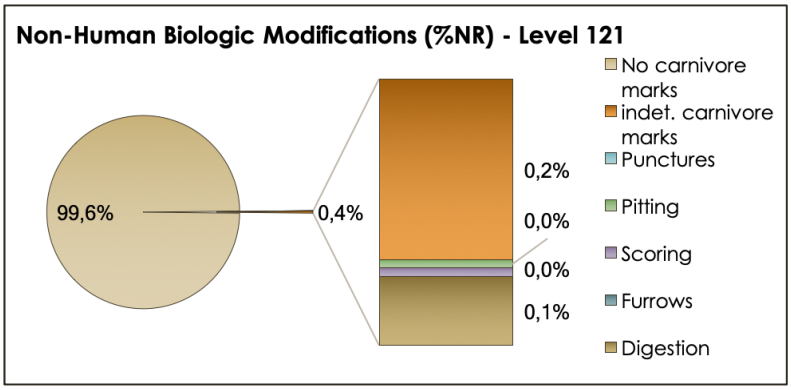
Appendix Table C.3.47 summarized the observed breakage pattern. Green fractures dominate the faunal accumulation in Level 121 and so the dominance of biological accumulating agents. Dry fractures are scarcely represented.

Appendix Table C.3.47: Breakage pattern, Level 121 (only bones identified taxonomically or in animal size classes).

Breakage- profile	NISP	%NISP
Green fracture	619	83.0
Green and dry fracture	3	0.4
Green and recent	3	0.4
Dry fracture	1	0.1
Recent fracture	11	1.5
Indeterminate	109	14.6
Total	746	100

Non-Human Biological Agents

Carnivore marks were identified on several faunal remains, although representing low carnivore activities for Level 121. See Appendix Figure C.3.19. Four long bones (including ibex and chamois) show pitting and scoring marks from gnawing. However, main modifications observed were digestions marks on metapodial and phalanges on red deer, ibex and medium ungulate sized species. All these carnivore marks identified were found on bones located in both excavated squares, V9 and V10. Digested bones include only a metapodial and feet bones from red deer and ibex, which seem to represent vulture activities. Other bite marks were found on an ibex femur, a chamois ulna and two other long bone fragments.



Appendix Figure C.3.19: Carnivore activities registered in Level 121.

Human activities

In Level 121 cut marks dominate the alterations to the faunal assemblage, followed by impacts and artificial/ intentional modifications (Appendix Table C.3.48). Cut marks resemble skinning, defleshing, and disarticulation activities, they were found on all body parts instead of feet bones. In 87.5% cut marks are located on long bones, the rest include antler, head and rib fragments. Spit 5 in square V9 contained the most (81.3%) cut marked bones. Impact marks, though, were only found on long bones, including two phalanges. Most of this impact marked bones come from square V9 spit 5 (69.4%). Only one bone was found among the individual registered bones that has partially carbonized modification marks still with a green fracture identifiable. The osseous artifacts assemblage within Level 121 comprise the following objects: two bone flakes, one antler manufacture debris, three *sagaie* antler point fragments that include two tips, five bone tools where three shows used ends and two were used as wedges, one needle fragment and one pendant.

Appendix Table C.3.48: Number of specimen with anthropogenic modifications in Level 121.

Species	Cut marks	Impacts	Burning
Capra pyrenaica	13	8	
Rupicapra rupicapra	1	1	
Cervus elaphus	25	21	
S Ungulate	2		
M Ungulate	17	4	1
L Ungulate	3		
S-M Size		1	
M-L Size	10	4	
Indeterminate		433	700
Total	71	472	701

Human-carnivore interactions

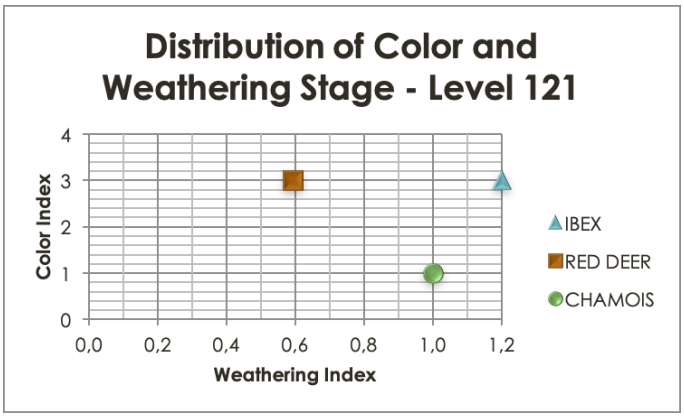
The relative frequency of specimen with direct anthropogenic modifications among the registered bones in Level 121 is eight times higher than that of carnivore marks, but the bones with no direct modification marks (about 60.2%NR) dominate the faunal assemblage. See Appendix Table C.3.49.

Appendix Table C.3.49: Anthropogenic vs. carnivore modifications on specimen from Level 121.

Species	Anthropogenic	Carnivore	Both
Capra pyrenaica	21	4	
Rupicapra rupicapra	2		1
Cervus elaphus	48	3	
S Ungulate	7	1	
M Ungulate	27		
L Ungulate	3		
S Size	1		
S-M Size	1		
M-L Size	12	2	
Indeterminate	434	51	
Total: (100%)	556 (90.1%)	61 (9.9%)	1 (0.2%)

Post-depositional modifications

In Level 121 is a not very often case observed that the weathering stage from Spanish ibex and chamois are closer together than to red deer (Appendix Figure C.3.20), which could be the results of accumulation (and lying on the surface) during different seasons of dryer or wetter conditions. On the other hand, appear red deer and ibex in very similar coloration indices indicating similar stable post-depositional conditions in sediments with decomposing organic remains and bacteria activity (MARÍN-ARROYO ET AL. 2008), where chamois shows a two-point lower index. Such inclusion of lighter colored bones from chamois, might be the result of mixing of bones that chamois had a different depositional context.



Appendix Figure C.3.20: Color and Weathering Index, Level 121.

Level 121 - Summary

The preyed ungulates comprising four red deer, four ibex and three chamois also include young individuals. Although carnivore marks are present in form of bite and digestion marks, human modification marks dominate the assemblage testifying skinning, defleshing, and disarticulation activities on site. Human site

occupation was possible during cold season, and bone impact marks were commonly found. Interestingly was found in Level 121 only one bone carbonized, although the excavators described a simple hearth structure with fire-cracked rocks possible indicating cooking activities (STRAUS ET AL. 2013). Post-depositional preservation is good, but coloration differences indicate not uniform accumulation of bones.

Level 120 - Summary

The part of Level 120 included within this faunal analysis comprise one red deer fragment and 58 indeterminate specimens. Since this is a layer of compacted back dirt at the base of the looter hole sediment mixing is possible. Level 120 was only excavated in squares U10 (55). Few human (NR=2) and carnivore (NR=1) modifications were observed.

Appendix C.4 Initial Magdalenian (Cabin Area)

Faunal analysis was done on Initial Magdalenian Levels 21, 20, 19 and 18 located in the Cabin Area (Vestibule Front). Materials origin from a deep sondage in square J2, thus it is a tiny sample in contrast to the larger occupations found in the Vestibule Rear currently under study by M.Carvalho and data are unavailable.

Level 21 – Quantification

Two bones and seven teeth were identified. See Appendix Table C.4.1. The *Capra pyrenaica* teeth (P2, P4, incisor) are all permanent ones, representing a minimum of one adult individual. The distal phalanx was complete. *Cervus elaphus* is represented by a left mandible with M1, M2 and M3. M1 is heavily worn and M3 is completely formed, both presumably from the same old individual. An upper tooth was also identified.

Appendix Table C.4.1: Faunal quantification, Level 21.

Species	NISP	Weight	MNE	MNI	Weight/NISP
Capra pyrenaica	4	7.8	3	1	1.95
Cervus elaphus	5	41	3	1	8.20
Total	**9**	**48.8**	**6**	**2**	**5.08**

Level 20 – Quantification

See Appendix Table C.4.2. A right lower P4 from Spanish ibex that was heavily worn indicate an adult individual. I identified also fragments of a radius and proximal phalanx. A proximal left shaft fragment from a metatarsal was identified coming from *Cervus elaphus*.

Appendix Table C.4.2: Faunal quantification, Level 20.

Species	NISP	Weight	MNE	MNI
Capra pyrenaica	3	10.3	3	1
Cervus elaphus	1	6.4	1	1
Total	**4**	**16.7**	**4**	**2**

Level 19 - Quantification

Together I identified 490 bones and 18 teeth in Level 19. See Appendix Table C.4.3.

Appendix Table C.4.3: Faunal quantification, Level 19.

Species	NISP	Weight	MNE	MNI
Capra pyrenaica	9	62.3	7	1
Cervus elaphus	2	16.7	2	1
M Ungulate	1	3.6	1	/
S-M Size	1	1.7	1	/
M-L Size	1	1.3	1	/
Indeterminate	494	183.1	/	/
Total	**508**	**268.7**	**12**	**2**

Capra pyrenaica

Two lower M2s are identified: one from the right and another from the left side, and based on abrasion degree, development and taphonomic stage, the left M2 and one M3 probably belong to the same, adult individual. See Appendix Table C.4.4.

Appendix Table C.4.4: Spanish ibex remains, Level 19.

Capra pyrenaica (Level 19)	NISP	MNE				MNI			
Bone	ALL	All	inf	Juv	adu	All	inf	juv	adu
Upper teeth	2	1				1			
Lower teeth	3	2			1	1			1
Lumbar vert.	1	1				1			
Femur	1	1				1			
Calcaneus	1	1				1			
Phalanx prox.	1	1				1			
Total	9	7	0	0	1	1	0	0	1

Cervus elaphus

Two bones are represented from *Cervus elaphus* in Level 19, these are a right femur fragment and a complete second phalanx.

Anatomically identified by size classes

The corona of a lower molar, a long bone shaft fragments from a medium- to large- size animal and a vertebra from a medium- size ungulate.

Level 18 – Quantification

In Level 18, I identified in total 1707 bones and 44 teeth. See Appendix Table C.4.5.

Appendix Table C.4.5: Faunal quantification, Level 18.

Species	NISP	Weight	MNE	MNI
Equus ferus	1	4.6	1	1
Capra pyrenaica	28	169	19	3
Cervus elaphus	32	144.1	12	2
Ursus arctos	1	0.5	1	1
M Ungulate	1	1.9	1	/
M-L Size	1	5	1	/
Indeterminate	1687	671.6		
Total	**1751**	**996.7**	**35**	**7**

Equus ferus

One small fragment of a horse talus represented by is proximal articular surface. This bone belongs to a subadult or older individual. The fracture is smoothed perpendicular to the bone's axis and was categorized as a green fracture.

Capra pyrenaica

Within this level there were two right M1s. One of those teeth represents a mature/ senile animal with strong tooth abrasion and a massive root (M1 height of the crown HC=5,44 mm) compared to the other M1 found in the same level HC= 21,02mm, probably being an adult individual. Two complete carpals (*c.radiale* and *c.intemedium*) were identified; while the last one is very large in dimensions and probably originate from a male individual. It is possible that the mature and the male characteristic corresponding to the same animal. Two individuals are also represented by metacarpals, with one not fused onto the distal epiphyses, thus corresponding to an animal of less than 2 years of age. See Appendix Table C.4.6.

Appendix Table C.4.6: Spanish ibex remains, Level 18.

Capra pyrenaica (Level 18)	NISP	MNE				MNI			
Element	All	All	sub	adu	sen	All	sub	adu	sen
Viscerocranium/Maxilla	1	1				1			
Upper teeth	5	1		1		1		1	
Mandible	1	1		1		1		1	
Lower teeth	3	2		1	1	2		1	1
Cervical vert.	1	1				1			
Indet. vert.	1	1				1			
Ulna	2	1				1			
Carpals	2	2		2		2		1	
Metacarpus	2	2	1	1		2	1	1	
Pelvis	3	2				1			
Femur	3	1				1			
Tibia	1	1	1			1	1		
Talus	1	1				1			
Tarsals	1	1				1			
Metatarsus	1	1				1			
Total	28	19	2	6	1	3	1	1	1

Cervus elaphus

A deciduous Incisor 3 indicating an animal that had not completely acquired its permanent teeth, and therefore representing a subadult or younger individual. A loose distal radius epiphysis also identifies a younger than adult individual. Thus, based on teeth, there are individuals, a subadult and an adult. See Appendix Table C.4.7.

Appendix Table C.4.7: Red deer remains, Level 18.

Cervus elaphus (Level 18)	NISP	MNE			MNI		
Element	All	All	juv	adu	All	juv	adu
Antler	18						
Upper teeth	2	1		1	1		1

Lower teeth	1	1	1		1	1	
Humerus	2	2			1		
Radius	2	2	1		1	1	
Metacarpus	1	1			1		
Femur	1	1			1		
Tibia	1	1			1		
Tarsals	1	1			1		
Metapodial	2	1		1	1		1
Phalanx prox.	1	1			1		
Total	32	12	2	2	2	1	1

Ursus arctos

During analysis, I found one brown bear tooth. It is a complete right lower premolar (P4).

Anatomically identified by size classes

A number of 1689 fragments have been categorized in size classes. A cranium fragment from a medium-size ungulate is represented by a compact bone. An axis vertebra could be determined as coming from a medium- to large- size mammal. The other specimen are categorized as 32 teeth, 201 long bone shafts, 1235 spongy bone and 219 indeterminate fragments.

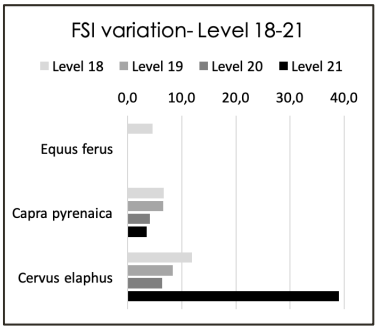
Seasonality

Capra pyrenaica lower M3- dentin start to melt together, 30-36 months old, winter-spring

Level 21 to 18 - Taphonomy

Faunal preservation

One large red deer mandible fragment in level 21 disrupt the trend of otherwise smaller fragments in older levels compared with the younger ones. Ibex fragments are generally smaller than from red deer.



Appendix Figure C.4.1: Fragment Size Index (FSI) variation among species in Level 18-21.

What is remarkable about the levels of the Initial Magdalenian from the small J2 test pit that they contain more complete teeth than bones. From Spanish ibex there are 6 completely preserved upper teeth: two P2s, two M1s, one M2 and one M3, and eight lower teeth: one incisor, three P4s, one M1, two M2s and one M3 as well as two carpals, one talus, one tarsal and one medial phalanx. The fewer red deer remains comprise two upper premolars, one lower M3 and one medial phalanx. Extraordinary is the find of a complete lower P4 from the rarely present species, brown bear (*Ursus arctos)* from Level 18.

Breakage pattern. All Initial Magdalenian bones identified are dominated by green fractures and indeterminate fractures, only some bones show a mixture of green and recent fractures (Appendix Table C.4.8).

Appendix Table C.4.8: Breakage pattern, Level 18-21 (only bones identified taxonomically or in animal size classes).

Breakage- profile	NISP	%NISP
Green fracture	173	87.8
Green and recent	3	1.5
Indeterminate	21	10.7
Total	**197**	**100**

Non-Human Biological Agents

One distal phalanx from a red deer shows digestion marks next to five other digested bones that imply vulture activity. These bones was found in square J2, Levels 18 and 19.

Human activities

Bones with impact marks dominate the Initial Magdalenian finds from the test pit in the vestibule front ('Cabin') excavation area (Appendix Table C.4.9). Cut-marked bones come from Levels 18 (90%) and 19 (10%); they resemble disarticulation activities and were found on red deer humerus, radius and tarsal bone and on ibex ulna, metacarpal, pelvic, calcaneus and tarsal bone. Impact marks were found on eighteen bones in Levels 18 (72.2%), 19 (11.1%) and 20 (16.7%). Bone flakes were indeterminate bones mainly from Levels 18 and 19. One bone was used for some sort of activity, showing a smoothed end; this osseous artifact comes from Level 18.

Appendix Table C.4.9: Number of specimen with anthropogenic modifications in Level 18-21.

Species	Cut Marks	Impacts	Tool
Capra pyrenaica	7	11	
Cervus elaphus	3	7	1
Indeterminate		136	
Total	**10**	**154**	**1**

Human-carnivore interactions

The relative frequency of anthropogenic modifications (93.6%) among the individually registered bones in Levels 18-21 contrast with only a few ones carrying carnivore marks (digested bone) from Level 19. See Appendix Table C.4.10.

Appendix Table C.4.10: Anthropogenic vs. carnivore modifications on specimen from Level 18-21.

Species	Anthropogenic	Carnivore
Capra pyrenaica	16	
Cervus elaphus	10	1
Indeterminate	136	10
Total: (100%)	162 (93.6%)	11 (6.4%)

Post-depositional modifications

The bones from Levels 18 to 21 are well, without weathering marks and all have a white-beige color that could be referred to as the natural bone color without discoloration.

Levels 18-21 – Summary

The Initial Magdalenian faunal remains from Levels 18 to 21 are all well preserved without coloration changes or weathering marks. They are the result of human activities, but it was also identified some sort of carnivore presence by digestion marks on bones. The samples are in comparison to the other ones very small, because these levels were only dug in one subsquare of square J2.

Appendix C.5 Lower Magdalenian (Cabin Area)

The major contribution to this faunal study was obtained from Lower Magdalenian levels located in the Vestibule Front of the cave. The Lower Magdalenian deposits in this area include a late phase of this occupation, comprising Levels 15 and 16, dating between 15.2 and 15.0 uncal BP. The main archaeological deposits, Level 17, is a massive palimpsest and was subdivided into samples for study as explained in Appendix B. The faunal assemblages studied include the samples 17-12, 17-10, 17-8 and 17-6 in the Cabin excavation area comprised of squares H1-4, I2-4 and J2-4. These multiple occupations are bracketed between radiocarbon dates of 15.7 and 15.3 uncal BP.

Level 17 (12) – Quantification

The faunal spectra were quantified in Level 17-12 as follows (Appendix Table C.5.1).

Appendix Table C.5.1: Faunal quantification, Level 17—12.

Species	NR	Weight	MNE	MNI
Equus ferus	10	96.6	8	2
Bos/Bison	8	99.8	5	1
Capra pyrenaica	739	2 991.8	218	16
Rupicapra rupicapra	4	27.2	4	2
Cervus elaphus	822	6 824.8	144	9
Capreolus capreolus	3	20.7	3	1
Canis lupus	2	5.3	2	1
Vulpes vulpes	1	0.1	1	1
Birds	2	0.4	2	1
Amphibia	1	0.1	1	1
Fish	1	0.4	1	1
S Ungulate	57	137.4		
M Ungulate	165	394.6		
L Ungulate	21	127.4		
XS Carnivore	1	0.4		
S Size	2	2.9		
S-M Size	20	39.8		
M-L Size	318	777.0		
Indeterminate	13 037	3 643.0		
Total	**15 214**	**15 189.7**	**389**	**36**

Equus ferus (Boddaert, 1785)

The horse remains are always sparse within the Lower Magdalenian assemblages. Study unit 17-12 contained ten horse specimens. Two M3s were determined next to two other upper premolars/molars. The upper M3 is unworn and the lower one is heavily worn, thus belonging to two different individuals. The right one of two tibia fragments have a fused distal epiphysis. A calcaneus, a tarsal and a complete sesamoid bone are present. A thoracic vertebra specimen was cataloged as coming from horse.

Capra pyrenaica (Schinz, 1838)

The identified horn remains present many corpus fragments, some with the base connecting to the frontal bone; at least one male and female are represented. One large cranium fragment with horn cores belong definitively to a male individual. Upper teeth reached the highest NISP for *Capra pyrenaica* in subsample 17-12 between all elements identified. Thirteen upper M1 were counted, representing a minimum of six individuals. Four dP2s represent at least three juvenile or younger animals and eight M3 stay for at least six much older individuals. A tiny porous condyloid process from a mandible indicates a neonate Capra was introduced into the side. Lower teeth include eight lower M1s (five of them from the right side), three dP3s (MNI=2) and four M3s (MNI=3). Many thoracic and lumbar vertebra specimens are represented that were possible to count on the basis their number of spinous process. The scapula fragments were unfused in two cases (fusing at about 20 months) that belong to juvenile or younger individuals. Humerus: three infantile individuals are recorded, one is unfused and two are fusing indicating at least three animals under an age of one year. The fused proximal radius fragments belong to five adults and one fusing specimen indicate an infantile individual. One distal metacarpal epiphyses is unfused coming from a juvenile or younger individual. Thirteen acetabulum fragments from the pelvis are identified. They represent at least seven adults, one juvenile and an auricular surface at the wing of the ilium from a neonate individual. The identified fragments from the femur bone belong to 15 adult elements and three unfused proximal femur specimens represent at least one right and left juvenile element. Femur identifications show the highest MNI for ibex bones. One fusing and two unfused distal parts of the tibia represent juvenile or younger bones. The other nine distal tibia fragments are fused and are categorized as coming from adult individuals. Tarsal bones, talus and calcaneus indicate several adults. Two calcanei specimens that are unfused indicate juveniles, but the other tarsal fragments also show some porous bones that presumably belong to juvenile or younger individuals. A distal epiphysis from a metatarsal is unfused coming from a juvenile or younger animal. Two proximal phalanges are fusing and two are unfused among 27 recovered specimens, therefore indicating at least one infantile animal. Another four intermediate phalanges also indicate infantile animals. Two distal phalanges are porous and belong presumably to neonate animal. See Appendix Table C.5.2.

Appendix Table C.5.2: Ibex remains, Level 17—12.

Capra pyrenaica (Level 17-12)	NISP	MNE					MNI				
Element	All	All	neo	inf	juv	adu	All	neo	inf	juv	adu
Horn	14	4			1	3	3			1	2
Cranium	15	2				1	1				1
Viscerocranium/Maxilla	24	3*			1*	2*	1			1	1
Upper teeth	72	13			4	8	9			3	6
Mandible	42	7	1*		1*	5*	7	1		1	5
Lower teeth	54	8			3	4	5			2	3
Hyoid	5	1					1				
Cervical vert.	2	1					1				

Thoracic vert.	17	5					1				
Rib	19	6					1				
Lumbar vert.	14	2				1	1				1
Sacral vert.	1	1					1				
Caudal vert.	1	1					1				
Indet. vert.	1	1					1				
Scapula	48	9			2	7	7			1	6
Humerus	26	6		3		3	5		3		2
Radius	23	6			1	5	5			1	4
Ulna	14	5				4	4				4
Ulna-Radius	10	2				2					
Carpal unit	10	5				5	4				4
Metacarpus	17	7	1		1	5	6	1		1	4
Pelvis	28	15	1		1	13	8	1		1	7
Femur	60	15			2	15	10			1	9
Patella	1	1					1				
Tibia	47	12			3	9	8			3	5
Talus	5	5			1	4	4			1	3
Calcaneus	8	6			2	4	6			2	4
Tarsal unit	8	4			3	1	4			3	1
Metatarsus	21	8			1	7	8			1	7
Metapodial	11										
Phalanx prox.	41	27		4		23	5		1		4
Phalanx med.	30	18		4		14	3			1	2
Phalanx dist.	17	14	2			12	4	1			3
Sesamoid	26	8					2				
Humerus-Femur	4										
Long bone	1										
Total	737	218	4	11	25	150	16	1	3	3	9

Bos/Bison

Eight faunal remains were identified as coming from a large bovid, *Bos sp.* or *Bison sp.* . One head fragment is a maxillary specimen with the right facial tubercle. Six axial elements were identified as three cervical, one lumbar, one indetermined vertebrae and a sacrum fragment. Finally, I found a complete distal phalange, which according to its morphology presumably belonged an old bison.

Rupicapra rupicapra (Linnaeus, 1758)

Four chamois bones were identified. A right radius fragment with the radial tuberosity and a right as well as left tibia fragments represent all together a minimum of one grown up individual. A complete distal phalange, on the other hand, belongs to a neonate animal.

Cervus elaphus (Linnaeus, 1758)

Many antler fragments (n=83) were identified in this unit, including 7 tines. An upper dP4 with thin roots show only the very early wear stage and a maxilla is very tiny of porous bone presumably belong to a neonate animal. The mandible and lower milk teeth also suggest a juvenile individual. Seven spinous processes in thoracic vertebrae were identified. An unfused scapula glenoid cavity fragment represents a juvenile or younger animal. Three right proximal epiphyses of humerus are unfused and five times is the nutrient canal

on a left skeletal element present. A right and a left radius were identified along with other adult elements. Unfused ulna fragments might indicate a young animal. Very porous metacarpal bone fragments also refer to a young individual. (They killed Bambi!) The evidences are two left ilium fragments with an unfused acetabulum and the wing of the ilium that refers to a neonate. Femur fragments show the highest NISP for deer bones within this level. Two left distal epiphyses and two metaphysis are unfused in femur. The other femur fragments show two right and two left nutritional canal. Tibia fragments represent at least one juvenile animal, as two distal shaft remains have unfused metaphysis. A minimum of three individuals represent the nutrient canal identified on proximal tibia fragments. Several left and right porous bone fragment indicate young animals, an unfused metatarsal was not identified. One proximal epiphysis from the proximal phalange of red deer is fusing indicating an animal in its second year (17-20 months old). Two intermediate phalanges are unfused, referring to an infantile animal under the age of 11 months. The distal phalange was identified 17 times, including a neonate and six fully developed ones indicating at least two adult animals.

Each of the elements upper teeth, humerus, metacarpal and pelvic fragments represent a MNI of five adults for red deer within this unit, three juveniles and one neonate. The antler fragments found within the faunal assemblage possible not indicate killed deer males, rather than shed antlers picked up on the ground. See Appendix Table C.5.3.

Appendix Table C.5.3: Red deer remains, Level 17-12.

Cervus elaphus (Level 17-12)	NISP	MNE				MNI			
Element	All	All	inf	juv	adu	All	inf	juv	adu
Antler	83				1	1			1
Cranium	21	2		1	1	2		1	1
Viscerocranium/Maxilla	44	3*	1*	1*	1*	3	1	1	1
Upper teeth	47	13	1	1	11	7	1	1	5
Mandible	19	4*		2*	2*	2		1	1
Lower teeth	31	8		2	6	5		1	4
Hyoid	2	1				1			
Cervical vert.	6	2				1			
Thoracic vert.	13	7				1			
Sternum	5	1				1			
Rib	19	6				1			
Lumbar vert.	8	5				1			
Sacral vert.	2	1				1			
Indet. vert.	5	4				1			
Scapula	21	3		1	2	2		1	1
Humerus	56	8		4	6	8		3	5
Radius	32	5		3	2	4		2	2
Ulna	16	3		1	2	2		1	1
Ulna-Radius	5				2	1			
Carpal unit	1	1				1			
Metacarpus	39	8		1	6	6		1	5
Pelvis	18	6		1	6	6		1	5
Femur	73	8		1	7	6		1	5
Tibia	78	5		1	4	3		1	2
Talus	2	2			2	2			2
Calcaneus	6	3			3	3		1	2
Metatarsus	57	6		2	4	3		1	2
Metapodia	32					1			
Metapodia-minor	1	1				1			

Phalanx prox.	6	4			4	1			1
Phalanx med.	17	9		3	6	2		1	1
Phalanx dist.	17	13	1	1	11	4	1	1	2
Phalanx atro.	8	4			3	1			
Sesamoid	8	4				1			1
Humerus-Femur	14					1			
Long bone	10					1			
Total	822	143	2	23	89	9	1	3	5

Capreolus capreolus (Linnaeus, 1758)

Three faunal remains were classified to the small cervid, roe deer. Two long bone fragments (a tibia and a radius) belong to the right body side, but the latter has a more porous structure. A distal phalange was also identified. Hence at least there were two individuals.

Canis lupus (Linnaeus, 1758)

Two wolf remains were identified. The glenoid cavity comes from a right scapula. A complete and fully developed intermediate phalange was found within this study unit.

Vulpes vulpes (Linnaeus, 1758)

A slightly worn left premolar is the only evidence of a fox within this study unit.

Bird remains

A proximal humerus and another long bone shaft were classified as coming from small birds. The humerus has a porous structure probably belong to a young individual.

Amphibian remains

A frog or toad ilium fragment with acetabulum was determined.

Fish remains

One cranial fish fragment was classified.

Anatomically identified by size classes

The three cervical fragments from a large artiodactyl are porous and indicate a younger animal. The medium to large size mammals include following unfused bones: one lumbar vertebrae, four indeterminate vertebrae, one sacral bone, a pubis fragment, one irregular bones and twelve long bone fragments. A long bone and a vertebra is fusing. Subsequent elements were identified within an unfused stage in the medium sized artiodactyl group: one cervical vertebra, eight indeterminate vertebrae, a proximal humerus, one irregular bone and two long bone fragments. A long bone, a tibia and a vertebra fragment are unfused within the group of the small to medium sized mammals. Four specimens are unfused from the bone fragments that were classified as small artiodactyl: one each of ulna, sacral bone, thoracic vertebra and indeterminate vertebra. One undetermined cranium fragment is from a fetal animal. 172 fragments are very tiny in dimensions, porous and come from minimum one fetal animal of probably ungulate size class. See Appendix Table C.5.4.

Appendix Table C.5.4: Faunal remains by size classes, Level 17-12. *=NR.

Size classes (Level 17-12)	L Ungulate	M-L Size	M Ungulate	S-M Size	S Ungulate	S Size	XS Carnivore	Indeterminate
Element	NISP	NISP	NISP	NISP	NISP	NISP	NISP	NISP
Cranium		32	6	3		1		1
Viscerocranium/Maxilla	1	3	1					
Mandible		3	4		2			
Teeth			1					231
Hyoid			1					
Cervical vert.	4	6	4	1				
Thoracic vert.	2	4	3	1	1			
Rib	2	28	29	6	9	1		1
Sternum		4	1					
Lumbar vert.	1	9	4		2			1
Sacral vert.		2			1			
Indet. vert.	3	23	16	2	2			
Scapula		4	2		5			
Humerus		1	6		1			
Radius	2	2	5		1			
Ulna					2		1	
Ulna-Radius			1					
Pelvis		13	2					
Femur		2	3	2	3			
Patella			1					
Tibia		2	3	1	5			
Calcaneus					1			
Metapodial		1	2		3			
Phalanx prox.	1							
Humerus-Femur	2	6	11		5			
Long bone	3	113	48	4	13			939
Flat bone		12	3					3
Irregular bone		27	2					10
Spongy bone								10304*
Indeterminate		21	6		1			1547*
Total	21	318	165	20	57	2	1	13037

Seasonality

Red deer were hunted in autumn and many ibex were killed in early winter to mid spring indicating cold season occupation of the cave.

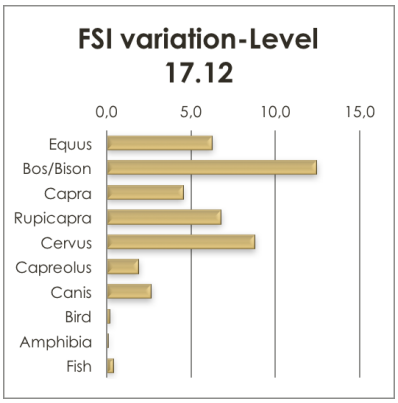
Level 17(12) - Taphonomy

Faunal preservation

Number of complete skeletal elements. Study Sample 17.12 shows an extraordinary number of 229 complete elements, far greater than have been seen in the earlier levels of the Initial Magdalenian, the Solutrean, the Gravettian or the Middle Paleolithic. The most complete elements come from head and feet body parts. From horse is a complete upper and lower tooth preserved as well as one sesamoid. A complete nasal bone, a

complete mandible, 65 upper and 39 lower complete teeth comprise the Spanish ibex head parts. Additionally, I identified a complete caudal vertebra, ten carpals, two calcanei, three tali and three tarsal bones. Two distal phalanges and 24 sesamoids were completely preserved. From chamois were also one entire distal phalanx registered. A high number of complete teeth were also found in red deer, with 35 upper and 22 lower teeth. Among the bones were identified one talus from red deer plus four distal phalanges, four atrophic phalanges and four sesamoids. From wolf comes a complete medial phalanx and from fox, a lower tooth identified. Finally, I found a complete medium artiodactyl-sized knee bone.

The largest sized fragments were registered among large bovid and red deer bones, which are followed by chamois, horse and ibex bones. Roe deer and wolf bones appear in smaller fragment compared to the other ungulates. The fragments of fox, birds, amphibian and fish are tiny. See Appendix Figure C.5.1.



Appendix Figure C.5.1: Fragment Size Index (FSI) variation among species in Level 17.12.

Appendix Table C.5.5 summarized the observed breakage pattern. Green fractures (74.9%NISP) dominate the fracture pattern of the studied faunal remains from study sample 17-12. Bones that show green and dry fractures are the second most abundant form observed among the broken bones, followed by undefined and recent fractures.

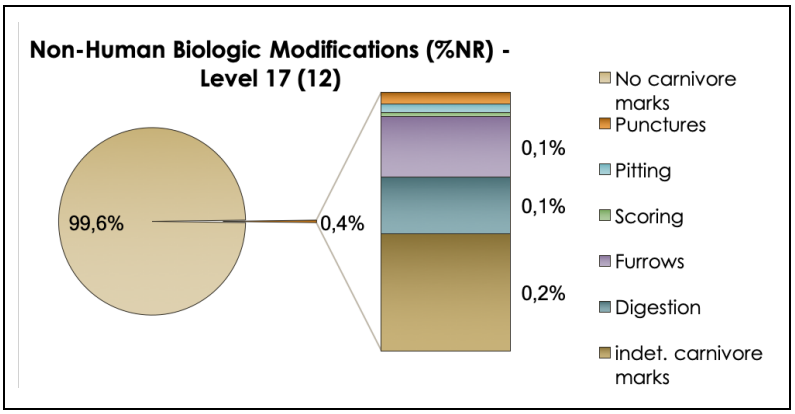
Appendix Table C.5.5: Breakage type, Level 17-12 (only bones identified taxonomically or in animal size classes).

Breakage- profile	NISP	%NISP
Green fracture	1 397	74.9
Green and dry fracture	190	10.2
Green fracture, two phases	12	0.6
Dry fracture	7	0.4
Recent fracture	93	5.0
Indeterminate	166	8.9
Total	**1 865**	**100**

Non-Human Biological Agents

Bite and digestion marks together effected about 0.4% of the faunal assemblage, which represent low carnivore activities in study sample 17-12 (Appendix Figure C.5.2). Digested bones are teeth, carpals, tibia,

metapodial and phalanges. Bones found with bite marks are cranial, humerus, ulna, tibia, long bones, vertebrae, scapula, metapodial, phalanges and sesamoid. Five of these bones show digestion and bite marks on the same element, which are a long bone fragment, two lumbar vertebrae fragments and two phalanges.



Appendix Figure C.5.2: Carnivore activities observed in Level 17 (12).

Most of non-human bone modifications were found on ibex bones (NISP=15), while ten of them showing digestion marks similar to what is described as vulture activity. All red deer remains with carnivore modifications do not show digestion marks, but do display pitting, chewing and furrow evidence.

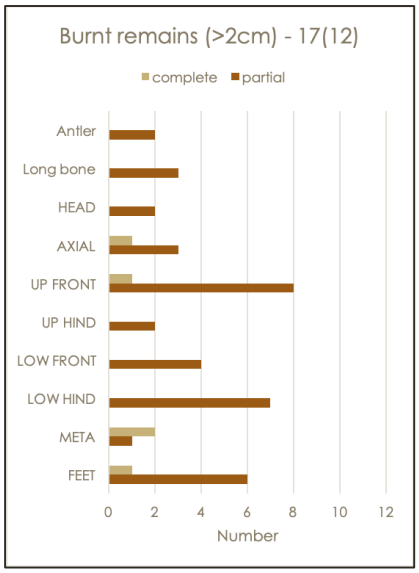
Human activities

In study sample 17-12 impact marks dominate over cut marks, but interestingly there was a relatively low number of cut marks observed in red deer, as well as a relatively low number of impact marks on Spanish ibex bones. See Appendix Table C.5.6. Cut marks were found on all body elements and they were dominantly found in square H4 (35.3%NR) and I4 (30%NR) among all cut marked bones. Impact marks were also found on all body parts as well as dominate square H4 (33.2%NR) and I4 (22.5%NR) in the numbers of impacted bones. Bone and antler artifacts types identified in Sample 17-12 are the following: flakes, blank production waste, failures and cores, tools (*sagaie*, needle, wedges, retoucheur, used bones), decorated elements with cut marks or red ochre, and tooth pendants. Artifacts concentrate in the squares I4 (28.3%NR), H3 (22.8%NR), H4 (17.4%NR) and H2 (14.1%NR). Other objects of the osseous industry already presorted and separated during excavation are not included in these totals, but a synoptic presentation in Straus et al. (2018) is dedicated to them.

Appendix Table C.5.6: Number of specimen with anthropogenic modifications in Level 17-12.

Species	Cut marks	Impacts	Burning	Artifact
Equus ferus	3	3		
Bos/Bison	3	5		
Capra pyrenaica	123	28	13	9
Rupicapra rupicapra		3	2	1
Cervus elaphus	2	279	17	48
Capreolus capreolus		2		
S Ungulate	17	9		1
M Ungulate	44	33	5	12
L Ungulate	1	1		1
S-M Size	3	4		
M-L Size	35	56	8	19
Indeterminate	1	2	1	1
Total	**232**	**425**	**46**	**92**

Burned bones show mainly reddish roasting (65.2%NR) or black-partial carbonization (21.7%NR) marks. The burning degree varies among the different bone types, thus, the different body parts (compare Appendix Figure C.5.3). Long bones seem to show more often reddish roasting marks than head, axial or feet bones. Individually recorded burnt bones were found mostly in squares H3 (21.7%NR) and H4 (28.3%NR).



Appendix Figure C.5.3: Burning evidence by body parts in Sample 17-12.

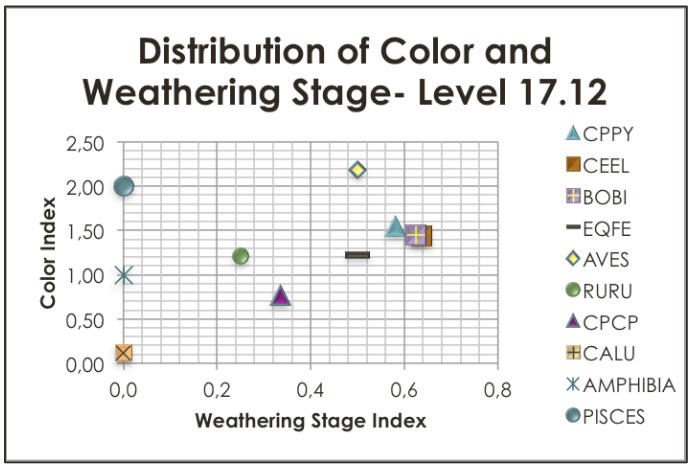
Human-carnivore interactions

Anthropogenic modifications were observed in 8.4%NR of the registered faunal remains in study sample 17-12, and only 0.4%NR showed carnivore marks. Varied species were involved in human activities, see Appendix Table C.5.7. In a few cases (six times) were and overlap of human and carnivore modifications observed. Most of the bones, though, do not show modification marks.

Appendix Table C.5.7: Number of specimen with anthropogenic vs. carnivore modifications from Level 17-12.

Species	Anthropogenic	Carnivore	Both
Equus ferus	4		
Bos/Bison	5		1
Capra pyrenaica	274	15	2
Rupicapra rupicapra	3		
Cervus elaphus	391	4	2
Capreolus capreolus	2		
S Ungulate	23	2	
M Ungulate	70	4	1
L Ungulate	10		
S-M Size	6		
M-L Size	91	2	
Indeterminate	396	29	
Total: 1337 (100%NR)	**1275 (95.4%NR)**	**56 (4.2%NR)**	**6 (0.4%NR)**

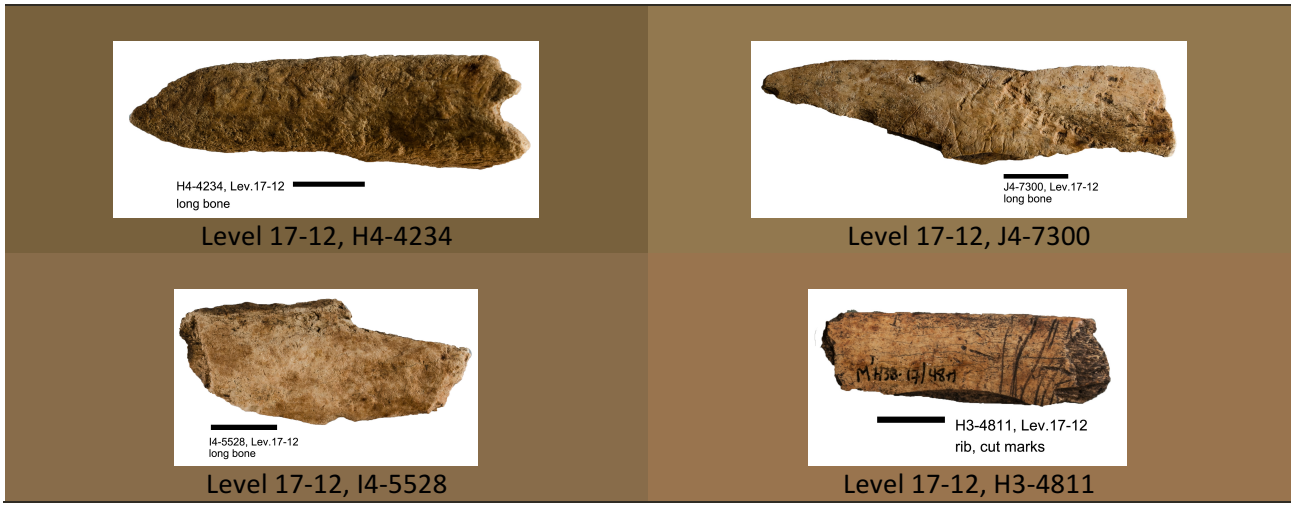
Interestingly to see in the color and weathering index distribution (Appendix Figure C.5.4) is the close clustering of the supposed to be main prey species of Spanish ibex, red deer, Bos/Bison and horse remains in study sample 17-12 indicating similar accumulation and depositional contexts. Bird as well as fish remains show a slightly higher color index. Chamois and roe deer are somewhat in the middle, separated from the other ungulates, by a lower weathering index. The bones from wolf, amphibian and fish all together do not show weathering.



Appendix Figure C.5.4: Color and Weathering Index, Level 17-12.

Level 17 (12) – Summary

The dual exploitation of two main game species red deer and ibex derive from human activities and concentrate in cold season occupation of the cave, specifically marked by young red deer hunting in autumn and ibex in early winter to mid spring. Large bovids and horse were accumulated, but never got really important at El Mirón, possible due their habitat ranges out of the site catchment area. Although wolf and fox are present under the faunal remains, non-human agents had a minor role as accumulator with modification marks concentrating on ibex. All faunal remains are well preserved with good identification of modification marks, and dominantly brown coloration types such are shown in the photographs below (Appendix Figure C.1.5) show low diagenetic alterations of the faunal assemblage from Level 17 (sublevel 12) =17(12).



Appendix Figure C.5.5: Examples of the faunal material from Level 17-12.

Level 17(10) – Quantification

The faunal spectra were quantified in Level 17-10 as follows (Appendix Table C.5.8). Sample 17—10 contain 27 544 fragments of bones and 708 of teeth.

Appendix Table C.5.8: Faunal quantification, Level 17—10.

Species	NR	Weight	MNE	MNI
Equus ferus	8	119.7	6	2
Bos/Bison	8	303.1	4	2
Capra pyrenaica	999	3 160.5	321	14
Rupicapra rupicapra	11	15	8	2
Cervus elaphus	949	8 458.8	134	13
Capreolus capreolus	3	5.1	3	2
Rangifer tarandus	1	0.2	1	1
Vulpes vulpes	1	0.1	1	1
Lepus sp.	2	1.1	1	1
Bird	5	4.2	3	1
Amphibia	4	0.5	2	1
Fish	2	0.2		
S Ungulate	2	4.5		
M Ungulate	63	142.6		
L Ungulate	9	65.4		
S Carnivore	1	0.3		
S-M Size	1	3.1		
M-L Size	512	1 359.9		
Indeterminate	25 671	6 916.5		
Total	**28 252**	**20 560.8**	**484**	**40**

Equus ferus (Boddaert, 1785)

Eight faunal remains have been identified as horse, coming from a juvenile and an adult. I recognized a lower complete fully worn milk molar dP3, which shows root absorption in progress and another enamel fragment. Among the bones were classified a right humerus shaft piece that contain a nutritional canal. Two metacarpal fragments were identified; one has a porous structure of a juvenile individual and a long, longitudinal cut mark with a spiky profile. The landmark of the *trochanter major* at the proximal part of a femur was identified; and the same specimen is characterized by green fracture with a direct impact notch on the proximal-lateral part of the bone. One proximal part of a talus was classified as horse and the following modifications were observed on this bone: green fracture from flaking activity while the direct hammer striking platform is still visible and six parallel, short, deep cut marks close to the articulating face in a right angle to the element axis. The thoracic vertebra with part of the spinal process shows four deep chop marks and green and dry fracture patterns. Together these horses remain accumulation seem to be the results of human activity. The identified horse remains are well preserved (no weathering to first stage of weathering) and show light discolorations with yellow, brown, grey colors.

Bos/Bison

Faunal remains from large bovid (aurochs or bison) total an NISP of eight. One complete lower, heavily worn left milk molar dP3 with root absorption already started, represent a juvenile animal. Two right femur fragments including the landmarks *fossa supracondylaris* and *trochanter tertius* coming from an adult. There

are fragments from a cervical and a thoracic vertebra. Two other long bone shafts also belong to a large bovid Bos/Bison within this level. Another indeterminate specimen with a very thick compact bone was also identified.

Capra pyrenaica (Schinz, 1838)

In total, I have identified 170 teeth and 817 bones from Spanish ibex within Level 17, Sample 10. As summarized in Appendix Table C.5.9, among the horn fragments classified as Spanish ibex I found at least one female and one male individual. The cranium parts comprise twelve specimens and the following bones were identified: frontal, temporal, sphenoid and occipital bones. The facial cranium parts include fragments from nasal, zygomatic and maxillar bones. In total, there are seven *processus articularis* from the mandible identified, six right ones and three of them from neonates and one from a Juvenile. Seven hyoid fragments were identified. Seven hemi-mandible were identified based on the articulating surface: three lefts from neonates, two left juveniles, one left adult and a right one. The maxMNE for upper teeth is based on M2s with a count of fifteen, but MNI counts for juveniles based on milk teeth (one left dP3 and a P4) and for adults on M3's (six left and four right), representing one juvenile and six adults, respectively. Lower teeth counts comprise four left (dP3 and dP4) and two right (dP3) juvenile mandible elements as well as seven left and four right M3's, indicating four juveniles and seven adults. The axial part is represented by an MNE of five cervical vertebrae (based on corpus counts), five thoracic (based on corpus counts), five lumbar (based on spinal process), four other vertebra (based on corpus counts) and one sacral bone. Shoulder elements comprise seven *fossa glenoidales*, by which on a minimum a male, a female and one young animals are included (based on measurements/ dimensions). The landmark *foramen nutritium* was used to estimate the MNE of humerus elements to fifteen within this study unit, while two adults and two infantile animals were classified. One of these infantiles is represented by a fusing distal humerus fragment (11-13 months old, spring death). Four left and right proximal radius fragments were identified and account for four individuals and two unfused distal epiphyses indicating two younger animals. Ulna fragments include three right and left proximal parts with the articular surface of the element. Five carpal units are present by two left *c.ulnare*, two right *c.intermedium* and two porous carpal bones (*c.radial*, *c.quartum*) that represent a minimum of one juvenile individual. Seven left and ten right proximal metacarpal fragments represent an MNE of seventeen elements, while three distal epiphyses are unfused that a minimum of two metacarpals are from a juvenile animal. An additional distal metacarpal part is fusing, indicating also a juvenile individual that was 23-26 months old and died in spring-early summer. From the pelvis bone, I identified three right and left acetabulum fragments. Femur MNE was counted based on three left *Trochanter tertius*, six right *Foramen nutritium* and minimum one right and left unfused distal Epiphyses representing together a MNI of nine. Four nearly complete knee bones were identified, two from the left side. Several tibia elements were estimated, three right nutritional canals and one left indicate four elements. One distal unfused tibia specimen indicates a juvenile or younger animal. Another distal unfused epiphysis that is very spongy and porous in its structure indicate a fetal individual (winter-spring dead). One proximal tibia element is fusing and another four epiphyses fragments are unfused. Three tali are present, two of them from the left side. Calcaneus fragments comprise three right and one left element, while a refit of one right calcanei is included. A juvenile left proximal epiphyses as well as a calcaneus without proximal epiphyses are also present. Nine tarsal units were counted based on five left *t.centroquartale*, three right *t.malleolare* and one porous structured *t.quartum*. Metatarsal elements are presented by seven proximal right and left as well as one proximal right and left porous structured element indicating a juvenile, while another distal epiphysis is fusing also coming from a Juvenile (23-26 months old, spring-early summer death). Altogether I identified 31 proximal parts of the proximal phalange, including one fetal, five unfused epiphyses from infantiles and one fusing from an animal of the age of 11-15 months (spring-early summer death). In total were counted 19 distal parts from the

medial phalanges, comprising three unfused epiphyses from infantiles and one fusing from an individual of 9-13 months old (late winter-spring death). Among the bones were identified a minimum of 14 distal phalanges with seven proximal from the left and five from the right side, these build the calculation base for an MNI estimation of two adults. Another tiny distal phalanx comes from a fetal animal (winter-spring death) and four very porous specimens represent minimum one juvenile animal. Seventy-one sesamoid bones were identified, with three porous ones, which is a MNI of one Juvenile and five Adults.

Appendix Table C.5.9: Ibex remains, Level 17—10.

Capra pyrenaica (Level 17-10)	NISP	MNE					MNI				
Element	All	All	neo	inf	juv	adu	All	neo	inf	juv	adu
Horn	18	2				2	2				2
Cranium	12	2					1				2
Viscerocranium/Maxilla	22	3*				3*	2			1	6
Upper teeth	71	15				11	7	1		3	3
Mandible	39	7*	3*		2*	2*	4	1		2	1
Lower teeth	92	17			5	12	11			4	7
Indet. teeth	7										
Hyoid	7						4				
Cervical vert.	23	5					1				
Thoracic vert.	16	5					1				
Rib	46	6				6	1				1
Lumbar vert.	18	5					1				
Sacral vert.	5	1					1				
Indet vert.	11	4									
Scapula	19	7				6	3				3
Humerus	49	15		2		3	4		1		2
Radius	33	8			2	1	3			1	1
Ulna	16	6				6	3				3
Ulna-Radius	4										
Carpal unit	16	5			1	4	3			1	2
Metacapus	35	17			2	15	10			2	8
Pelvis	22	10				6	3				3
Femur	62	9				9	6				6
Patella	4	4				2	2				2
Tibia	32	10	1		1	4	5	1		1	3
Talus	3	3				3	2				2
Calcaneus	9	5			1	4	4			1	3
Tarsal unit	21	9			1	8	5			1	4
Metatarsus	36	16			2	14	8			1	3
Metapodia	28										
Phalanx prox.	60	31	1	5	1	24	6	1	1	1	3
Phalanx med.	39	19		3		14	4		1		3
Phalanx dist.	26	14	1	4		11	4	1	1		2
Phalanx indet.	1										
Sesamoid	71	71			3	68	6			1	5
Humerus-Femur	8										
Long bone	6										
Total	987	321	3	14	19	233	14	1	1	4	8

Rupicapra rupicapra (Linnaeus, 1758)

Eleven faunal remains from chamois have been identified within Level 17, Sample 10. The four teeth recognized include an upper, left complete P2 and a lower right molar, left P2 and P3. A mandible corpus fragment belongs to an infantile individual as teeth abrasion just had started before its dead probably in spring. One left humerus shaft fragment contains a nutritional canal. The pelvic ilium bone with the *facies auricularis* was identified as chamois. A fused proximal phalange fragment indicates a juvenile or older animal. One distal phalange has a porous bone structure and indicates a fetal/neonate animal (winter/spring death). The second distal phalange comes from an adult, but shows digestion marks similar to what is known in bearded vulture activity.

Cervus elaphus (Linnaeus, 1758)

In total 71 teeth and 878 bones were identified from red deer within study unit 17-10. See Appendix Table C.5.10. Two tine fragments were identified among the 101 recorded antler pieces*. From cranial parts are presents five temporal bone that include three *pars petrosa*, two occipital and one basis specimen, ten fragments come from right and left maxillary, two frontal, a zygomatic bones and a Incisivum. Two right *foramen mandibulae* as well as left mandible fragments were identified. Three upper milk molar dP4s (two left, one right) and eight upper premolars P4s (five right, three left) represent together seven individuals (two juveniles, five adults). Among the lower teeth it is possible to estimate a minimum of one juvenile and three adults, by a lower right dP3 and dP4 and three lower right of each, P2s and M3s. Three fragments from an atlas accompany the 16 cervical vertebrae identified specimens with five corpus parts. Nine thoracic vertebrae include three corpus parts and 18 rib fragments include six heads, four of them from the right side. Lumbar vertebrae number thirteen pieces with three corpus parts. Among the identified humerus fragments were found eight left and six right nutritional canals, while two of the right distal humerus fragments are in an unfused stage and represent two infantile individuals. Six right distal parts of the radius are presented; one of them is an unfused epiphysis, indicating three individuals. Four left proximal Ulna fragments were identified with one representing a metaphysis, another metaphysis from the right side comes from an infantile. All four different carpals identified come from the right side and are a MNI of one. Three right and one left proximal metacarpal parts were counted. Two right and one left acetabulum fragment are identified. Most femur fragments counted contain the *fossa supracondylaris* that was observed four left ones and seven right times next to one right and left porous structured juvenile bone. The MNI calculation based on tibia specimen include four left and five right nutritional canals and one left distal epiphyses unfused, making a total of five Adults and one Juvenile. One calcaneus fragment without its epiphyses indicates a juvenile individual. Two primer tarsal bone indicate minimum one animal. The most abundant part of the metatarsus is the proximal epiphyses that were identified three times from the left side and four times on the right side. The articulating face of the proximal phalanges was identified 13 times, while four of them are unfused and indicate minimum one juvenile or younger animal. Nine proximal medial phalanges indicate a MNI of two. Ten distal parts of the distal phalange indicate two adults and two neonate individuals. Sesamoids are present from a minimum of two animals.

(*Upon completion of faunal analysis, more antler remains were found by L.G. Straus in July 2019. Three specimens are antler bases with part of attached skull representing killed male deer. Since fully grown antler will be present from September to January in red deer, those animals were killed within the same temporary frame and information were updated on seasonality and male/female ratio

calculations within the respected locations of Chapter 4.2. Those additional specimens did not change MNI counts and were not added to NISP counts afterwards.

Three adult male individuals were determined as antler beams were huge and antler bases had varied dimension of 60.2x50.1 mm (H3c/74-3280), 69.2x53.2 mm (H3d/74-3154) and 81.15x71.2 mm (H2d/57-2411). The largest one showed beam and brow tine cut marks.

A base of a shed antler was shed with rosette and part of beam and brow tine and measured on the base 70.0x59.6 mm (H3d/74-3235). Six other antler (beam) fragments were also found with cut marks. Comments and measurements were made by L.G.Straus.)

Appendix Table C.5.10: Red deer remains, Level 17-10.

Cervus elaphus (Level 17-10)	NISP	MNE					MNI				
Element	All	All	neo	inf	juv	adu	All	neo	inf	juv	adu
Antler	101										
Cranium	8	3					2				
Viscerocranium/Maxilla	14	2*				2	1				1
Upper teeth	47	9			3	5	5			2	3
Mandible	15	3*				3	2				2
Lower teeth	20	6			1	3	4			1	3
Teeth	4										
Cervical vert.	21	5				1	1				1
Thoracic vert.	9	3					1				
Rib	18	5				5	1				1
Lumbar vert.	13	1					1				
Sacral vert.	2	1					1				
Indet. vert.	3										
Scapula	19	2				2	1				1
Humerus	64	14		2		12	10		2		8
Radius	47	3				3	2				2
Ulna	15	7		1		6	4		1		4
Ulna-Radius	5										
Carpal units	4	1				1	1				1
Metacarpus	40	3				3	2				2
Pelvis	24	4				3	2				2
Femur	118	13			2	11	9			2	7
Patella	1	1				1	1				
Tibia	101	10			1	9	5				4
Talus	2	2					1				
Calcaneus	4	2			1	1	2				1
Tarsal unit	2	2				2	1				1
Metatarsus	70	7				7	4				4
Metapodia	29										
Metapodia atrophic	4										
Phalanx prox.	24	13			4	7	3			1	2
Phalanx med.	10	9				9	2				2
Phalanx dist.	15	8	2			6	3	1			2
Phalanx atro.	22										
Sesamoid	13					6	2				2
Humerus-Femur	20										
Long bone	21										
Total	949	134	2	3	12	108	13	1	2	2	8

Capreolus capreolus (Linnaeus, 1758)

Two right calcaneus fragments and a medial phalange were identified as coming from roe deer within Level 17-10.

Rangifer tarandus

The first and, until now, only reindeer remain within El Mirón cave is a complete lower left incisor I3, which is a tooth pendant with slightly skewed sawing marks creating two grooves on the frontal part of the root presumably for attaching it onto material such as a string or clothing. See Appendix Figure C.5.6.



Appendix Figure C.5.6: Reindeer ornament from Level 17-10.

Vulpes vulpes (Linnaeus, 1758)

Only one fox tooth was identified among the faunal remains from Level 17 in Sample 10. It is a complete lower, right P2.

Lepus sp.

Two long bone shafts are identified from hare, which are from a femur and an indeterminate long bone.

Bird remains

Five bones are classified as bird remains. An undetermined proximal part of a phalanx belongs to a bird. A distal shaft fragment and a proximal carpometatarsus, including the articulating face as a landmark were also identified

A distal radius fragment with the articulating face is presumably from a young animal and is identified as vulture species. Another also clearly identified black vulture bone (identified by A.B.Marín-Arroyo at the MNHN of Paris) is a left proximal epiphysis to shaft humerus fragment from the overlying study sample 9, unknown of age, but possible adult; see Appendix Figure C.5.7.



Appendix Figure C.5.7: Large humerus fragments from a black vulture from Level 17.

Amphibian remains

Three amphibian bone fragments are included within the faunal remains; a pelvis iliac bone, proximal radius fragment and another long bone part.

Anatomically identified by size classes

Among the taxonomically indeterminate large artiodactyl bones was identified an all around left radius shaft fragment that is large in size and has a completely fine spongy structure allover representing a fetal bone. The class of the medium to large sized animals contains several examples of no fully developed bones. Four bones are fusing; the head of a rib fragment and three long bone shaft fragments. Other bone fragments are present in an unfused stage: one proximal rib, a humerus or femur metaphysis, a distal radius, a proximal tibia, 14 long bone fragments, one lumbar vertebra four sacral bone parts, a sternal bone, twelve vertebra fragments and three indeterminate fragments. Several bones with a porous structure were also identified: one frontal cranial bone, three mandible ramus, a tibia shaft, a humerus or femur shaft, six long bone shafts, one epiphyses, a vertebra and two indeterminate fragments. An unfused rib was also categorized as coming from a medium sized artiodactyl as well as a unfused long bone fragment. Three more porous structured fragments were classified. Among the small artiodactyl size bones were found two bones with a porous structure, possibly from young individuals, a left femur shaft and mandible ramus. A caudal vertebra is fusing and another tiny indeterminate vertebra is present among the indeterminate bones. See Appendix Table C.5.11.

Appendix Table C.5.11: Faunal remains by size classes, Level 17-10.

Size classes (Level 17-10)	L Ungulate	M Ungulate	S Ungulate	M-L Size	S-M Size	S Carnivore	Indeterminate
Element	NISP	NISP	NISP	NISP	NISP	NISP	NISP
Cranium		1		12			1
Viscerocra.				16			
Mandible		1	1	13			
Teeth		1		1			456
Hyoid				1			
Cervical vert.				5			
Thoracic vert.	1			7			
Rib	1	10		20			
Sternum				2			
Lumbar vert.	2	1		6			
Sacral vert.				4			
Caudal vert.		1		1			2
Indet. vert.		1		33			1
Scapula		1		7		1	
Humerus		3		1	1		
Radius	1			4			
Pelvis				9			
Femur		4	1	3			
Tibia		1		8			
Talus				1			
Metapodial				2			
Phalanx indet.				1			
Sesamoid				1			
Humerus-Femur	1	7		10			

Long bone	3	30		208			1630
Flat bone				9			
Irregular bone		1		13			
Spongy bone							20440*
Indeterminate				114			3141*
Total	9	63	2	512	1	1	25671

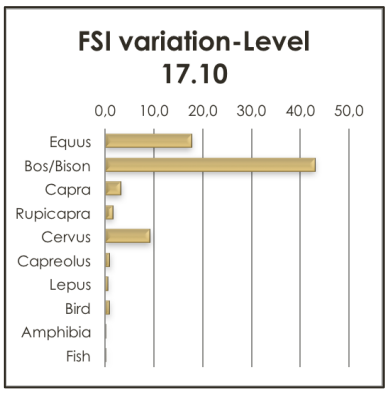
Seasonality

Some of the ungulate fetal bones indicate winter/spring occupations and killing of pregnant females, but hunting also focused of red deer in late summer to early autumn and ibex in late autumn-early winter according to not-fully grown individuals.

Level 17(10) - Taphonomy

Faunal preservation

The FSI distribution among species is dominated by a very high FSI index from Bos/ Bison (37.9g) for study sample 17.10 as one very large femur shaft was identified, which additionally is a bone used as tool artifact with use -retouch from possible levering activities. Horse remains were also found in quite larger pieces followed in size by red deer remnants. In general ibex, chamois and roe deer bones were identified as smaller fragments (1.4 -3.2g), followed by hare, bird and fox remains (0.1-0.8g). See Appendix Figure C.5.8.



Appendix Figure C.5.8: Fragment Size Index (FSI) variation among species in Level 17.10.

Number of Complete skeletal elements. In study sample 17.10 body parts of head and feet are the most of complete skeletal elements from 319. A complete lower tooth of both horse and Bos/Bison were found. Spanish ibex has the most complete elements within this unit. The body part head contains a complete nasal bone, 58 upper and 47 lower teeth. Other complete bones are four knee, 14 carpal, 15 tarsal bones, two tali and one calcaneus. The complete feet bones from ibex comprise seven phalanges and 68 sesamoid. Complete chamois bones identified are one upper and two lower teeth, and one phalanx. Red deer remains include 40 complete upper and 12 complete lower teeth, three carpals, one talus and two tarsal bones, one atrophic metapodial, two phalanges, 17 atrophic phalanges and 3 sesamoids. The lower incisor from reindeer was preserved in a complete state. A complete lower tooth from fox was also registered. Two complete caudal vertebrae and another one tooth were also recorded in the database.

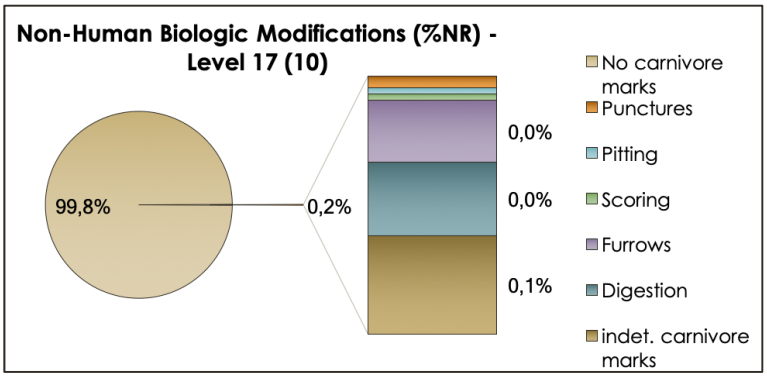
Appendix Table C.5.12 summarized the observed breakage pattern. Green fractures (74.8%) dominate the fracture pattern of the studied faunal remains from unit 17-10. This amount is followed by green and dry fractures. Undefined fractures are the third- most represented fracture patterns.

Appendix Table C.5.12: Breakage type, Level 17-10 (only bones identified taxonomically or in animal size classes).

Breakage- profile	NISP	%NISP
Green fracture	1548	74.8
Green and dry fracture	221	10.7
Green fracture, two phases	19	0.9
Dry fracture	7	0.3
Recent fracture	80	3.9
Indeterminate	194	9.4
Total	**2 069**	**100**

Non-Human Biological Agents

Carnivore marks were identified on 25 faunal remains in study sample 17.12, which represents low carnivore activities within this level (Appendix Figure C.5.9). All digestion marks are attributed to vulture activities and effected teeth, carpal bones, atrophic phalanges, phalanges and sesamoid bones. Bite marks are located on long bones, vertebrae, shoulder and pelvic bone, tarsal and phalanges.



Appendix Figure C.5.9: Carnivore activities observed in Level 17 (12).

Digestion marks are all found on red deer and ibex bones, plus one on chamois and one on a medium- to large- size mammal bone in sample 17-10. The bird remains identified carry marks from small carnivore activities.

Human activities

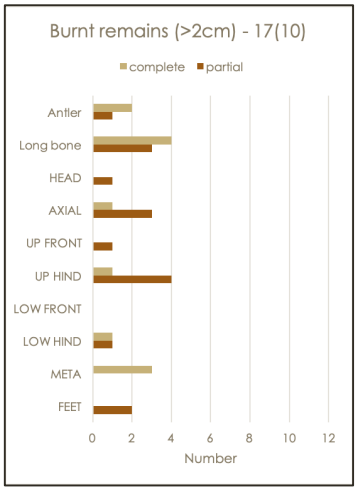
The anthropogenic modifications observed are dominated by impact marks and cut marks and were found on all body parts in different animal species (Appendix Table C.5.13). Even when the highest number of cut-marked bones were found in square H3 (20.5%), several other squares also contained more than 10%; they are I2 (10.1%), I3 (11.1%), I4 (13.1%), J3 (15.9%) and J4 (13.7%). Impact marks on bones were found also on a more evenly distribution with the following locations with more than 10%: H2 (10%), H3 (19.9%), I2 (14.4%), I4 (12%), J3 (14.7%), and J4 (11.7%).

Bone artifacts are also quite evenly distributed as they are present in square H3 to15.2%, in I2 to16.7%, I3 to 12.9%, in I4 to 12.9% and in J4 to 15.2%. Bone and antler artifacts types identified in Sample 17-10 are the following: flakes, blank production waste and failures, tools (*sagaie's*, needles, wedges, retouchers, used bones), decorated elements with cut marks or red ochre, and tooth pendants. Other objects of the osseous industry already presorted and separated during excavation are not included in these totals, but were summarized by Straus et al. (2018).

Appendix Table C.5.13: Number of specimen with anthropogenic modifications in Level 17.10.

Species	Cut marks	Impacts	Burning	Artifact
Equus ferus	4	4		
Bos/Bison	4	4		
Capra pyrenaica	175	219	8	18
Rupicapra rupicapra	2	2		
Cervus elaphus	213	322	18	74
Capreolus capreolus		1		
Rangifer tarandus				1
Lepus sp.	1	1		
Bird	2			
M Ungulate	20	12		3
L Ungulate	1	1		1
S-M Size		1		
M-L Size	75	65	10	29
Indeterminate	6			6
Total	**503**	**632**	**36**	**132**

Burnt faunal remains, on the other hand, are more concentrated in three squares, I3, I4 and J3 with each containing 19.4% of the burnt bones. Different degrees of burning were observed among the animal remnants, which are dominated by reddish roasting marks (36.1%), then completely carbonized (27.8%) and partially carbonized (22.2%). Heavily burnt elements (complete carbonized to calcined) are antler, rib, metapodial, knee bone, talus, phalanges and only partially burnt elements (roasted to partially black) are mainly long bones and vertebrae (Appendix Figure C.5.10).



Appendix Figure C.5.10: Distribution of Burning degree among the body parts, Level 17-10.

Human-carnivore interactions

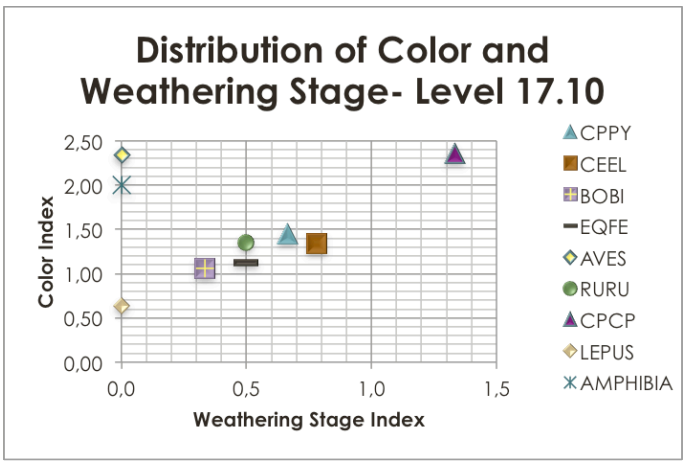
The portion of anthropogenic modifications on faunal remains is drastically higher than the carnivore marks, although they are present. Two red deer bones, a metatarsal and tibia shaft fragment, were registered with both, human and carnivore modification marks (pitting and gnawing). Most of the individually recorded faunal remains (94.8%NR), though, do not show direct modification marks. See Appendix Table C.5.14.

Appendix Table C.5.14: Number of specimen with anthropogenic vs. carnivore modifications from Level 17-10.

Species	Anthropogenic	Carnivore	Both
Equus ferus	6		
Bos/Bison	4		
Capra pyrenaica	332	8	
Rupicapra rupicapra	3	1	
Cervus elaphus	435	7	2
Capreolus capreolus	1		
Rangifer tarandus	1		
Lepus sp.	2		
Bird	2	1	
M Ungulate	24		
L Ungulate	3		
IND M-L Size	133	5	
IND	482	21	
Total: 1473 (100%NR)	**1 428 (97%NR)**	**43 (2.9%NR)**	**2 (0.1%NR)**

Post-depositional modifications

The weathering and color index seem to be nearly correlated as among the main prey species red deer, ibex, chamois, roe deer, Bos/Bison and horse the higher the weathering stage the higher the color pigmentation is. Hare, amphibian and bird bones seem to be set apart, showing no weathering traces. See Appendix Figure C.5.11.



Appendix Figure C.5.11: Color and Weathering Index, Level 17.10.

Level 17 (10) – Summary

The dietary role of two horse and two bos/bison individuals is unclear, red deer and ibex heavily dominate the faunal assemblage of Level 17—10, and where focused for dietary purpose. That is shown by intensite modification marks of cut marks, impact, burning, etc. Eight adult red deer would have provided the most biomass accompanied by eight adult ibex, although growing stages of individuals indicate time-shifted hunting. Longer duration of occupation of more people are indicted with hunting red deer in late summer to early autumn followed by ibex in late autumn-early winter. The varied carnivore marks include digestion marks, possible occurred by vulture in absence of humans and bite marks. Preservation of faunal remains is good (compare also Appendix Figure C.5.12) and post-depositional alterations are very similar among all bovids, horse and red deer inferring same accumulation, depositional and diagenetic contexts of these prey. However, weathering cracks on some of these bones show that they have been lying on the surface temporary, maybe during warmer season, in generally dry sediments.



Appendix Figure C.5.12: Examples from the faunal material from Level 17-10.

Level 17(8) – Quantification

The faunal assemablge from Level 17-8 contain 53 195 bones and 1 111 teeth. See Appendix Table C.5.15.

Appendix Table C.5.15: Faunal quantification, Level 17-8.

Species	NR	Weight	MNE	MNI
Equus ferus	6	86.0	5	1
Bison priscus & Bos/Bison	22	382.7	15	1
Capra pyrenaica	940	2 498.4	304	20
Rupicapra rupicapra	12	20.6	9	1
Cervus elaphus	796	5 724.9	165	13
Capreolus capreolus	1	3.6	1	1
Lepus sp.	2	0.6	2	1
Bird	6	2.3	2	2
Fish	6	0.2		

S Ungulate	5	2.5		
M Ungulate	94	308.0		
L Ungulate	20	202.8		
S Carnivore	2	1.1		
<XS Size	2	8.0		
M-L Size	503	1 706.7		
XL Size	2	17.4		
Indeterminate	51 887	11 089.0		
Total	**54 306**	**22 054.8**	**503**	**40**

Equus ferus (Boddaert, 1785)

Six horse remains were identified with the Sample 8 from Level 17. One nasal fragment, an upper pre/molar and two lower pre/molar fragments comprise the head remains attributed to horse. A radial carpal bone was identified from the left side. One long bone in form of a tibia shaft fragment from a young individual was identified.

Bison priscus & Bos/Bison

A plantar femur shaft fragment that includes the nutritional canal on the medio-distal part of the bone and the *fossa supracondylaris femoris* shows the structure characteristic for Bison morphology.

More (NISP=21) large bovid fragments were identified that were not clearly to determine, if coming from aurochs (*Bos primigenius*) or bison (*Bison priscus*). These remains include two teeth; a complete upper P3 and a crown of a lower pre/molar. A right and a left humerus fragment are presented by the landmarks *foramen nutritium* and *tuberositas deltoidea*, respectively. Each of the two *facies interosseum* fragments embodies one radius bone as they come from the right and left side. Two metacarpal specimens resemble the *sulcus longitudinalis dorsalis* from an MNE of one. A left supracondyloid fossa fragment and a right bone with an interior foramen nutritium from femur represent another two elements. Two tibia shaft fragments were identified. A proximal phalange and a proximal part of a medial phalange specimen represent the feet bones. The axial remains are represented by a cervical vertebrae bone part and four rib fragments.

Capra pyrenaica (Schinz, 1838)

From Spanish ibex, I have identified 230 teeth and 708 bone fragments within the study Sample 8 of Level 17. See Appendix Table C.5.16. The cranium is represented by three occipitals, two temporal bones and three base fragments. The zygomatic and maxillary fragments mark the facial elements identified from the head. All parts of the mandible bone were identified including diastema, corpus, ramus, articulating face and muscular process, while four of these fragments have a porous structure probably belonging to young animals and three of these overlap at the left articulating process. Three hyoid fragments represent the right hyoid process. The axial presence is comprised of two atlas fragments, seven cervical, four thoracic, seven lumbar, one caudal, one undefined vertebrae and 26 rib fragments with nine rib heads. Shoulder fragments represent a minimum of a right and a left side from adult individuals as well as an infantile (9-13 months old, spring death). Humerus was mainly by shaft fragments identified that contained seven left and four right nutritional canals. A small proximal radius shaft fragment represents an infantile animal and a distal epiphysis a juvenile. For the ulna I identified four proximal shaft fragments which represent four individuals. Each carpal, *c. intermedium* and *c. secundum y tertium*, represents an MNI of four for ibex within this study unit. The proximal articular surface from metacarpals was identified six times; one specimen is porous in its structure and presumably indicates a juvenile individual. Five right acetabula from the pelvic bone are present indicating five animals, with one female included. Among the femur fragments were identified two proximal epiphyses and three proximal fused parts representing an MNI of one juvenile and two adults. Tibia

fragments contribute four right and left nutritional canals as well as distal epiphyses, two additional distal epiphyses are unfused indicating a Juvenile. From talus different right and left fragments are present, but landmarks overlap only at the right lateral part. The MNI of a Juvenile and three Adults for calcaneus fragments were estimated base on two unfused, right and left proximal epiphyses and three left articulating faces. Tarsal fragments are represented by a porous and three right and left *t. secundum y tertium* bones. The skeletal element metatarsus is represented by proximal parts with seven left and six right ones, while one distal part is fusing indicating a juvenile animal (23-26 months old, spring death) showing the same age as another distal metapodial fusing fragment. One proximal (11-15 months old, spring death) and two medial (9-13 months old, spring death) fusing phalanges indicate minimum one animal that died with circa one year of age. A very small, porous medial phalanx represents a fetal animal (winter-spring death).

Appendix Table C.5.16: Ibex remains, Level 17-8.

Capra pyrenaica (Level 17-8)	NISP	MNE					MNI				
Element	All	All	fet	inf	juv	adu	All	fet	inf	juv	adu
Horn	3										
Cranium	11	5				5	3				3
Viscerocranium	4	3*				3*	2				2
Upper teeth	87	24			6	18	15			3	12
Mandible	28	9*			4*	5*	7			3	4
Lower teeth	127	27			5	22	16			3	13
Teeth indet.	16										
Hyoid	7					3	3				3
Cervical vert.	10	3				3	3				3
Thoracic vert	4	1					1				
Rib	28	9				8	1				1
Lumbar vert.	7	2					1				
Caudal vert.	1	1					1				
Vert. indet.	1	1					1				
Scapula	12	3		1		2	2		1		1
Humerus	34	11				11	7				7
Radius	21	4			1	3	3			1	2
Ulna	18	5				5	4				4
Ulna/Radius	5										
Carpal unit	32	7				6	4				4
Metacarpus	17	8				8	6				6
Pelvis	22	9				9	5				5
Femur	46	5			2	3	2			1	2
Tibia	35	10			2	8	5			2	3
Talus	5	3			2	3	2				2
Calcaneus	6	3			2	2	3			1	2
Tarsal unit	23	8				7	4				4
Metatarsus	29	16				15	9				
Metapodial	22										
Phalanx prox.	77	19		4		16	15		2		13
Phalanx med.	60	21	1	4		16	14	1	3		10
Phalanx dist.	23	16				15	9				9
Phalanx indet.	1										
Sesamoid	114	86									
Humerus/Femur	2										
Long bone indet.	3										
Total	941	309	1	9	24	189	20	1	3	3	13

Rupicapra rupicapra (Linnaeus, 1758)

In total were identified as chamois four lower teeth and eight bones within Sample 17-8. The identified isolated teeth comprise complete lower left canine and P4 as well as a right P2, next to a fragment of an incisor. Bone fragments classified as radius include a left proximal articular surface and a right *facies interosseum*. Two left ulna shaft fragments are present. A complete left ulnar carpal bone was identified coming from chamois. Two femur fragments include the following landmarks: right *trochanter tertius* and left *foramen nutritium*. A medial phalange was recognized as being chamois.

Cervus elaphus (Linnaeus, 1758)

Altogether I identified 65 teeth and 731 bone specimens as red deer within Level 17, Sample 8. See Appendix Table C.5.17. Antler fragments with a number of 135 fragments were abundantly recorded within this unit, which include three tine fragments. A right and a left *pars petrosa*, a zygomatic and a maxillary bone identify head fragments. Two left articulating processes and one right represent minimum three mandible elements and two individuals. Three right upper P2s and P4s, respectively, represent adult individuals and one upper dP4 a Juvenile. Right and left lower milk molars (dP2, dP3, dP4) also represent juvenile animals, but lower three, left P2s indicate again three adults. The number of vertebrae identified was estimated based on the representation of the corpus fragments. Humerus MNI's counts mirror the number of nine right nutritional canals identified. Radius fragments present at least two individuals with two proximal epiphyses identified. From ulna right and left fragments are present, representing at least one of each side. Two right *c. intermedium* and two left *c. radiale* identify a minimum of two carpal units from each side within this study unit. Seven left and four right proximal fragments comprise the MNI of metacarpal elemental parts. One unfused ilium fragment represents a juvenile. The second most identified single skeletal element is the femur with also the highest MNI, estimated by number of eleven fragments containing the right *fossa supracondylaris,* including one young individual. The highest NISP with 97, though, belongs to tibia fragments, while the identified right nutritional canals represent an MNI of eight including a porous bone from a younger animal. Among the distal tibia parts two metaphysis, one right unfused epiphyses and one right fused distal part also represent minimum one juvenile and one adult. The lateral part of the talus including the articulating face was identified two times from the left side counting for a MNI of two. The *tuber calcanei* is represented four times and one fragment is unfused indicating a juvenile or younger individual and other fragments show the stage of fusing for a juvenile-subadult animal (26-29 months old, summer death). All three different tarsal bones come from the left side and embody, therefore, only one individual. Four left and one right proximal metatarsal fragment were identified that count for minimum three individuals. Phalanges count a total of 78 items that represent an MNE of 59. Seven left and six right distal articulating faces represent proximal phalanges of minimum two individuals older than juvenile, though right and left unfused ones are identified, too. Three left and four right distal parts of the medial phalange was identified and counts for an MNI of one. The distal phalanx fragments comprise three left and four right parts and another distal specimen from a neonate animal indicating a late spring/summer death.

Appendix Table C.5.17: Red deer remains, Level 17-8.

Cervus elaphus (Level 17-8)	NISP	MNE					MNI				
Element	All	All	neo	inf	juv	adu	All	neo	inf	juv	adu
Antler	135										
Cranium	3	2				1	1				1
Viscerocranium	1	1*					1				
Upper teeth	21	5			1	4	4			1	3
Mandible	14	3*				3*	2				2
Lower teeth	36	7			2	5	4			1	3
Teeth indet.	8										
Hyoid	3	3				3	2				2
Cervical vert.	8	3					1				
Thoracic vert.	5	2					1				
Rib	14	4					1				
Lumbar vert.	13	4					1				
Sacrum	1	1					1				
Caudal vert.	1	1					1				
Vertebrae indet.	5	2									
Scapula	11	1					1				
Humerus	47	12				12	9				9
Radius	29	3				4	2				2
Ulna	9	2				2	1				1
Ulna/Radius	5										
Carpal unit	7	4				4	2				2
Metacarpus	48	11				11	7				7
Pelvis	11	3			1	2	3			1	2
Femur	70	9			1	14	11			1	10
Tibia	97	14			2	7	8			1	7
Talus	2	2				2	2				2
Calcaneus	7	2			1	1	2			1	1
Tarsal unit	3	1				1	1				1
Metatarsus	52	5				5	3				3
Metapodial indet.	22										
Meta. atrophic	2										
Phalanx prox.	34	21		2		6	3		1		2
Phalanx med.	9	7				7	1				1
Phalanx dist.	11	8	1			7	2	1			1
Phalanx atrophic	24	23					3				
Sesamoid	8	3				3	1				1
Humerus/Femur	4										
Long bone indet.	16										
Total	796	165	1	2	8	101	13	1	1	1	10

Capreolus capreolus (Linnaeus, 1758)

A proximal shaft from an ulnar bone was identified as coming from roe deer.

Lepus spec.

Two hare bones were registered. One proximal femur with its articulating face from the right side and the distal shaft from a metapodial are present.

Bird remains

Six bird bones were identified within Level 17, Sample 8. During analysis were classified five long bone fragments, where one is a femur distal epiphysis form a young individual. A distal phalanx was also found coming from a bird.

Anatomically identified by size classes

Appendix Table C.5.18 summarizes specimen anatomically identified. The lumbar vertebra presumably from a large bovid is fused. The pelvic fragment from a large sized artiodactyl is fused. Within the category of medium sized artiodactyl has one long bone shaft a porous structure, one is an unfused metaphysis and another is a distal epiphysis, all three indicating young animals. The bones classified as medium to large sized mammal include several indicators for young animals. Among the axial skeletal part were found: small and porous bone structure in ribs and ten unfused vertebrae fragments indicating young animals, and two lumbar vertebrae were fused indicating am older individual. An unfused humerus or femur fragments together with two unfused epiphyses, eight metaphysis fragments and five porous shaft fragments represent young animals. The assemblage also contained 224 fetal/neonate bones.

Appendix Table C.5.18: Faunal remains by size classes, Level 17-8. *=NR.

Size classes (Level 17-8)	XL Size	L Ungulate	M-L Size	M Ungulate	S Ungulate	S Carnivore	< XS Size	Indeter.
Element	NISP	NISP	NISP	NISP	NISP	NISP	NISP	NISP
Cranium			23	4				
Viscerocra.			1					
Mandible			4	2				
Lower teeth		1			2			
Teeth			4					800
Cervical vert.		2	4	2				
Rib		2	28	4	2	1		
Lumbar vert.	1	1	6	2				
Sacral vert.			2					
Indet. Vert.			32	5				
Humerus		1	3	1				
Radius			1					
Carpal unit			1					
Pelvis		1	2	1				
Femur				1	1			
Tibia				1				
Talus		1						
Tarsal unit			1					
Metapodial			2				1	
Phalanx med.			1					
Phalanx dist.		1						
Sesamoid			1					
Humerus-Femur			9					
Radius-Tibia				9				
Long bone			301			1		3429

Flat bone	1	9	3	50				
Irregular bone			16					2
Spongy bone				12				41679*
Indeterminate		1	58				1	5753*
Total	2	20	503	94	5	2	2	51663

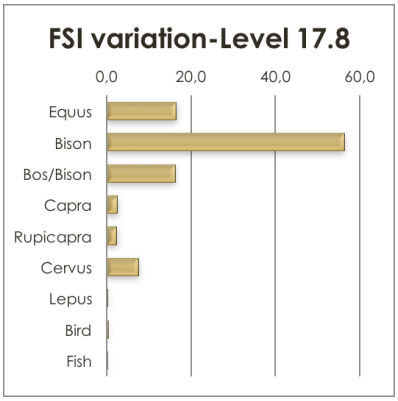
Seasonality

Ungulate fetal bones also attest winter/ spring kills of pregnant adults. Other indicator for season of death show a large range from late summer-autumn until mid-spring, repeatedly showing that intensity in red deer kills precede that of ibex kills.

Level 17(8) – Taphonomy

Faunal preservation

Relatively similar large fragments were found from Bos/Bison and horse in study sample 17.8, which are followed according to the size index from red deer. The other species, Spanish ibex, chamois and roe deer are registered with comparably small fragments. The fragments of hare and birds are tiny. See Appendix Figure C.5.13.



Appendix Figure C.5.13: Fragment Size Index (FSI) variation among species in Level 17.8.

Number of Complete skeletal elements. Study Sample 17.8 shows also a representative number of complete elements of 385 among the entire studied animal finds. Most of the complete elements come from head and feet body parts. From horse there is a complete carpal bone preserved and from bison a complete upper tooth. Spanish ibex head and body parts consist of 63 upper and 82 lower complete teeth. 29 carpal and 15 tarsal bones, five phalanges and 108 sesamoid bone accompany the ibex complete elements. For chamois I registered the following complete bones: three lower teeth and one carpal bone. Red deer remains include also several complete elements, which are 16 upper and 18 lower teeth, one caudal vertebrae, six carpal bones, one tarsal bone, one atrophic metapodial, two phalanges, 21 atrophic phalanges and eight sesamoid bone. Two complete lower teeth coming from a small artiodactyl and one sesamoid from a medium to large sized mammal.

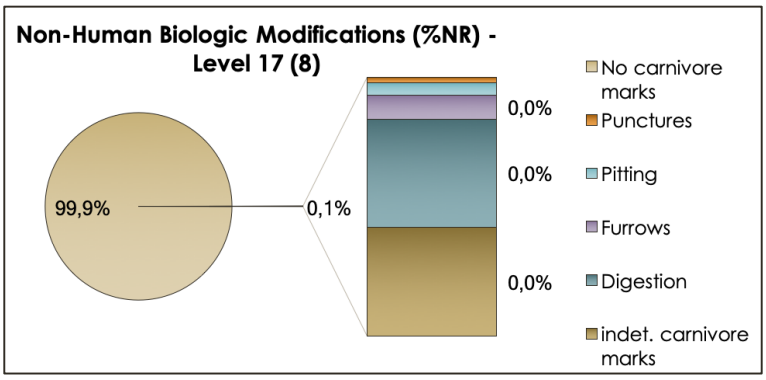
Appendix Table C.5.19 summarized the observed breakage pattern. Green fractures (78.2%) dominate the fracture pattern of the studied faunal remains from study sample 17-8, while 12.5% are registered as undefined. Other fracture patterns such are dry or recent are quite infrequently present among the studied animal bones.

Appendix Table C.5.19: Breakage type, Level 17-8 (only bones identified taxonomically or in animal size classes).

Breakage- profile	NISP	%NISP
Green fracture	1 289	78.2
Green and dry fracture	79	4.8
Green fracture, two phases	20	1.2
Dry fracture	12	0.7
Recent fracture	42	2.5
Indeterminate	206	12.5
Total	**1 557**	**100**

Non-Human Biological Agents

Carnivore marks were identified on only 26 faunal remains, which represents evidence of low carnivore activity within this study sample –17.8% (Appendix Figure C.5.14). Digested bones include teeth, vertebrae, carpal bones, phalanges, a metapodial and two long bone fragments, most of them were found in squares I3 and J3. The seven bite marks identified are dominated by chewing marks. Bite marks are located on a rib, long bones, pelvic bone, sesamoid and phalanx.



Appendix Figure C.5.14: Carnivore activities observed in Level 17 (12).

Most carnivore modifications were found on red deer and Spanish ibex bones in study sample 17.8. Hare bones in the deposit carry small carnivore activities.

Human activities

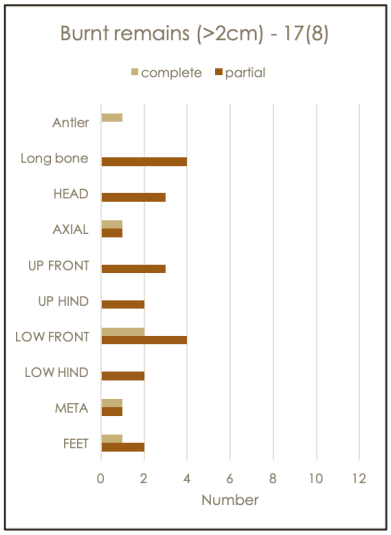
Study sample 17-8 contains generally less anthropogenic marks identified compared with sample 17-10. The relative frequency of impact marks is dominant within this distribution (Appendix Table C.5.20). Square J3 reveals in every category of anthropogenic modifications the highest number of remains and seems to have been the center of carcass-processing activities within this human occupation. Cut –marks and impacts were found on all body parts.

Appendix Table C.5.20: Number of specimen with anthropogenic modifications in Level 17.8.

Species	Cut marks	Impacts	Burning	Artifact
Bison priscus	1	1		
Bos/Bison	4	8	2	1
Capra pyrenaica	68	127	5	3
Rupicapra rupicapra	2	3		
Cervus elaphus	87	195	16	45
Capreolus capreolus	1			
Lepus sp.		1		
S Ungulate		1		
M Ungulate	10	12	1	1
L Ungulate	4	6		
<XS Size	1	1		
M-L Size	29	62	4	14
Indeterminate	2		1	1
Total	**209**	**417**	**29**	**65**

Completely carbonized bones concentrate along the J-squares (J2, J3, J4) at the eastern end of the Outer Vestibule excavation area, while roasted bones are scattered throughout. Completely carbonized bones include vertebrae, carpals and sesamoids. Partially burnt bones and reddish roasted elements are mainly long bones, phalanges and teeth (compare Appendix Figure C.5.15).

Bone and antler flakes dominate the osseous artifacts followed by bone tools; all together they were concentrated in square J3 (40%) and J2 (24.6%). Other objects of the osseous industry already presorted and separated during excavation are not included in these totals, but Straus et al. (2018) summarized them in a publication.



Appendix Figure C.5.15: Distribution of burning degree among the body parts in sample 17.8.

Human-carnivore interactions

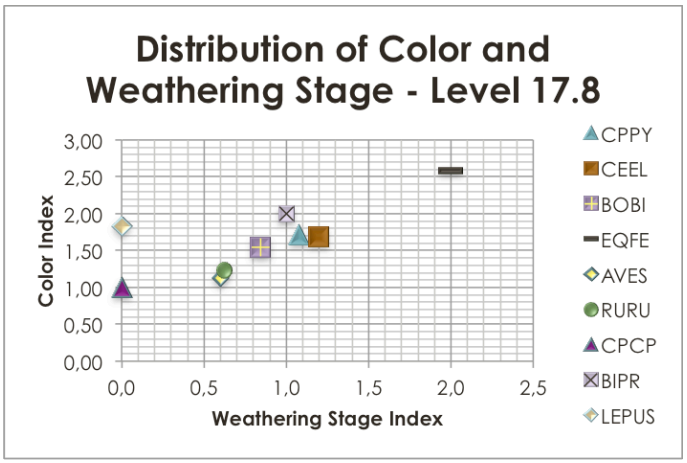
Direct anthropogenic modification marks dominate the analyzed fauna in study sample 17-8, and a low percentage showed carnivore marks. Most of the bones (97.3%NR) from this sample, though, do not show modification marks. See Appendix Table C.5.21.

Appendix Table C.5.21: Number of specimen with anthropogenic vs. carnivore modifications from Level 17-8.

Species	Anthropogenic	Carnivore
Equus ferus		
Bison priscus	1	
Bos/Bison	10	
Capra pyrenaica	176	8
Rupicapra rupicapra	3	
Cervus elaphus	259	5
Capreolus capreolus	1	
Lepus sp.	1	1
Bird		
Fish		
S Ungulate	1	1
M Ungulate	14	1
L Ungulate	9	1
CAR S		
<XS Size	1	
M-L Size	87	5
XL Size		
Indeterminate	868	26
Total: 1479 (100%NR)	**1 431 (96.8%NR)**	**48 (3.2%NR)**

Post-depositional modifications

Similar to study sample 17.10, sample 17.8 displays a correlation between the degree of the weathering index and coloration of the bones. Red deer and Spanish ibex, the main prey species, scatter in the plot close together, accompanied by Bos/Bison bones. Horse remains show the most advanced weathering stage as well as the highest coloration index. Chamois and bird bones show less weathering and coloration. Hare and roe deer bones do not show weathering processes, but their coloration falls within the range of the other species. See Appendix Figure C.5.16.



Appendix Figure C.5.16: Color and Weathering Index, Level 17.8.

Level 17 (8) – Summary

The biomass accumulated during El Mirón occupations of Level 17-8 is highest among the observed samples with 13 adult (and 3 juvenile) ibex, and ten adult red deer. Again, intensive site use seemed to were based on first targeting red deer for prey in late summer-autumn and later ibex during winter-spring. Among those faunal remains were found many cut marks, impact marks, and evidence of burning, especially concentrating in square J3 which were possible a center of carcasses processing activities. Again represent a few bones digestion and bite marks, showing that carnivores only had little access to these faunal leftovers. The group of preyed taxa has slightly darker coloration types and somewhat advanced weathering than what have been observed in the underlying sample, but still relatively good preservation conditions as shown in the following photographs (Appendix Figure C.5.17).



Appendix Figure C.5.17: Examples from the faunal material from Level 17-8.

Level 17(6) – Quantification

Level 17-6 contained 39196 bones and 1426 teeth as summarized by species in Appendix Table C.5.22.

Appendix Table C.5.22: Faunal quantification, Level 17-6.

Species	NR	Weight	MNE	MNI
Equus ferus	3	34.8	3	1
Bos/Bison	1	8.9	1	1
Capra pyrenaica	366	726.3	136	10
Rupicapra rupicapra	4	1.4	3	1
Cervus elaphus	156	888.1	42	3
Capreolus capreolus	3	3.1	2	1
Canis lupus	2	1.8	1	1
Bird	3	1.3	2	1
S Ungulate	2	2.6		
M Ungulate	29	77		
L Ungulate	4	22.9		
M Carnivore	1	0.3		
M-L Size	112	484.7		
Indeterminate	39 936	5 998.5		
Total	**40 622**	**8 251.7**	**190**	**19**

Equus ferus (Boddaert, 1785)

Enamel from a lower tooth was identified as coming from a horse within Level 17, Sample 6. Two more bone fragments include a horse metatarsal and a complete sesamoid.

Bos/Bison

One radius fragment from a large bovis (Bos sp. or Bison) was identified.

Capra pyrenaica (Schinz, 1838)

The teeth summarized numerically comprise the highest NISP in ibex. Upper milk molars (2 each of dP3 and dP4) were identified as belonging to two juveniles and each of the five permanent left P2 indicate an adult. Three right lower milk teeth dP4 also indicate juvenile or younger animals and six right permanent M3s indicate adults. Head elements from Spanish ibex represented within sample 6 of Level 17 comprise the following bone fragments: two horn, a palatine plate, two mandible corpora and three hyoids. From the axial part are present two ribs and one lumbar vertebrae fragment. The upper frontal body part stands for a MNI of one, while humerus shafts are present from the right and the left side. Radius specimens indicate three proximal left parts and one right distal metaphysis. For the ulna one right and one left element were identified. With the carpal bones identified, an estimation of five MNI was calculated based on the bone *c. secundum y tertium*. Minimum one right and one left metacarpal, pelvic bone and femur are present, but one unfused proximal femur suggests a juvenile individual. An unfused, distal tibia and unfused calcaneus could represent the same individual as mentioned above. The second and third tarsal bone is represented four times from the right side and two times from the left one. A juvenile is also present by unfused distal metatarsal epiphyses. The proximal, medial and distal phalanges as well as the sesamoid indicate two adults and one infantile individual. See Appendix Table C.5.23.

Appendix Table C.5.23: Spanish ibex remains, Level 17—6.

Capra pyrenaica (Level 17-6)	NISP	MNE				MNI			
Element	All	All	inf	juv	adu	All	inf	juv	adu
Horn	2								
Viscerocranium/Maxilla	1	1*			1*	1			1
Upper teeth	46	9		2	7	6		1	5
Mandible	2	2*			2*	1			1
Lower teeth	82	13		3	10	9		3	6
Teeth	8								
Hyoid	3	3			3	2			2
Rib	2	1			1	1			1
Lumbar vert.	1								
Scapula	2	1				1			
Humerus	7	2			2	1			1
Radius	5	4	1		4	3	1		3
Ulna	4	2			2	1			1
Carpal unit	22	9			9	5			5
Metacarpus	2	2			2	1			1
Pelvis	4	2			2	1			1
Femus	7	3		1	2	2		1	1
Tibia	9	4		1	3	3		1	2
Talus	1	1				1			

Calcaneus	3	1		1		1		1	
Tarsal unit	14	6		1	5	5		1	4
Metatarsus	7	4		1	3	2		1	2
Metapodia	10								
Phalanx prox.	36	22	4		9	3	1		2
Phalanx med.	34	18	4		14	3	1		2
Phalanx dist.	11		2		8	3	1		2
Sesamoid	39	29		1	28	5		1	4
Humerus-Femur	1								
Long bone	1								
Total	366	136	11	11	114	10	1	3	6

Rupicapra rupicapra (Linnaeus, 1758)

Four chamois teeth within the faunal assemblage comprise two lower I2, a lower dI1 and an upper P2, together they represent an MNI of one.

Cervus elaphus (Linnaeus, 1758)

The best represented elements are the lower teeth; they also account for the most individuals. A number of 21 individually collected antler fragments come from red deer. Head elements identified include a *pars petrosa* and a corpus and ramus fragment from the mandible. Upper teeth include one milk tooth (dP2) and right and left teeth. Lower teeth include two P2s and one dP3, representing two adults and one Juvenile, respectively. Shoulder, humerus, ulna and metacarpal specimens represent a minimum of one individual, but among the radius fragments I found an overlap at the distal epiphysis indicating two individuals. The hind extremities are represented by femur, tarsals and metatarsals for one individual. but a tibia nutritional canal count implies the presence of two individuals, including one juvenile with an unfused proximal epiphysis that is also indicated by another unfused, distal metapodial epiphysis. Three proximal and three medial phalanges represent an MNI of one. Three distal phalanges include a porous one that indicates a juvenile along with other fully developed ones. See Appendix Table C.5.24.

Appendix Table C.5.24: Red deer remains, Level 17-6.

Cervus elaphus (Level 17-6)	NISP	MNE			MNI		
Element	All	All	juv	adu	All	juv	adu
Antler	21						
Cranium	1	1			1		
Upper teeth	10	3	1	2	2	1	1
Mandible	2	2*		2*	1		1
Lower teeth	23	4	1	2	3	1	2
Teeth	4						
Rib	1	1			1		
Lumbar vert.	3	2		1	1		1
Scapula	2	1		1			1
Humerus	3	2		2			1
Radius	8	3		3			2
Ulna	3	1		1			1
Ulna-Radius	1						
Metacarpus	10	2		2			1
Pelvis	3	1		1			1

Femur	6	3		2	2		1
Tibia	12	4	1		2	1	
Tarsal unit	1	1		1	1		1
Metatarsus	13	2		2	1		1
Metapodia	7		1		1	1	
Metapodia atrophic	1						
Phalanx proximal	4	3		3	1		1
Phalanx medial	4	2		2	1		1
Phalanx distal	3	3	1	2	2	1	1
Phalanx atrophic	5	2		2	1		1
Sesamoid	4	1			1		
Long bone	1						
Total	156	42	5	29	3	1	2

Capreolus capreolus (Linnaeus, 1758)

A lower milk tooth dI1 is slightly worn (infantile) and a heavily worn M1 (adult) are present from roe deer. A third phalanx was also identified.

Canis lupus (Linnaeus, 1758)

The proximal and medial phalange from a wolf is represented within the faunal remains from study unit 17-6; the proximal part of the medial one is fused, while the complete proximal one is fusing.

Bird remains

The proximal and two distal phalanges represent minimum one bird individual within these faunal remains.

Anatomically identified by size classes

Two unfused vertebrae were identified; one from a medium -size artiodactyl and another from a medium- to large- size mammal. The level contained 187 fetal/neonate bones. See Appendix Table C.5.25.

Appendix Table C.5.25: Faunal remains by size classes, Level 17-6. *=NR.

Size classes (Level 17-6)	L Ungulate	M-L Size	M Ungulate	S Ungulate	M Carnivore	Indeterminate
Element	NISP	NISP	NISP	NISP	NISP	NISP
Cranium	1	4	2	1		
Upper teeth					1	
Mandible	1		1			
Teeth			1			1244
Cervical vert.		2				
Rib	1	4	4			1
Sternum						
Lumbar vert.		1				
Sacral vert.			1			
Indet. vert.		3	3			
Radius			1	1		
Tibia		1				
Tarsal unit		1				
Sesamoid			1			

Humerus-Femur		2	1			
Long bone	1	89	14			1879
Irregular bone						1
Spongy bone						33222*
Indeterminate		5				3589*
Total	4	112	29	2	1	39936

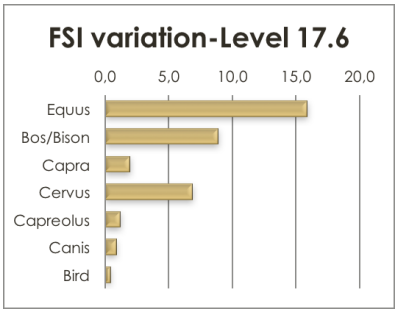
Seasonality

Ungulate kills concentrate in late autumn-early winter seasonality, although the accumulation of fetal bones could be the results of kills until spring. Shorter occupation duration could be also the result of Level 17-6 assemblages being the smallest of the studied ones.

Level 17(6) - Taphonomy

Faunal preservation

Bos/Bison and horse have the largest registered bones, followed by red deer and then ibex bones. Roe deer, chamois, wolf and bird remains are rather small. See Appendix Figure C.5.18.



Appendix Figure C.5.18: Fragment Size Index (FSI) variation among species in Level 17.6.

Number of Complete skeletal elements. Study sample 17-6 contains 188 complete elements mainly from head and feet. One horse sesamoid bone is completely preserved. Complete Spanish ibex elements are the following: 27 upper and 49 lower teeth, 19 carpal bones, twelve tarsal bones, 3 phalanges and 33 sesamoid bones. Chamois only includes one upper and two lower teeth. For red deer there are eight upper and 15 lower complete teeth registered in the database, as well as one tarsal bone, five atrophic phalanges and four sesamoid. Roe deer remains include two complete lower teeth and wolf remnants two complete phalanges, as well as remains of bird were found.

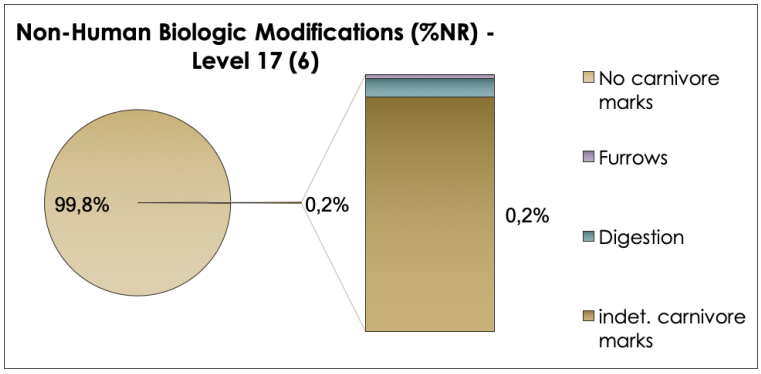
Appendix Table C.5.26 summarized the observed breakage pattern. Green fractures (77.6%) dominate the fracture pattern of the studied faunal remains from sample 17-6. Bones where it was not possible to differentiate between dry, green or recent fractures belong to the unidentified category, which is the second -most abundant one found in this unit.

Appendix Table C.5.26: Breakage type, Level 17-6 (only bones identified taxonomically or in animal size classes).

Breakage- profile	NISP	%NISP
Green fracture	304	77.6
Green and dry fracture	8	2.0
Green fracture, two phases	12	3.1
Dry fracture	10	2.6
Recent fracture	5	1.3
Indeterminate	53	13.5
Total	**392**	**100**

Non-Human Biological Agents

Only six times were carnivore marks identified within study sample 17.6 (Appendix Figure C.5.19) on red deer and ibex bones. Carnivore modification marks are dominated by digestion marks probably related to vulture activities. Gnawing marks were found on a rib of medium to large size. The digested bones are the following: two teeth, one metapodial and one phalanx; they are all on red deer or ibex bones.



Appendix Figure C.5.19: Carnivore activities observed in Level 17 (12).

Human activities

In study sample 17.6 shows red deer with the most modifications marks, closely followed by Spanish ibex. These faunal remains are dominated by impacts from human activities, followed by cut marks on bones. Cut -marks were found on all body parts, despite the upper hind. Cut- marked bones scatter mostly among the J-squares on the eastern border of the Outer Vestibule excavation area. Impact marks were found mainly on long bones and phalanges. These leftovers from bone-cracking activities were found mainly in the J-squares along the eastern part of the excavation area and in square H2 in the southwest corner. Burning was only noted on five long bones, with four reddish, roasted bones and one completely carbonized one. Most of the osseous artifacts were found in squares J3, J4, H1 and H2. Other objects of the osseous industry already presorted and separated during excavation are not included in these totals, but were published by Straus et al. (2018). See Appendix Table C.5.27.

Appendix Table C.5.27: Number of specimen with anthropogenic modifications in Level 17.6.

Species	Cut marks	Impacts	Burning	Artifact
Capra pyrenaica	6	32		1
Cervus elaphus	16	27	2	4
Capreolus capreolus		1		
M Ungulate	1	4	1	1
M-L Size	9	14	2	5
Indeterminate	2			3
Total	**34**	**78**	**5**	**14**

Human-carnivore interactions

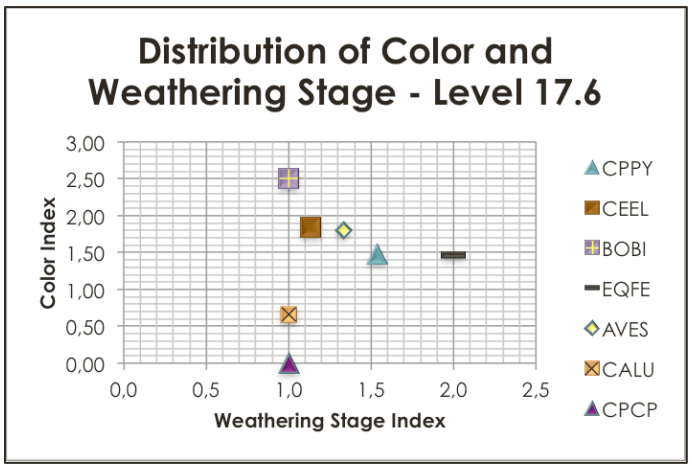
Anthropogenic modifications were found only in 1.3% of the specimens among the registered faunal remains in study sample 17-6, but carnivore marks were found on far fewer: 0.2%. A comparably high amount (98.5%) of faunal remains does not show any direct modification mark that could be linked to human or carnivore actions. See Appendix Table C.5.28.

Appendix Table C.5.28: Number of specimen with anthropogenic vs. carnivore modifications from Level 17-6.

Species	Anthropogenic	Carnivore
Capra pyrenaica	30	2
Cervus elaphus	30	2
Capreolus capreolus	1	
M Ungulate	6	
M-L Size	20	1
Indeterminate	457	64
Total: 613 (100%NR)	**544 (88.7%NR)**	**69 (11.3%NR)**

Post-depositional modifications

All bones in study sample 17.6 showed at least the first degree of weathering, but maximum the second stage. Horse has the most advanced weathering stage, while red deer, ibex and bird are in between and Bos/Bison, wolf and roe deer has the lowest. For Bos/Bison bones I registered the darkest coloration in contrast to wolf and roe deer bones which are light. See Appendix Figure C.5.20.



Appendix Figure C.5.20: Color and Weathering Index, Level 17.6.

Level 17 (6) – Summary

Horse and large bovid continue to be sparsely represented, never showing MNE or MNI comparable to the two main game species red deer and ibex. These late evidences of the massive Level 17 occupations, however, are dominated by ibex (6 adults) compared with red deer (2 adults) in terms of number of individuals as well as skeletal elements, which were killed in late autumn-early winter season.

Impact marks were more often observed than cut marks, and carnivore marks were rarely found.

The weathering stage of the horse bones are the same as in the level before, and the continued separation of roe deer remains, here accompanied with wolf remains, may indicate an accumulation context independent from the main game species.

Level 16 – Quantification

In Level 16 I identified 32 438 bones and 2 282 teeth. See Appendix Table C.5.29.

Appendix Table C.5.29: Faunal quantification, Level 16.

Species	NR	Weight	MNE	MNI
Equus ferus	3	15.3	3	1
Bos/Bison	1	4.2	1	1
Capra pyrenaica	628	1 199.7	255	15
Rupicapra rupicapra	4	6.4	3	2
Cervus elaphus	358	1 284.2	115	7
Canis lupus	7	4.9	7	1
Lepus sp.	2	1.4	2	1
Bird	7	0.8	7	1
Fish	1	0.1	1	1
S Ungulate	11	6.6		
M Ungulate	96	170.8		
L Ungulate	15	68.2		
S Carnivore	4	1.4		
M Carnivore	2	1.2		
S Size	1	0.2		
M-L Size	226	394.9		
Indeterminate	33 354	8 745.6		
Total	**34 720**	**11 905.9**	**394**	**30**

Equus ferus (Boddaert, 1785)

Two enamel fragments (7g and 3.2g) were identified as coming from horse. A complete sesamoid is also present within the Level 16 faunal remains.

Bos/Bison

From a large Bovid (Bos sp. or Bison) comes a milk molar identified, representing a juvenile or younger animal.

The most abundant specimens from ibex identified within Level 16 are teeth (total 168), phalanges (total 120) and sesamoids (84), followed by carpal and tarsal bones.

The ibex body parts of the head within Level 16 represented by an occipital and a temporal fragment, seven corpora of the mandible and two hyoid fragments. Six upper, right M3s are counted indicating adults and two upper left dP3 and dP4 each represent two juvenile or younger animals. The lower teeth confirm the MNI of two juveniles, but eight lower, right M3s indicate eight adults. Axial skeletal elements are represented by most parts, but sternal and sacral bones are not identified, within this assemblage one rib fragment comes from a fetus. Two nutritional canals on the caudal margin of the element count for two shoulder bones. The landmark of the nutritional canal was three times identified on humerus fragments within this Level, totaling two animals. Two left, proximal articulating faces on radius represent two individuals; though on ulna, four left proximal parts are present. The most frequent element within Level 16 is the second and third carpal, which was counted 16 times; ten of them belong to the right side. Five proximal, right metacarpal articulating face fragments count for five individuals; one distal epiphysis specimen is fused and two are unfused. The upper hind body part is only once represented by each element pelvic and femur. The MNI from tibia was estimated based on two right, two left distal parts (adults), one distal fusing (juvenile, 19-24 months old, winter/spring death) as well as two unfused distal metaphysis (juvenile or younger). Three complete and two proximal parts of right tali give an MNI of five, The tarsals represent a maximum MNI of three with three right and left *os tarsii secundum y tertium* bones. Proximal metatarsal fragments were identified five times from the left side and three times one the right, making them an MNI of five. Proximal phalanx MNI counts are based on distal articular surfaces (NISP=33), though including three unfused elements. One of the 21 medial phalanges is fusing (infantile, 9-13 months old, winter/spring dead) and three are unfused (infantile) counted based on the proximal end. A minimum of two individuals is represented by 15 proximal end of the distal phalange. The number of sesamoids can be counted upon 84 elements including a fetus and a juvenile, thus indicating a total MNI of eight. See Appendix Table C.5.30.

Appendix Table C.5.30: Spanish ibex remains, Level 16.

Capra pyrenaica (Level 16)	NISP	MNE					MNI				
Element	All	All	neo	inf	juv	adu	All	neo	inf	juv	adu
Cranium	2	1					1				
Upper teeth	58	13			3	10	8			2	6
Mandible	7	1				1	1				1
Lower teeth	98	18			4	14	10			2	8
Teeth	12										
Hyoid	2										
Cervical vert.	2	1					1				
Thoracic vert.	1	1					1				
Rib	15		1			1	2	1			1
Lumbar vert.	2	1					1				
Caudal vert.	1	1					1				
Indet. vert.	1										
Scapula	2	2				2	1				1
Humerus	13	3				3	2				2
Radius	9	2				2	2				2
Ulna	16	6					4				
Ulna-Radius	3										
Carpal unit	49	16				16	10				10

Metacarpus	17	9			1	9	5			1	4
Pelvis	6	2				2	1				1
Femur	13	2				2	1				1
Tibia	22	7			3	4	4			2	2
Talus	9	7				7	5				5
Calcaneus	6	3			1	2	2			1	1
Tarsal unit	21	6				6	3				3
Metatarsus	18	8				8	5				5
Metapodia	14										
Phalanx prox.	50	33			3	30	6			1	5
Phalanx med.	43	21		4		17	5		2		3
Phalanx dist.	27	15					2				
Sesamoid	84	84	1		1		8	1		1	6
Humerus-Femur	3										
Long bone	1										
Total	627	255	2	4	16	136	15	1	2	2	10

Rupicapra rupicapra (Linnaeus, 1758)

Only four teeth from chamois are present: a right upper, right and left, slightly worn lower molars, as well as a lower left, fully worn P4. The different abrasion degrees indicate two individuals.

Cervus elaphus (Linnaeus, 1758)

The teeth identified (64) represent the most abundant species in Level 16 as red deer, while tibia, metatarsal fragments and atrophic phalanges are also often present. The 21 individually recorded antler items include one tine and several beam fragments pieces, that all can possible come from shed antlers and do not necessarily indicate killed animals, because of their fully compact structure. Cranial parts include maxillary, temporal, sphenoidal and occipital fragments. Red deer mandibles are present in fragments from the diastema gap, the corpus and processes of the ramus. One cervical, two lumbar, two other vertebrae fragments and three ribs comprise the axial body part. Only one shoulder element was identified from two cranial margin fragments, compared with minimum two humerus bones estimated from two left nutritional canals. The element radius represents two individuals, as there are fully grown bone parts (juvenile to adult) as well as a fusing proximal end (infantile, 5-8 months, autumn/winter dead). Ulna is represented by a fragment from the right and left side. A right and a left ulnar carpal were identified. Among all metacarpal specimens at least one right element is present. The upper hind element is present by right and left parts of minimum one individual. In tibia were recognized six nutritional canals present, embodying an MNI of three. The anterior process and the articulating face from a right calcaneus were identified, standing for one element. A neonate central tarsal bone also belongs to the lower hind body part. Metatarsal fragments represent a neonate (unfused, same age as a fawn in the bioarchaeological reference collection at the University of Cantabria; (MARÍN-ARROYO ET AL. 2019)), an infantile by the small dimensions of the unfused distal epiphyses and an adult by the fully-grown pieces. All ten proximal phalanges and nine medial phalanges are fused and represent a MNI of only two. Among the eleven developed-distal phalanges, there are two tiny, porous ones coming from a neonate. A NISP of 18 phalanges represents an MNE of 18 and an MNI of two. See Appendix Table C.5.31.

Appendix Table C.5.31: Red deer remains, Level 16.

Cervus elaphus (Level 16)	NISP	MNE					MNI				
Element	All	All	neo	inf	juv	adu	All	neo	inf	juv	adu
Antler	25										
Cranium	5	1				1	1				1
Viscerocranium	1	1*					1				
Upper teeth	21	4			1	6	4			1	3
Mandible	5	2*				2*	1				1
Lower teeth	28	6			3	3	4			2	2
Teeth	15										
Cervical vert.	1	1					1				
Rib	3	1					1				
Lumbar vert.	2	1					1				
Indet. vert.	2										
Scapula	2	1					1				
Humerus	16	3					2				
Radius	13	2		1		1	2		1		1
Ulna	3	2				2	2				1
Ulna/radius	1	1					1				
Carpal unit	2	2				2	1				1
Metacarpus	21	1			1	1	1				1
Pelvis	2	1				1	1				1
Femur	16	4				4	2				2
Tibia	24	6			1	5	3			1	2
Calcaneus	2	1				1	1				1
Tarsal unit	2	1	1			1	1	1			1
Metatarsus	31	3	1	1		1	3	1	1		1
Metapodial indet.	21										
Meta. Atrophic	5	3					1				
Phalanx prox.	15	10					2				
Phalanx med.	10	9					2				
Phalanx dist.	12	11	2			9	3	1			2
Phalanx atrophic	27	22	1			21	4	1			3
Sesamoid	18	18					2				
Humerus/femur	7										
Total	358	115	5	2	6	59	7	1	1	2	3

Canis lupus (Linnaeus, 1758)

Seven faunal remains were identified as wolf bones: a right and a left pisiform carpal, a fourth proximal metacarpal, two fused medial and two distal phalanges. Minimum one individual is present in Level 16 faunas.

Lepus europeaus

A complete fourth, left metacarpal was identified as hare, together with a complete left talus.

Bird remains

Seven bird bones were identified within Level 16. The bird remains comprise a head of a femur, a proximal phalange and five distal phalanges.

Fish remains

One fish vertebrae were identified among the Level 16 faunal remains.

Anatomically identified by size classes

A fusing distal metapodial, a spongy, unfused vertebra and a porous structured medial phalange indicate younger animals from medium sized artiodactyls.

Within the category of medium to large sized animals were identified an unfused rib that may origin from a young cervid. Further unfused elements are a distal humerus (infantile), three metapodial fragments (juvenile), one digit-half of a metapodial (fetal), four vertebras and seven long bone fragments (five metaphysis, two epiphyses). A fetal rib was categorized as coming from a small- size ruminant.

The distal epiphyses from a radius was unfused coming from a small -size carnivore. Four indeterminate- size class fragments are fetal elements and three have a porous structure such as is found in young, growing bone. From general bags were identified 205 fetal/neonate bones. All fetal bones indicate a winter to early spring death, as fertilization normally occurs in autumn and birth in spring. See Appendix Table C.5.32.

Appendix Table C.5.32: Faunal remains by size classes, Level 16. *=NR.

Size classes (Level 16)	L Ungulate	M-L Size	M Ungulate	S Ungulate	S Size	M Carnivore	S Carnivore	Indeter.
Element	NISP	NISP	NISP	NISP	NISP	NISP	NISP	NISP
Cranium		16	6		1			1
Upper teeth				1		1		
Mandible		5	2					
Lower teeth		1					1	
Teeth		41	3				1	1997
Cervical vert.		3						
Thoracic vert.		2						
Rib		13	12	3				3
Lumbar vert.		2	2					
Sacral vert.		1						
Caudal vert.		1	1					
Indet. vert.	1	13	5					
Scapula		1						
Humerus		3						
Radius	1	2					1	1
Ulna		1				1		
Pelvis		3	3					
Femur		1	2					
Patella		1						
Tarsal unit				1				
Metatarsus				1				
Metapodial		7	3					
Phalanx med.			1				1	1
Phalanx indet.				1				1
Sesamoid			3	1				
Humerus-Femur		8	5					
Long bone	13	96	48	3				82

Spongy bone								28889*
Indeterminate		5						2369*
Total	15	226	96	11	1	2	4	33344

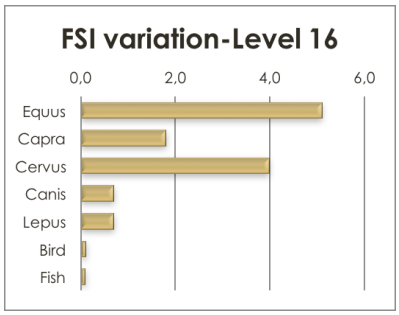
Level 16 - Seasonality

The seasonality of death of prey species changed so far as long ranges of death season disappear and occupational peaks occur for autumn, winter and spring separately for ibex. Red deer was now killed in early spring-summer, much more similar to season of death estimations proposed by studies of the later Magdalenian occupations at El Mirón by Marín-Arroyo (2010).

Level 16 - Taphonomy

Faunal preservation

The largest sized fragments were registered among large bovid and horse bones, which are followed by red deer, ibex and chamois bones. The other species show a fragment size index under 1g. See Appendix Figure C.5.21.



Appendix Figure C.5.21: Fragment Size Index (FSI) variation among species in Level 16.

Number of complete skeletal elements. Level 16 contains a relatively high number (22%; NR=314) of complete bones among the registered faunal remains. The most complete elements come from head and feet body parts, followed by lower front and hind elements. From horse is a complete sesamoid bone preserved. Spanish ibex complete elements comprise 22 upper and 54 lower teeth, another tooth, one caudal vertebrae, 44 carpal bones, three talus, 17 tarsal bones, five phalanges and 82 sesamoid bones. Chamois on the other hand only contains one upper and one lower complete tooth. From red deer were registered eight upper and nine lower complete teeth, one carpal, two tarsal, four atrophic metapodial, 19 atrophic phalanges, two phalanges and 18 sesamoid bone. One carpal and three phalanges are completely preserved from wolf. There are also recorded a complete metacarpus and talus from hare and two phalanges from a bird. Other complete bones registered are a tooth, knee bone, tarsal bones, sesamoid and phalanges.

Appendix Table C.5.33 summarized the observed breakage pattern. In Level 16 have more than half of the bones an undefined fracture pattern, which is followed by green fractures. The third most observed patterns are dry fractures, which possible imply some kind of diagenetic alterations among this unit.

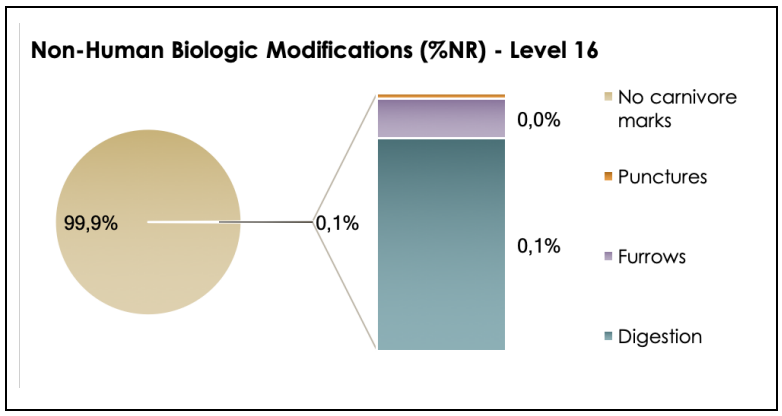
Appendix Table C.5.33: Breakage type, Level 16 (only bones identified taxonomically or in animal size classes).

Breakage- profile	NISP	%NISP
Green fracture	206	34.3
Green and dry fracture	13	2.2
Green fracture, two phases	18	3.0
Dry fracture	30	5.0
Recent fracture	20	3.3
Indeterminate	313	52.2
Total	**600**	**100**

Non-Human Biological Agents

Carnivore marks are sparsely represented within Level 16 (Appendix Figure C.5.22). Digested bones include teeth, long bone fragments, phalanges and sesamoid bones, mainly found in H3, H4 and J3. The eight bite marks identified are dominated by chewing marks. Bite marks are located on long bones, cervical vertebrae, a rib fragment and phalanges and are distributed on bones found mainly in square J3.

Most carnivore modifications were found on the species ibex and red deer bones. One wolf metacarpal is digested.



Appendix Figure C.5.22: Carnivore activities observed in Level 17 (12).

Human activities

In Level 16 cut-marked remains constitute the highest amount of anthropogenic modifications followed by impact marks. Cut- marks were found on all body parts; they are spatially concentrated in square J3 (39,1%) and squares H3 (13.0%) and H4 (13,9%). Impact marks on bones were found on long bones, pelvic bones and phalanges. These impacted bones also were concentrated in squares, J3 (24,7%), H3 (21%) and H4 (25,9%). Among the burnt bones are two completely carbonized, five partially and eight show reddish-roasting modifications. Almost all of the roasted bones were found in square J3 and one in J4. Osseous artifacts identified during the present faunal study are comprised mostly of bone tools, points and decorated objects and blank production waste and failures are also present from bone and antler. Most of the osseous artifacts were found in J3 (39.1%NR) and H4 (21.1%NR). Objects of the osseous industry already presorted and separated are not included in these totals. See Appendix Table C.5.34.

Appendix Table C.5.34: Number of specimen with anthropogenic modifications in Level 16.

Species	Cut marks	Impacts	Burning	Artifact
Capra pyrenaica	35	30	2	2
Cervus elaphus	27	35	4	10
S Ungulate	1			
M Ungulate	12	1	2	1
L Ungulate	2	2		
CAR M	1			
S Size	1			
M-L Size	17	12	1	4
Indeterminate	19	1	5	21
Total	**115**	**81**	**14**	**38**

Human-carnivore interactions

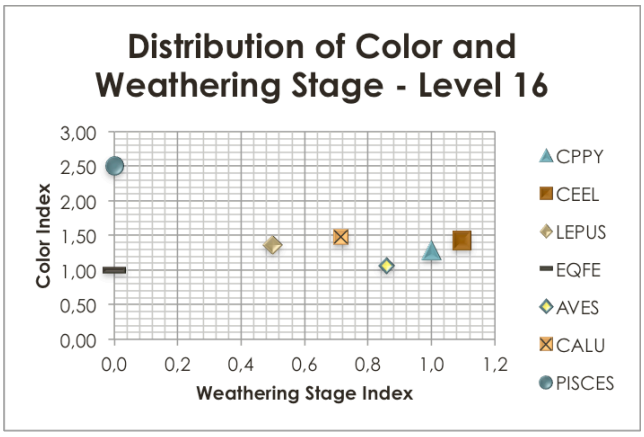
Anthropogenic as well as carnivore marks are concentrated among red deer and Spanish ibex bones within Level 16. An additional modification marks from a carnivore hold a wolf bone. Most of the bones (97.8%), though, do not show modification marks. See Appendix Table C.5.35. Human-carnivore alternating use of the cave, possible seasonally is likely.

Appendix Table C.5.35: Number of specimen with anthropogenic vs. carnivore modifications from Level 16.

Species	Anthropogenic	Carnivore	Both
Capra pyrenaica	52	4	
Cervus elaphus	55	3	
Canis lupus		1	
S Ungulate		1	
M Ungulate	10	2	
L Ungulate	1	1	1
M Carnivore		1	
S Size	1		
M-L Size	30	3	
Indeterminate	537	46	
Total: 749 (100%NR)	**686 (91.6%NR)**	**62 (8.3%NR)**	**1 (0.1%NR)**

Post-depositional modifications

All main prey species show a very similar color index, while fish shows a darker coloration. The weathering stages, though, are further distributed with horse having stage zero and red deer and Spanish ibex around stage 1. The other species are distributed in between. This could be the results of temporary separated accumulated, but were seasonally. See Appendix Figure C.5.23.



Appendix Figure C.5.23: Color and Weathering Index, Level 16.

Level 16 – Summary

The combination of prey taxa is very similar to the last occupation in Level 17-6, with numbers of ibex (=ten adults) are higher than from red deer (=3 adults) by MNE and MNI. The season of occupation changed towards more similar mobility patterns as what is described for later Upper and Final Magdalenian levels with seasonally logistic visits to the montane site El Mirón in contrast to mainly longer-cold season occupations of earlier Lower Magdalenian levels. It seems that ibex focused exploitation by humans are the major reasons to visit the site. The variation of weathering stages might indicate that carcass remains of different animals were not accumulate simultaneously, but seasonally time-shifted. Greyish colorations of bones, increased root activity and calcite crust might indicate seasonal high presence of water in the cave, which may made El Mirón not suitable for longer stays of larger groups. The preservation of items also varies due to the degree of diagenetic modifications of the bones, where on some bones it is difficult to identify even cut marks, which may be underrepresented. See photographs in Appendix Figure C.5.24 that show examples of bones from the faunal assemblage of Level 16.



Level 16, H4-1231



Level 16, J3-684



Level 16, H3-1033



Level 16, J3-502



Appendix Figure C.5.24: Examples from the faunal material from Level 16.

Level 15 – Quantification

The whole faunal assemblage from Level 15 contained fragments of 18 141 bones and 1 848 teeth. See Appendix Table C.5.8.

Appendix Table C.5.36: Faunal quantification, Level 15.

Species	NR	Weight (g)	MNE	MNI
Equus ferus	1	9.8	1	1
Bos/Bison	2	16.3	2	1
Capra pyrenaica	504	952.2	146	11
Rupicapra rupicapra	9	9.6	6	2
Cervus elaphus	353	1 316.6	93	6
Canis lupus	8	3.4	7	1
Vulpes vulpes	1	0.5	1	1
Lepus sp.	1	0.8	1	1
Rodent	1	0.1	1	1
Bird	8	1.5	4	1
S Ungulate	7	3.5		
M Ungulate	55	96.5		
L Ungulate	15	91.8		
<XS Size	2	0.3		
S Size	1	0.2		
M-L Size	161	396.8		
XL Size	3	47.7		
Indeterminate	18 812	5 553.9		
Total	**19 944**	**8 501.5**	**262**	**26**

Equus ferus (Boddaert, 1785)

The characteristic enamel features of a horse enamel premolar or molar fragment was identified.

Capra pyrenaica (Schinz, 1838)

The Spanish ibex is represented by 500 NISP, making up a minimum of 146 skeletal elements and 11 individuals. The highest NISP is for lower and upper teeth; these are followed by sesamoids, carpals and phalanges. The following bones represent the head: three basal cranial, two horn, a frontal and a maxillary fragment. There are seven mandible and two hyoid specimens. Scapula, humerus, ulna, pelvic and femur MNI calculations indicate a minimum of one animal, but two right proximal radii as well as two right tibia nutritional canals imply a minimum of two. Seven individuals are represented by carpals could not be

differentiated further by age. Five distal and proximal metacarpal parts with one distal unfused indicate minimum one infantile alongside four grown- ups. Different right and left tarsal bones represent three individuals, including talus and calcaneus. All phalange MNE together (total= 57) represent two adults and a Juvenile or younger animal. The total count of sesamoids resembles a minimum of three individuals.

The maximum MNI represent minimum eight adult individuals, which are calculated by eight left and seven right M3's. Four milk teeth from ibex indicate at least one juvenile individual. Other bones represented also at least one juvenile- aged individual by the skeletal elements: unfused metacarpal and metatarsal as well as a fusing distal tibia; the latter represents an animal that died with an age of 19-24 months (second winter/spring). Another fusing bone found is a medial phalange, but indicating an infantile individual 9-13 months old (first winter/spring). Two unfused phalanges could also come from this Infantile or a younger one. A metapodial fragment that is unfused between the third and fourth digit (death in winter) represent a fetus. Axial parts were hardly identified by species level, but here exemplified by cervical, caudal vertebrae and ribs. See Appendix Table C.5.37.

Appendix Table C.5.37: Ibex remains, Level 15.

Capra pyrenaica (Level 15)	NISP	MNE					MNI				
Element	All	All	fet	inf	juv	adu	All	fet	inf	juv	adu
Horn	2						1				
Cranium	3	1					1				
Viscerocranium/Maxilla	3	2*			1*	1*	2			1	1
Upper teeth	66	16			1	15	9			1	8
Mandible	7	2*				2*	1				1
Lower teeth	78	12			1	11	7			1	6
Teeth	23										
Hyoid	2	1					1				
Cervical vert.	1	1					1				
Rib	6	2				2	1				1
Caudal vert.	2	2				2	1				1
Scapula	2	2				2	1				1
Humerus	12	2				2	1				1
Radius	4	2				2	2				2
Ulna	9	2				2	1				1
Ulna-Radius	2										
Carpal unit	42	13				13	7				7
Metacarpus	15	6		1		5	5		1		4
Pelvis	4	1					1				
Femur	7	2				2	1				1
Tibia	10	3				3	3				3
Talus	9	6				6	3				3
Calcaneus	7	4				4	3				3
Tarsal unit	12	5				5	3				3
Metatarsus	14	6		2		4	3		1		2
Metapodia	19		1				1	1			
Phalanx prox.	43	25			3	14	3			1	2
Phalanx med.	41	21			2	15	3			1	2
Phalanx dist.	13	11				11	2				2
Phalanx indet.	1										
Sesamoid	45		1				3	1			3
Total	504	146	2	3	7	120	11	1	1	1	8

Bos/Bison

One large bovid (Bos or Bison) is represented by a lower, left premolar with a developed root and slightly abrasion on the occlusal surface. The second fragment contains a dorsal fusion line of a metacarpal.

Rupicapra rupicapra (Linnaeus, 1758)

Six teeth (one upper, five lower) identified belong to chamois. Minimum a juvenile and an adult individual are represented, because both, a dP4 and a M3, were classified as slightly worn. Three distal phalanges were identified; one of them is a distal part of a neonate phalange. Together these specimens identified comprise six skeletal elements.

Cervus elaphus (Linnaeus, 1758)

Nine red deer antler fragments were registered in Level 15 individually. Four temporal fragments, an unfused occipital and a maxillary are the fragments that represent the head. Red deer teeth are numerously present, with 26 upper, 29 lower and 13 indeterminate ones. One juvenile is embodied by an upper milk molar dP3 and together with two right M3s they represent three animals. Lower teeth include a dP3 and three M3s, also representing together three animals (one infantile, two adults). The axial elements identified are two thoracic, one lumbar, one caudal vertebrae and two undermined vertebrae fragments, one of them from a neonate. The MNE count of humerus fragments is based on the number of nutritional canals observed. Three overlapping fragments from the proximal articulating face on Radius identify at least two individuals. Two distal, left (fused) Ulna fragments identify an MNI of two. The size variation between two carpals (*carpale secundum y tertium*) represent two animals, possible male and female. The proximal articular--- surfaces represented by metacarpals indicate an MNI of two adults, while an unfused distal metapodial comes from a Neonate. Tibia fragments stand for the highest MNI count of four for Level 15, which are estimated by the number of nutritional canals identified. Calcaneus and tarsal fragments represent right and left parts, but no overlaps, therefore, maximum one individual. Three proximal metatarsal specimens give an MNI of two. The number of each phalanx, atrophic and sesamoid represented was divided by the number of elements within the body with a result of maximum three animals accumulated within this level.

Only one fusing bone and a proximal tibia, was found from red deer within Level 15, but age determination on this part is difficult as it fuses over a long time. On the other hand there is the unfused distal tibia which is an indicator for a juvenile. The slightly worn lower dP3 and M1 originated from a neonate, while the heavily worn upper dP3 derived from a juvenile. The unfused proximal phalanx and five very porous, still developing distal phalanges indicate at least one neonate. See Appendix Table C.5.38.

Appendix Table C.5.38: Red deer remains, Level 15.

Cervus elaphus (Lev 15)	NISP	MNE				MNI			
Element	All	All	neo	juv	adu	All	neo	juv	adu
Antler	11								
Cranium	5	2				1			
Viscerocranium	1	1*				1			
Upper teeth	27	4		1	3	3		1	2
Mandible	2	1*				1			
Lower teeth	29	5	1		4	3	1		2
Teeth	14								
Thoracic vert.	2	2	1			1	1		
Lumbar vert.	1	1				1			
Caudal vert.	1	1				1			

Indet. Vert.	2	2	1			1	1		
Scapula	1	1				1			
Humerus	16	4			3	2			2
Radius	10	2			2	1			1
Ulna	5	2			2	2			2
Carpal	2	2				1			
Metacarpus	29	4	1		4	3	1		2
Pelvis	4	1			1	1			1
Femur	8	2		1	1	2		1	1
Tibia	20	7		1	7	4		1	4
Calcaneus	3	2			2	1			1
Tarsal	5	2			2	1			1
Metatarsus	36	3			3	2			2
Metapodial	10								
Meta. atrophic	1								
Phalanx prox.	24	17	1			3	1		
Phalanx med.	12	8				2			
Phalanx dist.	11	7	5	2	1	3	1	1	1
Phalanx atrophic	35	9				3			
Phalanx indet.	3								
Sesamoid	21	3	1		6	3	1		2
Humerus-Femur	2								
Total	353	93	11	5	41	6	1	1	4

Canis lupus (Linnaeus, 1758)

A total of eight faunal remains from Level 15 belong to the species *Canis lupus*, including a complete lower, right I3 that is slightly worn. The other specimens from wolf present phalanges: two proximal medial phalanges and five phalange fragments represent four distal parts of this element. The MNI calculation is one.

Vulpes vulpes (Linnaeus, 1758)

The faunal inventory includes a complete lower, left canine from a fox, with a developed root and traces of slight abrasion. The measurements of the total length of the canine of 22.74mm support the identification of red fox, as it is larger than observations made in Eurasian polar fox with mean values of 14.14mm (SZUMA 2008).

Lepus

The faunal inventory includes one complete left calcaneus of a hare.

Rodentia

There is a not further identifiable enamel fragment of a rodent.

Bird remains

In total there are six identified bird bones. A shaft fragment represents a tibia and a sacral bone is nearly complete preserved. Additional were classified three distal phalanges and two not further identifiable bones, which show the fragile and compact structural morphology of bird bones.

The radius fragment from an indeterminate large artiodactyl is an unfused and porous fetal bone. The medium- size artiodactyl category contains two enamel fragments; one is heavily worn and another is only slightly worn and an unfused epiphysis from a long bone is included. Within the category of indeterminate medium- to large- size animals were classified the most specimens of presumably young age compared with the other size classes. Four enamel fragments are slightly worn, and two show root development. An unfused caput from a rib, an unfused distal metaphysis from a femur and a small, porous metapodial indicate young individuals. One long bone fragment is unfused of fetal size. An unfused and a porous long bone indicate a young animal. A fusing long bone fragment possible represents a humerus. A proximal tibia fragment that is fusing represents a small artiodactyl. One sesamoid and one talus presumably come from a neonate individual. The taxonomically indeterminate specimen, presumably from medium sized ungulate, include 112 fetal/neonate bones. See Appendix Table C.5.39.

Appendix Table C.5.39: Faunal remains by size classes, Level 15. *=NR.

Size classes (Level 15)	XL Size	L Ungulate	M-L Size	M Ungulate	S Ungulate	S Size	<XS Size	Indeterminate
Element	NISP	NISP	NISP	NISP	NISP	NISP	NISP	NISP
Cranium			11	3				1
Viscerocranium			2					
Mandible			1					
Teeth			18	7				1575
Cervical vert.				1				
Thoracic vert.				1				
Rib		3	8	7		1	2	
Lumbar vert.			5					
Caudal vert.			2					
Indet. vert.			13	2				
Scapula			1					
Humerus				1				
Radius		1	2					
Pelvis			1					
Femur			1					
Tibia	2	4	3	1	1			
Talus					1			
Metapodial			4					
Phalanx dist.								1
Sesamoid					2			
Humerus-Femur			9	3				
Radius-Tibia								
Long bone	1	7	72	29	2			30
Spongy bone								16226*
Indeterminate			8		1			967*
Total	3	15	161	55	7	1	2	18800

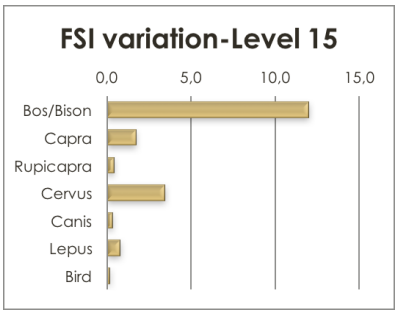
Level 15 - Seasonality

The seasonal trend in site occupation is continued from Level 16 onwards, although by progressively focusing hunting of ibex in summer-autumn first, and again in winter and again in spring. Red deer was then hunted in-between, in late autumn- early winter.

Level 15 - Taphonomy

Faunal preservation

In Level 15, relatively large- size fragments were registered among large bovids and horse bones, which are followed by red deer, then ibex and chamois bones. Wolf, fox, hare, rodent and bird bone fragments are rather tiny. See Appendix Figure C.5.25



Appendix Figure C.5.25: Fragment Size Index (FSI) variation among species in Level 15.

Number of complete skeletal elements. The complete bones (NR=221) in Level 15 are dominated by head, lower front and feet body parts, while Spanish ibex yields the biggest portion of complete elements. For ibex I identified complete 13 upper, 36 lower teeth and one indeterminate tooth fragment, one caudal vertebra, 38 carpal bones, four talus and six tarsal bones, one metacarpal, one phalanx and 43 sesamoid bones. The complete chamois bones are only two lower teeth and one phalanx. Two upper and ten lower complete teeth are preserved from red deer as well as one caudal vertebra, two carpals, three tarsal, one atrophic, 26 atrophic metapodials, 26 atrophic phalanges, four phalanges and 18 sesamoid bones. A lower tooth was identified from a wolf and a fox. A complete calcaneus comes from hare. Another complete elements are one tarsal, two sesamoid and one caudal vertebra.

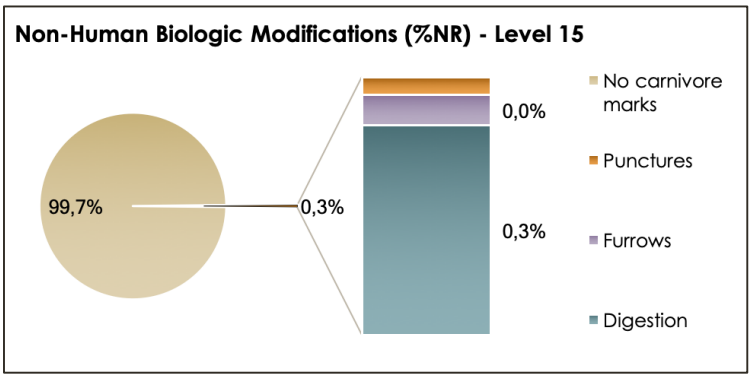
Appendix Table C.5.40 summarized the observed breakage pattern. The Level 15 fracture pattern is dominated by indefined fractures followed by green fractures.

Appendix Table C.5.40: Breakage type, Level 15 (only bones identified taxonomically or in animal size classes).

Breakage- profile	NISP	%NISP
Green fracture	124	26.2
Green and dry fracture	17	3.6
Green fracture. two phases	19	4.0
Dry fracture	13	2.7
Recent fracture	12	2.5
Indeterminate	289	61.0
Total	**474**	**100**

Non-Human Biological Agents

Carnivore marks were identified on 37 faunal remains in Level 15 (Appendix Figure C.5.26). Digested bones include mainly phalanges, one tarsal bones and a few long bone fragments. The eleven bite marks on bones identified were found on a mandible, rib, vertebrae, metatarsus, tibia and long bone fragments. Bite marks are mainly found in squares H3 and H4, along with digestion marks. Digested bones that indicate vulture activities dominate the carnivore marks. Most carnivore modifications were found on red deer and ibex bones. The one hare calcaneus shows digestion carnivore marks, indicating a non-human accumulation.



Appendix Figure C.5.26: Carnivore activities observed in Level 17 (12).

Human activities

Level 15 shows a more or less similar amounts of cut and impact marks on bones. Cut-marks are located on long bones, ribs, phalanges, carpal and tarsal bones. Impact marks are located on long bones, up to 46% on phalanges. Most of the bones with impact marks were found in squares H3 (32.6%) and H4 (23.3%) in the NW corner of the excavation area. Only two bones were found partially and one completely carbonized within this level among the individually registered remains; they were located in squares H2 and H3. Osseous artifacts identified during the present faunal study (and mainly origin from general bags) were found in all squares except partial square H1 and in the I-squares in the middle of the Outer Vestibule excavation area. The different artifacts comprise of four decorated bones, five bone flakes and five tools. Objects of the osseous industry presorted and separated during excavations are not included in these totals. See Appendix Table C.5.41.

Appendix Table C.5.41: Number of specimen with anthropogenic modifications in Level 15.

Species	Cut marks	Impacts	Burning	Artifact
Capra pyrenaica	8	14	2	1
Cervus elaphus	7	23		4
S Ungulate				1
M Ungulate	9	1	1	1
L Ungulate	3	1		
<XS Size	1			
M-L Size	13	4		3
Indeterminate	3			3
Total	**44**	**43**	**3**	**13**

Human-carnivore interactions

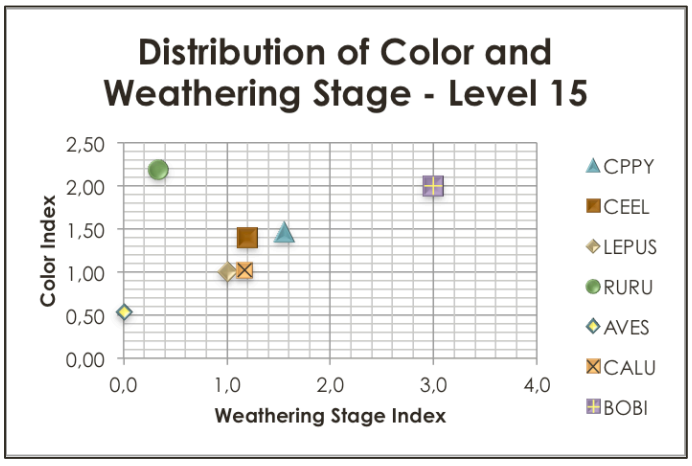
Compared with the other Lower Magdalenian levels, Level 15 has a relatively low rate (1.2%) of anthropogenic modification marks. Carnivore marks, however, are poorly represented (0.3%). In 3 of the faunal remains I found an overlap of anthropogenic and carnivore marks. A comparably high proportion of bones (98.5%), though, does not show any direct modification marks. See Appendix Table C.5.42.

Appendix Table C.5.42: Number of specimen with anthropogenic vs. carnivore modifications from Level 15.

Species	Anthropogenic	Carnivore	Both
Capra pyrenaica	17	12	
Cervus elaphus	32	14	2
Lepus sp.		1	
S Ungulate	1		
M Ungulate	12	1	1
L Ungulate	4		
<XS Size	1		
M-L Size	18	6	
Indeterminate	152	26	
Total: 300 (100%NR)	**237 (79%NR)**	**60 (20%NR)**	**3 (1%NR)**

Post-depositional modifications

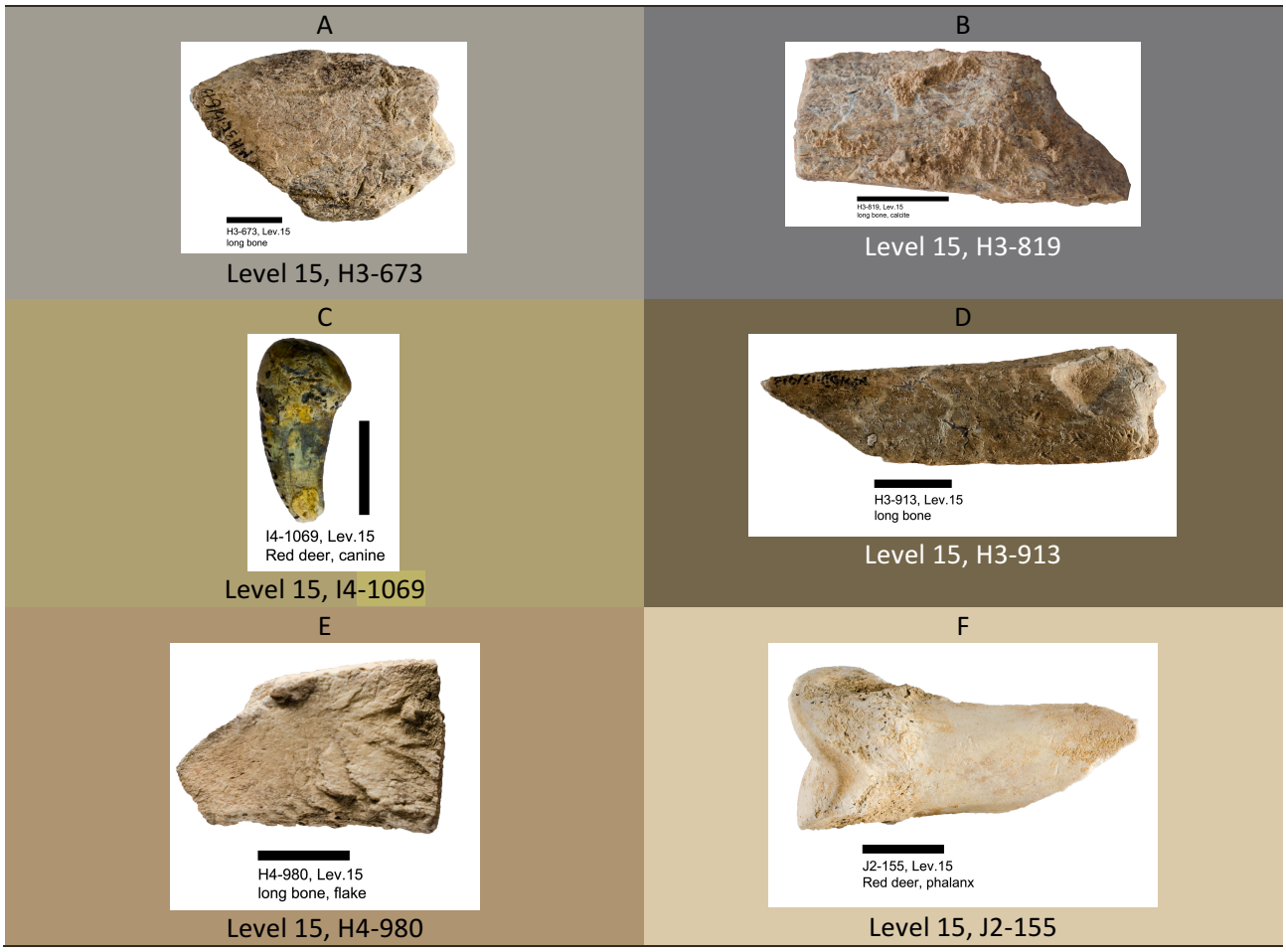
In Level 15 red deer and ibex were grouped close together with wolf and hare remains according to the weathering and color indices Bos/Bison shows a more advanced weathering stage, but a similar color index with chamois bones. Bird bones seemed to be set apart no weathering and low discoloration. See Appendix Figure C.5.27.



Appendix Figure C.5.27: Color and Weathering Index, Level 15.

Level 15 – Summary

Prey taxa concentrate again on ibex with eight adults compared with red deer with a minimum four adults identified, and young ungulates were only hunted in small quantities. Human exploitation of the catchment areas around the El Mirón montane site get increasingly logistical with seasonal hunts of ungulate species. Butchering and bone cracking activities are present. Simultaneous increase the occurrence of carnivore species in this levels with identification of wolf and red fox representing alternating cave use. The preservation of Level 15 were the worst from all faunal remains here studied with high degree of water damage, root activities, calcite concretions and greyish colorations demonstration an increase of sediment humidity or even running/dripping water (see photographs Appendix Figure C.5.28-A, B, C, D). The few bone fragments that also belong to this level, but not show any weathering, coloration or damage (see photograph Appendix Figure C.5.28-F) seemed to be deposited after this humid event that affected the other bones or their deposition close to the southern wall of the cave protected them from any water damage.



Appendix Figure C.5.28: Examples from the faunal material from Level 15.

Appendix C.6 Lower Magdalenian (Burial Area, within the SE rear Vestibule)

This faunal assemblage was studied deciphering the context of the El Mirón human burial located in the Vestibule Rear behind the engraved block. The fauna from the Lower Magdalenian Level 504, also containing the remains of the human burial, was studied from squares W7 (5,6,7), X5 (5,6), X6 (11,12,13), X7 (5,5.1,6,7),

Y5 (7,8), Y6 (12,13) and Y7 (4). The human burial pit was dug into Level 504, which was the surface level at that moment. Radiocarbon dates were obtained from an animal bone from Level 504 aged to 15.7 uncal BP and a human bone aged to 15.5 uncal BP.

Level 504 – Quantification

During the archaeological study of Level 504 by my dissertation director (A.B.Marín-Arroyo) and me were found 710 bones 107 teeth from animals. The detailed faunal study of the burial Level 504 was also already published to contextualize the human burial from El Mirón (MARÍN-ARROYO & GEILING 2015). It were also identified 87 fragments from human among the faunal leftovers, which were then send to Carretero et al. for detailed anthropological analysis, were fully published (CARRETERO ET AL. 2015) and were not further studied here. See Appendix Table C.6.1.

Appendix Table C.6.1: : Faunal quantification, Level 504.

Species	NR	MNE	MNI
Homo sapiens	55	35	1
Equus ferus	7	6	1
Capra pyrenaica	386	222	8
Rupicapra rupicapra	5	4	1
Cervus elaphus	214	85	4
Canis lupus	1	1	1
Vulpes vulpes	1	1	1
M Ungulate	202		
Indeterminate	2		
Total FAUNA	**818**	**307**	**12**

Equus ferus (Boddaert, 1785)

Seven specimens were identified as coming from horse within Level 504. An indeterminate incisor is the only element that represents the head. The other parts include feet elements, for example, two proximal sesamoids, a talus fragments that include the *Trochlea talii* and two tarsal fragments (*t.secundum & tertium* and *t.centrale*).

Capra pyrenaica (Schinz, 1838)

From ibex bones were identified different ones that represent a juvenile or younger animal: nine upper and three lower milk teeth, unfused distal humerus (fusing 11-13 months), small and porous carpal bones (Carp.23 and Carp.radiale), unfused distal tibia (fusing 19-24 months), unfused four proximal and four medial phalanges (fusing 9-15 months). Adults are well represented by high numbers of teeth, carpal and tarsal bones. See Appendix Table C.6.2.

Appendix Table C.6.2: Ibex remains, Level 504.

Capra pyrenaica (Level 504)	NISP	MNE			MNI		
Element	All	All	juv	adu	All	juv	adu
Horn	5			4			2
Cranium	3	1	1	1	1	1	1
Viscerocranium/Maxilla	3	2		1	1		1
Upper teeth	22	12	3		2	1	
Mandible	14	5	2	2	3	1	1
Lower teeth	50	38	9*	7	8	4	7
Teeth indet.	7	5			1		
Hyoid	4	4		3	4		3
Cervical vert.	12	2		9	1		1
Thoracic vert.	4	2		3	1		1
Rib	11	6	1	5	1	1	1
Lumbar vert.	6	4		4	1		1
Sacral vert.	1	1		1	1		1
Caudal vert.	3	3		3	1		1
Indet vert.	1						
Scapula	2	2		1	1		1
Humerus	14	4			3		
Radius	13	6	1	1	3	1	1
Ulna	7	3	1	2	2	1	1
Ulna-Radius	5						
Carpal units	19	19	2	17	4	1	3
Metacarpus	11	4		2	2		1
Pelvis	9	5		2	3		1
Femur	6	3	1	2	2	1	2
Patella	1	1			1		
Tibia	4	2	1	1	2	1	1
Talus	2	2		2	1		1
Calcaneus	6	3	1	5	3	1	1
Tarsal unit	6	6		4	4		4
Metatarsus	14	6		2	3		2
Metapodia	19		1			1	
Phalanx prox.	32	17	4	13	3	1	2
Phalanx med.	30	19	4	15	3	1	2
Phalanx dist.	13	10		10	2		2
Sesamoid	27	25			2		
Total	386	222	4	17	8	1	7

Rupicapra rupicapra (Linnaeus, 1758)

Three teeth and three bones were classified as chamois elements. Two complete and one fragment, all from the left side, were identified of a first or second molar (M1-2) with two are slightly worn and one is fully worn. A right and left distal shaft fragment and a distal humerus were found within the assemblage.

Cervus elaphus (Linnaeus, 1758)

When all the unfused phalanges (six distal, two middle and one proximal) are combined, they could represent one neonate/infantile individual died in late spring. Further indicate the presence of a juvenile died in spring an unfused distal tibia fragment (fusing 20-23 months). Adults are well represented by relative high numbers of fragments from mandible, metacarpal and phalanges. See Appendix Table C.6.3.

Appendix Table C.6.3: Red deer remains, Level 504.

Cervus elaphus (Level 504)	NISP	MNE				MNI		
Element	All	All	neo	juv	adu	All	juv	adu
Antler	20							
Cranium	2	2			2	1		1
Viscerocranium/Maxilla	1	1*				1		
Upper teeth	9	8		1	2	1	1	1
Mandible	7	5*			4	4	1	3
Lower teeth	10	10		1	2	2	1	1
Teeth indet.	3	2				1		
Hyoid	1	1			1	1		1
Cervical vert.	5	4			3	1		1
Thoracic vert.	2	2			2	1		1
Rib	3	2				1		
Lumbal vert.	3	1			2	1		1
Scapula	2	1			1	1		1
Humerus	15	3			2	3		1
Radius	3	1			1	1		1
Ulna-Radius	1							
Metacarpus	7	3			3	2		2
Pelvis	4	2			2	1		1
Femur	21	3			2	2		1
Tibia	10	3		2	1	3	1	1
Talus	1	1			1	1		1
Tarsal unit	4	4		2	2	1	1	1
Metatarsus	13	2			2	2		1
Metapodia	6							
Metapodia atrophic	3	2			2	1		1
Phalanx proximal	11	7	1		6	2	1	1
Phalanx medial	19	12	2		11	3	1	2
Phalanx distal	10	8	6		2	2	1	1
Phalanx atrophic	4	4			4	1		1
Sesamoid	6	6			4	1		1
Humerus-Femur	2							
Long bone	1	1				1		
Total	209	95	6	2	11	4	1	3

Canis lupus (Linnaeus, 1758)

One complete right pisiform carpal was identified from a wolf.

Vulpes vulpes (Linnaeus, 1758)

One complete proximal phalange from a fox was found in a developmental stage at which the proximal part is fusing to the metaphysis.

Homo sapiens

The following Appendix Table C.6.4 list the human remains that were found during faunal studies.

Appendix Table C.6.4: Human remains identified in Level 504 during faunal studies.

Homo sapiens (Level 504)	NISP	MNE
Element	All	All
Lower teeth	1	1
Cervical vert.	5	3
Thoracic vert.	5	3
Rib	8	2
Lumbar vert.	2	2
Sacral vert.	1	1
Indet. vert.	1	
Scapula	2	2
Carpal unit	4	2
Metacarpus	2	2
Pelvis	2	2
Patella	2	2
Talus	1	1
Calcaneus	1	1
Tarsal bone	1	1
Metatarsus	7	2
Metapodia	1	
Phalanx prox.	2	1
Phalanx med.	4	4
Phalanx dist.	3	3
Total	55	35

Among the faunal assemablge were identified several human remains, which were here not further investigated, instead the detailed anthropological studies were done by (CARRETERO ET AL. 2015); they wrote: the individual of middle-age was a robust female of ca. 159 cm in height and weighing ca. 59.6 kg, with good health status is represented by a mandible (including eleven teeth), two isolated maxillary teeth and 95 fragments of postcranial bones and 13 undetermined fragments.

Anatomically identified by size classes

Among taxonomically classified bones, some developmental stage variations are observable. Unfused long bone fragments include specimen from the epiphyses of the humerus head and four indeterminate long bone metaphysis fragments. Along the axial skeleton are unfused three cervical, six lumbar, two sacral, one thoracic and eight indeterminate vertebrae fragments. Porous bone structures were found on two ribs, a long bone shaft fragment and a distal part of a medial phalange also indicate minimum one young animal. A right shoulder *Spina scapulae* and a metaphysis fragment from a humerus origin from a fetal animal. See Appendix Table C.6.5.

Appendix Table C.6.5: Faunal remains by size classes, Level 504. *=NR.

Size classes - 504	M Ungulate
Bone	NISP
Antler	1
Cranium	12
Viscerocranium/Maxilla	1
Mandible	1
Teeth indet.	2

Cervical vert.	8
Thoracic vert.	1
Sternum	3
Rib	50
Lumbar vert.	13
Sacrum	5
Caudal vert.	1
Indet. vert.	12
Scapula	2
Humerus	5
Radius	2
Ulna-Radius	1
Pelvis	4
Femur	3
Tibia	2
Metapodia	2
Phalanx medial	1
Humerus-Femur	5
Long bone	47
Indeterminate	20*
Total	204

Seasonality

The few young individuals killed indicate spring occupations, which is also supported by the presence of fetal bones indicated adult kills during winter-spring, a pattern similar to the other Lower Magdalenian occupations studied here.

Level 504 - Taphonomy

Faunal preservation

The preservation of the faunal assemblage of Level 504 is good. Over half of the Level 504 fracture pattern observed are indeterminate fractures, which are followed by green fractures. Appendix Table C.6.6 summarized the observed breakage

Appendix Table C.6.6: Breakage type, Level 504 (only bones identified taxonomically or in animal size classes).

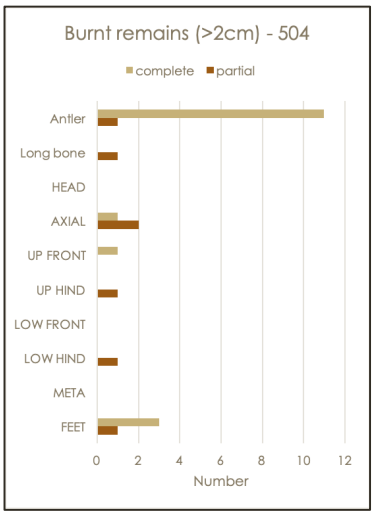
Breakage profile	NISP	%NISP
Green fracture	206	33.1
Dry fracture	37	5.9
Recent fracture	59	9.5
Indeterminate	320	51.4
Total	**622**	**100**

Modifications of the faunal assemblage

Human activities include defleshing and disarticulation marks in 9.8%NR of the total number of remains (=NR). In presence of bone flakes and points of impact on bones (11.5%NR), green bone fractures are the

result of bone marrow extraction. In Level 504 were found in total 23 burnt bone remains, seven of which were only burnt partially. Partially burning can occur by roasting or building a fire just on the surface where bones were lying in the sediments (compare Appendix Figure C.5.15).

We were able to make five refits of broken bones and four articulations. Among the former there are a phalanx broken open for its marrow and a rib that had been broken as it was disarticulated from a thoracic vertebra.



Appendix Figure C.6.1: Distribution of burning evidence among the body parts in Level 504.

Among the more relevant biostratinomic modifications are a few traces of the activity of carnivores (1.6%NR) and rodents (two cases).

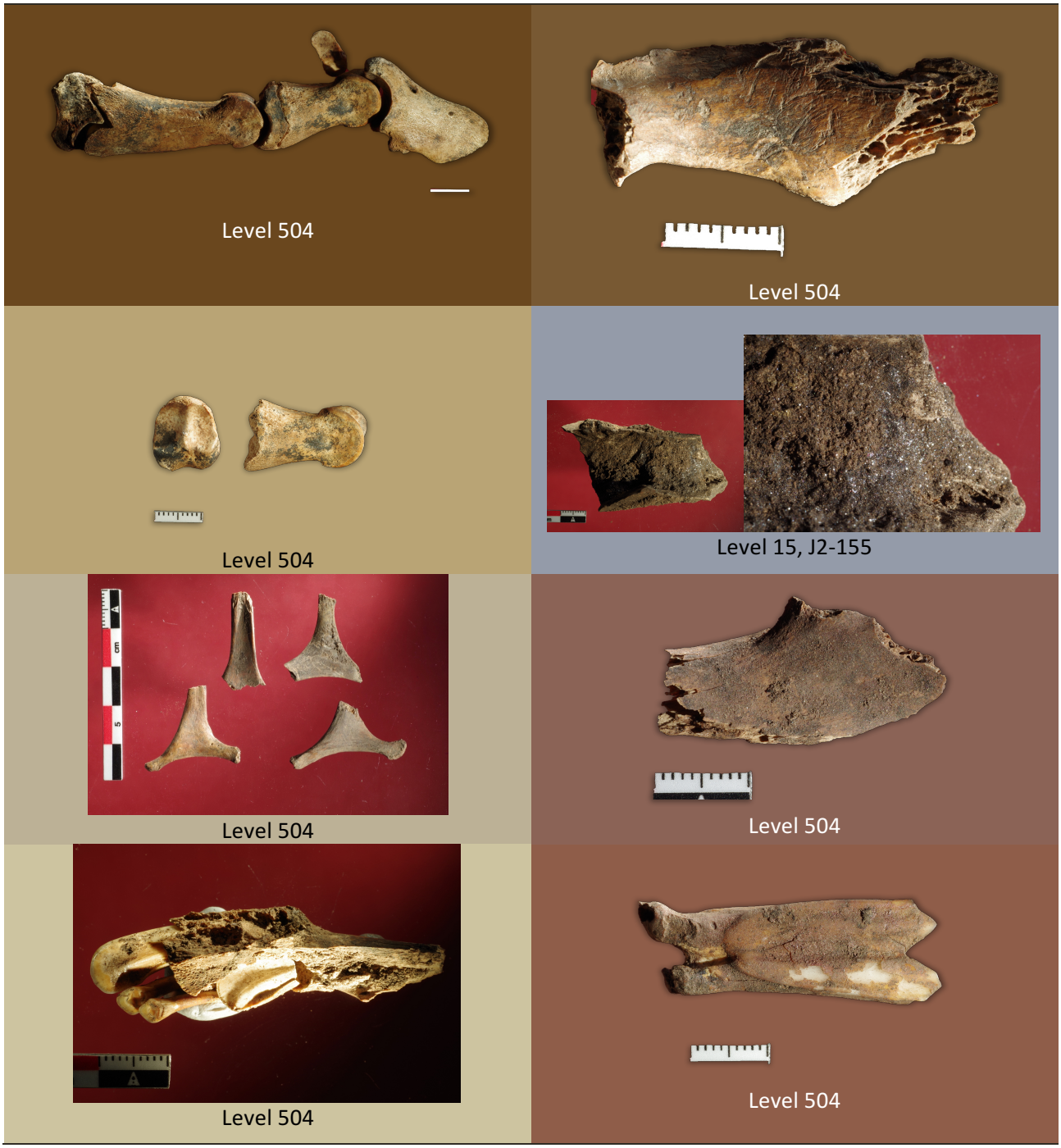
Diagenetic alterations were observed in terms of weathering marks identified in 12%NR, with a predominance of the initial state (9%NR), manganese dendrites are present on 29%NR of the bones, attesting to at least temporary ponding in the burial area, as also indicated by water dissolution marks on 5%NR. It should be highlighted that some of the animal remains were found with intensive red ochre cover, coming from the red ochre burial. Those animal remains lying on the surface were probably covered accidently during preparation of the red ochre to cover the human bones as their 3D-distribution seemed to represent the living floor revealed by spatial analysis (GEILING & MARÍN-ARROYO 2015).

The summary of taphonomic modifications was also published (MARÍN-ARROYO & GEILING 2015).

Level 504 – Summary

The pattern of animal species and ages represented in the assemblage indicates consumption of both adult and juvenile red deer and ibex, although with a clear dominance in adult individuals, a pattern which is also seen in the contemporaneous Lower Magdalenian Levels 15, 16 and 17, and not in earlier Late Middle Paleolithic, Gravettian, Solutrean occupations or later Middle/Upper/Final Magdalenian occupations – mainly probably also due to comparable low MNI of most of the other faunal assemblages. The faunal assemblage of Level 504 was clearly and simply accumulated by humans during cold seasons for reasons of their subsistence with evidence of defleshing and disarticulation cut marks as well as impact marks on bones and bone flakes. Refits and rearticulation indicate that the place behind the engraved block might have been

more a garbage place at time of deposition rather than for daily activities, and the at most slightly disturbance of the surrounding sediments took place during the burial itself. Based on the C14 dates form Level 504 and Level 17, it seemed to occur contemporaneous the deposition of Level 504 animal bones with Sample 10 from Level 17 and the human burial with Sample 6 of Level 17, just at the end of the intensive Lower Magdalenian occupations. Photographs (Appendix Figure C.6.2) show diagenetic preservation of the faunal assemblage from Level 504.



Appendix Figure C.6.2: Faunal material from Level 504.

Appendix D Osteometry data

Osteometric data were used to identify size variation among animal individuals. The obtained results were analyzed by distribution of measurements to make demographic estimates. Following Appendix Table D.1 lists osteometric measurements taken with a caliper by anatomical elements and species.

Measurement codes have the following meaning:

B Tooth greatest breadth on the occlusal surface. measured rectangular to lingual in lower teeth and to buccal in upper teeth -teeth; =b (KLEIN ET AL. 1981)

BC Tooth greatest breadth of the column. measured on ERJ; = RT (D'ERRICO & VANHAEREN 2002)

HC Teeth. crown height, measured from occlusal lowest point between the two cusps of the enamel to the ERJ (in lower molars measured on lingual surface and in upper molars measured on buccal surface); =h (KLEIN ET AL. 1981)

LC Tooth length of the column/neck, measured on enamel- root junction (ERJ); = RW (D'ERRICO & VANHAEREN 2002)

B Greatest breadth, measured from medial to lateral

Bdist Greatest breadth on distal epiphyses; = Bd (VON DEN DRIESCH 1976)

BFD Breadth of articulating surface, distal; = BT (VON DEN DRIESCH 1976)

Bprox Greatest breadth on proximal epiphyses; = BG (VON DEN DRIESCH 1976)

HT Height of the trochlea incision; =SHT (VON DEN DRIESCH 1976; FERNANDEZ 2001)

SDCm Smallest diameter of medial condyle, lateral part (FERNANDEZ 2001)

T Greatest depth. measured from anterior to posterior

TM Greatest depth of the sagittal crest of the distal medial condyle; = Dd (VON DEN DRIESCH 1976)

Tdist Greatest depth on distal epiphyses/ measured from anterior to posterior

Tprox Greatest depth on proximal epiphyses; = GLP (VON DEN DRIESCH 1976)

Appendix Table D.1: Osteometry of El Mirón measurable faunal remains.

Lower dP4, Capra pyrenaica

Level	17-10	17-10	17	17-6	17	17-10	16	17-12	17	17-8	130	128	121	122	125
B	6.88	6.87	5.91	6.64	6.79	6.33	6.49	6.87	5.73	6.45	7.19	6.02	6.96	6.12	7.28
LC	/	/	12.03	14.16	13.51	12.87	13.6	/	11.98	13.51	12.92	10.98	12.87	15.36	14.1

Lower M1, Capra pyrenaica

Level	15	15	15	15	16	16	16	16	17-6	17-6	17-8	17-8	17-8	17-8	17-8
LC	*14.36	14.45	15.47	15.25	13.73	11.7	11.96	12.2	11.28	12.1	12.07	11.94	11.53	/	11.1
BC	9.3	8.86	/	9.62	8.3	7.81	8.39	8.25	7.11	8.48	8.71	8.55	8.1	8.05	7.97
HC	8.91	11.92	24.38	26.8	8.69	11.97	12.19	13.87	9.65	22.65	7.22	9.35	10.37	10.51	11.21
sex/age				adult			senil								

Level	17-8	17-8	17-8	17-8	17-8	17-8	17-8	17-10	17-10	17-10	17-10	17-12	17-12	17-12	17-12
LC	11.18	/	9.94	11.33	/	11.99	10.67	10.79	11.74	12.01	11.22	11.71	11.39	13.29	11.06
BC	7.47	7.79	8.02	8.03	8.26	8.24	6.6	7.25	8.29	7.96	6.55		8.05	8.52	7.1
HC	11.63	12.82	15.58	16.31	16.52	17.37	19.71	6.2	14.46	20.25	20.74	5.03	8.31	10.12	17.28
sex/age														adult	

Level	17-12	17	17	17	17	18	18	122	128	129
LC	11.69	10.62	10.89	11.79	15.19	12.33	10.64	10.93		11.8
BC	7.71	7.01	8.09	5.82	9.22	7.45	6.6	7.16		7.92
HC	*21.88	17.36	21.83	22.82	27.38	5.44	21.02	6.2	9.51	35.52

Lower M2, Capra pyrenaica

Level	15	16	16	16	17	17	17-10	17-12	17-12	17-12	17-6	17-8	17-8	17-8	17-8
B	14.62	14.11	14.08	15.66	11.69	14.05	14.59	13.72	11.2	14.62	14.32	14.72	14.05	13.49	13.21
LC	8.89	8.78	8.65	9.13	7.85	9.35	8.44	7.69	7.87	7.98	8.42	9.83	8.76	8.58	9.03
HC	30.97	20.94	25.61	33.63	15.74	36.03	25.68	19.97	23.44	35.6	34.33	13.15	17.96	22.66	26.62
sex/age	preadu.	adult	adult	preadu.	adult	preadu.		adult	preadu.	preadu.	adult	adult	adult	adult	adult

Level	17-8	17-8	17-8	17-8
B		13.96		13.62
LC		9.15	9.87	9.33
HC	30.69	32.27	37.06	
sex/age	preadu.	juvenil	preadu.	

Lower M3, Capra pyrenaica

Level	15	15	15	15	15	16	16	17-6	17-8	17-8	17-8	17-8
LC							17.14	25.98	25.04	28.27	26.06	18.32*
BC	*8.00		8.45	9.18		8.32	8.95	8.27	8.13	8.76	8.58	9.72
HC	31.43	27.41	37.5	32.41	7.57	25.77	25.6	31.12	26.35	27.6	38.17	32.55
sex/age	preadu.	preadu.	preadu.									

Level	17-8	17-8	17-8	17-8	17-8	17-8	17-8	17-10	17-10	17-10	17-10	17-10	17-10	17-10	17-10
LC						25.75	28.94	27.46	26.13						
BC						9.25	9.41	9.36	7.39	9.08	9.14	8.95	10.18	9.03	9.86
HC	31.73	20.56	36.22	29.6	32.64	28.8	33.29	38.97	33.39	26.09	33.67	34.02		41.05	21.45
age						juvenile									

Level	17-12	17	17	17	17	17	17
LC	25.34	27.69	27.77	24.25			
BC		7.77	7.44	7.28		7.55	8.2
HC	*28.65	36.04	36.87	32.36	21.54	34.65	34.47
sex/age					young		

Upper dP4, Capra pyrenaica

Level	15	16	16	17	17	17	17	17	17-10	17-12	17-6	17-8	17-8	17-8
LC	9.23	10.2	*10.12	9.49	10.21	10.65	9.74	10.19	*9.59	11.47	9.88	10.32	10.28	
BC	10.29	9.68	*9.29	8.48	9.88	8.97	9.89			*11.14	10.42	10.1	10.56	10.09
HC	9.78	8.28	6.14	6.78	11.77	4.98	8.75	9.21	9.37	8.38	7.65	10.8	4.78	9.08
sex/age	infantil	juvenil	juvenil					infantil	juvenil	juvenil	juvenil	infantil	juvenil	juvenil

Upper M1, Capra pyrenaica

Level	15	16	16	17-6	17-6	17-6	17-8	17-8	17-8	17-8	17-8	17-8	17-8	17-8	17-8
LC	13.43	12.62	10.47	10.29	9.62	11.77	12.92	11.1	10.73	10.88	10.59	9.5		9.91	11.87
BC	13.51	13.3	12.5	11.93	11.84	11.89	12.5	12.49		12.79	11.83	12.21		12.22	12.2
HC	13.61	12.6	6.99	28.6	15.9	9.38	24.12*	27.58	26.47	25.89	20.98	19.87	15.47	13.76	13.72
sex/age	adult	mature	senil	adult	adult	mature	juvenil	adult	mature	adult	adult	adult	mature	mature	adult

Level	17-8	17-8	17-8	17-8	17-10	17-10	17-10	17-10	17-10	17-10	17-10	17-10	17-10	17-10	17-10
LC	10.48	9.56	9.73	6.87	10.29	9.96	10.72		10.51	*8.40	11.01	9.88	11.1	10.94	11.55
BC	12.47	12.44	11.14	10.12	12.13	12.19	11.73	12.1	11.95	12.84	12.85		12.59	12.96	12.56
HC	11.59	9.73	8.31	7.07	33.3	28.49	28.22	27.28	23.63	20.42	18.38	12.27	11.67	9.29	7.57
sex/age	mature	adult	mature	mature	juvenil	juvenil	juvenil	adult	juvenil	adult	mature	mature	mature	mature	mature

Level	17-12	17-12	17-12	17-12	17-12	17-12	17-12	17-12	17-12	17-12	17-12	17-12	17-12
LC			10.14	9.69	*11.55	10.43	10.32	10.6	9.75	9.75	10.54	12.2	10.59
BC			11.44	11.14	*12.31	11.39	12.76	12.22	11.79	11.56	11.6	12.56	11.44
HC	*25.99	*22.37	*21.38	35.86	33.45	29.25	25.34	23.86	21.64	19.59	12.44	11.42	10.95
sex/age	adult	mature	adult	juvenil	juvenil	juvenil	mature	mature	mature	mature	mature	mature	mature

Level	17	17	17	17	17	17	17	121
LC	11.11	10.46	9.24	10.99	10.55	11.69	10.18	12.33
BC	12.68	11.15		12.34	12.86	12.41	11.99	13.51
HC	32.7	31.74	30.22	30.04	24.65	20.23	13.5	10.83
sex/age		young					preadu.	

Upper M2, Capra pyrenaica

Level	15	15	15	15	15	16	17-6	17-6	17-8	17-8	17-8	17-10	17-10	17-10	17-10
LC	13.17	14.15	10.33		13.64	11.44	17.61	13.92	12.53	11.71	12.42	13.43	14.13	12.23	15.09
BC	14.26	14.79	11.97	*13.67		*14.42	12.8	13.89	13.23	13.76	13.55	14.24	13.55	13.7	13.56
HC	28.31	16.47	10.9	37.78	32.28	13.95	32.35	12.38	28.37	31.15	25.88	29.25	38.86	36.52	33.14
sex/age	adult	mature	mature	preadu.	adult	mature	juvenil	mature	mature	preadu.	mature	mature	preadu.	preadu.	preadu.

Level	17-10	17-10	17-10	17-10	17-10	17-10	17-10	17-10	17-10
LC	14.51	13.1	*13.17	14.08		13.23	14.51	13.29	*14.18
BC	14.44	14.55	*15.19	14.49	12.18	14.29	15.01	12.38	*11.68
HC	37.38	21.83	30.33	26.23		16.99	30.12	32.96	40.33
sex/age	adult		mature	mature	preadu.	mature	preadu.	adult	preadu.

Level	17-12	17-12	17-12	17-12	17-12	17-12	17-12	17-12	17-12	17-12	17-12	17	17	17
LC	10.37	12.34	9.8	13.17	14.03	11.72	10.19		12.69	12.28	13.24	12.96	*14.52	12.07
BC	12.33	11.83	11.65	13.1	13.31	13.17	11.54		13.87	14.05	13.67	11.98	12.65	11.93
HC	17.51	10.67	19.73		34.7	28.43	21.65	*30.02	16.96	33.84	35.47	35.81	*41.49	23.85
sex/age	mature	mature	mature		mature	adult	mature	mature	mature	mature	preadu.			preadu.

Upper M3, Capra pyrenaica

Level	15	15	15	15	15	15	15	15	16	16	16	16	17-6	17-6
LC	22.48	17.65		20.35	21.45	21.18	21.75	*14.51	15.56				20.8	25.19
BC	13.48	12.66			*15.05	*13.77	*12.74	13.54	13.64	14.32	15.26	14.1	14.96	14.68
HC	19	23.16	24.34	27.71	28.38	30.33	*32.00		32.89				18.82	36.05
sex/age	preadu.	adult	adult	adult	adult	preadu.	preadu.		adult	adult	adult		mature	adult

Level	17-8	17-8	17-8	17-8	17-8	17-8	17-8	17-8	17-8	17-8	17-8
LC	20.74	15.37	19.92	13.99	13.89			15.8	14.9		
BC	14.23	14.04	13.4	14.4	14.32		13.27		14.87	14.81	14.28
HC	15.03	21.51	22.93	26.44	28.62	30.57	32.6	34.54	36.31	39.04	37.86*
sex/age	adult	adult	adult	adult	adult	adult	adult	preadu.	preadu.	adult	preadu.

Level	17-10	17-10	17-10	17-10	17-10	17-10	17-10	17-12	17-12	17-12	17-12	17-12	17-12	17-12
LC		20.34	20.46			20.3		22.18	22.5	*21.80	16.69	22.5	22.46	21.81
BC	14.7	13.16	14.8		14.25	13.82	14.92	13.22	15.04	15.87	13.59	13.49	14.19	14.56
HC	19.28	23.02	29.09	33.99	36.06	38.15		30.47	30.49	31.19	35.57	38.18	40.37	43.02
sex/age	adult	adult	adult	preadu.	preadu.	preadu.	preadu.	adult	adult	adult	preadu.	adult	preadu.	preadu.

Level	17	17	17	17	17	17	17
LC	18.02	21.23	19.87	18.44	24.26	21.15	20.64
BC	12.25	13.65	12.41	12.51	14.76	13.67	13.1
HC	23.36	27.61	31.44	36.48	36.65	40.21	*36.20
sex/age	mature	mature	preadu.	adult	preadu.	adult	preadu.

Scapula, Capra pyrenaica

Level	17-08	17-10	17-10	17-10	17-10	17-12	17-12	17-12	17-12	17-12	17-12	17-12	17	17	17
Tprox	25.08	22.65	23.38	29.66	31.14	19.93	23.44	24.08	24.56	25.59	26.26	26.71	18.42	21.04	23.3
Bprox	35.72	34.32	36.64	43.27	39.81	27.83	33.64	35.01	35.88	37.5	39.05	38.34			34.86
Sex				male	male										

Level	17	17	17	17	17	17	17	17	17	17	17	17	17	17
Tprox	23.57	23.68	24.1	24.12	25.46	25.92	26.54	28.6	28.95	28.95	29.23	31.53	31.72	32.09
Bprox		35.27	33.28	35.86	37.2	38.23	38.84	42.5	41.8	42.43	42.67	45.91	43.08	44.44
Sex								male	male	male	male	male	male	male

Level	CAL	CAL	CAL	CAL	CAL-M	CAL-M	CAL-M	CAL-M	CAL-M	LB1	LB2	LC	M1	M3
Tprox	23.8	24.4	25.2	25.4	30.3	30.6	30.6	30.7	33.1	20.54	22.11	26.84	23.91	18.43
Bprox	36.2	35.4	37.5	36	44.1	41.8	43	45.6	47.2	31.65	32.94	37.49	33.23	23.99
Sex					male	male	male	male	male					

Humerus, Capra pyrenaica

Level	16	17-10	17-10	17-10	17-10	17	17	17	17	17	17	17	17	17	17
HT	18.49	19.13	16.94	17.4	18.64	16.38	16.63	16.7	16.84	17.04	17.06	17.07	17.16	17.21	17.23
Bfd	40.17	32.05	34.78	35.91	35.97	33.48	33.81	34.17	33.35	32.68	35.36		33.76	36.1	34.18
Sex	male														

Level	17	17	17	17	17	17	17	17	17	17	122
HT	17.25	17.49	17.86	18.02	18.02	18.74	18.86	19.01	19.21	19.55	16.89
Bfd	36.7	34.1	34.27	36.11	40.72	39.47	40.68	42.46	40.71	40.19	34.74
Sex					male	male	male	male	male	male	

Level	LB1	LB2	LC	M1	M2	M3
HT	15.42	15.12	16.42	15.49	17.02	14.72
Bfd	29.8	31.16	34.88	33.35	39.35	29.88

C.secundum y tertium, Capra pyrenaica

Level	15	16	16	16	16	16	16	16	16	16	16	16	16	16
Tdist	16.65	16.4	16.69	17.08	17.17	17.29	17.44	17.46	17.74	17.81	17.92	18.04	18.08	18.12
Sex	young/ female	young/ female	young/ female	female	female	female	female	female	female	female	female	female	female	female

Level	16	16	16	17-6	17-6	17-6	17-6	17-8	17-8	17-8	17-8	17-8	17-8
Tdist	18.8	19.5	20.52	15.33	18.01	18.24	16.84	15.13	16.04	18.1	18.14	18.18	19.85
Sex	male	male	male		female	female	female			female	female	female	male

Level	17-10	17-10	17-12	17-12	17
Tdist	16.49	16.97	17.26	17.95	20.84
Sex		female	female	female	male

C.quartum, Capra pyrenaica

Level	15	15	15	15	15	15	16	16	16	16	16	16	16
Tprox	11.61	12.02	13.1	13.57	13.88	15.05	9.9	11.04	11.04	11.85	12.05	12.25	12.37
Sex	female	female	male	male	male	male	young/ female	female	female	female	female	female	female

Level	16	16	16	17-6	17-6	17-6	17-6	17-6	17-8	17-8	17-10	17-10	17-10	17
Tprox	13.43	13.47	13.52	10.74	11.37	11.7	13.6	14.76	11.45	14.36	12.13	13.85	14.76	13.59
Sex	male	male	male	young/ female	female	female	male	male	female	male	young/ female	male	male	male

C.radiale, Capra pyrenaica

Level	15	15	15	16	15	15	16	15	15	15	15	16
Tprox	25.97	23.54	23.23	21.66	19.35	20.92	20.2	20.07	24.12	20.4	21.74	20.97
Sex/age	male	male	male	female	young/ female	female	female	female	male	female	female	female

Level	17-8	17-8	17-8	17-8	17-10	17-12
Tprox	20.13	25.13	20.53	21.44	24.91	21.3
Sex/age	female	male	female	female	male. old	female

C.ulnare, Capra pyrenaica

Level	15	15	15	15	16	16	16	16	17-8	17-8	17-8	17-8	17-8	17-8
Tdist	15.99	16.04	17.41	20.36	14.16	15.43	19.11	19.64	15.62	16.24	16.69	17.06	17.17	20.38
Sex/age	young/ female	female	female	male	young/ female	young/ female	male	male	young/ female	female	female	female	female	male

Level	17-10	17-10	17-10	17-10	17-12	17-12	17-12	17-12
Tdist	15.17	15.98	17.34	21.74	15.96	16.54	17.38	17.47
Sex/age	young/ female	young/ female	female	male	young/ female	female	female	female

Tibia distal, Capra pyrenaica

Level	17	17-12	17-12	17-12	17-12	17-8	17-8	CAL-M	CAL-M	CAL-M	122	122
Bdist	31.01	33.88	30.86	35.06	36.22	30.2	30.14	34.7	36.1	36.4	28.75	28.61
Tdist	24.32	26.92	24.91	27.34	27.45	23.68	24.1	27.6	28.8	27	22.04	22.38
sex	female	male	female	male	male	female	female	male	male	male		

Sesamoid distal, Capra pyrenaica

Level	16	16	16	16	16	16	16	16	17-6	17-6	17-6	17-6	17-6	17-6	17-6
B	10.61	11.69	12.59	14.3	15.27	15.98	16.01	16.77	9.75	11.2	13.45	14.39	14.95	15.43	16.94
T	5.65	6.36	7.2	8.64	9.26	8.63	9.54	9.24	5.84	6.34	7.34	8.42	8.82	9.35	9.87
sex/age										young					

Level	17-6	17-8	17-8	17-8	17-8	17-8	17-8	17-8	17-8	17-8	17-8	17-8	17-8	17-8	17-8
B	17.6	10.75	11.77	12.35	12.69	13.17	13.39	13.42	13.62	13.69	14.29	14.47	14.54	14.67	14.78
T	10.01	5.26	7.01	6.96	6.69	7.36	6.87	7.73	8.66	7.1	7.48	7.99	8.89	8.5	8.2

Level	17-8	17-8	17-8	17-8	17-8	17-8	17-8	17-8	17-8	17-10	17-10	17-10	17-10	17-10	17-10
B	14.94	15.05	15.29	15.41	16.48	17.05	17.12	17.64	17.8	9.88	10.36	11.21	11.54	11.85	12.31
T	8.05	9.31	7.96	8.48	10.39	10.38	10.37	9.94	10.56	6.07	5.77	6.55	6.01	7.22	6.97
sex/age										young	young	young			

Level	17-10	17-10	17-10	17-10	17-10	17-10	17-10	17-10	17-10	17-10	17-10	17-10	17-10	17-10	17-10
B	12.68	12.82	12.86	13.03	13.13	13.49	13.98	14.01	14.44	14.55	14.62	14.65	14.79	15.01	15.1
T	7.76	7.92	6.96	9.26	7.93	6.63	8.04	7.38	8.33	8.2	7.57	7.41	7.73	8.87	7.46

Level	17-10	17-10	17-10	17-10	17-10	17-10	17-10	17-10	17-10	17-12	17-12	17-12	17-12	17-12	17-12
B	15.41	15.53	15.55	15.75	16.45	16.58	16.71	16.84	17.67	11.98	13.35	13.43	13.7	13.72	15.26
T	8.25	8.64	8.91	8.79	9.03	8.49	10.11	10.06	10.31	6.48	7.76	7.75	7.47	8.18	8.29

Level	17-12	17-12	121
B	15.65		11.03
T	8.27	9.19	6.13

Caninus, Cervus elaphus

Level	15	16	16	16	16	17-6	17-6	17-8	17-10	17-10	17-12	121	128
LC	9.33	7.78	7.96	8.18	10.7	5.95	6.4	6.85	3.84	4.73	5.08	7.81	8.09
BC	3.92	5.13	4.84	4.84	4.26	4.55	4.72	5.1	2.78	3.72	4.15	5.03	5.43
sex/age	male	adult	adult	adult	male							adult	adult

Appendix E NISP, MNE, and MNI of prey species

Results of zooarchaeological analysis are summarized for Number of faunal remains (NR) and Number of Identified Specimen (NISP) in Appendix Table E.1 and their relative portions in Appendix Table E.2, for Minimum Number of identified Elements (MNE) in Appendix Table E.3 and their relative portions in Appendix Table E.4, and Minimum Number of identified Individuals (MNI) in Appendix Table E.5 and their relative portions in Appendix Table E.6.

Detailed skeletal quantification is given for:

- Red deer in Late Middle Paleolithic, Gravettian and Solutrean levels in Appendix Table E.7
- Red deer in Initial and Lower Magdalenian levels in Appendix Table E.8
- Ibex in Late Middle Paleolithic, and Gravettian n levels in Appendix Table E.9
- Ibex in Solutrean levels and Lower Magdalenian burial in Appendix Table E.10
- Ibex in Lower Magdalenian levels in Appendix Table E.11
- Chamois in Appendix Table E.12
- Elements in size classes in Appendix Table E.13

When possible, they were differentiated by age classes Fetal (=F), Neonate (=N), Infantile (=I), Juvenile (=J) and Adult (=A).

Appendix Table E.1: Species representation by numbers of faunal remains of all levels.

NR	130	129	128	127	126	125	124	123	122	121	120	21	20	19	18	17 (12)	17 (10)	17 (8)	17 (6)	16	15	504	TOTAL
Mammuthus primigenius			1																				**1**
Equus ferus	2						1								1	10	8	6	3	3	1	7	**42**
Bison priscus																		1					**1**
Bos/Bison									2							8	8	21	1	1	2		**43**
Capra pyrenaica	54	26	86	26	8	97	59	12	107	77		4	3	9	28	741	1001	941	366	628	504	386	**5 163**
Rupicapra rupicapra	10	1	10		9	5	10	2	19	22						4	11	12	4	4	9	5	**137**
Cervus elaphus	15	8	44	20	14	73	59	7	106	107	1	5	1	2	32	822	949	796	156	358	353	214	**4 142**
Rangifer tarandus																	1						**1**
Capreolus capreolus																1	1		3				**5**
Ursus arctos	1														1								**2**
Canis lupus	3		2		1											2			2	7	8	1	**26**
Panthera pardus			1																				**1**
Vulpes vulpes								1								1	1				1	1	**5**
Lepus sp.	6	15	64	3		1	3			1							2	2		2	1		**100**
Oryctolagus cuniculus				3																			**3**
Amphibia						1										1	4						**6**
Bird	69	27	117	31	12	4	2		3	4						2	5	6	3	7	8		**300**
Fish	5	1	4			1			2	1						1	2	6		1			**24**
Leporids/ Birds	104	41	708																				**853**
L Ungulate			1			3	3		3	6						21	9	20	4	15	15		**100**
M Ungulate	20	6	20	4	5	63	58	13	40	54				1	1	165	63	94	29	96	55	202	**989**
S Ungulate			4	1	9	10	19	2	23	14						57	2	5	2	11	7		**166**
S Carnivore			1			1											1	2	1	6			**12**
XS Carnivore																1							**1**
XL Size																		2			3		**5**
M-L Size	11	6	30	4		4	5		81	59				1	1	318	512	503	112	226	161		**2 034**
S-M Size						14	15		23	4				1		20	1						**78**
S Size	1									1						2				1	1		**6**
<XS Size		1	3						1									2			2		**9**
→NISP **total**	301	132	1096	92	59	276	234	37	410	350	1	9	4	14	64	2176	2577	2419	686	1366	1131	816	**14 250**
→NR indeterminate	2694	1083	4435	1503	924	4671	3416	344	5961	17020	58			494	1687	13037	25671	51887	39936	33354	18812	2	**226 989**
NR total	**2995**	**1215**	**5531**	**1595**	**982**	**4948**	**3650**	**381**	**6371**	**17370**	**59**	**9**	**4**	**508**	**1751**	**15214**	**28252**	**54306**	**40622**	**34720**	**19943**	**818**	**241 239**

Appendix Table E.2: Relative species representation by numbers of faunal remains of all levels.

%NISP	130	129	128	127	126	125	124	123	122	121	120	21	20	19	18	17 (12)	17 (10)	17 (8)	17 (6)	16	15	504	TOTAL
Mammuthus primigenius			0.1																				0
Equus ferus	0.7						0.4								1.6	0.5	0.3	0.2	0.4	0.2	0.1	0.9	0.3
Bison priscus																							0
Bos/Bison									0.5							0.4	0.3	0.9	0.1	0.1	0.2		0.3
Capra pyrenaica	17.9	19.7	7.8	28.3	13.6	35.1	25.2	32.4	26.1	22.0		44.4	75.0	64.3	43.8	34.1	38.8	38.9	53.4	46.0	44.6	47.3	36.2
Rupicapra rupicapra	3.3	0.8	0.9		15.3	1.8	4.3	5.4	4.6	6.3						0.2	0.4	0.5	0.6	0.3	0.8	0.6	1.0
Cervus elaphus	5.0	6.1	4.0	21.7	23.7	26.4	25.2	18.9	25.9	30.6	100	55.6	25.0	14.3	50	37.8	36.8	32.9	22.7	26.2	31.2	26.2	29.1
Rangifer tarandus																							0
Capreolus capreolus																			0.4				0
Ursus arctos	0.3														1.6								0
Canis lupus	1.0		0.2		1.7											0.1			0.3	0.5	0.7	0.1	0.2
Panthera pardus			0.1																				0
Vulpes vulpes								2.7								0.1	0.1				0.1	0.1	0
Lepus sp.	2.0	11.4	5.8	3.3		0.4	1.3			0.3							0.1	0.1		0.1	0.1		0.7
Oryctolagus cuniculus				3.3																			0
Amphibia						0.4											0.2						0
Bird	22.9	20.5	10.7	33.7	20.3	1.4	0.9		0.7	1.1						0.1	0.2	0.2	0.4	0.5	0.7		2.1
Fish	1.7	0.8	0.4			0.4			0.5	0.3							0.1	0.2		0.1			0.2
Leporids/Birds	34.6	31.1	64.6																				6.0
L Ungulate			0.1			1.1	1.3		0.7	1.7						1.0	0.3	0.8	0.6	1.1	1.3		0.7
M Ungulate	6.6	4.5	1.8	4.3	8.5	22.8	24.8	35.1	9.8	15.4				7.1	1.6	7.6	2.4	3.9	4.2	7.0	4.9	24.8	6.9
S Ungulate			0.4	1.1	15.3	3.6	8.1	5.4	5.6	4.0						2.6	0.1	0.2	0.3	0.8	0.6		1.2
S Carnivore			0.1			0.4												0.1	0.1	0.4			0.1
XS Carnivore																							0
XL Size																		0.1			0.3		0
M-L Size	3.7	4.5	2.7	4.3		1.4	2.1		19.8	16.9				7.1	1.6	14.6	19.9	20.8	16.3	16.5	14.2		14.3
S-M Size						5.1	6.4		5.6	1.1				7.1		0.9							0.5
S Size	0.3									0.3						0.1				0.1	0.1		0
<XS Size		0.8	0.3						0.2									0.1			0.2		0.1
%NISP total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
%NISP total	10.1	10.9	19.8	5.8	6.0	5.6	6.4	9.7	6.4	2.0	1.7	100	100	2.8	3.7	14.3	9.1	4.5	1.7	3.9	5.7	99.8	5.9
%NR indeterminate	89.9	89.1	80.2	94.2	94.1	94.4	93.6	90.3	93.6	98.0	98.3	0	0	97.2	96.3	85.7	90.9	95.5	98.3	96.1	94.3	0.2	94.1
%NR total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Appendix Table E.3: Minimum Number of Elements (MNE) of all levels and species.

MNE	130	129	128	127	126	125	124	123	122	121	120	21	20	19	18	17 (12)	17 (10)	17 (8)	17 (6)	16	15	504	TOTAL
Mammuthus primigenius			/																				**0**
Equus ferus	1						1								1	8	6	5	3	3	1	7	**36**
Bison priscus																		1					**1**
Bos/Bison									1							5	4	15	1	1	2		**29**
Capra pyrenaica	34	20	40	12	8	55	28	10	58	34		3	3	7	19	218	321	307	136	263	146	222	**1944**
Rupicapra rupicapra	10	1	7		7	4	10	2	10	17						4	8	9	3	3	6	2	**103**
Cervus elaphus	8	7	28	17	5	36	29	3	54	35	1	3	1	2	12	143	134	165	42	115	93	85	**1018**
Rangifer tarandus																	1						**1**
Capreolus capreolus																3	3	1	2				**9**
Ursus arctos	1														1								**2**
Canis lupus	3		1		0											2			1	7	7	1	**22**
Panthera pardus			1																				**1**
Felis sp.					1																		**1**
Vulpes vulpes								1								1	1				1	1	**5**
Lepus sp.	6	14	49	3		1	3			1							1	2		2	1		**83**
Oryctolagus cuniculus				3																			**3**
Bird	1	2	2	2	2	2	2		3	1						2	3	2	2	7	4		**37**
Fish	1	1	1			1			1	1						1	1	1		1			**10**
Total	**65**	**45**	**129**	**37**	**23**	**99**	**73**	**16**	**127**	**89**	**1**	**6**	**4**	**9**	**33**	**387**	**483**	**508**	**190**	**402**	**261**	**318**	**3305**

Appendix Table E.4: Relative Minimum Number of Elements (MNE) of all levels and species.

%MNE	*130*	*129*	*128*	*127*	*126*	*125*	*124*	*123*	*122*	*121*	*120*	*21*	*20*	*19*	*18*	*17 (12)*	*17 (10)*	*17 (8)*	*17 (6)*	*16*	*15*	*504*	*TOTAL*
Mammuthus primigenius			/																				*0*
Equus ferus	*1.5*						*1.4*								*3.0*	*2.1*	*1.2*	*1.0*	*1.6*	*0.7*	*0.4*	*2.2*	*1.1*
Bison priscus																		*0.2*					*0*
Bos/Bison									*0.8*							*1.3*	*0.8*	*3.0*	*0.5*	*0.2*	*0.8*		*0.9*
Capra pyrenaica	*52.3*	*44.4*	*31.0*	*32.4*	*34.8*	*55.6*	*38.4*	*62.5*	*45.7*	*38.2*		*50*	*75.0*	*77.8*	*57.6*	*56.3*	*66.5*	*60.4*	*71.6*	*65.4*	*55.9*	*69.8*	*58.8*
Rupicapra rupicapra	*15.4*	*2.2*	*5.4*		*30.4*	*4.0*	*13.7*	*12.5*	*7.9*	*19.1*						*1.0*	*1.7*	*1.8*	*1.6*	*0.7*	*2.3*	*0.6*	*3.1*
Cervus elaphus	*12.3*	*15.6*	*21.7*	*45.9*	*21.7*	*36.4*	*39.7*	*18.8*	*42.5*	*39.3*	*100*	*50*	*25.0*	*22.2*	*36.4*	*37.0*	*27.7*	*32.5*	*22.1*	*28.6*	*35.6*	*26.7*	*30.8*
Rangifer tarandus																	*0.2*						*0*
Capreolus capreolus																*0.8*	*0.6*	*0.2*	*1.1*				*0.3*
Ursus arctos	*1.5*														*3.0*								*0.1*
Canis lupus	*4.6*		*0.8*													*0.5*			*0.5*	*1.7*	*2.7*	*0.3*	*0.7*
Panthera pardus			*0.8*																				*0*
Felis sp.					*4.3*																		*0*
Vulpes vulpes								*6.3*								*0.3*	*0.2*				*0.4*	*0.3*	*0.2*
Lepus sp.	*9.2*	*31.1*	*38.0*	*8.1*		*1.0*	*4.1*			*1.1*							*0.2*	*0.4*		*0.5*	*0.4*		*2.5*
Oryctolagus cuniculus				*8.1*																			*0.1*
Bird	*1.5*	*4.4*	*1.6*	*5.4*	*8.7*	*2.0*	*2.7*		*2.4*	*1.1*						*0.5*	*0.6*	*0.4*	*1.1*	*1.7*	*1.5*		*1.1*
Fish	*1.5*	*2.2*	*0.8*			*1.0*			*0.8*	*1.1*						*0.3*	*0.2*	*0.2*		*0.2*			*0.3*
%MNE total	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*

Appendix Table E.5: Minimum Number of Individuals (MNI) of all levels and species.

MNI	130	129	128	127	126	125	124	123	122	121	120	21	20	19	18	17 (12)	17 (10)	17 (8)	17 (6)	16	15	504	TOTAL
Mammuthus primigenius			/																				**0**
Equus ferus	1						1								1	2	2	1	1	1	1	1	**12**
Bison priscus																		1					**1**
Bos/Bison									1							1	2	1	1	1	1		**8**
Capra pyrenaica	3	2	3	2	3	4	4	1	5	4		1	1	1	3	16	14	20	10	15	11	8	**131**
Rupicapra rupicapra	2	1	1		1	2	3	1	2	3						2	2	1	1	2	2	1	**27**
Cervus elaphus	2	2	3	3	2	4	3	1	3	4	1	1	1	1	2	9	13	13	3	7	6	4	**88**
Rangifer tarandus																	1						**1**
Capreolus capreolus																1	2	1	1				**5**
Ursus arctos	1														1								**2**
Canis lupus	2		1		0											1			1	1	1	1	**8**
Panthera pardus			1																				**1**
Felis sp.					1																		**1**
Vulpes vulpes								1								1	1				1	1	**5**
Lepus sp.	2	2	6	3		1	1			1							1	1		1	1		**20**
Oryctolagus cuniculus				3																			**3**
Bird	1	1	1	2	1	1	1		1	1						1	1	2	1	1	1		**17**
Fish	1	1	1			1			1	1						1	1	1		1			**10**
Total	15	9	17	13	8	13	13	4	13	14	1	2	2	2	7	35	40	42	19	30	25	16	**341**

Appendix Table E.6: Relative Minimum Number of Individuals (MNI) of all levels and species.

%MNI	*130*	*129*	*128*	*127*	*126*	*125*	*124*	*123*	*122*	*121*	*120*	*21*	*20*	*19*	*18*	*17 (12)*	*17 (10)*	*17 (8)*	*17 (6)*	*16*	*15*	*504*	*TOTAL*
Mammuthus primigenius			/																				*0.3*
Equus ferus	*6.7*						*7.7*								*14.3*	*5.7*	*5.0*	*2.4*	*5.3*	*3.3*	*4.0*	*6.3*	*3.5*
Bison priscus																		*2.4*					*0.3*
Bos/Bison									*7.7*							*2.9*	*5.0*	*2.4*	*5.3*	*3.3*	*4.0*		*2.3*
Capra pyrenaica	*20*	*22.2*	*17.6*	*15.4*	*37.5*	*30.8*	*30.8*	*25.0*	*38.5*	*28.6*		*50*	*50*	*50*	*42.9*	*45.7*	*35.0*	*47.6*	*52.6*	*50*	*44.0*	*50*	*38.4*
Rupicapra rupicapra	*13.3*	*11.1*	*5.9*		*12.5*	*15.4*	*23.1*	*25.0*	*15.4*	*21.4*						*5.7*	*5.0*	*2.4*	*5.3*	*6.7*	*8.0*	*6.3*	*7.9*
Cervus elaphus	*13.3*	*22.2*	*17.6*	*23.1*	*25.0*	*30.8*	*23.1*	*25.0*	*23.1*	*28.6*	*100*	*50*	*50*	*50*	*28.6*	*25.7*	*32.5*	*31.0*	*15.8*	*23.3*	*24.0*	*25.0*	*25.8*
Rangifer tarandus																	*2.5*						*0.3*
Capreolus capreolus																*2.9*	*5.0*	*2.4*	*5.3*				*1.5*
Ursus arctos	*6.7*														*14.3*								*0.6*
Canis lupus	*13.3*		*5.9*													*2.9*			*5.3*	*3.3*	*4.0*	*6.3*	*2.3*
Panthera pardus			*5.9*																				*0.3*
Felis sp.					*12.5*																		*0.3*
Vulpes vulpes								*25.0*								*2.9*	*2.5*				*4.0*	*6.3*	*1.5*
Lepus sp.	*13.3*	*22.2*	*35.3*	*23.1*		*7.7*	*7.7*			*7.1*							*2.5*	*2.4*		*3.3*	*4.0*		*5.9*
Oryctolagus cuniculus				*23.1*																			*0.9*
Bird	*6.7*	*11.1*	*5.9*	*15.4*	*12.5*	*7.7*	*7.7*		*7.7*	*7.1*						*2.9*	*2.5*	*4.8*	*5.3*	*3.3*	*4.0*		*5.0*
Fish	*6.7*	*11.1*	*5.9*			*7.7*			*7.7*	*7.1*						*2.9*	*2.5*	*2.4*		*3.3*			*2.9*
%MNI total	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*

Appendix Table E.7: Quantification of red deer skeletal elements by ages for Late Middle and Early Upper Paleolithic and Solutrean levels.

Level	130			129				128				
Cervus elaphus	NISP	MNE		NISP	MNE			NISP	MNE			
Element	All	All	J	All	All	F	A	All	All	F	J	A
Antler	3	1						1				
Cranium								1	1			1
Viscerocra./Maxilla								1	1		1	
Upper teeth								1	1			
Mandible								1	1			1
Lower teeth	1	1	1					3	1		1	
Teeth												
Hyoid												
Cervical vert.												
Thoracic vert.												
Rib	1											
Lumbar vert.												
Sacral vert.												
Caudal vert.												
Indet. vert.												
Scapula												
Humerus				1	1		1	3	1			
Radius								4	2	1	1	
Ulna								3	3	1	2	
Ulna-Radius								2				
Carpal unit								1	1			
Pelvis								1	1			
Femur								2	1		1	
Patella												
Tibia								1	1			
Talus												
Calcaneus												
Tarsal unit												
Metacarpus	1	1						2	1			
Metatarsus	2	1		1	1			2	1		1	
Metapodia	3											
Meta. atro.												
Phalanx prox.								1	1			
Phalanx med.	1	1						2	2			
Phalanx dist.	2	2	1	2	2	1	1	7	7	4		3
Phalanx atro.				1	1			1	1			
Phalanx indet.												
Sesamoid	1	1		3	2							
Humerus-Femur												
Radius-Tibia												
Long bone								1				
Total	15	8	2	8	7	1	1	40	28	6	4	8

Level	127						126				125					124					123		122					121				
Cervus elaphus	NISP	MNE					NISP	MNE			NISP	MNE				NISP	MNE				NISP	MNE	NISP	MNE				NISP	MNE			
Element	All	All	I	J	A		All	All	J	A	All	All	I	J	A	All	All	F	I	A	All	All	All	All	I	J	A	All	All	I	J	A
Antler	1						1				11	1				5					1		10					25				
Cranium																							2	1								
Viscerocra./Maxilla																												1	1		1	
Upper teeth	1	1									2	2	1		1	2	1		1				4	1			1	5	3	2		1
Mandible	1	1					1	1	1		4	2		1	1	1	1						1	1								
Lower teeth	2	2		1	1		1			1	5	3	2		1	3	3		1	2			1	1			1	2	2	1		1
Teeth																																
Hyoid											1	1																				
Cervical vert.	2	2					1									2	1			1			1	1								
Thoracic vert.																																
Rib							1				1	1				2	1															
Lumbar vert.																1	1											1	1			
Sacral vert.																																
Caudal vert.											1	1																				
Indet. vert.																							1	1								
Scapula																																
Humerus							1	1			4	1			1	2	1						6	2			1	6	3			
Radius											3	1		1		4	1						5	1				2	1			
Ulna											1	1											1	1				3	3			3
Ulna-Radius																												1	1			
Carpal unit							1	1								1	1						2	1								
Pelvis																							1	1								
Femur							1	1			8	2			1	1	5	1			1	2	1	10	2			1	9	3		1	2
Patella	1	1									1	1																				
Tibia							1	1			1	1				1	3	1			1	1	8	2			1	18	4			4
Talus	3	2									1	1																				
Calcaneus											1	1				1	1															
Tarsal unit											1	1				2	1															
Metacarpus											7	2			1	1	3	1					2	2			1	3	2		1	1
Metatarsus	2	1			1		1				2	1			1		6	1		1	3	1	8	2		1	1	12	2		1	1
Metapodia	1	1					1				1	1					1			1			9	2	1	1		4				
Meta. atro.											1	1											1	1				2	2			
Phalanx prox.	1	1									2	2				4	2						9	5		2	1	1	1			
Phalanx med.	1	1														1	1						1	1				1	1			
Phalanx dist.	2	2	1				1				3	2	1			3	2	2					6	3	2	1		2	1			
Phalanx atro.											4	4				3	3						11	11				2	1			
Phalanx indet.																							1					1	1	1		
Sesamoid	2	2					2				1	1				4	4						2	2				2	2			
Humerus-Femur																							2					1				
Radius-Tibia																												2				
Long bone											1	1											1					1				
Total	20	17	1	1	2		14	5	1	1	68	36	4	5	6	59	29	2	4	5	7	3	106	45	3	5	8	107	35	4	4	13

Appendix Table E.8: Quantification of skeletal elements by ages of red deer: Initial and Lower Magdalenian from Cabin and Burial Area.

Level	21		20	19		18			17(12)					17(10)					17(8)					17(6)				16					15					504				
Cervus elaphus	NISP	MNE	NISP	NISP	MNE	NISP	MNE		NISP	MNE				NISP	MNE				NISP	MNE				NISP	MNE			NISP	MNE				NISP	MNE				NISP	MNE			
Element	All	All	All	ALL	All	All	All	J	All	All	F	J	A	All	All	N	I	J	A	All	All	N	I	J	A	All	All	J	A	All	All	N	I	J	A	All	All	N	I	J	A	All	All	N	J	A
Antler									**83**	**1**			*1*	**101**						**20**						**21**				**25**						**11**						**20**				
Cranium									**21**	**2**		*1*	*1*	**8**	**3**					**2**	**2**				*1*	**1**	**1**			**5**	**1**				*1*	**5**	**2**					**2**	**2**			***1***
Maxilla									**44**	**3***	*1**	*1**	*1**	**14**	**2***				*2*	**1**	**1***									**1**	**1***					**1**	**1***					**1**	**1***			
Upper teeth	**1**	**1**		**1**	**1**	**2**	**1**		**47**	**13**	*1*	*1*	*11*	**47**	**9**			*3*	*5*	**9**	**8**			*1*	*4*	**10**	**3**	*1*	*2*	**21**	**4**			*1*	*6*	**27**	**4**			*1*	*3*	**9**	**8**			***1 1***
Mandible	**1**	**1**							**19**	**4***		*2**	*2**	**15**	**3***				*3*	**7**	**5***				*3**	**2**	**2***		*2**	**5**	**2***				*2**	**2**	**1***					**7**	**5***			***3***
Lower teeth	**3**	**1**				**1**	**1**	*1*	**31**	**8**		*2*	*6*	**20**	**6**			*1*	*3*	**10**	**10**			*2*	*5*	**23**	**4**	*1*	*2*	**28**	**6**			*3*	*3*	**29**	**5**	*1*		*4*	**10**	**10**			***1 1***
Teeth														**4**						**3**	**2**					**4**				**15**						**14**						**3**	**2**			
Hyoid									**2**	**1**										**1**	**1**				*3*																	**1**	**1**			***1***
Cervical vert.									**6**	**2**				**21**	**5**				*1*	**5**	**4**								**1**	**1**											**5**	**4**			***1***
Thoracic vert.									**13**	**7**				**9**	**3**					**2**	**2**															**2**	**2**	*1*				**2**	**2**			***1***
Sternum									**5**	**1**																																			
Rib									**19**	**6**				**18**	**5**				*5*	**3**	**2**					**1**	**1**			**3**	**1**											**3**	**2**			
Lumbar vert.									**8**	**5**				**13**	**1**					**3**	**1**					**3**	**2**		*1*	**2**	**1**					**1**	**1**					**3**	**1**			***1***
Sacral vert.									**2**	**1**				**2**	**1**																														
Caudal vert.																																					**1**	**1**								
Indet. vert.									**5**	**4**				**3**																**2**						**2**	**2**	*1*							
Scapula									**21**	**3**		*1*	*2*	**19**	**2**				*2*	**2**	**1**					**2**	**1**	*1*		**2**	**1**					**1**	**1**					**2**	**1**			***1***
Humerus						**2**	**2**		**56**	**8**		*4*	*6*	**64**	**14**		*2*		*12*	**15**	**3**				*12*	**3**	**2**		*2*	**16**	**3**					**16**	**4**			*3*		**15**	**3**			***1***
Radius						**2**	**2**	*1*	**32**	**5**		*3*	*2*	**47**	**3**				*3*	**3**	**1**				*4*	**8**	**3**		*3*	**13**	**2**		*1*		*1*	**10**	**2**			*2*		**3**	**1**			***1***
Ulna									**16**	**3**		*1*	*2*	**15**	**7**		*1*		*6*						*2*	**3**	**1**		*1*	**3**	**2**				*2*	**5**	**2**			*2*						
Ulna-Radius									**5**				*2*	**5**						**1**						**1**				**1**	**1**											**1**				
Carpal unit									**1**	**1**				**4**	**1**				*1*						*4*					**2**	**2**				*2*	**2**	**2**								
Pelvis									**18**	**6**		*1*	*6*	**24**	**4**				*3*	**4**	**2**			*1*	*2*	**3**	**1**		*1*	**2**	**1**				*1*	**4**	**1**			*1*		**4**	**2**			***1***
Femur						**1**	**1**		**73**	**8**		*1*	*7*	**118**	**13**			*2*	*11*	**21**	**3**			*1*	*14*	**6**	**3**		*2*	**16**	**4**				*4*	**8**	**2**			*1*	*1*	**21**	**3**			***1***
Patella														**1**	**1**				*1*																										
Tibia						**1**	**1**		**78**	**5**		*1*	*4*	**101**	**10**			*1*	*9*	**10**	**3**			*2*	*7*	**12**	**4**	*1*		**24**	**6**			*1*	*5*	**20**	**7**			*1*	*7*	**10**	**3**		*2*	***1***
Talus									**2**	**2**			*2*	**2**	**2**					**1**	**1**				*2*																		**1**	**1**			***1***
Calcaneus									**6**	**3**			*3*	**4**	**2**			*1*	*1*					*1*	*1*					**2**	**1**				*1*	**3**	**2**			*2*						
Tarsal unit						**1**	**1**							**2**	**2**				*2*	**4**	**4**				*1*	**1**	**1**		*1*	**2**	**1**		*1*		*1*	**5**	**2**			*2*		**4**	**4**		*2*	***1***
Metacarpus						**1**	**1**		**39**	**8**		*1*	*6*	**40**	**3**				*3*	**7**	**3**				*11*	**10**	**2**		*2*	**21**	**1**			*1*	*1*	**29**	**4**	*1*		*4*		**7**	**3**			***2***
Metatarsus									**57**	**6**		*2*	*4*	**70**	**7**				*7*	**13**	**2**				*5*	**13**	**2**		*2*	**31**	**3**	*1*	*1*		*1*	**36**	**3**			*3*		**13**	**2**			***1***
Metapodia				**1**	**1**	**2**	**1**		**32**					**29**						**6**						**7**		*1*		**21**						**10**						**6**				
Meta. atro.									**1**	**1**				**4**						**3**	**2**					**1**				**5**	**3**					**1**						**3**	**2**			***1***
Phalanx prox.						**1**	**1**		**6**	**4**			*4*	**24**	**13**			*4*	*7*	**11**	**7**				*6*	**4**	**3**		*3*	**15**	**10**					**24**	**17**	*1*				**11**	**7**	*1*		***1***
Phalanx med.									**17**	**9**		*3*	*6*	**10**	**9**				*9*	**19**	**12**		*2*		*7*	**4**	**2**		*2*	**10**	**9**					**12**	**8**					**19**	**12**	*2*		***2***
Phalanx dist.									**17**	**13**	*1*	*1*	*11*	**15**	**8**	*2*			*6*	**10**	**8**	*1*			*7*	**3**	**3**	*1*	*2*	**12**	**11**	*2*			*9*	**11**	**7**	*5*	*2*	*1*		**10**	**8**	*6*		***1***
Phalanx atro.									**8**	**4**			*3*	**22**						**4**	**4**					**5**	**2**		*2*	**27**	**22**	*1*			*21*	**35**	**9**					**4**	**4**			***1***
Phalanx indet.																																					**3**									
Sesamoid									**8**	**4**				**13**					*6*	**6**	**6**				*3*	**4**	**1**			**18**	**18**					**21**	**3**	*1*		*6*		**6**	**6**			***1***
Humerus-Femur									**14**					**20**						**2**										**7**						**2**						**2**				
Radius-Tibia																																													
Long bone									**10**					**21**						**1**	**1**					**1**																	**1**	**1**			
Total	**5**	**3**	**0**	**2**	**2**	**14**	**12**	***1***	**822**	**144**	***2***	***23***	***89***	**949**	**134**	***2***	***3***	***12***	***108***	**209**	**95**	***1***	***2***	***8***	***101***	**156**	**42**	***5***	***29***	**358**	**115**	***5***	***2***	***6***	***59***	**353**	**93**	***11***	***5***	***41***		**209**	**95**	***6***	***2***	

Appendix Table E.9: Quantification of skeletal by ages of Spanish ibex: Late Middle Paleolithic and Early Upper Paleolithic.

Level	130					129				128			
Capra pyrenaica	NISP	MNE				NISP	MNE			NISP	MNE		
Element	All	All	*I*	*J*	*A*	All	All	*J*	*A*	All	All	*J*	*A*
Horn										1	1		
Cranium													
Viscerocra./Maxilla	2	1								1	1		
Upper teeth	4	3								4	2	*1*	*1*
Mandible						1	1	*1*		2	1		
Lower teeth	8	2	*1*			2	1			14	2	*1*	*1*
Teeth													
Hyoid										1	1		
Cervical vert.													
Thoracic vert.													
Rib										3	1		
Lumbar vert.						1	1			1	1		
Sacral vert.													
Caudal vert.													
Indet. vert.													
Scapula	1	1											
Humerus										1	1		
Radius	1	1		*1*						2	1		
Ulna	1	1		*1*		2	2			2	1		
Ulna-Radius						1				1			
Carpal unit	2	2		*1*	*1*								
Pelvis	1	1								1	1		
Femur	1	1				2	1			2	2	*1*	
Patella	1	1								1	1	*1*	
Tibia										6	2	*1*	*1*
Talus	1	1											
Calcaneus						1	1						
Tarsal unit	1	1		*1*		1	1			3	2		
Metacarpus	1	1								1	1		
Metatarsus						1	1			1	1		
Metapodia	3									3			
Phalanx prox.	8	5		*1*	*1*	2	2	*1*	*1*	3	3		
Phalanx med.	11	7		*3*	*4*	6	5			7	5	*1*	*1*
Phalanx dist.	3	3				6	4	*2*	*2*	5	5	*1*	*1*
Phalanx indet.													
Sesamoid	4	2								4	2		
Humerus-Femur													
Radius-Tibia													
Long bone													
Total	**54**	**34**	***1***	***8***	***6***	**26**	**20**	***4***	***3***	**70**	**38**	***7***	***5***

Appendix Table E.10: Quantification of skeletal elements by ages of Spanish ibex: Solutrean and burial Level 504.

Level	127				126			125					124					123			122					121						504			
Capra pyrenaica	**NISP**	**MNE**			**NISP**	**MNE**		**NISP**	**MNE**				**NISP**	**MNE**				**NISP**	**MNE**		**NISP**	**MNE**				**NISP**	**MNE**					**NISP**	**MNE**		
Element	All	All	*I*	*A*	All	All	*A*	All	All	*N*	*J*	*A*	All	All	*N*	*J*	*A*	All	All	*A*	All	All	*F*	*J*	*A*	All	All	*F*	*I*	*J*	*A*	All	All	*J*	*A*
Horn	**2**	**1**						**5**	**1**				**1**																		**5**			
Cranium								**1**	**1**				**1**													**1**	**1**				*1*	**3**	**1**		
Viscerocra./Maxilla																																**3**	**2**		
Upper teeth	**2**	**1**		*1*	**1**	**1**		**5**	**2**		*1*	*1*	**6**	**2**			*2*				**7**	**3**		*1*	*2*	**5**	**2**			*1*	*1*	**22**	**12**		
Mandible								**7**	**3**	*1*		*2*	**3**	**2**							**3**	**2***				**3**	**1**		*1*			**14**	**5**		
Lower teeth	**5**	**2**	*1*	*1*	**3**	**3**	*1*	**11**	**4**		*2*	*2*	**5**	**1**			*1*	**2**	**1**	*1*	**11**	**3**		*1*	*2*	**9**	**3**			*2*	*1*	**50**	**38**	*1*	*7*
Teeth													**1**	**1**							**1**										**7**	**5**		
Hyoid	**1**	**1**																								**1**	**1**				**4**	**4**		
Cervical vert.													**1**	**1**							**2**	**1**									**12**	**2**		
Thoracic vert.								**2**	**2**												**2**	**1**									**4**	**2**		
Rib								**1**	**1**				**2**	**1**				**1**	**1**		**2**	**1**				**2**	**1**					**11**	**6**		
Lumbar vert.								**1**	**1**																	**1**	**1**					**6**	**4**		
Sacral vert.																																**1**	**1**		
Caudal vert.								**1**	**1**																							**3**	**3**		
Indet. vert.								**1**	**1**																							**1**			
Scapula																																**2**	**2**		
Humerus								**1**	**1**				**2**	**1**				**1**	**1**		**6**	**2**				**8**	**3**	*1*				**14**	**4**		
Radius								**3**	**1**				**7**	**2**			*1*				**3**	**2***				**5**	**2**				*2*	**13**	**6**		
Ulna	**2**	**1**						**1**	**1**				**1**	**1**		*1*										**1**	**1**					**7**	**3**		
Ulna-Radius																					**2**	**2**									**5**			
Carpal unit	**2**	**1**						**2**	**2**				**2**	**2**				**1**	**1**		**3**	**3**				**5**	**1**					**19**	**19**		
Pelvis								**1**	**1**												**3**	**1**									**9**	**5**		
Femur								**8**	**2**		*1*	*1*	**4**	**1**							**5**	**2**				**8**	**2**					**6**	**3**		
Patella																																**1**	**1**		
Tibia								**1**	**1**				**1**	**1**							**9**	**4**		*3*	*1*	**6**	**2**					**4**	**2**		
Talus																					**1**	**1**									**2**	**2**		
Calcaneus								**1**	**1**				**1**	**1**							**1**	**1**				**1**	**1**			*1*		**6**	**3**		
Tarsal unit								**1**	**1**				**1**	**1**							**6**	**4**	*2*								**6**	**6**		
Metacarpus								**2**	**1**				**3**	**2**	*1*		*1*	**1**	**1**		**3**	**1**				**3**	**2**		*1*			**11**	**4**		
Metatarsus	**1**	**1**																			**3**	**2**				**2**	**1**					**14**	**6**		
Metapodia								**2**	**2**		*1*	*1*	**2**		*1*						**3**	**1**				**5**		*1*				**19**			
Phalanx prox.	**2**							**19**	**7**		*4*	*3*	**4**	**1**		*1*		**3**	**2**		**12**	**9**				**2**	**2**					**32**	**17**		
Phalanx med.					**1**	**1**		**12**	**10**			*1*	**3**	**2**	*1 inf*	*1*	*1*	**1**	**1**		**7**	**4**		*1*		**3**	**3**		*1*			**30**	**19**		
Phalanx dist.	**5**	**3**	*2*		**3**	**3**		**5**	**5**	*1 fet*		*4*	**6**	**4**		*1*	*1*				**2**	**2**	*1*			**3**	**3**		*1*			**13**	**10**		
Phalanx indet.																																			
Sesamoid	**4**	**1**						**2**	**2**				**1**	**1**				**2**	**2**		**9**	**9**										**27**	**25**		
Humerus-Femur																					**1**	**1**				**2**									
Radius-Tibia																																			
Long bone								**1**					**1**													**1**	**1**								
Total	**26**	**12**	***3***	***2***	**8**	**8**	***1***	**97**	**55**	***1***	***9***	***15***	**59**	**28**	***2***	***4***	***7***	**12**	**10**	***1***	**107**	**58**	***3***	***6***	***5***	**77**	**34**	***2***	***4***	***4***	***5***	**386**	**222**	***1***	***7***

Appendix Table E.11: Quantification of skeletal elements by ages of Spanish ibex in Lower Magdalenian levels.

Level	21			20		19			18			17(12)						17(10)						17(8)						17(6)					16						15				
Capra pyrenaica	**NISP**	**MNE**		**NISP**	**MNE**	**NISP**	**MNE**		**NISP**	**MNE**		**NISP**	**MNE**					**NISP**	**MNE**					**NISP**	**MNE**					**NISP**	**MNE**				**NISP**	**MNE**					**NISP**	**MNE**			
Element	All	All	*A*	All	All	All	All	*A*	All	All	*J* *A*	All	All	*N*	*I*	*J*	*A*	All	All	*F*	*I*	*J*	*A*	All	All	*F*	*I*	*J*	*A*	All	All	*I*	*J*	*A*	All	All	*F*	*I*	*J*	*A*	All	All	*F*	*I*	*J*	*A*
Horn												**14**	**4**			*1*	*3*	**18**	**2**				*2*	**3**						**2**												**2**					
Cranium												**15**	**2**				*1*	**12**	**2**					**11**	**5**				*5*						**2**	**1**					**3**	**1**				
Viscerocra./Maxilla									**1**	**1**		**24**	**3***			*1**	*2**	**22**	**3***				*3**	**4**	**3***				*3**	**1**	**1***			*1**							**2**	**2***			*1**	*1**
Upper teeth	**1**	**1**				**2**	**1**		**5**	**1**	*1*	**72**	**13**			*4*	*8*	**71**	**15**				*11*	**87**	**24**			*6*	*18*	**46**	**9**		*2*	*7*	**58**	**13**			*3*	*10*	**66**	**16**			*1*	*15*
Mandible									**1**	**1**	*1*	**42**	**7***	*1**		*1**	*5**	**39**	**7***	*3**		*2**	*2**	**28**	**9***			*4*	*5**	**2**	**2***			*2**	**7**	**1**				*1*	**7**	**2***				*2**
Lower teeth	**2**	**1**	*1*	**1**	**1**	**3**	**2**	*1*	**3**	**2**	*2*	**54**	**8**			*3*	*4*	**92**	**17**			*5*	*12*	**127**	**27**			*5*	*22*	**82**	**13**		*3*	*10*	**98**	**18**			*4*	*14*	**78**	**12**			*1*	*11*
Teeth												**/**						**7**						**16**						**8**					**12**						**23**					
Hyoid												**5**	**1**					**7**						**7**					*3*	**3**	**3**			*3*	**2**	**1**					**2**	**1**				
Cervical vert.									**1**	**1**		**2**	**1**					**23**	**5**					**10**	**3**				*3*						**2**	**1**					**1**	**1**				
Thoracic vert.												**17**	**5**					**16**	**5**					**4**	**1**										**1**	**1**										
Rib												**19**	**6**					**46**	**6**				*6*	**26**	**9**				*8*	**2**	**1**			*1*	**15**			*1*		*1*	**6**	**2**				*2*
Lumbar vert.						**1**	**1**					**14**	**2**				*1*	**18**	**5**					**7**	**2**					**1**					**2**	**1**										
Sacral vert.												**1**	**1**					**5**	**1**																											
Caudal vert.												**1**	**1**											**1**	**1**										**1**	**1**					**2**	**2**				*2*
Indet. vert.									**1**	**1**		**1**	**1**					**11**	**4**					**1**	**1**										**1**										
Scapula												**48**	**9**			*2*	*7*	**19**	**7**				*6*	**12**	**3**		*1*		*2*	**2**	**1**			*2*	**2**	**2**				*2*	**2**	**2**				*2*
Humerus												**26**	**6**		*3*		*3*	**49**	**15**		*2*		*3*	**34**	**11**				*11*	**7**	**2**			*2*	**13**	**3**				*3*	**11**	**2**				*2*
Radius				**1**	**1**							**23**	**6**			*1*	*5*	**33**	**8**			*2*	*1*	**21**	**4**			*1*	*3*	**5**	**4**	*1*		*4*	**9**	**2**				*2*	**4**	**2**				*2*
Ulna									**2**	**1**		**14**	**5**				*4*	**16**	**6**				*6*	**17**	**5**				*5*	**4**	**2**			*2*	**16**	**6**					**9**	**2**				*2*
Ulna-Radius												**10**	**2**				*2*	**4**						**5**											**3**						**2**					
Carpal unit									**2**	**2**	*2*	**10**	**5**				*5*	**16**	**5**			*1*	*4*	**32**	**7**				*6*	**22**	**9**			*9*	**49**	**16**				*16*	**42**	**13**				*13*
Pelvis									**3**	**2**		**28**	**15**	*1*		*1*	*13*	**22**	**10**				*6*	**22**	**9**				*9*	**4**	**2**			*2*	**6**	**2**				*2*	**4**	**1**				
Femur						**1**	**1**		**3**	**1**		**60**	**15**			*2*	*15*	**62**	**9**				*9*	**46**	**5**			*2*	*3*	**7**	**3**		*1*	*2*	**13**	**2**				*2*	**7**	**2**				*2*
Patella												**1**	**1**					**4**	**4**				*2*																						
Tibia									**1**	**1**	*1*	**47**	**12**			*3*	*9*	**32**	**10**	*1*		*1*	*4*	**35**	**10**			*2*	*8*	**7**	**4**		*1*	*3*	**22**	**7**			*3*	*4*	**10**	**3**				*3*
Talus									**1**	**1**		**5**	**5**			*1*	*4*	**3**	**3**				*3*	**5**	**3**			*2*	*3*	**1**	**1**			*7*	**9**	**7**				*7*	**9**	**6**				*6*
Calcaneus						**1**	**1**					**8**	**6**			*2*	*4*	**9**	**5**			*1*	*4*	**6**	**5**			*2*	*3*	**3**	**1**		*1*		**6**	**3**			*1*	*2*	**7**	**4**				*4*
Tarsal unit									**1**	**1**		**8**	**4**			*3*	*1*	**21**	**9**			*1*	*8*	**23**	**8**				*7*	**14**	**6**		*1*	*5*	**21**	**6**				*6*	**12**	**5**				*5*
Metacarpus									**2**	**2**	*1* *1*	**17**	**7**	*1*		*1*	*5*	**35**	**17**			*2*	*15*	**17**	**8**				*8*	**2**	**2**			*2*	**17**	**9**			*1*	*9*	**15**	**6**	*1*			*5*
Metatarsus									**1**	**1**		**21**	**8**			*1*	*7*	**36**	**16**			*2*	*14*	**29**	**16**				*15*	**7**	**4**		*1*	*3*	**18**	**8**				*8*	**14**	**6**	*2*			*4*
Metapodia												**11**						**28**						**22**						**10**					**14**						**18**	*1*				
Phalanx prox.				**1**	**1**	**1**	**1**					**41**	**27**			*4*	*23*	**60**	**31**	*1*	*5*	*1*	*24*	**77**	**19**	*4*			*16*	**36**	**22**	*4*		*9*	**50**	**33**			*3*	*30*	**43**	**25**			*3*	*14*
Phalanx med.												**30**	**18**			*4*	*14*	**39**	**19**			*3*	*14*	**60**	**21**	*1*	*4*		*16*	**34**	**18**	*4*		*14*	**43**	**21**		*4*		*17*	**40**	**21**			*2*	*15*
Phalanx dist.	**1**	**1**										**17**	**14**	*2*			*12*	**26**	**14**	*1*	*4*		*11*	**23**	**16**				*15*	**11**		*2*		*8*	**27**	**15**					**13**	**11**				*11*
Phalanx indet.																		**1**						**1**																		**1**					
Sesamoid												**26**	**8**					**71**	**71**			*3*	*68*	**114**	**86**					**39**	**29**	*1*		*28*	**84**	**84**	*1*		*1*	*82*	**45**		*1*			
Humerus-Femur												**4**						**8**						**2**						**1**					**3**										
Radius-Tibia																																														
Long bone												**1**						**6**						**3**						**1**					**1**										
Total	**4**	**3**	*1*	**3**	**3**	**9**	**7**	*1*	**28**	**19**	*2* *7*	**737**	**218**	*4*	*11*	*25*	*150*	**987**	**321**	*3*	*14*	*19*	*233*	**938**	**309**	*1* *9*	*24*	*189*		**364**	**136**	*12*	*10*	*114*	**628**	**263**	*2* *4*	*16*	*218*		**500**	**146**	*2* *3*	*7*	*120*	

Appendix Table E.12: Quantification of skeletal elements by ages of chamois.

Level	130					129				128				125				124					122				121				17(10)		
R. rupicapra	NISP	MNE				NISP	MNE			NISP	MNE			NISP	MNE			NISP	MNE				NISP	MNE			NISP	MNE			NISP	MNE	
Element	All	All	*I*	*J*	*A*	All	All	*J*	*A*	All	All	*J*	*A*	All	All	*J*	*A*	All	All	*I*	*J*	*A*	All	All	*I*	*A*	All	All	*I*	*A*	All	All	*A*
Horn										**1**	**1**																					
Cranium																																
Viscerocra./Maxilla	**2**	**1**								**1**	**1**																**2**	**2**	*1*				
Upper teeth	**4**	**3**								**4**	**2**	*1*	*1*	**1**	**1**		*1*	**1**	**1**	*1*							**1**	**1**			*1*	*1*	*1*
Mandible						**1**	**1**	*1*		**2**	**1**																**1**	**1**			*1*	*1*	
Lower teeth	**8**	**2**	*1*			**2**	**1**			**14**	**2**	*1*	*1*					**2**	**2**			*1*	**4**	**1**		*1*	**6**	**3**	*1*	*2*			
Teeth																																
Hyoid										**1**	**1**												**1**	**1**								
Cervical vert.																							**1**	**1**								
Thoracic vert.																																
Rib										**3**	**1**																					
Lumbar vert.						**1**	**1**			**1**	**1**																					
Sacral vert.																																
Caudal vert.																																
Indet. vert.																																
Scapula	**1**	**1**																														
Humerus										**1**	**1**																					
Radius	**1**	**1**		*1*						**2**	**1**							**1**	**1**													
Ulna	**1**	**1**		*1*		**2**	**2**			**2**	**1**																**1**	**1**					
Ulna-Radius						**1**				**1**																						
Carpal unit	**2**	**2**		*1*	*1*									**1**	**1**	*1*		**1**	**1**				**1**	**1**								
Pelvis	**1**	**1**								**1**	**1**																**2**	**1**		*1*			
Femur	**1**	**1**				**2**	**1**			**2**	**2**	*1*																				
Patella	**1**	**1**								**1**	**1**	*1*																				
Tibia										**6**	**2**	*1*	*1*	**1**	**1**		*1*						**2**	**1**		*1*						
Talus	**1**	**1**																														
Calcaneus						**1**	**1**							**2**	**1**																	
Tarsal unit	**1**	**1**		*1*		**1**	**1**			**3**	**2**							**1**	**1**				**3**				**2**	**1**					
Metacarpus	**1**	**1**								**1**	**1**																					
Metatarsus						**1**	**1**			**1**	**1**																					
Metapodia	**3**									**3**																						
Phalanx prox.	**8**	**5**		*1*	*1*	**2**	**2**	*1*	*1*	**3**	**3**							**1**	**1**		*1*		**2**	**2**	*1*		**2**	**2**					
Phalanx med.	**11**	**7**		*3*	*4*	**6**	**5**			**7**	**5**	*1*	*1*					**1**	**1**													
Phalanx dist.	**3**	**3**				**6**	**4**	*2*	*2*	**5**	**5**	*1*	*1*					**2**	**2**				**3**	**3**	*2*		**2**	**2**					
Phalanx indet.																							**1**										
Sesamoid	**4**	**2**								**4**	**2**												**1**				**3**	**3**					
Humerus-Femur																																
Radius-Tibia																																
Long bone																																
Total	54	34	1	8	6	26	20	4	3	70	38	7	5	5	4	1	2	10	10	1	1	1	19	10	3	2	22	17	2	3	2	2	1

Appendix Table E.13: Quantification of all specimens identified anatomically to skeletal elements and only in size classes (combined small, medium to large size classes).

	130	129	128	127	126	125	124	123	122	121	120	21-18	504	17-12	17-10	17-8	17-6	16	15
Element	NISP	NISP	NISP	NISP	NISP	NISP	NISP	NISP	NISP	NISP	NISP	NISP	NISP	NISP	NISP	NISP	NISP	NISP	NISP
Horn													1						
Cranium	3		5	1	1	7	11		5	1		1	12	43	14	27	8	24	15
Viscerocra./Maxilla			1			2							1	5	16	1			2
Upper teeth																		1	
Mandible						1	1		1	2			1	9	15	6	2	7	1
Lower teeth		1								1		1				3		1	
Teeth	1			63	31	66	55	1	84	66		44	2	232	458	804	1245	2041	1600
Hyoid	1			1		1		1						1	1				
Cervical vert.	2		6		1	4	2	1	5	1		1	8	15	5	8	2	3	1
Thoracic vert.	1				1	4	1		7	3			1	11	8			2	1
Rib	3	4	5	33	19	59	49	11	65	132			50	76	31	36	9	31	21
Sternum				3	4	3		1		4			3	5	2		1		
Lumbar vert.	2	1	1			4	5		2	4			13	17	9	10	1	4	5
Sacral vert.	1		1										5	3	4	2	1	1	
Caudal vert.						1	1			1			1	0	4			2	2
Indet. vert.		1	6	17	11	50	58	6	87	121		1	12	46	35	37	6	19	15
Scapula			1			1	1		1				2	11	9			1	1
Humerus	1		1			2	1	1	2	3			5	8	4	5		3	1
Radius			1			1	1		2				2	10	5	1	2	4	3
Ulna	1					2			1					2				1	
Ulna-Radius			1										1	1					
Carpal unit																1			
Pelvis	2					3	1		4	2			4	15	9	4		6	1
Femur	1				1	4	6		3	1			3	10	8	2		3	1
Patella			1				1							1				1	
Tibia	2					5	5		2	2			2	11	9	1	1		11
Talus															1	1			1
Calcaneus	1				1		1		1					1					
Tarsal unit	2		1		2		2		1							1	1	1	
Metacarpus																			
Metatarsus							2			1								1	
Metapodia		1	1		1	1	3		12	6			2	6	2	3		10	4
Phalanx prox.					2	1	2		2	8				1					
Phalanx med.		1	2			1				1			1			1		2	
Phalanx dist.		1	1		1		2									1			1
Phalanx indet.										1					1			2	
Sesamoid	2				1	2	2		5	3					1	1	1	4	2
Humerus-Femur		1		1		2	2		1	4			5	24	18	9	3	13	12
Radius-Tibia										2						9			
Long bone	445	88	516	256	127	389	351	28	2049	776	12	248	47	1120	1871	3730	1983	242	141
Flat bone						2	2		4	1				18	9	63			
Irregular bone						2			4					39	14	18	1		
Spongy bone	1989	815	3205	904	646	3607	2568	286	3300	14784	44	1620		10304	20440	41691	33222	28889	16226
Indeterminate	1	1	3	232	88	1	380	23	482	1223	2	270	20	1575	3255	5813	3594	2374	976
Total	**2461**	**915**	**3759**	**1511**	**938**	**4228**	**3516**	**359**	**6132**	**17154**	**58**	**2186**	**204**	**13620**	**26258**	**52289**	**40083**	**33693**	**19044**

Appendix F Records used for spatial analysis

Spatial analyses are based on spit depths (=Z-spit) by counts and weights of each analytical category. Density Index (DI), Weight Density Index (WDI) and Fragments Size Index (FSI) were calculated as described in methods chapter 3.3.5 Spatial Analysis. Spatial data contribute to profile plot 2 (Appendix Table F.1), 4 (Appendix Table F.2) and 6 (Appendix Table F.3). Spatial data for density calculations are also given specifically for burnt bone (Appendix Table F.4) remains and bone flakes (Appendix Table F.5).

Appendix Table F.1: Counts and Weights for each spit unit and calculations of indices DI, WDI and FSI for the profile plot 2 (Code= Sample-Square-Subsquare)

Level	Code	Z-spit (in cm)	Sum COUNT	Sum WEIGHT (in g)	DI	WDI	FSI
15	2H1B	5	17	5.6	3.4	1.1	0.3
15	2H2B	6	431	112	71.8	18.7	0.3
15	2H2D	9	105	34.2	11.7	3.8	0.3
15	3H1B	3	29	12.1	9.7	4.0	0.4
15	3H2B	2	147	47.6	73.5	23.8	0.3
15	3H2D	1	68	28.2	68.0	28.2	0.4
15	3H3B	2	313	225.9	156.5	113.0	0.7
15	3H3D	6	421	180.9	70.2	30.2	0.4
15	3H4B	3	62	33.6	20.7	11.2	0.5
15	3H4D	3	34	15.7	11.3	5.2	0.5
15	4H1B	2	8	5.9	2.0	3.0	0.7
15	4H2B	3	868	277.1	289.3	92.4	0.3
15	4H2D	2	87	33.2	43.5	16.6	0.4
15	4H3B	5	451	171.8	90.2	34.4	0.4
15	4H3D	6	566	143.9	94.3	24.0	0.3
15	4H4B	9	461	233.3	51.2	25.9	0.5
15	4H4D	8	836	376.4	104.5	47.1	0.5
16	5H1B	8	36	19.1	4.5	2.4	0.5
16	5H2B	5	707	247.6	141.4	49.5	0.4
16	5H2D	8	141	41.9	17.6	5.2	0.3
16	5H3B	6	283	137.9	47.2	23.0	0.5
16	5H3D	3	459	171.7	153.0	57.2	0.4
16	5H4B	7	530	130	75.7	18.6	0.2
16	5H4D	7	556	163.7	79.4	23.4	0.3
17	6H1B	11	172	25	15.6	2.3	0.1
17	6H2B	7	537	99.1	76.7	14.2	0.2
17	6H2D	6	265	65.9	44.2	11.0	0.2
17	6H3B	6	928	317.7	154.7	53.0	0.3
17	6H3D	7	586	189.3	83.7	27.0	0.3
17	6H4B	1	906	47.9	906.0	47.9	0.1
17	6H4D	1	329	70.4	329.0	70.4	0.2
17	7H3B	3	297	43.3	99.0	14.4	0.1
17	7H3D	2	391	195.2	195.5	97.6	0.5
17	8H1B	7	52	4.2	7.4	0.6	0.1
17	8H2B	6	1612	377.6	268.7	62.9	0.2
17	8H2D	5	645	94.4	129.0	18.9	0.1
17	8H3B	4	1159	444.6	289.8	111.2	0.4
17	8H3D	7	1731	575.6	247.3	82.2	0.3
17	8H4B	1	605	90.9	605.0	90.9	0.2
17	8H4D	3	767	125.6	255.7	41.9	0.2

Level	Code	Z-spit (in cm)	Sum COUNT	Sum WEIGHT (in g)	DI	WDI	FSI
17	10H1B	1	10	1.3	10.0	1.3	0.1
17	10H2B	3	131	47.5	43.7	15.8	0.4
17	10H2D	4	199	101.1	49.8	25.3	0.5
17	10H3B	2	894	416.4	447.0	208.2	0.5
17	10H3D	3	810	265	270.0	88.3	0.3
17	10H4B	3	1259	145.6	419.7	48.5	0.1
17	10H4D	2	1130	130.3	565.0	65.2	0.1
17	12H2B	3	349	50	116.3	16.7	0.1
17	12H2D	3	55	8.2	18.3	2.7	0.1
17	12H3B	3	462	99.6	154.0	33.2	0.2
17	12H3D	3	510	97.6	170.0	32.5	0.2
17	12H4B	6	953	228.6	158.8	38.1	0.2
17	12H4D	5	709	158.9	141.8	31.8	0.2

Appendix Table F.2: Counts and Weights for each spit unit and calculations of indices DI, WDI and FSI for the profile plot 4 (Code= Sample-Square-Subsquare)

Level	Code	Z-spit (in cm)	Sum COUNT	Sum WEIGHT (in g)	DI	WDI	FSI
15	1I3B	6	1	0.4	0.2	0.1	0.4
16	2I3B	10	3	2.8	0.3	0.3	0.9
16	2I3D	10	6	5.1	0.6	0.5	0.9
16	3I2B	4	141	33.1	35.3	8.3	0.2
16	3I2D	6	151	40.9	25.2	6.8	0.3
16	3I3B	1	243	58.3	243.0	58.3	0.2
16	3I3D	4	31	87.5	7.8	21.9	2.8
15	3I4B	2	170	34.1	85.0	17.1	0.2
15	3I4D	1	297	64.6	297.0	64.6	0.2
16	4I2B	4	236	60.4	59.0	15.1	0.3
16	4I3B	3	652	165.6	217.3	55.2	0.3
16	4I3D	4	242	81.7	60.5	20.4	0.3
15	4I4B	6	876	129.7	146.0	21.6	0.1
15	4I4D	4	533	94.6	133.3	23.7	0.2
16	5I2B	7	280	56.5	40.0	8.1	0.2
16	5I2D	8	114	32.5	14.3	4.1	0.3
16	5I3B	8	391	113.5	48.9	14.2	0.3
16	5I3D	4	82	21.4	20.5	5.4	0.3
16	5I4B	8	1146	248.5	143.3	31.1	0.2
16	5I4D	8	1246	244.7	155.8	30.6	0.2
17	6I2B	1	60	12.4	60.0	12.4	0.2
17	6I2D	2	12	3.4	6.0	1.7	0.3
17	6I3B	3	167	71.5	55.7	23.8	0.4
17	6I3D	6	80	15.1	13.3	2.5	0.2
17	6I4B	3	1286	119.2	428.7	39.7	0.1
17	6I4D	6	2113	211.1	352.2	35.2	0.1
17	7I2B	3	405	81.5	135.0	27.2	0.2
17	7I2D	7	227	117.6	32.4	16.8	0.5
17	8I2B	5	215	107.1	43.0	21.4	0.5
17	8I2D	1	365	107.8	365.0	107.8	0.3
17	8I3B	4	951	267.2	237.8	66.8	0.3
17	8I3D	5	1562	548.1	312.4	109.6	0.4
17	8I4B	7	3092	349.4	441.7	49.9	0.1
17	8I4D	4	2367	291.1	591.8	72.8	0.1

Level	Code	Z-spit (in cm)	Sum COUNT	Sum WEIGHT (in g)	DI	WDI	FSI
17	101I4B	4	518	149.5	129.5	37.4	0.3
17	101I4D	4	430	84	107.5	21.0	0.2
17	10I2B	3	517	215.7	172.3	71.9	0.4
17	10I2D	2	269	67.1	134.5	33.6	0.2
17	10I3B	2	505	98.5	252.5	49.3	0.2
17	10I3D	1	673	134.7	673.0	134.7	0.2
17	10I4B	3	428	211.3	142.7	70.4	0.5
17	10I4D	3	1078	325.4	359.3	108.5	0.3
17	121I3B	4	207	77	51.8	19.3	0.4
17	12I3B	1	473	167	473.0	167.0	0.4
17	12I3D	1	131	47.6	131.0	47.6	0.4
17	12I4B	1	879	198.6	879.0	198.6	0.2
17	12I4D	1	558	173.4	558.0	173.4	0.3

Appendix Table F.3: Counts and Weights for each spit unit and calculations of indices DI, WDI and FSI for the profile plot 6 (Code= Sample-Square-Subsquare)

Level	Code	Z-spit (in cm)	Sum COUNT	Sum WEIGHT	DI	WDI	FSI
15	1J2B	14	58	24.1	4.1	1.7	0.4
15	1J2D	12	28	17.1	2.3	1.4	0.6
15	2J2B	8	47	11.9	5.9	1.5	0.3
15	2J2D	7	39	16.6	5.6	2.4	0.4
15	2J3B	5	152	63.7	30.4	12.7	0.4
15	2J3D	14	124	70.5	8.9	5.0	0.6
15	2J4B	2	15	2.9	7.5	1.5	0.2
15	2J4D	3	98	22.8	32.7	7.6	0.2
16	3J3B	6	632	120.3	105.3	20.1	0.2
16	3J3D	4	5	8.6	1.3	2.2	1.7
15	3J4B	3	789	60.2	263.0	20.1	0.1
15	3J4D	4	648	38.7	162.0	9.7	0.1
16	4J2B	7	56	45.7	8.0	6.5	0.8
16	4J2D	10	62	20.6	6.2	2.1	0.3
16	4J3B	6	1025	228.2	170.8	38.0	0.2
16	4J3D	6	453	129.2	75.5	21.5	0.3
16	4J4B	4	2298	160.6	574.5	40.2	0.1
16	4J4D	4	892	140.5	223.0	35.1	0.2
16	5J2B	3	4	2.5	1.3	0.8	0.6
16	5J2D	2	101	31.3	50.5	15.7	0.3
16	5J3B	2	502	157.1	251.0	78.6	0.3
16	5J3D	2	438	155.5	219.0	77.8	0.4
16	5J4B	2	532	50.4	266.0	25.2	0.1
16	5J4D	1	853	55.1	853.0	55.1	0.1
17	6J2B	4	486	148.8	121.5	37.2	0.3
17	6J2D	2	27	12.8	13.5	6.4	0.5
17	6J3B	7	604	138.4	86.3	19.8	0.2
17	6J3D	6	5	3.4	0.8	0.6	0.7
17	6J4B	16	5495	547.9	343.4	34.2	0.1
17	6J4D	13	3064	344.6	235.7	26.5	0.1
17	8J2B	3	750	265.1	250.0	88.4	0.4
17	8J2D	7	153	34.1	21.9	4.9	0.2
17	8J3B	6	1252	377	208.7	62.8	0.3
17	8J3D	5	1104	351.6	220.8	70.3	0.3

Level	Code	Z-spit (in cm)	Sum COUNT	Sum WEIGHT	DI	WDI	FSI
17	8J4B	2	2848	236.1	1424.0	118.1	0.1
17	8J4D	3	3144	189.7	1048.0	63.2	0.1
17	9J4B	1	162	57.6	162.0	57.6	0.4
17	9J4D	1	556	192.6	556.0	192.6	0.3
17	101J2B	3	265	66.7	88.3	22.2	0.3
17	101J3D	1	85	23.4	85.0	23.4	0.3
17	10J2B	8	119	57.5	14.9	7.2	0.5
17	10J2D	4	8	4.4	2.0	1.1	0.6
17	10J3B	2	1113	240.6	556.5	120.3	0.2
17	10J3D	2	217	42.1	108.5	21.1	0.2
17	10J4B	2	142	61.6	71.0	30.8	0.4
17	10J4D	2	995	142.4	497.5	71.2	0.1
17	11J3B	4	353	137.6	88.3	34.4	0.4
17	121J4B	3	108	99.4	36.0	33.1	0.9
17	121J4D	4	125	71.8	31.3	18.0	0.6
17	12J3B	2	151	147.9	75.5	74.0	1.0
17	12J4B	1	153	66.2	153.0	66.2	0.4
17	12J4D	2	205	72	102.5	36.0	0.4

Appendix Table F.4: Counts and Weights for each spit unit and calculations of indices DI, WDI and FSI for the taphonomic category of burnt bones. (Code= Sample-Square-Subsquare)

Level	Code	Z-spit (in cm)	Sum COUNT	Sum WEIGHT	DI	WDI	FSI
15	1J2A	10	1	0.1	0.10	0.01	0.10
15	1J2B	14	13	4.3	0.93	0.31	0.33
15	1J2D	12	5	1.2	0.42	0.10	0.24
15	2H1A	6	2	0.5	0.33	0.08	0.25
15	2H2A	7	5	0.5	0.71	0.07	0.10
15	2H2B	6	10	1.3	1.67	0.22	0.13
15	2H2D	9	20	1	2.22	0.11	0.05
15	2J2A	10	2	0.5	0.20	0.05	0.25
15	2J2B	8	3	1.6	0.38	0.20	0.53
15	2J2C	9	4	1.2	0.44	0.13	0.30
15	2J2D	7	3	2.5	0.43	0.36	0.83
15	2J3A	6	2	0.8	0.33	0.13	0.40
15	2J3B	5	10	3.1	2.00	0.62	0.31
15	2J3C	16	2	2.1	0.13	0.13	1.05
15	2J3D	14	1	1.1	0.07	0.08	1.10
15	2J4A	1	20	1	20.00	1.00	0.05
15	2J4B	2	1	0.2	0.50	0.10	0.20
15	2J4C	2	5	0.3	2.50	0.15	0.06
15	2J4D	3	9	1.5	3.00	0.50	0.17
15	3H2C	4	1	0.1	0.25	0.03	0.10
15	3H2D	1	1	0.1	1.00	0.10	0.10
15	3H3B	2	5	1.3	2.50	0.65	0.26
15	3H3C	7	3	1.1	0.43	0.16	0.37
15	3H3D	6	7	1.4	1.17	0.23	0.20
15	3H4A	2	2	0.1	1.00	0.05	0.05
16	3I2A	5	3	2	0.60	0.40	0.67
16	3I2B	4	1	0.5	0.25	0.13	0.50
16	3I2C	7	7	1.2	1.00	0.17	0.17
16	3I2D	6	4	0.4	0.67	0.07	0.10

Level	Code	Z-spit (in cm)	Sum COUNT	Sum WEIGHT	DI	WDI	FSI
16	3I3A	4	11	2.6	2.75	0.65	0.24
16	3I3B	1	9	1.8	9.00	1.80	0.20
16	3I3C	5	1	0.1	0.20	0.02	0.10
16	3I3D	4	16	2.8	4.00	0.70	0.18
15	3I4A	3	8	1.4	2.67	0.47	0.18
15	3I4B	2	2	0.2	1.00	0.10	0.10
15	3I4C	4	3	1.3	0.75	0.33	0.43
15	3I4D	1	9	1.6	9.00	1.60	0.18
16	3J3A	9	6	0.9	0.67	0.10	0.15
16	3J3B	6	33	7.5	5.50	1.25	0.23
16	3J3C	4	15	0.7	3.75	0.18	0.05
15	3J4A	9	20	2.5	2.22	0.28	0.13
15	3J4B	3	79	9.2	26.33	3.07	0.12
15	3J4C	5	5	0.5	1.00	0.10	0.10
15	3J4D	4	142	6.6	35.50	1.65	0.05
15	4H1A	4	1	0.8	0.25	0.20	0.80
15	4H1B	2	1	0.1	0.50	0.05	0.10
15	4H2A	3	2	0.4	0.67	0.13	0.20
15	4H2B	3	9	1.8	3.00	0.60	0.20
15	4H2D	2	1	0.2	0.50	0.10	0.20
15	4H3A	5	5	1.8	1.00	0.36	0.36
15	4H3B	5	2	0.5	0.40	0.10	0.25
15	4H3D	6	2	0.4	0.33	0.07	0.20
15	4H4A	7	5	0.7	0.71	0.10	0.14
15	4H4B	9	15	3.4	1.67	0.38	0.23
15	4H4C	4	6	0.9	1.50	0.23	0.15
15	4H4D	8	23	4.2	2.88	0.53	0.18
16	4I2A	5	7	0.9	1.40	0.18	0.13
16	4I2B	4	5	1.2	1.25	0.30	0.24
16	4I3A	2	11	1.6	5.50	0.80	0.15
16	4I3B	3	16	5.5	5.33	1.83	0.34
16	4I3C	4	13	3.8	3.25	0.95	0.29
16	4I3D	4	10	2.6	2.50	0.65	0.26
15	4I4A	7	13	2.8	1.86	0.40	0.22
15	4I4B	6	102	12.9	17.00	2.15	0.13
15	4I4C	4	51	9.1	12.75	2.28	0.18
15	4I4D	4	9	2	2.25	0.50	0.22
16	4J2A	12	5	1.2	0.42	0.10	0.24
16	4J2B	7	2	0.8	0.29	0.11	0.40
16	4J2C	13	12	2.8	0.92	0.22	0.23
16	4J2D	10	12	1	1.20	0.10	0.08
16	4J3A	3	47	5.9	15.67	1.97	0.13
16	4J3B	6	132	22.5	22.00	3.75	0.17
16	4J3C	9	4	2	0.44	0.22	0.50
16	4J3D	6	66	10	11.00	1.67	0.15
16	4J4A	3	19	5.1	6.33	1.70	0.27
16	4J4B	4	69	10	17.25	2.50	0.14
16	4J4C	7	165	17.5	23.57	2.50	0.11
16	4J4D	4	196	24.2	49.00	6.05	0.12
16	5H1A	5	2	0.7	0.40	0.14	0.35
16	5H2B	5	8	1	1.60	0.20	0.13
16	5H2C	8	3	0.5	0.38	0.06	0.17

Level	Code	Z-spit (in cm)	Sum COUNT	Sum WEIGHT	DI	WDI	FSI
16	5H3A	6	3	0.1	0.50	0.02	0.03
16	5H3B	6	4	0.9	0.67	0.15	0.23
16	5H3C	5	10	3.3	2.00	0.66	0.33
16	5H3D	3	3	1.4	1.00	0.47	0.47
16	5H4A	7	19	3.3	2.71	0.47	0.17
16	5H4B	7	5	1.6	0.71	0.23	0.32
16	5H4C	6	12	1.8	2.00	0.30	0.15
16	5H4D	7	12	1.5	1.71	0.21	0.13
16	5I2A	6	9	1.2	1.50	0.20	0.13
16	5I2B	7	7	1	1.00	0.14	0.14
16	5I2C	7	4	2.3	0.57	0.33	0.58
16	5I2D	8	9	1.8	1.13	0.23	0.20
16	5I3A	7	10	2	1.43	0.29	0.20
16	5I3B	8	5	0.9	0.63	0.11	0.18
16	5I3C	2	2	4.2	1.00	2.10	2.10
16	5I3D	4	7	1.2	1.75	0.30	0.17
16	5I4A	8	6	4.2	0.75	0.53	0.70
16	5I4B	8	96	12.4	12.00	1.55	0.13
16	5I4C	8	42	5.9	5.25	0.74	0.14
16	5I4D	8	31	6.2	3.88	0.78	0.20
16	5J2A	2	22	4.5	11.00	2.25	0.20
16	5J2D	2	11	3.5	5.50	1.75	0.32
16	5J3A	4	19	3.3	4.75	0.83	0.17
16	5J3B	2	41	11	20.50	5.50	0.27
16	5J3C	2	12	2.3	6.00	1.15	0.19
16	5J3D	2	34	11.3	17.00	5.65	0.33
16	5J4A	1	43	3.6	43.00	3.60	0.08
16	5J4B	2	20	3.2	10.00	1.60	0.16
16	5J4C	1	1	0.3	1.00	0.30	0.30
16	5J4D	1	155	6.5	155.00	6.50	0.04
17	6H1A	9	4	0.3	0.44	0.03	0.08
17	6H1B	11	15	2.9	1.36	0.26	0.19
17	6H2A	7	11	0.8	1.57	0.11	0.07
17	6H2B	7	14	1.4	2.00	0.20	0.10
17	6H2C	6	14	1.1	2.33	0.18	0.08
17	6H2D	6	18	2.5	3.00	0.42	0.14
17	6H3A	4	8	0.6	2.00	0.15	0.08
17	6H3B	6	12	1.3	2.00	0.22	0.11
17	6H3C	6	5	0.9	0.83	0.15	0.18
17	6H3D	7	6	1	0.86	0.14	0.17
17	6H4A	1	32	2.2	32.00	2.20	0.07
17	6H4B	1	87	2.9	87.00	2.90	0.03
17	6H4C	1	40	1.8	40.00	1.80	0.05
17	6H4D	1	7	2.8	7.00	2.80	0.40
17	6I2B	1	27	4.8	27.00	4.80	0.18
17	6I2C	2	8	1.2	4.00	0.60	0.15
17	6I2D	2	3	0.5	1.50	0.25	0.17
17	6I3A	7	5	1.6	0.71	0.23	0.32
17	6I3B	3	2	0.6	0.67	0.20	0.30
17	6I3C	4	9	2.1	2.25	0.53	0.23
17	6I3D	6	15	1.5	2.50	0.25	0.10
17	6I4A	3	83	3.8	27.67	1.27	0.05

Level	Code	Z-spit (in cm)	Sum COUNT	Sum WEIGHT	DI	WDI	FSI
17	6I4B	3	150	5.7	50.00	1.90	0.04
17	6I4C	7	14	2.8	2.00	0.40	0.20
17	6I4D	6	165	9.3	27.50	1.55	0.06
17	6J2A	3	7	0.9	2.33	0.30	0.13
17	6J2B	4	122	26	30.50	6.50	0.21
17	6J2C	1	1	0.4	1.00	0.40	0.40
17	6J2D	4	4	1.1	1.00	0.28	0.28
17	6J3A	5	32	4.7	6.40	0.94	0.15
17	6J3B	7	59	10.7	8.43	1.53	0.18
17	6J3C	4	21	7	5.25	1.75	0.33
17	6J4A	13	458	34.8	35.23	2.68	0.08
17	6J4B	16	735	73.6	45.94	4.60	0.10
17	6J4C	12	559	41.7	46.58	3.48	0.07
17	6J4D	13	124	14.8	9.54	1.14	0.12
17	7H3B	3	13	2.2	4.33	0.73	0.17
17	7H3C	2	11	1	5.50	0.50	0.09
17	7H3D	2	10	0.9	5.00	0.45	0.09
17	7I2A	4	51	14.7	12.75	3.68	0.29
17	7I2B	3	105	16.1	35.00	5.37	0.15
17	7I2C	5	14	3.1	2.80	0.62	0.22
17	7I2D	7	29	8.1	4.14	1.16	0.28
17	8H1A	1	6	0.2	6.00	0.20	0.03
17	8H1B	7	1	0.1	0.14	0.01	0.10
17	8H2A	5	61	5.8	12.20	1.16	0.10
17	8H2B	6	70	7.1	11.67	1.18	0.10
17	8H2C	6	39	5.6	6.50	0.93	0.14
17	8H2D	5	33	4.5	6.60	0.90	0.14
17	8H3A	7	55	8.6	7.86	1.23	0.16
17	8H3B	4	15	2.8	3.75	0.70	0.19
17	8H3C	6	43	8.2	7.17	1.37	0.19
17	8H3D	7	43	5.5	6.14	0.79	0.13
17	8H4B	1	14	0.7	14.00	0.70	0.05
17	8H4C	1	8	0.5	8.00	0.50	0.06
17	8H4D	3	32	2.4	10.67	0.80	0.08
17	8I2A	4	33	6.5	8.25	1.63	0.20
17	8I2B	5	21	10.7	4.20	2.14	0.51
17	8I2C	5	27	8.3	5.40	1.66	0.31
17	8I2D	1	35	9.7	35.00	9.70	0.28
17	8I3A	6	64	11.3	10.67	1.88	0.18
17	8I3B	4	112	24.4	28.00	6.10	0.22
17	8I3C	7	113	23.4	16.14	3.34	0.21
17	8I3D	5	270	42.6	54.00	8.52	0.16
17	8I4A	7	168	10.5	24.00	1.50	0.06
17	8I4B	7	192	14.8	27.43	2.11	0.08
17	8I4C	6	39	4.6	6.50	0.77	0.12
17	8I4D	6	128	11.1	21.33	1.85	0.09
17	8J2A	3	39	13.6	13.00	4.53	0.35
17	8J2B	3	81	35	27.00	11.67	0.43
17	8J2C	5	8	2.3	1.60	0.46	0.29
17	8J2D	7	12	4.8	1.71	0.69	0.40
17	8J3A	5	107	19.5	21.40	3.90	0.18
17	8J3B	6	149	44	24.83	7.33	0.30

Level	Code	Z-spit (in cm)	Sum COUNT	Sum WEIGHT	DI	WDI	FSI
17	8J3C	4	233	36.2	58.25	9.05	0.16
17	8J3D	5	270	55.7	54.00	11.14	0.21
17	8J4A	5	225	22.8	45.00	4.56	0.10
17	8J4B	2	1198	96	599.00	48.00	0.08
17	8J4C	6	859	50	143.17	8.33	0.06
17	8J4D	3	634	48	211.33	16.00	0.08
17	9J4A	3	131	31.3	43.67	10.43	0.24
17	9J4B	1	26	9.6	26.00	9.60	0.37
17	9J4C	2	97	25.7	48.50	12.85	0.26
17	9J4D	2	39	18.3	19.50	9.15	0.47
17	101J2A	4	24	5.2	6.00	1.30	0.22
17	101J2B	3	23	9.3	7.67	3.10	0.40
17	10H1A	1	7	3.3	7.00	3.30	0.47
17	10H2A	4	28	7.9	7.00	1.98	0.28
17	10H2B	3	4	0.8	1.33	0.27	0.20
17	10H2C	4	11	2.4	2.75	0.60	0.22
17	10H2D	4	27	13.4	6.75	3.35	0.50
17	10H3A	3	74	18	24.67	6.00	0.24
17	10H3B	2	69	21.4	34.50	10.70	0.31
17	10H3C	6	62	8.8	10.33	1.47	0.14
17	10H3D	3	75	22.7	25.00	7.57	0.30
17	10H4A	1	28	4.5	28.00	4.50	0.16
17	10H4B	3	69	10.9	23.00	3.63	0.16
17	10H4C	2	119	18	59.50	9.00	0.15
17	10H4D	2	62	12.6	31.00	6.30	0.20
17	10I2A	5	46	11.9	9.20	2.38	0.26
17	10I2B	3	53	19.5	17.67	6.50	0.37
17	10I2C	2	27	5.7	13.50	2.85	0.21
17	10I2D	2	15	2.9	7.50	1.45	0.19
17	10I3A	1	61	9.6	61.00	9.60	0.16
17	10I3B	2	80	12.1	40.00	6.05	0.15
17	10I3C	1	72	18.6	72.00	18.60	0.26
17	10I3D	1	72	20	72.00	20.00	0.28
17	10I4A	8	113	22.3	14.13	2.79	0.20
17	10I4B	7	68	18.7	9.71	2.67	0.28
17	10I4C	6	128	26	21.33	4.33	0.20
17	10I4D	7	231	36.9	33.00	5.27	0.16
17	10J2A	2	79	17	39.50	8.50	0.22
17	10J2B	8	5	1.2	0.63	0.15	0.24
17	10J2C	2	6	2.2	3.00	1.10	0.37
17	10J2D	4	1	1.3	0.25	0.33	1.30
17	10J3A	3	104	35.4	34.67	11.80	0.34
17	10J3B	2	158	39.3	79.00	19.65	0.25
17	10J3C	2	116	36.5	58.00	18.25	0.31
17	10J3D	3	53	6.8	17.67	2.27	0.13
17	10J4A	1	185	31	185.00	31.00	0.17
17	10J4B	2	14	11.5	7.00	5.75	0.82
17	10J4C	1	75	17.1	75.00	17.10	0.23
17	10J4D	2	188	50.7	94.00	25.35	0.27
17	11J3A	3	75	30.7	25.00	10.23	0.41
17	11J3B	4	85	24.9	21.25	6.23	0.29
17	121I3A	3	43	8.1	14.33	2.70	0.19

Level	Code	Z-spit (in cm)	Sum COUNT	Sum WEIGHT	DI	WDI	FSI
17	121I3B	4	77	26.1	19.25	6.53	0.34
17	12H2A	2	6	1.5	3.00	0.75	0.25
17	12H2B	3	13	3.4	4.33	1.13	0.26
17	12H2C	2	1	0.4	0.50	0.20	0.40
17	12H2D	3	2	0.2	0.67	0.07	0.10
17	12H3A	3	24	10.5	8.00	3.50	0.44
17	12H3B	3	84	23.9	28.00	7.97	0.28
17	12H3C	3	42	8.3	14.00	2.77	0.20
17	12H3D	3	97	24	32.33	8.00	0.25
17	12H4A	5	54	17.3	10.80	3.46	0.32
17	12H4B	6	50	16	8.33	2.67	0.32
17	12H4C	5	72	14.1	14.40	2.82	0.20
17	12H4D	5	53	13.6	10.60	2.72	0.26
17	12I3A	1	63	11	63.00	11.00	0.17
17	12I3B	1	132	29.6	132.00	29.60	0.22
17	12I3C	1	27	8	27.00	8.00	0.30
17	12I3D	1	31	16.4	31.00	16.40	0.53
17	12I4A	1	10	3.6	10.00	3.60	0.36
17	12I4B	1	31	4.1	31.00	4.10	0.13
17	12I4C	1	5	2.1	5.00	2.10	0.42
17	12I4D	1	22	4.4	22.00	4.40	0.20
17	12J3A	2	60	27.2	30.00	13.60	0.45
17	12J3B	2	15	8.3	7.50	4.15	0.55
17	12J4A	5	20	11.3	4.00	2.26	0.57
17	12J4B	4	15	7.3	3.75	1.83	0.49
17	12J4C	5	32	20.3	6.40	4.06	0.63
17	12J4D	6	19	9.6	3.17	1.60	0.51

Appendix Table F.5: Counts and Weights for each spit unit and calculations of indices DI, WDI and FSI for the taphonomic category of bone flakes. (Code= Sample-Square-Subsquare)

Level	Code	Z-spit (in cm)	Sum COUNT	Sum WEIGHT	DI	WDI	FSI
15	1I3A	3	1	0.3	0.33	0.10	0.30
15	1I3C	10	1	0.5	0.10	0.05	0.50
15	1J2A	10	3	2.5	0.30	0.25	0.83
15	1J2B	14	7	4.6	0.50	0.33	0.66
15	1J2C	10	3	3.6	0.30	0.36	1.20
15	1J2D	12	4	2.3	0.33	0.19	0.58
15	2H2B	6	3	1.7	0.50	0.28	0.57
15	2H2C	7	3	3.1	0.43	0.44	1.03
15	2J2A	10	3	1.9	0.30	0.19	0.63
15	2J2B	8	4	1.2	0.50	0.15	0.30
15	2J2D	7	16	8.1	2.29	1.16	0.51
15	2J3A	6	4	2.8	0.67	0.47	0.70
15	2J3B	5	15	11.1	3.00	2.22	0.74
15	2J3C	16	9	7.7	0.56	0.48	0.86
15	2J3D	14	4	5.4	0.29	0.39	1.35
15	2J4A	1	1	0.2	1.00	0.20	0.20
15	2J4D	3	2	0.4	0.67	0.13	0.20
15	3H2A	2	4	4.3	2.00	2.15	1.08
15	3H2B	2	1	0.2	0.50	0.10	0.20
15	3H2D	1	2	1.3	2.00	1.30	0.65

Level	Code	Z-spit (in cm)	Sum COUNT	Sum WEIGHT	DI	WDI	FSI
15	3H3B	2	1	0.3	0.50	0.15	0.30
15	3H3C	7	1	2.5	0.14	0.36	2.50
16	3I2B	4	1	1.4	0.25	0.35	1.40
16	3I2D	6	4	1.7	0.67	0.28	0.43
16	3I3A	4	6	4.2	1.50	1.05	0.70
16	3I3B	1	7	4.3	7.00	4.30	0.61
16	3I3D	4	12	7.3	3.00	1.83	0.61
15	3I4B	2	1	0.8	0.50	0.40	0.80
15	3I4C	4	1	1.4	0.25	0.35	1.40
16	3J3A	9	12	9.8	1.33	1.09	0.82
16	3J3B	6	15	16.2	2.50	2.70	1.08
16	3J3C	4	12	9.5	3.00	2.38	0.79
15	3J4A	9	7	1.6	0.78	0.18	0.23
15	3J4B	3	2	0.3	0.67	0.10	0.15
15	3J4C	5	4	0.3	0.80	0.06	0.08
15	4H2A	3	3	0.8	1.00	0.27	0.27
15	4H2B	3	2	2.8	0.67	0.93	1.40
15	4H2C	3	1	0.8	0.33	0.27	0.80
15	4H2D	2	2	0.4	1.00	0.20	0.20
15	4H3A	5	1	0.4	0.20	0.08	0.40
15	4H3B	5	9	3.5	1.80	0.70	0.39
15	4H3D	6	3	1.1	0.50	0.18	0.37
15	4H4A	7	2	2.3	0.29	0.33	1.15
15	4H4B	9	2	4.5	0.22	0.50	2.25
15	4H4C	4	3	5.5	0.75	1.38	1.83
15	4H4D	8	5	3.9	0.63	0.49	0.78
16	4I2A	5	3	2.8	0.60	0.56	0.93
16	4I2B	4	3	2.2	0.75	0.55	0.73
16	4I2C	2	3	1.8	1.50	0.90	0.60
16	4I3A	2	10	4.5	5.00	2.25	0.45
16	4I3B	3	13	10.4	4.33	3.47	0.80
16	4I3C	4	11	8.8	2.75	2.20	0.80
16	4I3D	4	12	7.7	3.00	1.93	0.64
15	4I4A	7	3	0.9	0.43	0.13	0.30
15	4I4B	6	1	1.1	0.17	0.18	1.10
15	4I4C	4	6	2.1	1.50	0.53	0.35
16	4J2A	12	4	3.8	0.33	0.32	0.95
16	4J2B	7	3	2.3	0.43	0.33	0.77
16	4J2C	13	8	8.5	0.62	0.65	1.06
16	4J2D	10	2	2.3	0.20	0.23	1.15
16	4J3A	3	9	4.8	3.00	1.60	0.53
16	4J3B	6	20	16.9	3.33	2.82	0.85
16	4J3C	9	5	2.8	0.56	0.31	0.56
16	4J3D	6	15	7.7	2.50	1.28	0.51
16	4J4A	3	6	2.8	2.00	0.93	0.47
16	4J4B	4	7	7.8	1.75	1.95	1.11
16	4J4C	7	2	0.5	0.29	0.07	0.25
16	4J4D	4	11	5.7	2.75	1.43	0.52
16	5H2A	7	1	2.1	0.14	0.30	2.10
16	5H2B	5	6	4.6	1.20	0.92	0.77
16	5H2C	8	6	10.7	0.75	1.34	1.78
16	5H2D	8	1	1.5	0.13	0.19	1.50

Level	Code	Z-spit (in cm)	Sum COUNT	Sum WEIGHT	DI	WDI	FSI
16	5H3A	6	9	18.2	1.50	3.03	2.02
16	5H3B	6	3	2.9	0.50	0.48	0.97
16	5H3C	5	33	42.9	6.60	8.58	1.30
16	5H3D	3	7	5.9	2.33	1.97	0.84
16	5H4A	7	29	21.8	4.14	3.11	0.75
16	5H4B	7	14	9.3	2.00	1.33	0.66
16	5H4C	6	18	11.4	3.00	1.90	0.63
16	5H4D	7	16	16.2	2.29	2.31	1.01
16	5I2A	6	9	3.1	1.50	0.52	0.34
16	5I2B	7	12	11.5	1.71	1.64	0.96
16	5I2C	7	3	1.7	0.43	0.24	0.57
16	5I2D	8	2	1.4	0.25	0.18	0.70
16	5I3A	7	8	4.1	1.14	0.59	0.51
16	5I3B	8	6	3	0.75	0.38	0.50
16	5I3C	2	7	2.6	3.50	1.30	0.37
16	5I3D	4	2	3.2	0.50	0.80	1.60
16	5I4A	8	10	9	1.25	1.13	0.90
16	5I4B	8	14	7.2	1.75	0.90	0.51
16	5I4C	8	9	9.2	1.13	1.15	1.02
16	5I4D	8	15	6.6	1.88	0.83	0.44
16	5J2A	2	3	3.1	1.50	1.55	1.03
16	5J2D	2	16	16.3	8.00	8.15	1.02
16	5J3A	4	3	0.8	0.75	0.20	0.27
16	5J3B	2	8	3.9	4.00	1.95	0.49
16	5J3C	2	3	2.1	1.50	1.05	0.70
16	5J3D	2	12	8.2	6.00	4.10	0.68
17	6H1A	9	2	1.3	0.22	0.14	0.65
17	6H1B	11	6	2.7	0.55	0.25	0.45
17	6H2A	7	10	3.4	1.43	0.49	0.34
17	6H2B	7	14	8.8	2.00	1.26	0.63
17	6H2C	6	15	6	2.50	1.00	0.40
17	6H2D	6	10	5.2	1.67	0.87	0.52
17	6H3A	4	2	0.7	0.50	0.18	0.35
17	6H3B	6	6	2.6	1.00	0.43	0.43
17	6H3C	6	3	5.3	0.50	0.88	1.77
17	6H3D	7	3	1.8	0.43	0.26	0.60
17	6H4A	1	7	2.9	7.00	2.90	0.41
17	6H4B	1	6	2.2	6.00	2.20	0.37
17	6H4C	1	8	2.7	8.00	2.70	0.34
17	6I2A	1	1	3.5	1.00	3.50	3.50
17	6I2B	1	3	1.7	3.00	1.70	0.57
17	6I2D	2	1	0.3	0.50	0.15	0.30
17	6I3A	7	3	0.9	0.43	0.13	0.30
17	6I3B	3	4	1.2	1.33	0.40	0.30
17	6I3C	4	3	1.7	0.75	0.43	0.57
17	6I4A	3	8	2.8	2.67	0.93	0.35
17	6I4B	3	3	0.5	1.00	0.17	0.17
17	6I4C	7	11	4.6	1.57	0.66	0.42
17	6I4D	6	13	6.8	2.17	1.13	0.52
17	6J2A	3	11	10	3.67	3.33	0.91
17	6J2B	4	9	10.3	2.25	2.58	1.14
17	6J2D	4	3	1.5	0.75	0.38	0.50

Level	Code	Z-spit (in cm)	Sum COUNT	Sum WEIGHT	DI	WDI	FSI
17	6J3A	5	4	3	0.80	0.60	0.75
17	6J3B	7	15	12.6	2.14	1.80	0.84
17	6J3C	4	5	2.5	1.25	0.63	0.50
17	6J4A	13	45	10	3.46	0.77	0.22
17	6J4B	16	100	27.5	6.25	1.72	0.28
17	6J4C	12	51	15.4	4.25	1.28	0.30
17	6J4D	13	69	29.4	5.31	2.26	0.43
17	7H3A	2	2	1.6	1.00	0.80	0.80
17	7H3C	2	8	3.3	4.00	1.65	0.41
17	7H3D	2	6	9.3	3.00	4.65	1.55
17	7I2A	4	15	28.3	3.75	7.08	1.89
17	7I2B	3	3	3.2	1.00	1.07	1.07
17	7I2C	5	11	5.2	2.20	1.04	0.47
17	7I2D	7	9	2	1.29	0.29	0.22
17	8H2A	5	25	10.4	5.00	2.08	0.42
17	8H2B	6	17	7.7	2.83	1.28	0.45
17	8H2C	6	6	2.9	1.00	0.48	0.48
17	8H2D	5	9	5.1	1.80	1.02	0.57
17	8H3A	7	30	13.1	4.29	1.87	0.44
17	8H3B	4	37	31.9	9.25	7.98	0.86
17	8H3C	6	36	21.1	6.00	3.52	0.59
17	8H3D	7	40	30.5	5.71	4.36	0.76
17	8H4A	3	4	1.5	1.33	0.50	0.38
17	8H4B	1	12	3.5	12.00	3.50	0.29
17	8H4C	1	8	1.8	8.00	1.80	0.23
17	8H4D	3	7	1.9	2.33	0.63	0.27
17	8I2A	4	15	27.1	3.75	6.78	1.81
17	8I2B	5	10	10.6	2.00	2.12	1.06
17	8I2C	5	11	9	2.20	1.80	0.82
17	8I2D	1	11	8.2	11.00	8.20	0.75
17	8I3A	6	34	18.9	5.67	3.15	0.56
17	8I3B	4	35	17.7	8.75	4.43	0.51
17	8I3C	7	43	44.7	6.14	6.39	1.04
17	8I3D	5	39	24.2	7.80	4.84	0.62
17	8I4A	7	38	24	5.43	3.43	0.63
17	8I4B	7	26	9.1	3.71	1.30	0.35
17	8I4C	6	30	31.1	5.00	5.18	1.04
17	8I4D	6	34	12	5.67	2.00	0.35
17	8J2A	3	12	5	4.00	1.67	0.42
17	8J2B	3	19	18.1	6.33	6.03	0.95
17	8J2C	5	1	1	0.20	0.20	1.00
17	8J2D	7	3	4.2	0.43	0.60	1.40
17	8J3A	5	42	38.5	8.40	7.70	0.92
17	8J3B	6	52	28.8	8.67	4.80	0.55
17	8J3C	4	31	35.8	7.75	8.95	1.15
17	8J3D	5	36	26.2	7.20	5.24	0.73
17	8J4A	5	15	4.3	3.00	0.86	0.29
17	8J4B	1	32	16.6	32.00	16.60	0.52
17	8J4C	6	48	19.5	8.00	3.25	0.41
17	8J4D	2	32	17.2	16.00	8.60	0.54
17	9J4A	3	3	1.4	1.00	0.47	0.47
17	9J4B	1	5	2.4	5.00	2.40	0.48

Level	Code	Z-spit (in cm)	Sum COUNT	Sum WEIGHT	DI	WDI	FSI
17	9J4C	2	5	5.3	2.50	2.65	1.06
17	9J4D	2	19	12.5	9.50	6.25	0.66
17	101J3D	1	4	1.7	4.00	1.70	0.43
17	10H1A	1	8	3.6	8.00	3.60	0.45
17	10H2A	4	28	10.9	7.00	2.73	0.39
17	10H2B	3	4	1.4	1.33	0.47	0.35
17	10H2C	4	5	1.4	1.25	0.35	0.28
17	10H2D	4	20	13.6	5.00	3.40	0.68
17	10H3A	2	9	4.3	4.50	2.15	0.48
17	10H3B	2	16	20.1	8.00	10.05	1.26
17	10H3C	6	8	2.4	1.33	0.40	0.30
17	10H3D	3	19	13.4	6.33	4.47	0.71
17	10H4A	1	9	3.1	9.00	3.10	0.34
17	10H4B	3	7	1.4	2.33	0.47	0.20
17	10H4C	2	5	3.5	2.50	1.75	0.70
17	10H4D	2	6	1.7	3.00	0.85	0.28
17	10I2A	5	11	6.6	2.20	1.32	0.60
17	10I2B	3	10	11.3	3.33	3.77	1.13
17	10I2C	2	4	1.7	2.00	0.85	0.43
17	10I2D	2	5	3.7	2.50	1.85	0.74
17	10I3A	1	14	5.2	14.00	5.20	0.37
17	10I3B	2	10	5.2	5.00	2.60	0.52
17	10I3C	1	13	7.6	13.00	7.60	0.58
17	10I3D	1	8	6	8.00	6.00	0.75
17	10I4A	8	6	3.4	0.75	0.43	0.57
17	10I4B	7	33	23.3	4.71	3.33	0.71
17	10I4C	6	38	28.9	6.33	4.82	0.76
17	10I4D	7	25	14.1	3.57	2.01	0.56
17	10J2A	6	24	7.2	4.00	1.20	0.30
17	10J2B	11	16	6.8	1.45	0.62	0.43
17	10J2C	2	7	2.2	3.50	1.10	0.31
17	10J2D	4	1	0.2	0.25	0.05	0.20
17	10J3A	3	42	14.8	14.00	4.93	0.35
17	10J3B	2	40	13.5	20.00	6.75	0.34
17	10J3C	2	38	12.3	19.00	6.15	0.32
17	10J3D	2	7	3.9	3.50	1.95	0.56
17	10J4A	1	11	3	11.00	3.00	0.27
17	10J4C	1	15	6.7	15.00	6.70	0.45
17	10J4D	2	14	15.6	7.00	7.80	1.11
17	11J3A	3	16	7.8	5.33	2.60	0.49
17	11J3B	4	8	5.3	2.00	1.33	0.66
17	12H2A	2	15	3.2	7.50	1.60	0.21
17	12H2B	3	8	2	2.67	0.67	0.25
17	12H2C	2	4	1.8	2.00	0.90	0.45
17	12H2D	3	4	4	1.33	1.33	1.00
17	12H3A	3	14	6.3	4.67	2.10	0.45
17	12H3B	3	19	9.7	6.33	3.23	0.51
17	12H3C	3	28	6.1	9.33	2.03	0.22
17	12H3D	3	16	3.9	5.33	1.30	0.24
17	12H4A	5	16	10.3	3.20	2.06	0.64
17	12H4B	6	28	7.1	4.67	1.18	0.25
17	12H4C	5	33	15.2	6.60	3.04	0.46

Level	Code	Z-spit (in cm)	Sum COUNT	Sum WEIGHT	DI	WDI	FSI
17	12H4D	5	20	8.2	4.00	1.64	0.41
17	12I3A	4	14	12	3.50	3.00	0.86
17	12I3B	5	35	27.1	7.00	5.42	0.77
17	12I3C	1	16	11.8	16.00	11.80	0.74
17	12I3D	1	8	7	8.00	7.00	0.88
17	12I4A	1	10	5.3	10.00	5.30	0.53
17	12I4B	1	11	6.4	11.00	6.40	0.58
17	12I4C	1	7	7.1	7.00	7.10	1.01
17	12I4D	1	11	4.6	11.00	4.60	0.42
17	12J3A	2	39	36.6	19.50	18.30	0.94
17	12J3B	2	23	26.1	11.50	13.05	1.13
17	12J4A	5	13	14.2	2.60	2.84	1.09
17	12J4B	4	11	16.6	2.75	4.15	1.51
17	12J4C	5	19	16.6	3.80	3.32	0.87
17	12J4D	6	16	17.6	2.67	2.93	1.10

Appendix G Stable isotope analysis on ungulate teeth

Data obtained after stable isotopic analysis of measuring oxygen in ungulate teeth in Appendix Table G.1 for single CO_3 and Appendix Table G.2 for mean PO_4 values.

Appendix Table G.1: Results of $\delta^{13}C$ and $\delta^{18}O$ stable isotope values on structural carbonate.

Code	Species	Level	Carb. Cont.%	$\delta^{13}C$ (V-PDB)	$\delta^{18}O$ (V-PDB)	$\Delta^{18}O_{CO3\text{-}PO4}$
H4-1792-2	*Capra pyrenaica*	17	8.54	-10.63	-4.17	9.7
H4-1792-3	*Capra pyrenaica*	17	8.18	-10.90	-3.10	9.9
H4-1792-4	*Capra pyrenaica*	17	7.72	-11.13	-2.62	9.2
H4-1792-5	*Capra pyrenaica*	17	6.77	-10.87	-3.07	8.8
H4-1792-6	*Capra pyrenaica*	17	7.47	-11.03	-3.86	9.3
H4-1792-7	*Capra pyrenaica*	17	7.76	-11.04	-3.88	10.1
H4-1792-8	*Capra pyrenaica*	17	8.15	-11.53	-6.05	8.3
H4-1792-9	*Capra pyrenaica*	17	7.90	-11.56	-5.53	8.2
H4-1792-10	*Capra pyrenaica*	17	7.36	-11.35	-5.81	7.5
H4-1792-11	*Capra pyrenaica*	17	7.84	-11.61	-4.22	8.7
H4-1792-13	*Capra pyrenaica*	17	7.78	-11.87	-3.87	8.5
H4-1792-14	*Capra pyrenaica*	17	7.54	-11.96	-4.29	6.6
H4-1792-15	*Capra pyrenaica*	17	7.04	-11.86	-3.15	7.8
H4-1792-16	*Capra pyrenaica*	17	8.38	-11.50	-2.76	8.3
H4-1792-17	*Capra pyrenaica*	17	7.45	-11.84	-3.09	8.0
I4-3427-2	*Capra pyrenaica*	17	7.06	-11.43	-4.19	8.1
I4-3427-3	*Capra pyrenaica*	17	7.43	-11.48	-5.03	6.7
I4-3427-4	*Capra pyrenaica*	17	6.76	-11.72	-4.08	8.3
I4-3427-5	*Capra pyrenaica*	17	6.72	-11.39	-4.77	8.0
I4-3427-6	*Capra pyrenaica*	17	6.84	-11.32	-5.43	8.0
I4-3427-7	*Capra pyrenaica*	17	7.06	-11.53	-5.29	8.5
I4-3427-8	*Capra pyrenaica*	17	6.16	-11.27	-5.13	8.4
I4-3427-9	*Capra pyrenaica*	17	7.30	-11.58	-5.14	7.8

I4-3427-10	*Capra pyrenaica*	17	7.12	-11.42	-3.96	8.8
I4-3427-11	*Capra pyrenaica*	17	6.88	-11.61	-4.53	7.8
I4-3427-12	*Capra pyrenaica*	17	7.59	-11.42	-4.32	8.4
I4-3427-13	*Capra pyrenaica*	17	7.10	-11.64	-4.26	8.2
I4-3427-14	*Capra pyrenaica*	17	7.17	-11.56	-4.47	8.2

Appendix Table G.2: Single measurements of $\delta^{18}O_{PO4}$ from intra-tooth stable isotope analysis.

ID	S-EVA	Level	Code	Taxon	ERJ mm	$\delta^{18}O_{PO4}$ (‰ VSMOW) triplet mean	SD
1	/	17	H4-1792-1	*Capra pyrenaica*	2.25		
2	34132	17	H4-1792-2	*Capra pyrenaica*	3.89	16.9	0.2
3	34133	17	H4-1792-3	*Capra pyrenaica*	5.56	17.8	0.2
4	34134	17	H4-1792-4	*Capra pyrenaica*	7.44	19.0	0.2
5	34135	17	H4-1792-5	*Capra pyrenaica*	8.93	19.0	0.3
6	34136	17	H4-1792-6	*Capra pyrenaica*	10.71	17.6	0.1
7	34137	17	H4-1792-7	*Capra pyrenaica*	12.24	16.8	0.2
8	34138	17	H4-1792-8	*Capra pyrenaica*	13.85	16.4	0.3
9	34139	17	H4-1792-9	*Capra pyrenaica*	15.34	17.0	0.3
10	34140	17	H4-1792-10	*Capra pyrenaica*	17.30	17.4	0.4
11	34141	17	H4-1792-11	*Capra pyrenaica*	18.65	17.9	0.3
12	34142	17	H4-1792-12	*Capra pyrenaica*	20.51	18.7	0.4
13	34143	17	H4-1792-13	*Capra pyrenaica*	22.47	18.4	0.3
14	34144	17	H4-1792-14	*Capra pyrenaica*	24.80	19.9	0.2
15	34145	17	H4-1792-15	*Capra pyrenaica*	27.10	19.9	0.1
16	34146	17	H4-1792-16	*Capra pyrenaica*	28.87	19.8	0.1
17	34147	17	H4-1792-17	*Capra pyrenaica*	30.23	19.7	0.2
18	/	17	J2-957-1	*Capra pyrenaica*	3.89		
19	34262	17	J2-957-2	*Capra pyrenaica*	5.71	18.2	0.3
20	34263	17	J2-957-3	*Capra pyrenaica*	7.61	18.9	0.1
21	34264	17	J2-957-4	*Capra pyrenaica*	9.70	17.5	0.2
22	34265	17	J2-957-5	*Capra pyrenaica*	11.76	16.6	0.1
23	34266	17	J2-957-6	*Capra pyrenaica*	13.48	15.9	0.0
24	34267	17	J2-957-7	*Capra pyrenaica*	14.87	15.8	0.0
25	34268	17	J2-957-8	*Capra pyrenaica*	16.71	16.1	0.1
26	34269	17	J2-957-9	*Capra pyrenaica*	18.00	16.1	0.3
27	34270	17	J2-957-10	*Capra pyrenaica*	19.56	16.7	0.1
28	34271	17	J2-957-11	*Capra pyrenaica*	21.40	17.3	0.2
29	34272	17	J2-957-12	*Capra pyrenaica*	22.24	17.8	0.2
30	34273	17	J2-957-13	*Capra pyrenaica*	24.21	18.4	0.2
31	34274	17	J2-957-14	*Capra pyrenaica*	25.93	18.5	0.1
32	34275	17	J2-957-15	*Capra pyrenaica*	27.73	18.8	0.2
33	34276	17	J2-957-16	*Capra pyrenaica*	30.16	18.1	0.1
34	34277	17	J2-957-17	*Capra pyrenaica*	31.83	17.2	0.1
35	34278	17	J2-957-18	*Capra pyrenaica*	33.13	16.8	0.1
36	/	17	J2-957-19	*Capra pyrenaica*	34.92		
37	/	17	H3-1648-1	*Capra pyrenaica*	2.24		
38	34281	17	H3-1648-2	*Capra pyrenaica*	3.88	18.7	0.1
39	34282	17	H3-1648-3	*Capra pyrenaica*	5.95	18.6	0.2
40	34283	17	H3-1648-4	*Capra pyrenaica*	7.99	18.0	0.1
41	34284	17	H3-1648-5	*Capra pyrenaica*	9.97	17.4	0.1
42	34285	17	H3-1648-6	*Capra pyrenaica*	12.29	17.5	0.1
43	34286	17	H3-1648-7	*Capra pyrenaica*	14.38	17.9	0.1

ID	S-EVA	Level	Code	Taxon	ERJ mm	$\delta^{18}O_{PO4}$ (‰ VSMOW) triplet mean	SD
44	34287	17	H3-1648-8	*Capra pyrenaica*	16.52	18.2	0.1
45	34288	17	H3-1648-9	*Capra pyrenaica*	18.19	18.6	0.2
46	34289	17	H3-1648-10	*Capra pyrenaica*	20.52	18.4	0.1
47	34290	17	H3-1648-11	*Capra pyrenaica*	22.27	18.5	0.1
48	34291	17	H3-1648-12	*Capra pyrenaica*	24.50	18.6	0.2
49	34292	17	H3-1648-13	*Capra pyrenaica*	26.35	18.4	0.2
50	34293	17	H3-1648-14	*Capra pyrenaica*	28.06	18.5	0.1
51	34294	17	H3-1648-15	*Capra pyrenaica*	29.92	18.5	0.2
52	/	16	H3-872-1	*Capra pyrenaica*	2.47		
53	34201	16	H3-872-2	*Capra pyrenaica*	4.83	16.7	0.1
54	34202	16	H3-872-3	*Capra pyrenaica*	6.50	17.2	0.0
55	34203	16	H3-872-4	*Capra pyrenaica*	8.27	17.4	0.1
56	34204	16	H3-872-5	*Capra pyrenaica*	10.42	16.3	0.2
57	34205	16	H3-872-6	*Capra pyrenaica*	12.99	15.6	0.2
58	34206	16	H3-872-7	*Capra pyrenaica*	14.56	15.3	0.3
59	34209	16	H3-872-8	*Capra pyrenaica*	16.34	16.1	0.3
60	34210	16	H3-872-9	*Capra pyrenaica*	18.29	16.2	0.1
61	34211	16	H3-872-10	*Capra pyrenaica*	19.77	16.7	0.2
62	34212	16	H3-872-11	*Capra pyrenaica*	21.65	17.0	0.0
63	34213	16	H3-872-12	*Capra pyrenaica*	23.62	17.5	0.1
64	34214	16	H3-872-13	*Capra pyrenaica*	25.55	17.7	0.1
65	34215	16	H3-872-14	*Capra pyrenaica*	27.24	17.7	0.1
66	34216	16	H3-872-15	*Capra pyrenaica*	28.92	18.0	0.0
67	/	15	H4-1061-1	*Capra pyrenaica*	1.12		
68	34186	15	H4-1061-2	*Capra pyrenaica*	2.70	16.8	0.0
69	34187	15	H4-1061-3	*Capra pyrenaica*	4.60	16.4	0.1
70	34188	15	H4-1061-4	*Capra pyrenaica*	6.77	17.6	0.1
71	34189	15	H4-1061-5	*Capra pyrenaica*	8.30	18.1	0.1
72	34190	15	H4-1061-6	*Capra pyrenaica*	10.42	17.8	0.1
73	34191	15	H4-1061-7	*Capra pyrenaica*	12.06	17.5	0.1
74	34192	15	H4-1061-8	*Capra pyrenaica*	13.92	16.8	0.1
75	34193	15	H4-1061-9	*Capra pyrenaica*	15.89	16.8	0.1
76	34194	15	H4-1061-10	*Capra pyrenaica*	18.24	17.4	0.1
77	34195	15	H4-1061-11	*Capra pyrenaica*	20.32	18.4	0.1
78	34196	15	H4-1061-12	*Capra pyrenaica*	22.25	19.2	0.2
79	34197	15	H4-1061-13	*Capra pyrenaica*	24.73	19.5	0.1
80	34198	15	H4-1061-14	*Capra pyrenaica*	26.48	19.3	0.1
81	34199	15	H4-1061-15	*Capra pyrenaica*	28.27	18.9	0.0
82	34200	15	H4-1061-16	*Capra pyrenaica*	29.96	18.7	0.1
83	/	17	H3-5278M3-1	*Capra pyrenaica*	1.20		
84	/	17	H3-5278M3-2	*Capra pyrenaica*	3.04		
85	34235	17	H3-5278M3-3	*Capra pyrenaica*	4.77	18.2	0.0
86	34236	17	H3-5278M3-4	*Capra pyrenaica*	7.32	18.0	0.1
87	34237	17	H3-5278M3-5	*Capra pyrenaica*	9.33	17.2	0.1
88	34238	17	H3-5278M3-6	*Capra pyrenaica*	11.43	16.3	0.1
89	34239	17	H3-5278M3-7	*Capra pyrenaica*	13.68	15.8	0.1
90	34240	17	H3-5278M3-8	*Capra pyrenaica*	15.59	15.9	0.2
91	34241	17	H3-5278M3-9	*Capra pyrenaica*	17.49	16.1	0.2
92	34242	17	H3-5278M3-10	*Capra pyrenaica*	20.00	16.9	0.0
93	34243	17	H3-5278M3-11	*Capra pyrenaica*	22.58	17.6	0.1
94	34244	17	H3-5278M3-12	*Capra pyrenaica*	24.44	17.9	0.1

ID	S-EVA	Level	Code	Taxon	ERJ mm	$\delta^{18}O_{PO4}$ (‰ VSMOW) triplet mean	SD
95	34245	17	H3-5278M3-13	*Capra pyrenaica*	26.88	18.1	0.1
96	34246	17	H3-5278M3-14	*Capra pyrenaica*	28.77	17.8	0.1
97	34247	17	H3-5278M3-15	*Capra pyrenaica*	31.24	17.5	0.1
98	34248	17	H3-5278M3-16	*Capra pyrenaica*	33.61	16.8	0.1
99	34249	17	H3-5278M3-17	*Capra pyrenaica*	35.68	16.5	0.1
100	34250	17	H3-5278M3-18	*Capra pyrenaica*	37.26	16.3	0.1
101	/	17	H3-5278M2-1	*Capra pyrenaica*	3.33		
102	/	17	H3-5278M2-2	*Capra pyrenaica*	4.72		
103	34251	17	H3-5278M2-3	*Capra pyrenaica*	7.11	17.7	0.1
104	34252	17	H3-5278M2-4	*Capra pyrenaica*	8.88	16.7	0.1
105	34253	17	H3-5278M2-5	*Capra pyrenaica*	11.05	16.2	0.2
106	34254	17	H3-5278M2-6	*Capra pyrenaica*	13.46	16.3	0.2
107	34233	17	H3-5278M2-7	*Capra pyrenaica*	16.00	16.6	0.2
108	34234	17	H3-5278M2-8	*Capra pyrenaica*	18.39	17.1	0.2
109	34257	17	H3-5278M2-9	*Capra pyrenaica*	20.15	17.8	0.1
110	34258	17	H3-5278M2-10	*Capra pyrenaica*	22.47	18.0	0.1
111	34259	17	H3-5278M2-11	*Capra pyrenaica*	25.41	18.2	0.0
112	34260	17	H3-5278M2-12	*Capra pyrenaica*	27.44	18.1	0.2
113	34261	17	H3-5278M2-13	*Capra pyrenaica*	29.70	17.8	0.2
114	/	17	H3-5278M2-14	*Capra pyrenaica*	32.06		
115	/	17	I4-3427-1	*Capra pyrenaica*	3.88		
116	34148	17	I4-3427-2	*Capra pyrenaica*	5.36	18.5	0.1
117	34149	17	I4-3427-3	*Capra pyrenaica*	7.60	19.0	0.2
118	34150	17	I4-3427-4	*Capra pyrenaica*	9.55	18.4	0.1
119	34151	17	I4-3427-5	*Capra pyrenaica*	11.69	18.0	0.3
120	34152	17	I4-3427-6	*Capra pyrenaica*	14.23	17.3	0.1
121	34153	17	I4-3427-7	*Capra pyrenaica*	17.00	17.0	0.1
122	34154	17	I4-3427-8	*Capra pyrenaica*	19.11	17.2	0.1
123	34155	17	I4-3427-9	*Capra pyrenaica*	21.67	17.8	0.1
124	34156	17	I4-3427-10	*Capra pyrenaica*	24.22	18.0	0.3
125	34157	17	I4-3427-11	*Capra pyrenaica*	26.34	18.4	0.2
126	34158	17	I4-3427-12	*Capra pyrenaica*	28.52	18.1	0.0
127	34159	17	I4-3427-13	*Capra pyrenaica*	30.63	18.3	0.2
128	34160	17	I4-3427-14	*Capra pyrenaica*	32.48	18.1	0.2
129	/	16	I2-396-1	*Capra pyrenaica*	1.10		
130	/	16	I2-396-2	*Capra pyrenaica*	3.26		
131	34217	16	I2-396-3	*Capra pyrenaica*	5.62	16.7	0.2
132	34218	16	I2-396-4	*Capra pyrenaica*	7.89	17.8	0.1
133	34219	16	I2-396-5	*Capra pyrenaica*	9.86	17.9	0.3
134	34220	16	I2-396-6	*Capra pyrenaica*	12.34	17.5	0.1
135	34221	16	I2-396-7	*Capra pyrenaica*	14.60	17.1	0.3
136	34222	16	I2-396-8	*Capra pyrenaica*	17.06	17.5	0.1
137	34223	16	I2-396-9	*Capra pyrenaica*	18.81	17.4	0.1
138	34224	16	I2-396-10	*Capra pyrenaica*	21.05	18.1	0.1
139	34225	16	I2-396-11	*Capra pyrenaica*	23.52	18.6	0.2
140	34226	16	I2-396-12	*Capra pyrenaica*	25.49	19.0	0.3
141	34227	16	I2-396-13	*Capra pyrenaica*	28.45	19.5	0.0
142	34228	16	I2-396-14	*Capra pyrenaica*	30.48	19.4	0.1
143	34229	16	I2-396-15	*Capra pyrenaica*	32.85	19.1	0.1
144	34230	16	I2-396-16	*Capra pyrenaica*	35.17	18.6	0.1
145	34302	17	I3-5535-1	*Equus ferus*	2.17	17.6	0.1

ID	S-EVA	Level	Code	Taxon	ERJ mm	$\delta^{18}O_{PO4}$ (‰ VSMOW) triplet mean	SD
146	34303	17	I3-5535-2	*Equus ferus*	3.64	18.2	0.1
147	34304	17	I3-5535-3	*Equus ferus*	5.81	17.3	0.3
148	34305	17	I3-5535-4	*Equus ferus*	10.56	17.5	0.1
149	34306	17	I3-5535-5	*Equus ferus*	14.34	18.0	0.2
150	34307	17	I3-5535-6	*Equus ferus*	18.96	17.2	0.1
151	34308	17	I3-5535-7	*Equus ferus*	23.39	16.9	0.2
152	34309	17	I3-5535-8	*Equus ferus*	27.51	16.5	0.0
153	34310	17	I3-5535-9	*Equus ferus*	31.13	16.5	0.2
154	34311	17	I3-5535-10	*Equus ferus*	34.84	16.6	0.1
155	34312	17	I3-5535-11	*Equus ferus*	38.45	17.0	0.1
156	34313	17	I3-5535-12	*Equus ferus*	42.93	17.2	0.1
157	34314	17	I3-5535-13	*Equus ferus*	46.49	17.2	0.1
158	34315	17	I3-5535-14	*Equus ferus*	49.97	17.2	0.0
159	34316	17	I3-5535-15	*Equus ferus*	53.42	17.4	0.1
160	34317	17	I3-5535-16	*Equus ferus*	56.72	17.1	0.0
161	34318	17	I3-5535-17	*Equus ferus*	60.39	17.1	0.3
162	34319	17	I3-5535-18	*Equus ferus*	64.15	17.2	0.1
163	34320	17	I3-5535-19	*Equus ferus*	66.33	16.9	0.2
164	34321	17	J3-4681-1	*Equus ferus*	2.66	16.6	0.2
165	34322	17	J3-4681-2	*Equus ferus*	5.80	17.1	0.2
166	34323	17	J3-4681-3	*Equus ferus*	9.65	16.7	0.2
167	34326	17	J3-4681-4	*Equus ferus*	12.69	16.6	0.3
168	34327	17	J3-4681-5	*Equus ferus*	15.59	16.9	0.0
169	34328	17	J3-4681-6	*Equus ferus*	19.17	17.1	0.1
170	34329	17	J3-4681-7	*Equus ferus*	22.71	17.4	0.2
171	34330	17	J3-4681-8	*Equus ferus*	26.79	17.5	0.2
172	34331	17	J3-4681-9	*Equus ferus*	29.76	17.4	0.2
173	34332	17	J3-4681-10	*Equus ferus*	33.32	17.5	0.1
174	34333	17	J3-4681-11	*Equus ferus*	36.56	17.7	0.3
175	34334	17	J3-4681-12	*Equus ferus*	39.90	17.7	0.2
176	34335	17	J3-4681-13	*Equus ferus*	43.76	17.5	0.0
177	34336	17	J3-4681-14	*Equus ferus*	47.48	17.3	0.2
178	34337	17	J3-4681-15	*Equus ferus*	51.12	17.5	0.1
179	34338	17	J3-4681-16	*Equus ferus*	55.23	17.5	0.1
180	34339	17	J3-4681-17	*Equus ferus*	59.14	17.2	0.1
181	34340	17	J3-4681-18	*Equus ferus*	62.96	17.0	0.2
182	34341	17	J3-4681-19	*Equus ferus*	65.89	17.1	0.1
183	34381	17	H3-3510-1	*Cervus elaphus*	0.45	17.2	0.1
184	/	17	H3-3510-2	*Cervus elaphus*	1.74		
185	34382	17	H3-3510-3	*Cervus elaphus*	2.86	16.6	0.1
186	/	17	H3-3510-4	*Cervus elaphus*	3.73		
187	34383	17	H3-3510-5	*Cervus elaphus*	4.71	16.7	0.1
188	/	17	H3-3510-6	*Cervus elaphus*	5.72		
189	34384	17	H3-3510-7	*Cervus elaphus*	6.72	16.9	0.2
190	/	17	H3-3510-8	*Cervus elaphus*	7.88		
191	34385	17	H3-3510-9	*Cervus elaphus*	8.78	17.5	0.2
192	/	17	H3-3510-10	*Cervus elaphus*	9.55		
193	34386	17	H3-3510-11	*Cervus elaphus*	10.45	17.7	0.0
194	/	17	H3-3510-12	*Cervus elaphus*	11.09		
195	34387	17	H3-3510-13	*Cervus elaphus*	11.75	18.0	0.0
196	/	17	H3-3510-14	*Cervus elaphus*	12.75		

ID	S-EVA	Level	Code	Taxon	ERJ mm	$\delta^{18}O_{PO4}$ (‰ VSMOW) triplet mean	SD
197	34388	17	H3-3510-15	*Cervus elaphus*	13.75	18.3	0.2
198	/	17	H3-3510-16	*Cervus elaphus*	14.71		
199	34389	17	H3-3510-17	*Cervus elaphus*	16.39	18.6	0.3
200	34342	17	I4-5083M3-1	*Cervus elaphus*	0.56	16.8	0.2
201	/	17	I4-5083M3-2	*Cervus elaphus*	1.63		
202	34343	17	I4-5083M3-3	*Cervus elaphus*	2.83	16.0	0.3
203	/	17	I4-5083M3-4	*Cervus elaphus*	3.80		
204	34344	17	I4-5083M3-5	*Cervus elaphus*	5.24	16.1	0.1
205	/	17	I4-5083M3-6	*Cervus elaphus*	6.27		
206	34345	17	I4-5083M3-7	*Cervus elaphus*	7.56	16.5	0.1
207	/	17	I4-5083M3-8	*Cervus elaphus*	8.56		
208	34346	17	I4-5083M3-9	*Cervus elaphus*	9.77	16.5	0.2
209	/	17	I4-5083M3-10	*Cervus elaphus*	11.06		
210	34347	17	I4-5083M3-11	*Cervus elaphus*	12.15	16.9	0.1
211	/	17	I4-5083M3-12	*Cervus elaphus*	13.33		
212	34370	17	I4-5083M3-13	*Cervus elaphus*	14.28	16.9	0.1
213	/	17	I4-5083M3-14	*Cervus elaphus*	15.49		
214	34371	17	I4-5083M3-15	*Cervus elaphus*	16.57	17.0	0.1
215	/	17	I4-5083M3-16	*Cervus elaphus*	18.03		
216	34372	17	I4-5083M2-1	*Cervus elaphus*	0.60	17.5	0.1
217	/	17	I4-5083M2-2	*Cervus elaphus*	1.39		
218	34373	17	I4-5083M2-3	*Cervus elaphus*	2.69	17.6	0.2
219	/	17	I4-5083M2-4	*Cervus elaphus*	3.86		
220	34374	17	I4-5083M2-5	*Cervus elaphus*	5.20	17.1	0.1
221	/	17	I4-5083M2-6	*Cervus elaphus*	6.11		
222	34375	17	I4-5083M2-7	*Cervus elaphus*	7.12	17.1	0.1
223	/	17	I4-5083M2-8	*Cervus elaphus*	7.95		
224	34376	17	I4-5083M2-9	*Cervus elaphus*	8.96	16.6	0.1
225	/	17	I4-5083M2-10	*Cervus elaphus*	9.89		
226	34377	17	I4-5083M2-11	*Cervus elaphus*	10.89	16.4	0.1
227	/	17	I4-5083M2-12	*Cervus elaphus*	11.87		
228	34378	17	I4-5083M2-13	*Cervus elaphus*	12.79	16.0	0.0
229	/	17	I4-5083M2-14	*Cervus elaphus*	13.59		
230	34379	17	I4-5083M2-15	*Cervus elaphus*	14.67	16.0	0.2
231	/	17	I4-5083M2-16	*Cervus elaphus*	15.61		
232	34380	17	I4-5083M2-17	*Cervus elaphus*	17.20	16.0	0.2

Appendix H Regional paleo-economic analysis

The here presented paleo-economic analysis combines different strings of data: topographic location, chronological relationship and economic data obtained from archeozoological studies in the region. These data are presented in this part of the appendix.

Appendix H.1 Topographic model of site locality

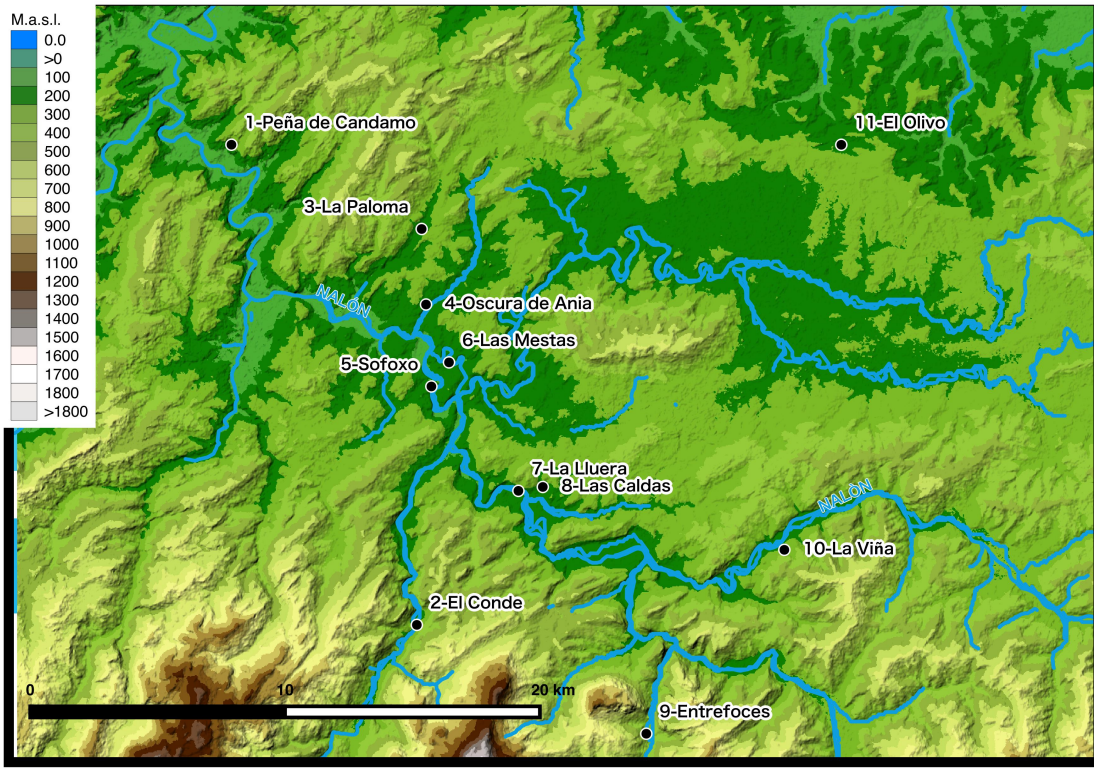
The studied region covers the area within the Cantabrian sea to the north, the Cordillera Cantabria/ Spanish Meseta to the southwest and the Pyrenees to the east.

Site location of the Cantabrian archaeological sites discussed in this analysis are shown in the

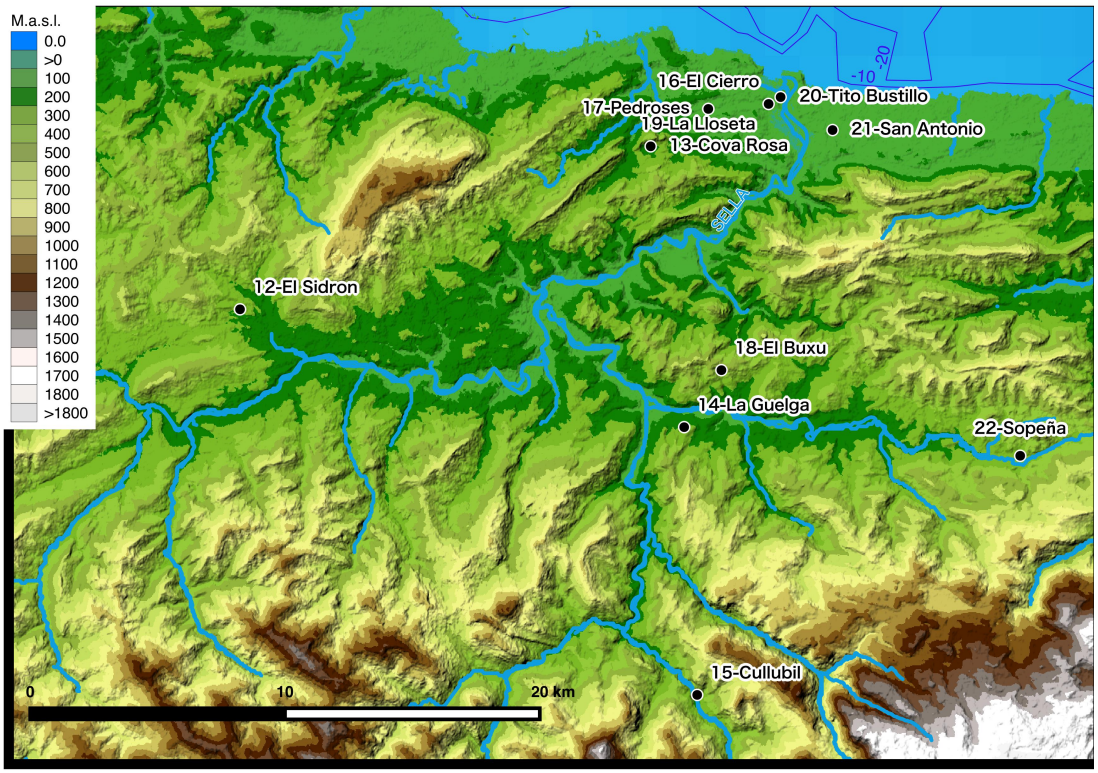
following maps, with locations of neighboring sites. Name of sites are listed in Appendix Table H.1.

Topographic maps (Digital Elevation Model - DEM) comprise following areas with archaeological sites discussed in this analysis:

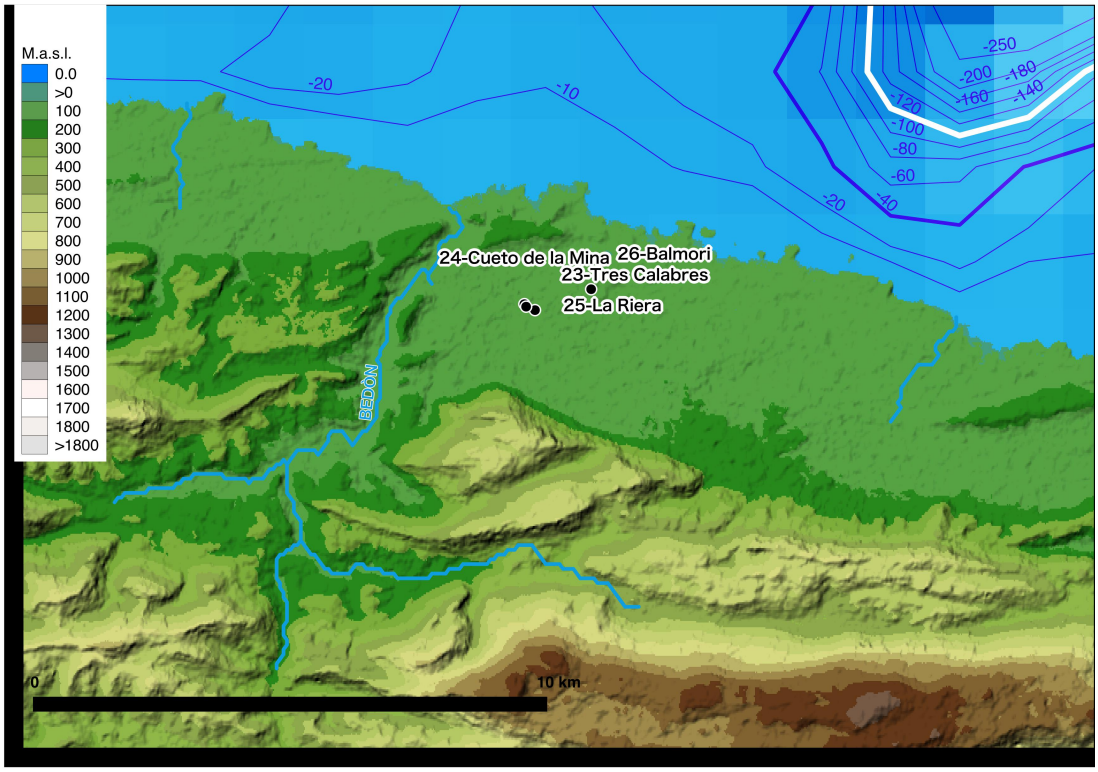
- Nalón River Valley and Llanera Plain (Appendix Figure H.1.1)
- Sella River Valley. (Appendix Figure H.1.2)
- Sella River Valley and La Llera coastal plain (Appendix Figure H.1.3)
- Cares River Valley (Appendix Figure H.1.4)
- Cares, Deva and Nansa River Valleys (Appendix Figure H.1.5)
- West-Central Cantabria coastal plain (Appendix Figure H.1.6)
- Besaya and Pas River Valleys (Appendix Figure H.1.7)
- Central Cantabria/ Santander coastal plain (Appendix Figure H.1.8)
- Central Cantabria/ Santander coastal plain, Miera, Asón and Carranza River Valleys (Appendix Figure H.1.9)
- Detail of Asón and Carranza River Valleys (Appendix Figure H.1.10)
- Urdiales Area, Western Vizcaya Interior and Bilbao coast (Appendix Figure H.1.11)
- Central Vizcaya Interior and Deba River Valley (Appendix Figure H.1.12)
- Central Vizcaya Interior, Deba River Valley and Ebro watershed (Appendix Figure H.1.13)
- Oka and Lea River Valleys (Appendix Figure H.1.14)
- Deba and Oria River Valleys and Ebro watershed (Appendix Figure H.1.15)
- Urola, Oria and Urumea River Valleys (Appendix Figure H.1.16)
- Urumea River Valley, Navarra and French Basque Country (Appendix Figure H.1.17)
- Miera, Asón and Carranza River Valleys and Ebro watershed (Appendix Figure H.1.18)
- Ebro watershed (Appendix Figure H.1.19)



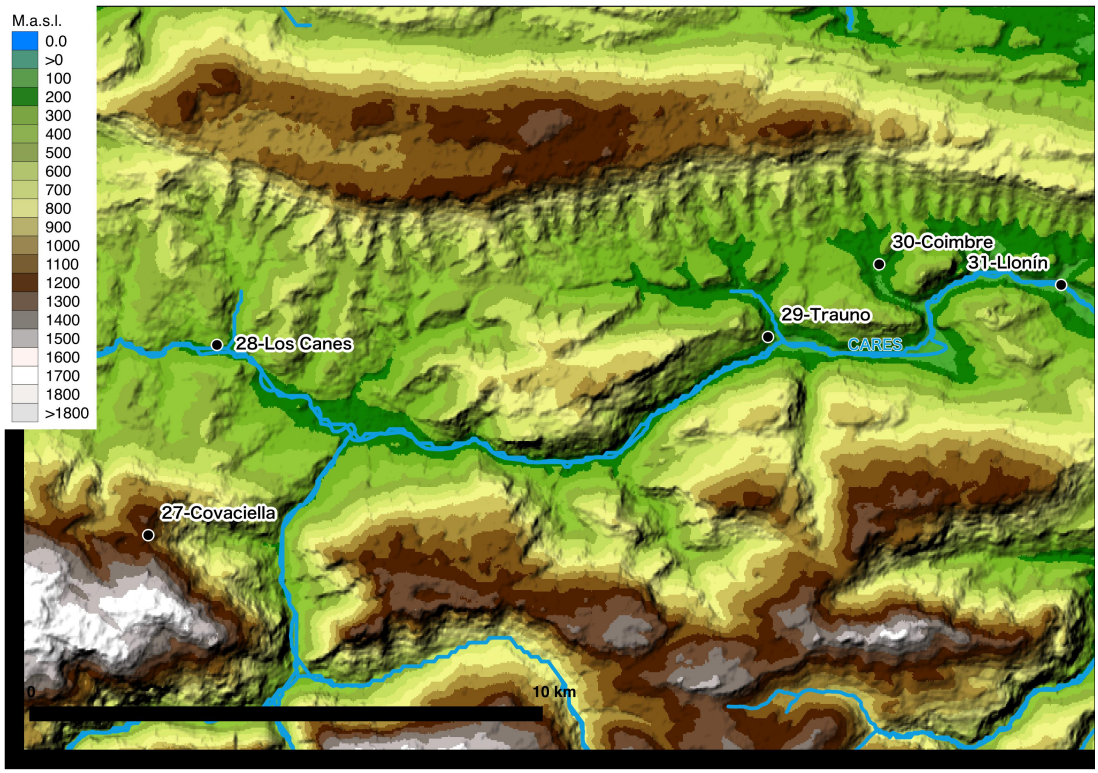
Appendix Figure H.1.1: Areas with archaeological sites discussed in this analysis, here: Nalón River Valley and Llanera Plain.



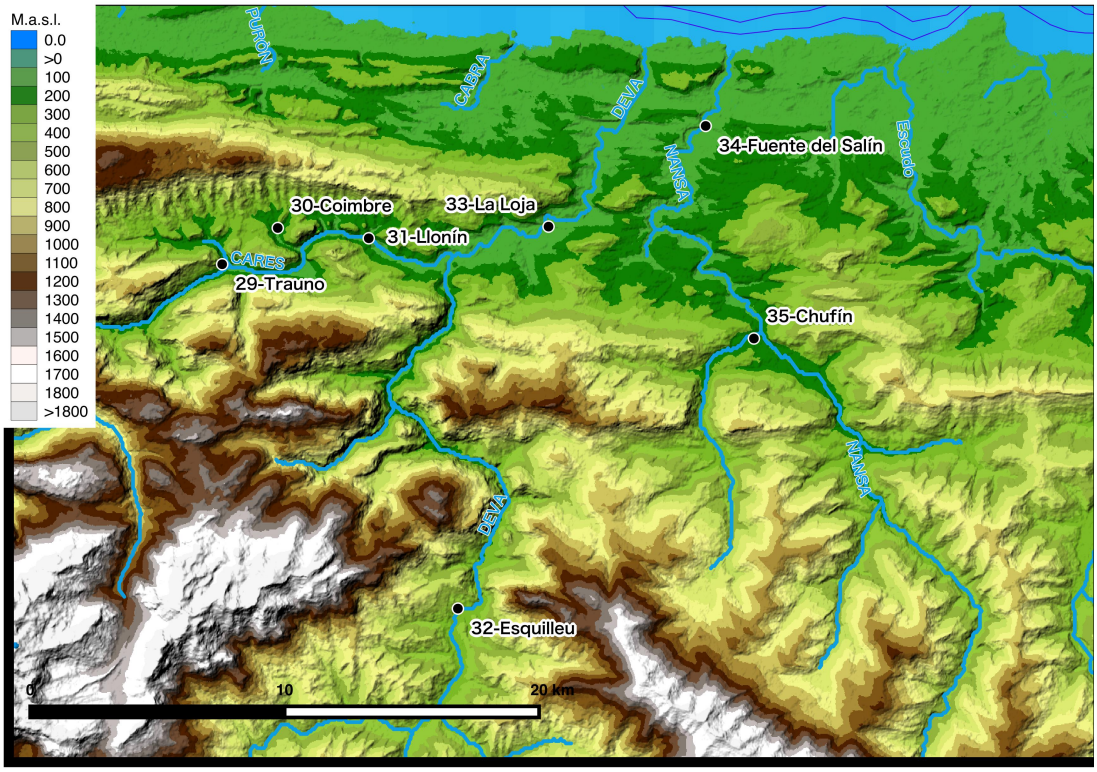
Appendix Figure H.2: Areas with archaeological sites discussed in this analysis, here: Sella River Valley.



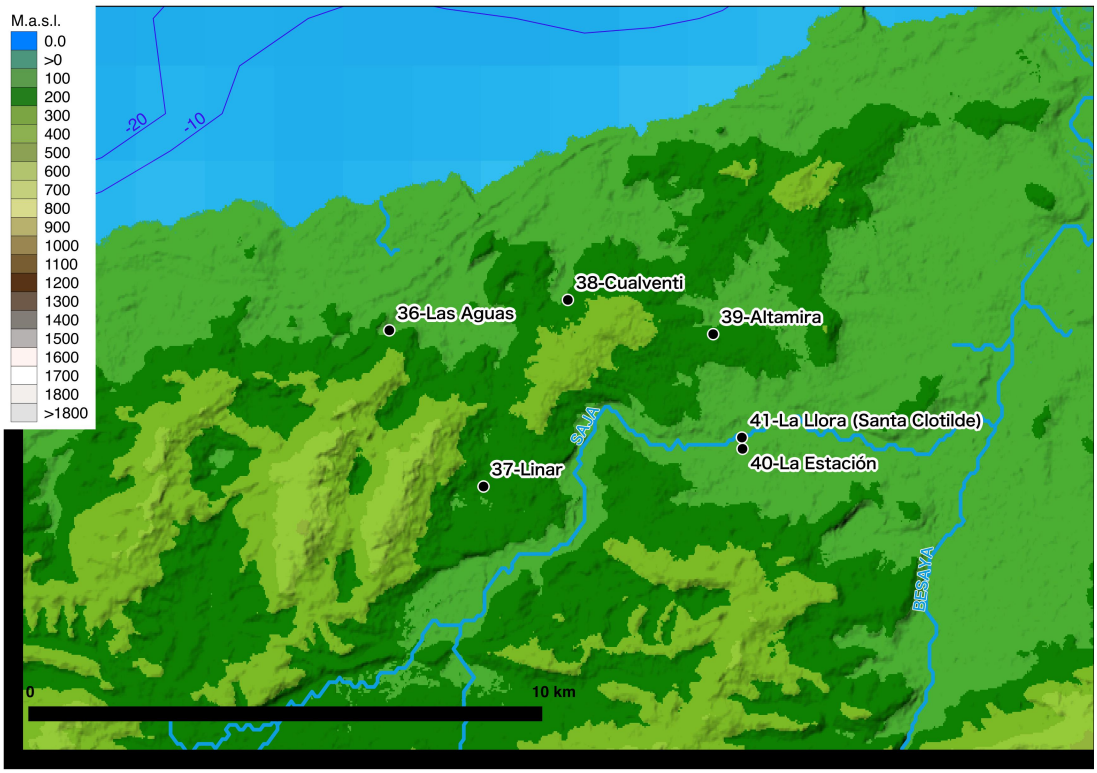
Appendix Figure H.1.3: Areas with archaeological sites discussed in this analysis, here: Bedón River Valley and La Llera coastal plain.



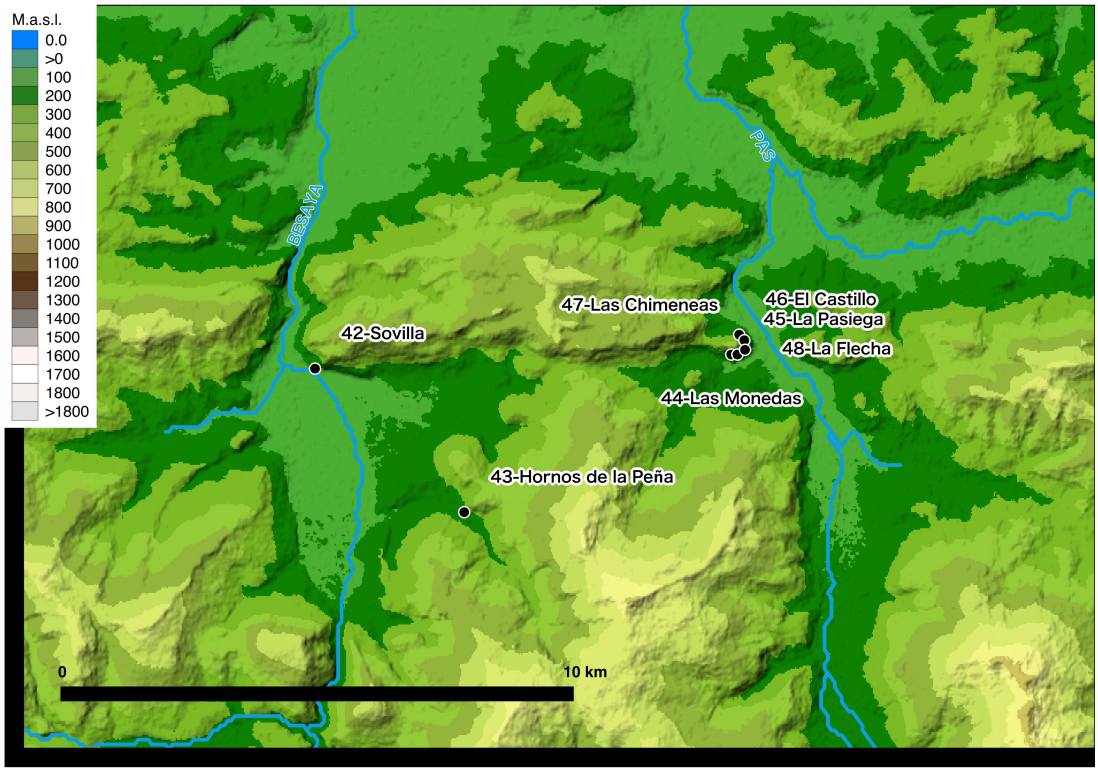
Appendix Figure H.1.4: Areas with archaeological sites discussed in this analysis, here: Cares River Valley.



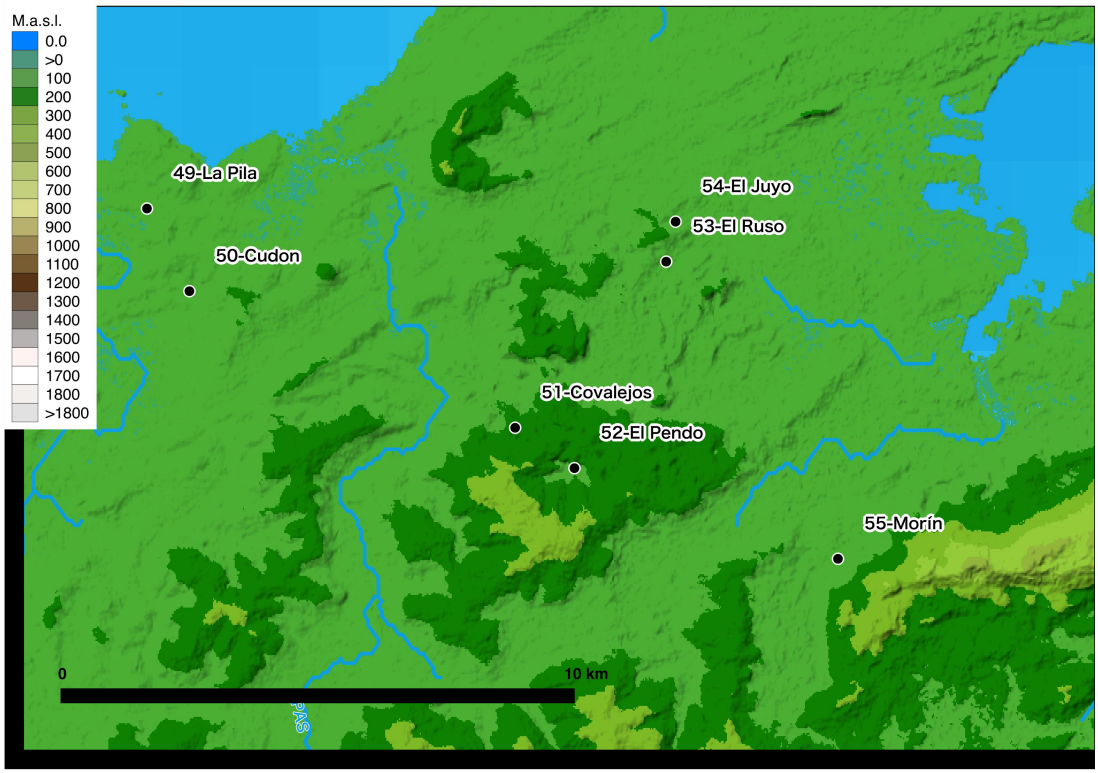
Appendix Figure H.1.5: Areas with archaeological sites discussed in this analysis, here: Cares, Deva and Nansa River Valleys.



Appendix Figure H.1.6: Areas with archaeological sites discussed in this analysis, here: West-Central Cantabria coastal plain.



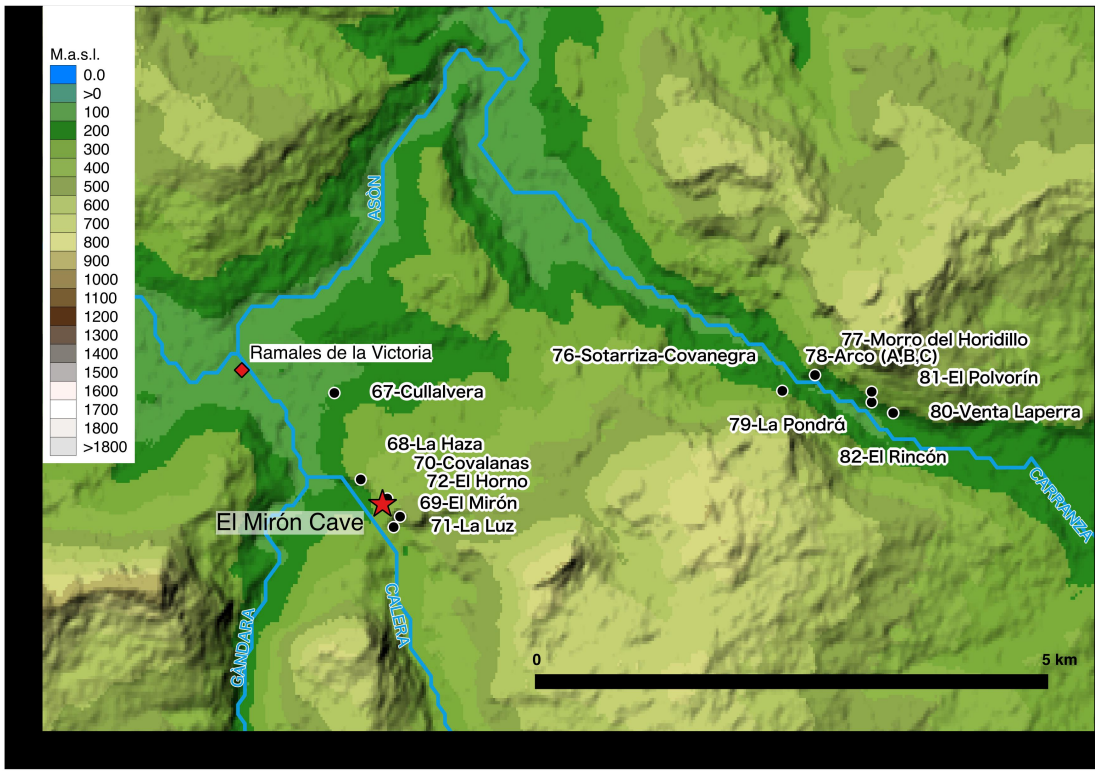
Appendix Figure H.1.7: Areas with archaeological sites discussed in this analysis, here: Besaya and Pas River Valleys.



Appendix Figure H.1.8: Areas with archaeological sites discussed in this analysis, here: Central Cantabria/ Santander coastal plain.



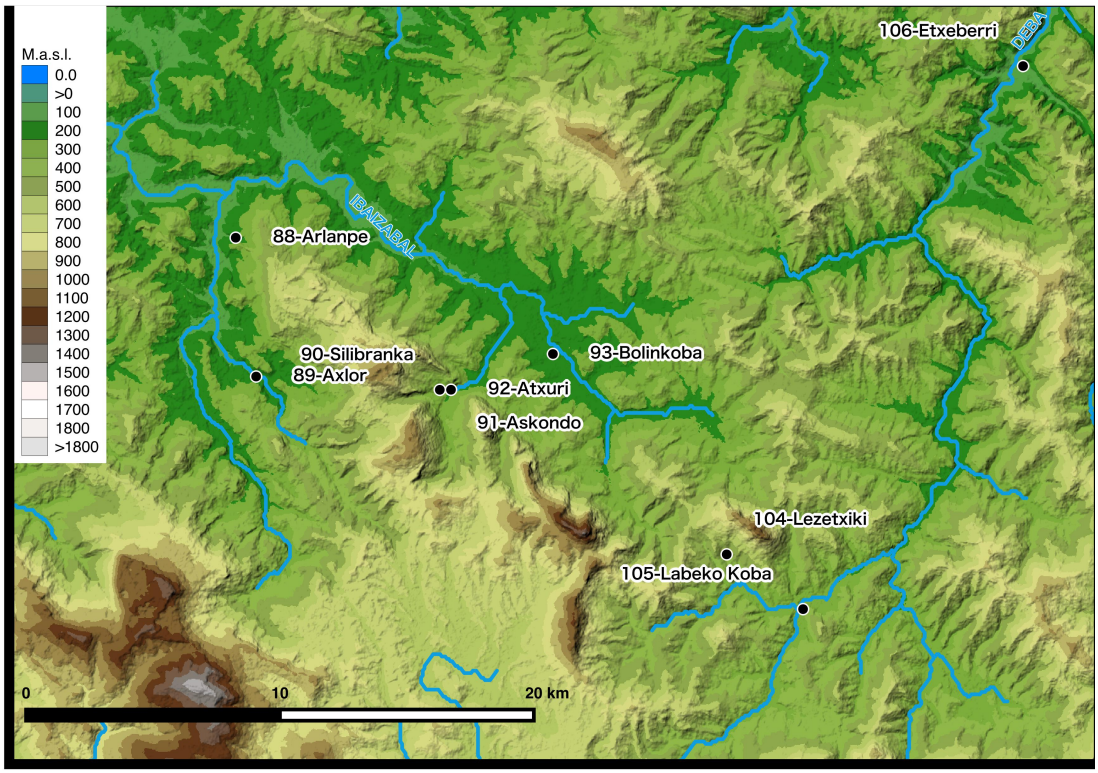
Appendix Figure H.1.9: Areas with archaeological sites discussed in this analysis, here: Central Cantabria/ Santander coastal plain, Miera, Asón and Carranza River Valleys.



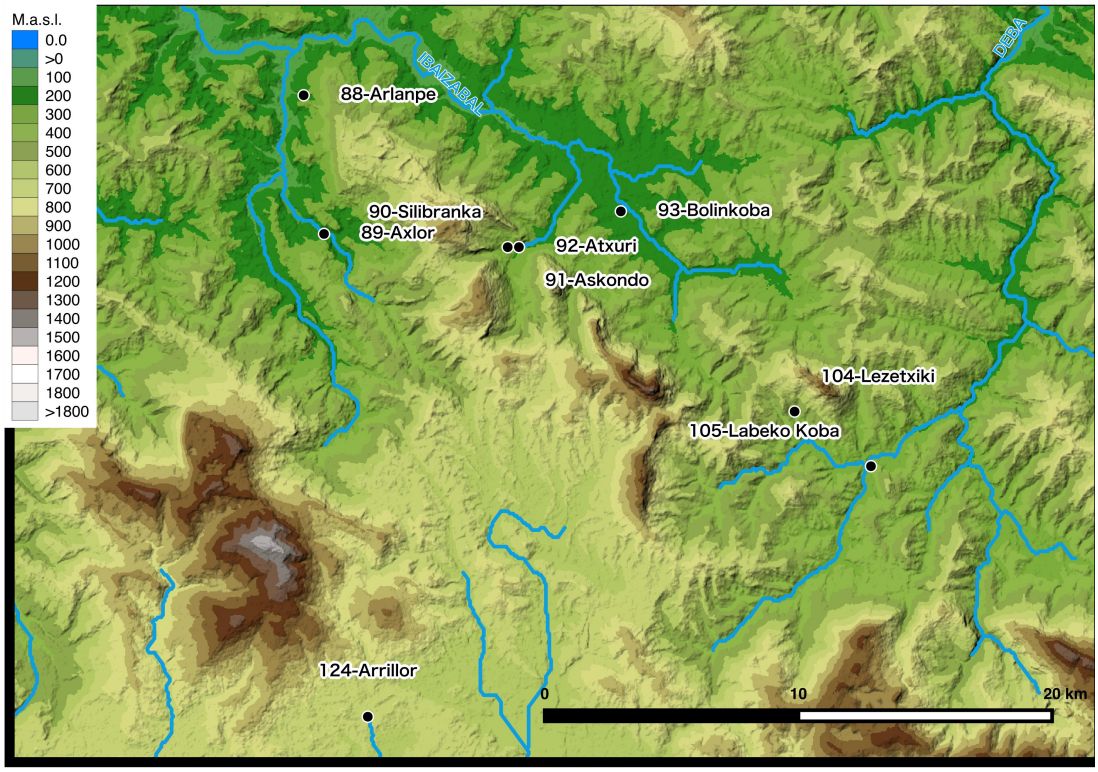
Appendix Figure H.1.10: Areas with archaeological sites discussed in this analysis, here: Detail of Asón and Carranza River Valleys.



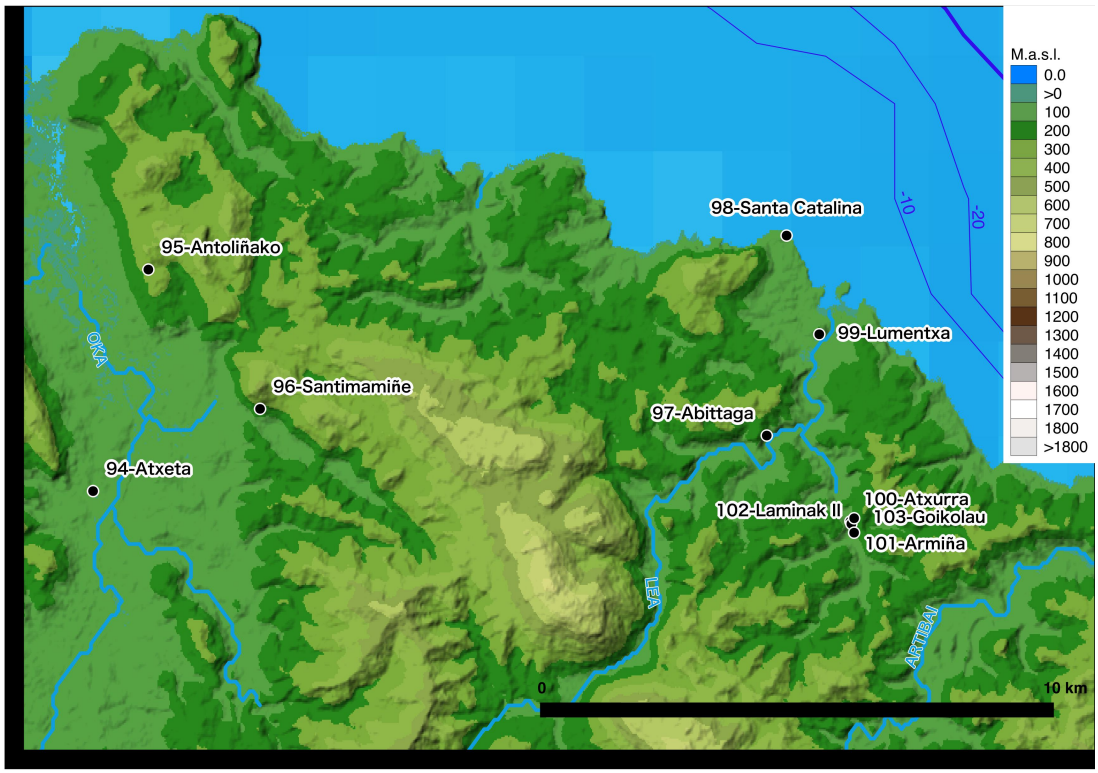
Appendix Figure H.1.11: Areas with archaeological sites discussed in this analysis, here: Urdiales Area, Western Vizcaya Interior and Bilbao coast.



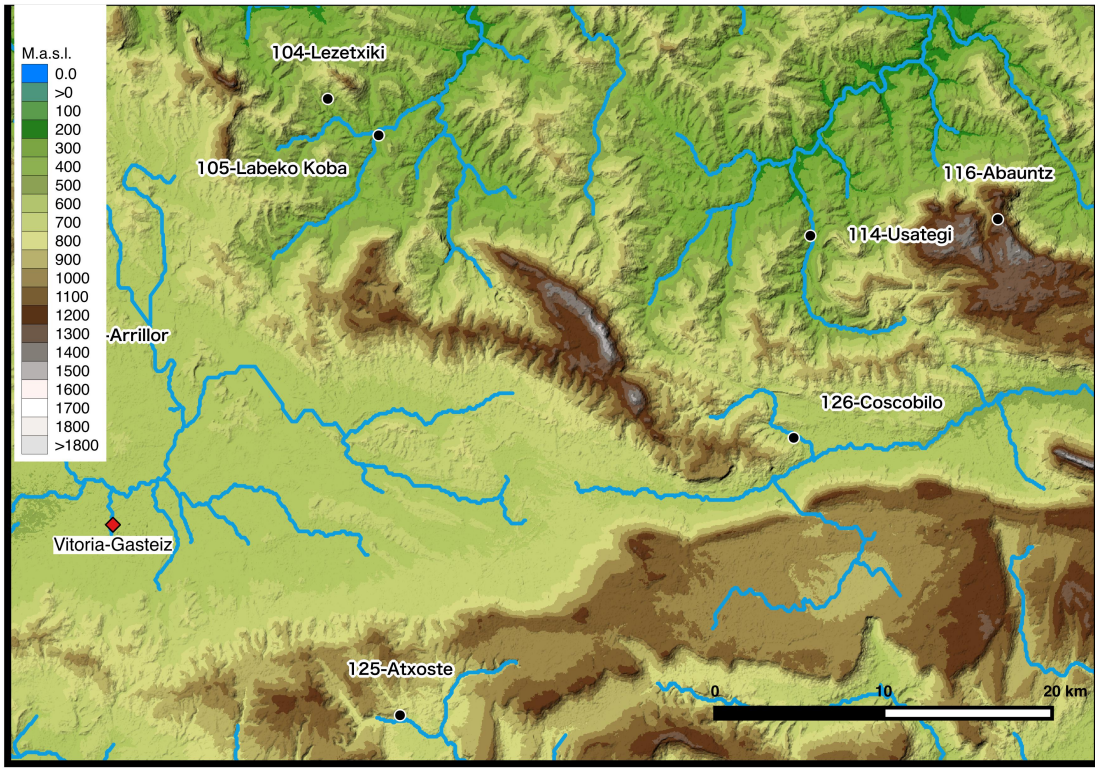
Appendix Figure H.1.12: Areas with archaeological sites discussed in this analysis, here: Central Vizcaya Interior and Deba River Valley.



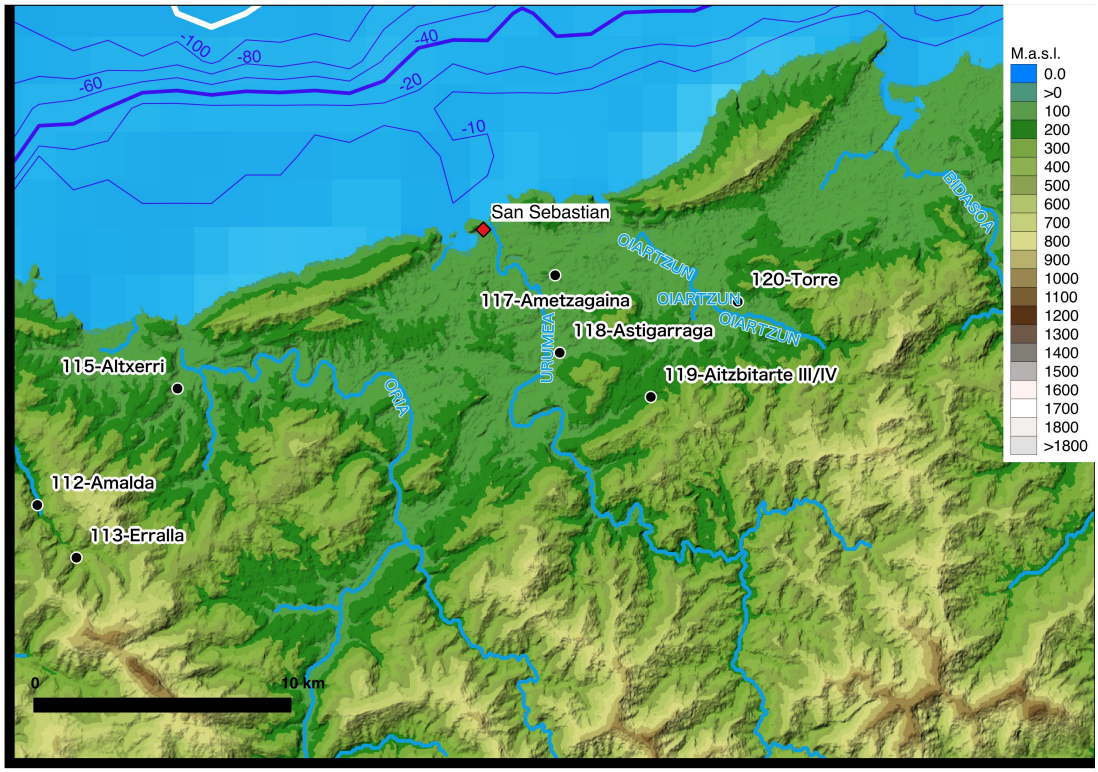
Appendix Figure H.1.13: Areas with archaeological sites discussed in this analysis, here: Central Vizcaya Interior, Deba River Valley and Ebro watershed



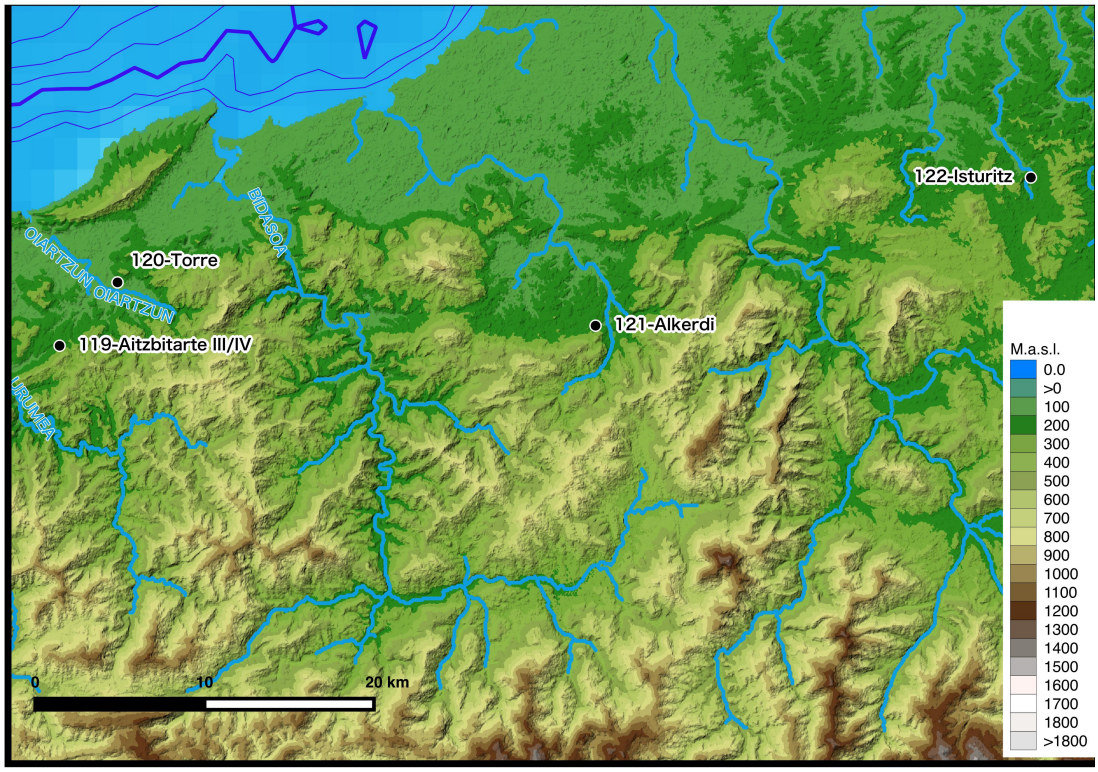
Appendix Figure H.1.14: Areas with archaeological sites discussed in this analysis, here: Oka and Lea River Valleys.



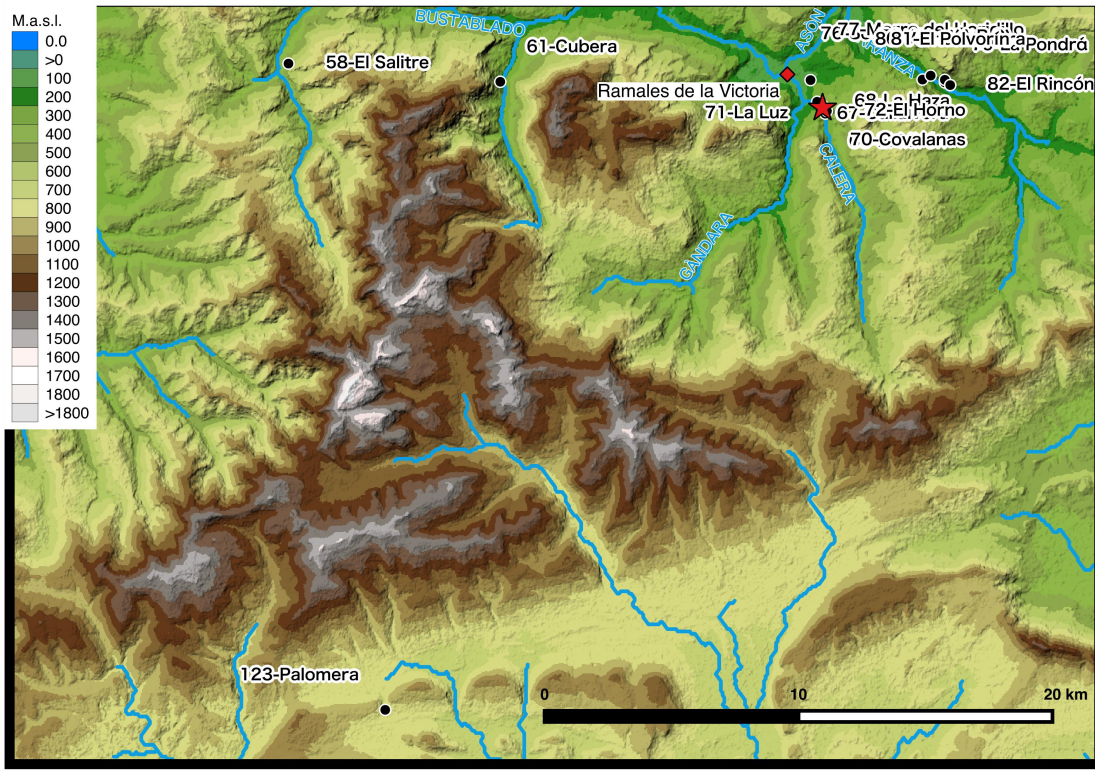
Appendix Figure H.1.15: Areas with archaeological sites discussed in this analysis, here: Deba and Oria River Valleys and Ebro watershed.



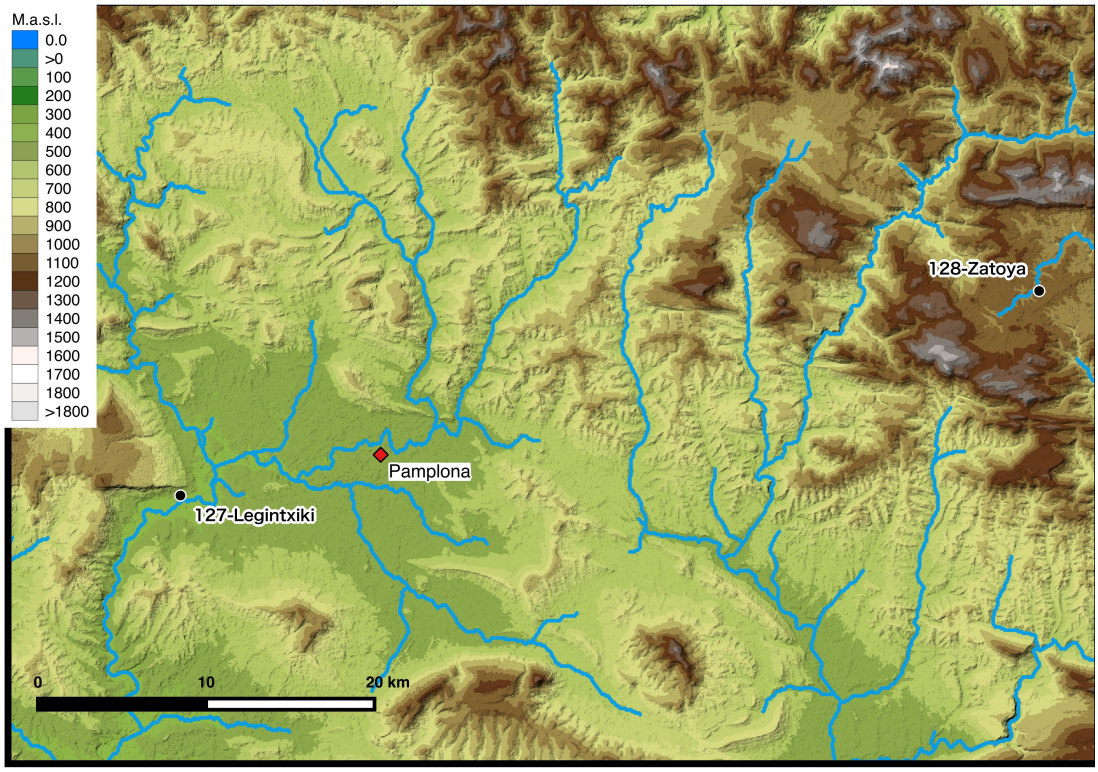
Appendix Figure H.1.16: Areas with archaeological sites discussed in this analysis, here: Urola, Oria and Urumea River Valleys.



Appendix Figure H.1.17: Areas with archaeological sites discussed in this analysis, here: Urumea, River Valley, Navarra and French Basque Country.



Appendix Figure H.1.18: Areas with archaeological sites discussed in this analysis, here: Miera, Asón and Carranza River Valleys and Ebro watershed.



Appendix Figure H.1.19: Areas with archaeological sites discussed in this analysis, here: Ebro watershed.

Appendix H.2 Site characteristics and occupation history

Appendix Table H.2.1 list sites used for regional economic analysis and their characteristics: location (Lat=Latitude, Long=Longitude), slope mean = mean of slope degree within the 10km radius of site catchment area, site altitude in reference to LGM coast of -120m below modern sea level, kilometer to the sea in reference to LGM coast of -120m below modern sea level and evidence of cultural activities. Appendix Table H.2 contain C14 dates used for age calibration and settlement model. Abbreviations used refer to the following: MP-Middle Paleolithic, AUR-Aurignacian, GRAV-Gravettian, SOL-Solutrean, IM-Initial Magdalenian, LM-Lower Magdalenian, MM-Middle Magdalenian, UM-Upper Magdalenian, FM-Final Magdalenian and AZI-Azilian.

Appendix Table H.2.1:Topography and cultural occupations of analyzed sites in the Cantabrian region.

ID	Site	Lat	Long	Slope mean	m.a.s.l. (LGM)	km to sea (LGM)	MP	AUR	GRAV	SOL	IM	LM	MM	UM	FM	AZI
1	Peña de Candamo	-6,073	43,456	15	325	25				1		LM				
2	Conde	-5,983	43,288	20	309	43	MOUST	AUR								
3	Paloma	-5,980	43,426	15	275	29					9--10	8			4	
4	Oscura de Ania	-5,979	43,400	15	240	32									FM	AZI
5	Sofoxo	-5,976	43,371	15	247	35							MM		FINAL MAGD	
6	Mestas	-5,968	43,380	15	232	34					Early Magd	Early Magd				
7	Lluera I & II	-5,934	43,335	15	232	40				SOL				UM		
8	Las Caldas	-5,922	43,336	15	277	40					3; XIV		II-VI,IV, IX,VII,VIII			
9	Entrefoces	-5,872	43,249	20	388	50						LM				
10	Viña	-5,806	43,314	15	340	46			GRAV				MM			
11	Olivo	-5,778	43,456	10	262	35							2			
12	Sidron	-5,329	43,386	20	323	39	MP									
13	Cova Rosa	-5,130	43,443	15	324	27				E		Low MAGD C/D				
14	Guelga	-5,114	43,345	20	339	35						LM				
15	Cullubil	-5,108	43,251	25	314	40							MM		Final MAGD	
16	Cierro	-5,102	43,457	15	207	24				SOL		LM				
17	Pedroses	-5,102	43,457	15	207	24						Madg inf				
18	Buxu	-5,096	43,365	20	508	33						LM				
19	Lloseta	-5,073	43,458	10	175	23						MAGD		UM		
20	Tito Bustillo	-5,067	43,461	10	133	23						1a, 2	1c	1b/ XIIC		
21	San Antonio	-5,042	43,449	15	151	24					Early Magd	Early Magd				
22	Sopeña	-4,952	43,335	20	370	22			I & III							
23	Tres Clabres	-4,868	43,421	15	163	11				SOL						
24	Cueto de la Mina	-4,857	43,426	10	153	9			H	E		LM		B		
25	Riera	-4,857	43,425	10	142	9			1	4,7,8,15,16,17	19(top,bot),12,17	19/20		21-23,24,26,27(low)		27 (up), 28, 29
26	Balmori	-4,834	43,424	10	142	8		6		5		LM	4			
27	Covaciella	-4,867	43,283	25	1240	20										
28	Canes	-4,850	43,317	25	328	17								MAGD		
29	Trauno	-4,717	43,318	25	266	14					Early Magd	Early Magd				
30	Coimbre	-4,690	43,331	25	248	13			6			4	2	1a, b, c		
31	Llonín	-4,646	43,327	25	155	16			GRAV	SOL	IM	LM		UPP MAGD		

32	Esquilleu	-4,603	43,197	25	382	29	MOUST									
33	Loja	-4,559	43,331	20	137	16							MM			
34	Fuente del Salín	-4,483	43,367	10	137	12			GRAV							
35	Chufín	-4,460	43,292	20	264	19				A/1						
36	Aguas	-4,197	43,379	10	172	14				D		B & C	(B)			
37	Linar	-4,174	43,351	10	120					boca 3		boca 2				
38	Cualventi	-4,154	43,384	10	245	16				6	6	6		2,4	1a	
39	Altamira	-4,119	43,378	10	255	18				lower	1924 & 1981 Magd.					
40	Estación	-4,112	43,359	10	161	20										
41	Llora (St.Clotilde)	-4,112	43,359	10	161	20							MAGD	MAGD		
42	Sovilla	-4,068	43,286	15	198	26								UM		
43	Hornos de la Peña	-4,032	43,261	15	275	28				C						
44	Monedas	-3,968	43,289	15	308	26	MOUST									
45	Pasiega	-3,966	43,289	15	304	26	MOUST									
46	Castillo	-3,966	43,292	15	305	26		18b,18c,16	GRAV		8	LM beta		6 inf		
47	Chimeneas	-3,964	43,291	15	314	26										
48	Flecha	-3,964	43,290	15	318	26	Moust dent.									
49	Pila	-4,017	43,433	5	143	11								IV	IV	
50	Cudon	-4,006	43,419	5	143	13	CHAT									
51	Covalejos	-3,928	43,394	10	242	16	D - M	B, C			Early Magd	Early Magd				
52	Pendo	-3,913	43,388	10	226	17				SOL		II c+d		II a+b	II	I
53	Ruso	-3,891	43,424	10	167	15			IVb	III						
54	Juyo	-3,889	43,431	10	166	14						4, 6, 7				
55	Morín	-3,850	43,372	10	145	21		7, 8	5a							1 (27)
56	Fuente del Frances	-3,705	43,393	15	170	22				SOL	Early Magd	Early Magd				
57	Garma	-3,667	43,433	10	288	17		C	F,E	G,H			I,J,K,L,M,N,O			
58	Salitre	-3,711	43,261	20	540	34		AUR		SOL				MAGD		
59	Pielago	-3,705	43,305	20	120											
60	Rascaño	-3,703	43,295	20	292	31		9	7			3, 4a, 5			2	1
61	Cubera	-3,608	43,255	20	380	32										
62	Cofresnedo	-3,590	43,317	20	380	26										
63	Emboscados	-3,588	43,332	20	380	24						MAGD	MAGD			
64	Otero	-3,536	43,357	15	201	21								UM		AZI
65	Cobrantes	-3,535	43,326	15	352	24										
66	Chora	-3,495	43,345	15	162	23									Final MAGD	AZI
67	Cullalvera	-3,458	43,255	20	235	32			Upper Pal.							
68	Haza	-3,455	43,248	20	366	33				SOL						
69	El Mirón	-3,453	43,245	20	398	33	130		129,128	120, 121, 122, 123,124,125,126,127	18,19,20,21,313,117–119.3	15,16,17, 110-116,312, 503.1,504,505	13,14,107,107.1,107.2,108	12,103,104,105,106, 307,308	11,11.1,11.2, 102.1,102.2,306	102,305
70	Covalanas	-3,452	43,246	20	449	33										
71	Luz	-3,451	43,243	20	347	33				SOL						
72	Horno	-3,450	43,244	20	413	33								1, 2		
73	Fragua	-3,427	43,444	5	348	40										
74	Perro	-3,425	43,450	10	120	12								2c		1, 2a/b
75	Valle	-3,418	43,297	15	300	27									FM	AZI
76	Sotarriza-Covanegra	-3,404	43,255	15	302	31								MAGD		
77	Morro del Horidillo	-3,400	43,257	15	302	31										
78	Arco (A,B,C)	-3,393	43,254	15	288	31										
79	Pondrá	-3,393	43,255	15	360	31										
80	Venta Laperra	-3,391	43,253	20	280	32	MP									
81	Polvorín	-3,391	43,253	20	280	32	x	xIII	GRAV							
82	Rincón	-3,391	43,253	20	280	32	MP									
83	Cuco	-3,240	43,390	10	185	18	Vb	III								
84	Lastrilla	-3,233	43,358	15	120											

85	Urdiales	-3,229	43,391	10	151	18											
86	Arenaza	-3,101	43,260	20	282	32											
87	Kurtzia	-2,958	43,402	5	166	14		AUR									
88	Arlanpe	-2,765	43,192	15	249	36				II, III							
89	Axlor	-2,755	43,143	15	235	41	MOUST										
90	Silibranka	-2,666	43,138	15	120										Final MAGD		
91	Askondo	-2,661	43,138	15	314	38		10									
92	Atxuri	-2,661	43,138	15	314	38				SOL							
93	Bolinkoba	-2,611	43,151	20	260	36			GRAV				MM				
94	Atxeta	-2,677	43,332	15	131	20				F			E (MAGD)				
95	Antoliñako	-2,664	43,371	10	335	16			GRAV								
96	Santimamiñe	-2,637	43,346	15	285	18						Csn-Camr	MM		Almp, Slnc	Arcp	
97	Abittaga	-2,514	43,342	15	197	15								UM	FM		
98	Santa Catalina	-2,509	43,377	10	120									III	II		
99	Lumentxa	-2,502	43,360	10	181	13					F	VII-VI		IV			
100	Atxurra	-2,494	43,327	15	186	15			GRAV/MAGD		Early Magd	Early Magd					
101	Armiña	-2,494	43,327	15	189	15				SOL				MAGD	MAGD		
102	Laminak II	-2,493	43,325	15	183	15								9 y 4			
103	Goikolau	-2,493	43,327	15	120									MAGD	MAGD		
104	Lezetxiki	-2,528	43,081	15	372	34	IIIb-VI	IIIa	II	II				Ia			
105	Labeko Koba	-2,508	43,061	20	351	41		V, VII									
106	Etxeberri	-2,384	43,252	20	148	19											
107	Ermittia	-2,370	43,270	15	204	17				V			III				
108	Praileaitz	-2,368	43,277	15	188	16						LM					
109	Urtiaga	-2,319	43,281	15	269	15					G	F			D	C	
110	Ekain	-2,267	43,237	15	185	20				VIII		VII		V	VI	II, III-V	
111	Danbolinzulo	-2,255	43,245	15	333	19											
112	Amalda	-2,201	43,227	20	262	19			VI	IV, V	IV						
113	Erralla	-2,182	43,209	20	352	20						V			III-I		
114	Usategi	-2,178	43,008	20	331	39				Perigord. sup.							
115	Altxerri	-2,133	43,268	15	131	13								MAGD			
116	Abauntz	-2,042	43,017	20	1275	39						C	e	2r, e(Harpoon)			
117	Ametzagaina	-1,951	43,308	10	229	13			GRAV								
118	Astigarraga	-1,948	43,281	15	137	16											
119	Aitzbitarte III/IV	-1,904	43,265	15	263	19			III,IV,Va,Vbsup, Vbmid	II	III	LM					
120	Torre	-1,862	43,299	15	200	18								MAGD			
121	Alkerdi	-1,516	43,276	15	255	36			2			LM					
122	Isturitz	-1,201	43,354	15	227	49			GRAV								
123	Palomera	-3,664	43,033	15	894	55									Magd-Azi	Magd-Azi	
124	Arrillor	-2,734	42,973	15	717	56	MOUST										
125	Atxoste	-2,475	42,753	15	813	70											
126	Coscobilo	-2,190	42,901	15	662	50				SOL							
127	Legintxiki	-1,790	42,794	15	533	67				SOL	MAGD	LM					
128	Zatoya	-1,168	42,903	20	1116	87			IIb am						II b		
Total	**Sites**						**16**	**14**	**25**	**35**	**19**	**40**	**19**	**31**	**22**	**14**	
Total	**Levels**						**27**	**20**	**32**	**48**	**26**	**52**	**34**	**46**	**27**	**19**	

Appendix H.3 Chronometric records used for radiocarbon model

Age of economic changes and settlement in the Cantabrian region was reconstructed by means of directly dated archaeological sequences based on radiocarbon dates. See Appendix Table H.3.1.

Appendix Table H.3.1: Radiocarbon dates used for chronology modelling.

Layer	Period	C14 age (uncal BP)	SD (±)	Lab-Number	Age (cal BP)	SD (±)	C14-Method	Reference
Abauntz, 2r	*UFM*	11760	90	OxA-5116	13660	90	AMS	(Utrilla 1982; Corchón-Rodríguez 2002)
Abauntz, C	*LM*	15800	350	Ly-1965	19050	390	?	(Utrilla 1982; Utrilla et al. 2012)
Abauntz, e2	*MM*	13500	160	OxA-5983	16530	330	AMS	(Utrilla 1982; Utrilla et al. 2012)
Abauntz, f	*SOL*	21600	200	GrN-21011	25690	350		(Utrilla et al. 2015)
Abrigo del Cuco, III	*AUR*	35050	650	OxA-32502	40070	980	UF AMS	(Marín-Arroyo et al. 2018b)
Aitzbitarte III, II	*GRAV*	19765	220	Ua-37959	23680	240	AMS	(Gómez-Olivencia et al. 2013)
Aitzbitarte III, III	*GRAV*	19230	200	Ua-24964	23080	220	AMS	(Gómez-Olivencia et al. 2013)
Aitzbitarte III, IV	*GRAV*	29020	320	OxA-32499	33480	390	UF AMS	(Marín-Arroyo et al. 2018b)
Aitzbitarte III, V	*GRAV*	24910	770	I-15208	29710	880	C14	(Altuna 1992)
Aitzbitarte III, Va	*GRAV*	31090	400	OxA-32420	35100	390	UF AMS	(Marín-Arroyo et al. 2018b)
Aitzbitarte III, Vb cent.	*GRAV*	30990	390	OxA-32416	35040	380	UF AMS	(Marín-Arroyo et al. 2018b)
Aitzbitarte III, Vb sup	*GRAV*	31600	400	OxA-32418	35480	440	UF AMS	(Marín-Arroyo et al. 2018b)
Aitzbitarte III, VI	*GRAV*	23830	345	Ua-2628	28790	470	AMS	(Soto 2003)
Alkerdi, 2	*GRAV*	26470	530	GrN-20322	31180	490	Conv.	(Barandiarán-Maestu 1995)
Altamira	*LM*	14480	250	GifA-90057	17570	250	AMS	(Gómez-Olivencia et al. 2013)
Altamira, 6	*SOL*	17200	90	GrA- 32760	20650	120	AMS	(Gómez-Olivencia et al. 2013)
Altamira, 7	*SOL*	18750	100	GrA- 30324	22610	100	AMS	(Gómez-Olivencia et al. 2013)
Altamira, 8	*GRAV*	21910	90	GrA-32765	26290	250	AMS	(Gómez-Olivencia et al. 2013)
Altamira, lower	*SOL*	18540	320	GifA-90045	22220	440	AMS	(Bernaldo de Quirós 1982)
Amalda, IV	*SOL*	21000	40	OxA-10103	24940	60	UF AMS	(Altuna 1990)
Amalda, V	*GRAV*	14745	75	OxA-32427	17860	40	UF AMS	(Marín-Arroyo et al. 2018b)
Amalda, VI	*GRAV*	28540	310	OxA-32426	33000	400	UF AMS	(Marín-Arroyo et al. 2018b)
Amalda, VII	*LMP*	42600	1600	OxA-34933	45950	1620	UF AMS	(Marín-Arroyo et al. 2018b)
Antoliñako, Lab	*GRAV*	22640	120	Beta-233766	27380	310	AMS	(Aguirre 2012)
Antoliñako, Lmbk inf/Smk	*EUP*	30640	240	Beta-251304	34750	270	AMS	(Aguirre 2012)
Antoliñako, Lmbk sup	*GRAV*	26080	200	Beta-215542	30990	310	AMS	(Aguirre 2012)
Antoliñako, Lmc	*SOL*	19020	120	Beta-230284	22910	170	AMS	(Aguirre 2012)
Arlanpe, 2	*GRAV*	23050	100	Beta-313143	27940	90	AMS	(Gómez-Olivencia et al. 2013)
Arlanpe, I	*MM*	14150	60	Beta-287336	17320	130	AMS	(Gómez-Olivencia et al. 2013)
Arlanpe, II	*IM*	17160	70	Beta-261389			AMS	(Rios-Garaizar et al. 2008)
Arlanpe, II	*SOL*	19000	340	I-11663	22850	360	C14	(Rios-Garaizar et al. 2008)
Arlanpe, III	*SOL*	17060	80	Beta 238178	20500	100	AMS	(Rios-Garaizar et al. 2008)
Arrillor, Lamc	*LMP*	45600	2300	OxA-22655	49150	2680	UF AMS	(Wood et al. 2014)
Arrillor, Lmc	*LMP*	44900	2100	OxA-21986	48370	2400	UF AMS	(Wood et al. 2014)
Axlor, IV	*LMP*	42010	1280	Beta-144262	45290	1260	AMS	(Gómez-Olivencia et al. 2013)
Berroberría	*UFM*	11600	130	OxA-978	13490	130	AMS	(Corchón-Rodríguez 1995)
Berroberría, G	*MM*	14430	290	BM-2375	17540	280	C14	(Corchón-Rodríguez 1995)
Bolinkoba, VI/F	*GRAV*	25280	210	OxA-32519	30150	200	UF AMS	(Marín-Arroyo et al. 2018b)
Chufín, A/1	*SOL*	17420	200	CSIC-258	20910	240	?	(Straus & Clark 1986; Soto 2003)
Cobrante, VI	*AUR*	35150	650	OxA-32505	40130	990	UF AMS	(Marín-Arroyo et al. 2018b)
Cofresnedo, Nivel 3.4	*EUP*	31360	310	GrA-20267	35270	360	AMS	(Straus et al. 2006)
Coimbre B, 1a	*UFM*	12840	70	Beta-297104	15410	90	?	(Álvarez-Alonso et al. 2017)
Coimbre B, Co.B.2	*MM*	13230	60	Beta-297105	16140	300	?	(Álvarez-Alonso et al. 2016)
Coimbre B, Co.B.4	*LM*	15710	60	Beta-340005	18790	50	?	(Álvarez-Alonso et al. 2016)
Coimbre B, Co.B.5.1	*IM*	16980	70	Beta-322480	20410	80	?	(Álvarez-Alonso et al. 2016)
Coimbre B, Co.B.6	*GRAV*	24190	110	Beta-340006	29080	330	?	(Álvarez-Alonso et al. 2017)
Covalejos, B (2)	*AUR*	34350	600	OxA-32549	39610	1010	UF AMS	(Marín-Arroyo et al. 2018b)
Covalejos, C (3)	*AUR*	34850	600	OxA-32512	39960	950	UF AMS	(Marín-Arroyo et al. 2018b)
Covalejos, I	*LMP*	43050	750	GrA-33811	46090	990	?	(Maroto et al. 2012; Schmidt et al. 2012)
Cueto de la Mina, B	*UFM*	11630	120	OxA-969	13520	130	AMS	(Castaños 1982)
Cueto de la Mina, E/V	*SOL*	19700	205	OxA-10122	23590	200	UF AMS	(Gómez-Olivencia et al. 2013)
Cueto de la Mina, H (VII)	*GRAV*	26470	520	Ua-3587	31180	490	AMS	(Castaños 1982)
Ekain, IXb	*EAUR*	31110	400	OxA-32424	35120	390	UF AMS	(Marín-Arroyo et al. 2018b)
Ekain, V	*UFM*	13350	250	CSIC-172	16250	470	?	(Altuna & Merino 1984; Soto 2003)
Ekain, VI	*UFM*	12050	190	I-9240	14160	350	?	(Altuna & Merino 1984; Soto 2003)
Ekain, VII	*LM*	15400	240	I-12226	18410	310	?	(Altuna & Merino 1984; Soto 2003)
Ekain, VIII	*SOL*	20900	450	I-13005	24980	570	?	(Altuna & Merino 1984; Soto 2003)
El Buxu, 1	*MAGD*	12600	70	GrA-2462	15070	130	AMS	(Soto 2003)
El Buxu, 2	*MAGD*	13720	280	GrN-18385	16720	430	C14	(Soto 2003)
El Buxu, SecD3	*SOL*	16730	500	GrN-19386	20040	620	C14	(Soto 2003)
El Castillo, 6	*UFM*	10310	120	OxA-970	12150	280	AMS	(Wood et al. 2014)
El Castillo, 8 c	*LM*	16850	220	OxA-971	20240	270	AMS	(Wood et al. 2014)
El Castillo, 12	*GRAV*	24070	150	Beta-242617	28950	350	AMS	(Wood et al. 2014)
El Castillo, 16	*AUR*	38600	1000	OxA-22200	42810	660	UF AMS	(Wood et al. 2014)
El Castillo, 16/17	*AUR*	39100	1000	OxA-22201			UF AMS	(Wood et al. 2014)
El Castillo, 18B	*AUR*	45800	2300	OxA-21972	49360	2700	UF AMS	(Wood et al. 2014)

Layer	Period	C14 age (uncal BP)	SD (±)	Lab-Number	Age (cal BP)	SD (±)	C14-Method	Reference
El Castillo, 18C	*AUR*	42000	1500	OxA-22203	45370	1420	UF AMS	(Wood et al. 2014)
El Castillo, 19		44900	2100	OxA-21974			UF AMS	(Wood et al. 2014)
El Castillo, 20(B2)	*LMP*	43300	2900	GifA-92506	47180	2860	AMS	(Wood et al. 2014)
El Castillo, 20C	*LMP*	48700	3400	OxA-22204	51650	3460	UF AMS	(Wood et al. 2014)
El Horno, 1	*UFM*	12530	192	GX-27457	14840	380	C14	(Costamagno & Fano 2005)
El Horno, 2	*UFM*	12250	191	GX-27456	14410	360	C14	(Costamagno & Fano 2005)
El Juyo, 4	*LM*	13920	240	I-10736	17180	260	C14	(Barandiarán-Maestu et al. 1985)
El Juyo, 6	*LM*	15300	700	M-830	18550	740	C14	(Barandiarán-Maestu et al. 1985)
El Juyo, 7	*LM*	14440	180	I-10738	17550	210	C14	(Barandiarán-Maestu et al. 1985)
El Mirón, 12	*UFM*	12970	70	GX-22132	15560	80	AMS	(Straus et al. 2002)
El Mirón, 14	*MM*	14600	190	GX-33383	17710	170	C14	(Straus et al. 2006)
El Mirón, 15	*LM*	15010	260	GX-23392	18220	280	C14	(Straus et al. 2002)
El Mirón, 16	*LM*	15180	100	GX-23415	18290	230	AMS	(Straus et al. 2002)
El Mirón, 17	*LM*	15700	190	GX-25853	18870	170	C14	(Straus et al. 2002)
El Mirón, 18	*IM*	16080	40	UGAMS-3366r	19190	90	AMS	(Straus & González-Morales 2010)
El Mirón, 19	*IM*	16600	40	UGAMS-3365r	19980	90	AMS	(Straus & González-Morales 2010)
El Mirón, 21	*IM*	16050	40	UGAMS-3364r	19150	90	AMS	(Straus & González-Morales 2010)
El Mirón, 104	*MM*	14120	35	UGAMS-15261	17250	80	AMS	(Straus, González-Morales, Higham, et al. 2015)
El Mirón, 105	*MM*	13490	40	UGAMS-9286	16770	60	AMS	(Straus, González-Morales, Higham, et al. 2015)
El Mirón, 106	*MAGD*	12460	180	GX-32382	14720	390	C14	(Straus et al. 2006)
El Mirón, 108	*MAGD*	13660	70	GX-22703	16910	60	AMS	(Straus et al. 2002)
El Mirón, 110	*LM*	14760	70	OxA-22091	17870	40	AMS	(Straus, González-Morales, Higham, et al. 2015)
El Mirón, 111	*LM*	15530	230	GX-24469	18530	340	C14	(Straus et al. 2002)
El Mirón, 112	*LM*	15430	75	OxA-22090	18650	50	AMS	(Straus, González-Morales, Higham, et al. 2015)
El Mirón, 114	*LM*	16470	50	GX-28209	19790	100	C14	(Straus et al. 2002)
El Mirón, 116	*LM*	15220	100	GX-23416	18310	240	AMS	(Straus et al. 2002)
El Mirón, 117	*IM*	17050	60	GX-25857	20480	80	AMS	(Straus et al. 2002)
El Mirón, 118	*IM*	15460	190	GX-31933	18440	300	Cxcnt.	(Straus, González-Morales, Higham, et al. 2015)
El Mirón, 119.2	*IM*	16320	160	GX-32656	19560	250	Conv.	(Straus & González-Morales 2007)
El Mirón, 121	*SOL*	18390	300	GX-32655	22070	390	Cxcnt.	(Straus & González-Morales 2007)
El Mirón, 125	*SOL*	18980	360	GX-24470	22810	400	C14	(Straus et al. 2002)
El Mirón, 126	*SOL*	18950	350	GX-24471	22780	400	C14	(Straus et al. 2002)
El Mirón, 127	*SOL*	19230	50	UGAMS-7216	23140	100	AMS	(Straus, González-Morales, Higham, et al. 2015)
El Mirón, 128	*EUP*	27580	210	GX-27113	32140	200	AMS	(González-Morales & Straus 2013)
El Mirón, 130	*LMP*	41280	1120	GX-27112	44810	1165	UF AMS	(Marín-Arroyo et al. 2018a)
El Mirón, 306	*UFM*	11650	50	GX-24468	13520	70	AMS	(Straus et al. 2002)
El Mirón, 308	*UFM*	12350	180	GX-28210	14540	380	AMS	(Straus et al. 2002)
El Mirón, 312	*LM*	15850	170	GX-31932	19000	190	C14	(Straus et al. 2006)
El Mirón, 313	*IM*	17400	270	GX-31194	20890	310	Conv.	(Straus & González-Morales 2007)
El Mirón, 503.1	*LM*	15120	40	UGAMS-7799	18260	220	AMS	(Straus et al. 2015b)
El Mirón, 504	*LM*	15460	40	M-14585	18670	30	AMS	(Straus et al. 2015b)
El Mirón, 505	*LM*	15670	40	UGAMS-15183	18760	30	AMS	(Straus et al. 2015b)
El Olivo, 2b	*MM*	13960	40	Beta-375569	17090	40	AMS	(Álvarez-Alonso 2014)
El Pendo, II	*UFM*	12470	170	OxA-995	14740	370	AMS	(González-Echegaray 1980; Straus 1992; Soto 2003)
El Pendo, II a+b	*UFM*	13050	150	OxA-976	15930	370	AMS	(González-Echegaray 1980; Straus 1992; Soto 2003)
El Pendo, II c+d	*LM*	14830	170	OxA-977	18130	280	AMS	(González-Echegaray 1980; Straus 1992; Soto 2003)
El Ruso, III	*SOL*	16410	210	Beta 70810	19680	310	?	(Soto 2003; Álvarez-Alonso 2007)
El Ruso, IV/b	*GRAV*	28510	300	OxA-32507	32970	390	UF AMS	(Marín-Arroyo et al. 2018b)
El Valle, II(C)	*UFM*	13820	610	GX-24640	16660	860	C14	(Straus et al. 2002)
Entrefoces, Bsup	*LM*	14690	200	Ly-2937	17980	310	?	(Álvarez-Alonso 2014)
Ermittia, III	*MM*	13525	125	Ua-4516	16710	170	AMS	(Altuna 1972; Straus 1992; Soto 2003)
Ermittia, V	*SOL*	17725	165	Ua-4521	21230	180	AMS	(Altuna 1972; Straus 1992; Soto 2003)
Erralla, III-I	*UFM*	12310	190	Ua-10191	14480	380	Conv.	(Straus 1992; Soto 2003; Gómez-Olivencia et al. 2013)
Erralla, V	*LM*	15740	240	I-12540	18940	240	Conv.	(Altuna et al. 1985)
Esquilleu, VI	*LMP*	43700	1400	OxA-19965	46950	1620	UF AMS	(Wood et al. 2014)
Fuente del Salín, II	*EUP*	22340	510	GrN-18574	26850	750	C14	(Bernaldo de Quirós 1982)
Hornos de la Peña, D	*GRAV*	20930	370	BM-1883R	25020	460	Conv.	(Bowman et al. 1990)
Kurtzia, lower level (a)	*LMP*	41400	2500	UGRA-293	45330	2140	C14	(Muñoz et al. 1990)
La Fragua, 4	*UFM*	12960	50	GX-29440	15530	60	C14	(Straus et al. 2006)
La Garma	*MM*	13410	120	AA-45581	16440	320	AMS	(Ontañón-Peredo 2003)
La Guelga	*MM*	14170	130	GrN-19387	17370	180	C14	(Corchón-Rodríguez 1995)
La Guelga, 3c	*LM*	14020	130	GrN-17255	17240	170	C14	(Corchón-Rodríguez 1995)
La Guelga, 9	*LMP*	43700	800	OxA-19244	46780	1120	UF AMS	(Wood et al. 2014)
La Guelga, I-Interna	*EUP*	32000	1600	GrN-18256	36820	1920	C14	(Fernández & Villa 1992)
La Lastrilla, X	*SOL*	18370	70	GrA-31478	22090	230	?	(Muñoz Fernandez & Montes Barquin 2007)
La Lloseta	*LM*	11830	50	Beta-170182	13700	70	AMS	(Utrilla 1996)
La Paloma, 4	*UFM*	12500	140	OxA-950	14840	290	AMS	(Straus 1992; Hoyos Gómez 1995)
La Paloma, 8	*LM*	14600	160	OxA-974	17740	120	?	(Straus 1992; Hoyos Gómez 1995)
La Pila, IV.4	*UFM*	12580	190	GifA-90033	14940	340	AMS	(Utrilla 1996)
La Riera, 1	*SOL*	19620	390	UCR-1270A	23550	450	C14	(Straus & Clark 1986)
La Riera, 4	*SOL*	20970	620	GaK-6984	25110	790	C14	(Straus & Clark 1986)
La Riera, 7	*SOL*	20000	210	Q-2934	23950	290	?	(Straus & Clark 1986)
La Riera, 8	*SOL*	20690	810	GaK-6981	24820	1000	C14	(Straus & Clark 1986)
La Riera, 10	*SOL*	19820	390	GaK-6447	23800	440	C14	(Straus & Clark 1986)
La Riera, 12	*SOL*	17210	350	GaK-6446	20680	400	C14	(Straus & Clark 1986)
La Riera, 15	*SOL*	17225	350	UCR-1272A	20690	400	C14	(Straus & Clark 1986)
La Riera, 16	*SOL*	18200	610	GaK-6983	21870	720	Conv.	(Straus & Clark 1986)
La Riera, 17	*SOL*	16900	200	GaK-6445	20300	240	C14	(Straus & Clark 1986)
La Riera, 19	*LM*	15230	300	Q-2116	18330	300	C14	(Straus & Clark 1986)
La Riera, 20	*MAGD*	17160	440	GaK-6980	20590	530	C14	(Straus & Clark 1986)
La Riera, 23	*UFM*	12620	300	UCR-1274D	14970	550	C14	(Straus & Clark 1986)
La Riera, 24	*UFM*	10890	430	GaK-6982	12660	540	C14	(Straus & Clark 1986)

Layer	Period	C14 age (uncal BP)	SD (±)	Lab-Number	Age (cal BP)	SD (±)	C14-Method	Reference
La Riera, 26	*UFM*	11850	85	Q-2925	13740	100	?	(Straus & Clark 1986)
La Riera, 27(lower)	*MAGD*	12270	400	UCR-1275D	14530	620	C14	(Straus & Clark 1986)
La Viña, IV	*MM*	13300	150	Ly-3317	16230	390	C14	(Álvarez-Alonso 2014)
La Viña, IX	*GRAV*	24640	190	Oxa-21688	29610	190	UF AMS	(Wood et al. 2014)
La Viña, VII	*GRAV*	23930	180	OxA-32516	28820	370	UF AMS	(Marín-Arroyo et al. 2018b)
La Viña, X	*GRAV*	28560	300	OxA-32550	33020	400	UF AMS	(Marín-Arroyo et al. 2018b)
La Viña, XI	*EUP*	20820	130	Oxa-21686	24810	110	UF AMS	(Wood et al. 2014)
La Viña, XII	*EAUR*	31500	400	Oxa-21689	35390	430	UF AMS	(Wood et al. 2014)
La Viña, XIII	*EUP*	30650	360	Oxa-21845	34800	350	UF AMS	(Wood et al. 2014)
Labeko Koba, IV	*EUP*	33550	550	OxA-21780	38480	1640	UF AMS	(Wood et al. 2014)
Labeko Koba, IV middle	*EUP*	23365	350	Ua-3035	28220	380	AMS	(Barandiarán-Maestu 1996)
Labeko Koba, IX lower	*CHA*	37800	900	OxA-22563	42320	550	UF AMS	(Wood et al. 2014)
Labeko Koba, V	*EUP*	34650	600	OxA-21779	39830	950	UF AMS	(Wood et al. 2014)
Labeko Koba, VI	*EUP*	32150	450	OxA-21841	36580	960	UF AMS	(Wood et al. 2014)
Labeko Koba, VII	*AUR*	35250	650	OxA-21840	40190	1000	UF AMS	(Wood et al. 2014)
Laminak II, 9 y 4	*UFM*	11700	140	Ua-2362	13580	150	?	(Soto 2003)
Las Caldas, Pasillo, 3	*SOL*	18250	300	Ly-2421	21950	390	C14	(Corchón-Rodríguez 1999)
Las Caldas, Sala I, 11	*SOL*	18305	295	Ua-15316	22000	380	AMS	(Corchón-Rodríguez 1999)
Las Caldas, Sala I, 9	*SOL*	17945	370	Ua-15315	21630	520	AMS	(Corchón-Rodríguez 1995, 1999)
Las Caldas, Sala II, -II	*UFM*	12590	120	Ua-10194	15040	200	AMS	(Corchón-Rodríguez 1995)
Las Caldas, Sala II, IX	*MM*	13370	110	Ua-10188	16380	330	AMS	(Corchón-Rodríguez 1995, 1999)
Las Caldas, Sala II, XII	*LM*	14495	130	Ua-2735	17660	130	AMS	(Corchón-Rodríguez 1995)
Las Caldas, Topera, 18	*SOL*	19000	280	Ly-2429	22880	290	C14	(Corchón-Rodríguez 1999)
Legintxiki, 1a	*LM*	14865	140	Ua-3397	18150	270	AMS	(Corchón-Rodríguez 1995)
Llonín, V	*GRAV*	28390	350	OxA-X-2640-48	32850	410	UF AMS	(Marín-Arroyo et al. 2018b)
Lloseta	*LM*	15200	412	Gak-2549	18330	370	C14	(Utrilla 1996)
Los Canes	*IM*	16500	200	AA-12165	19790	290	AMS	(Arias-Cabal & Suárez 1995)
Morín, 4	*GRAV*	23640	190	Poz-66758	28450	250	UF AMS	(Stuckenrath 1978; Maíllo Fernández et al. 2001)
Morín, 7	*EUP*	28655	840	SI-955B	33120	740	C14	(Stuckenrath 1978; Maíllo Fernández et al. 2001)
Morín, 8	*AUR*	40060	350	OxA-19084	43640	490	UF AMS	(Maroto et al. 2012)
Morín, 9	*AUR*	33430	250-230	GrA-33891	37680	880	UF AMS	(Maroto et al. 2012)
Morín, 11	*LMP*	41800	450	OxA-19083	44950	710	UF AMS	(Maroto et al. 2012)
Oscura de Ania, 3b	*MM*	13500	150	Gif-5407	16560	300	C14	(Straus et al. 2002)
Palomera, ?	*LM*	15600	230	Gif-1721	18730	240	C14	(Corchón-Rodríguez 2002)
Perro, 2c	*UFM*	12140	180	GrN-20962	14260	340	C14	(Straus et al. 2002)
Praileaitz I, Vestibulo	*LM*	14700	100	GrA-20462	17840	50	AMS	(Gómez-Olivencia et al. 2013)
Rascaño, 2	*UFM*	12282	164	BM-1450	14430	340	C14	(González-Echegaray & Barandiarán-Maestu 1981)
Rascaño, 3	*LM*	15173	160	BM-1452	18290	240	C14	(González-Echegaray & Barandiarán-Maestu 1981)
Rascaño, 4a	*LM*	15988	193	BM-1453	19150	240	C14	(González-Echegaray & Barandiarán-Maestu 1981)
Rascaño, 5	*IM*	16433	131	BM-1455	19720	210	C14	(González-Echegaray & Barandiarán-Maestu 1981)
Santimamiñe, Almp	*UFM*	12250	70	Beta-240903	14360	230	AMS	(López Quintana 2011)
Santimamiñe, Csn-Camr	*LM*	14650	80	Beta-240905	17820	40	AMS	(López Quintana 2011)
Santimamiñe, Slnc	*UFM*	12790	70	Beta-240902	15350	100	?	(López Quintana 2011)
Tito Bustillo, 1b/ XIIC	*UFM*	12850	90	OxA-6259	15410	110	AMS	(Straus 1992; Soto 2003)
Tito Bustillo, 1c	*MM*	13520	220	I-8332	16450	430	C14	(Moure-Romanillo & González-Morales 1988)
Tito Bustillo, 2	*MAGD*	14890	410	Ly-4212	18080	410	C14	(Moure-Romanillo & González-Morales 1988)
Urtiaga, D	*UFM*	10280	190	CSIC-64	12040	380	Conv.	(Corchón-Rodríguez 1995)
Urtiaga, F inf	*IM*	17050	140	GrN-5817	20500	160	Conv.	(Corchón-Rodríguez 1995)
Zatoya	*UFM*	11480	270	Ly-1399	13390	270	C14	(Corchón-Rodríguez 2002)
Zatoya, IIb am	*GRAV*	28870	730	GrN-239989	33260	670	?	(Corchón-Rodríguez 2002)

Appendix H.4 Criteria used for analysis of hunting strategies

Regional archeozoological analysis are based on published faunal data from the study area and focuses on NISP values of the main prey species (horse, Bos/Bison, ibex, chamois, red deer, reindeer, roe deer and wild boar). The degree of biodiversity of main prey species was determined by calculating the Inverse of Simpson's Index (I.SimpInd) (SIMPSON 1949; MARÍN-ARROYO 2013), the percentage of young individuals (lower ranked prey) and individuals from lower ranked species (roe deer and wild boar) per assemblage is shown; if available seasonality data was also included. Appendix Table H.4.1 is a summary of the compiled data.

Appendix Table H.4.1: NISP, ranking and seasonality data used for analysis of hunting strategies in the Cantabrian region.

Site, Level	Period	HORSE (NISP)	BOS/BISON (NISP)	IBEX (NISP)	CHAMOIS (NISP)	RED DEER (NISP)	REINDEER (NISP)	ROE DEER (NISP)	WILD BOAR (NISP)	SUM NISP (ungulate prey)	I.SimpInd	Ranking by Age	Ranking by Species	Seasonality
Abauntz, 2r	UM	45	5	23	19	19	1		1	113	3.9	0		
Abauntz, C	LM											/		X
Abauntz, e	MM	10	3	8	31	6	4	0	0	62	3.2	0	0	
Abauntz, e(Harpoon)	UM	120	27	82	186	91	2	1	4	513	4.1	0	6	
Abrigo del Cuco, III	GRAV	1	7	15		17				26	2.0	0		
Aitzbitarte III, II	SOL	1	54	4	114	61	2	1		237	2.9	23	8	
Aitzbitarte III, III	GRAV	5	221	1	258	117	7	3		612	2.9	27	6	X
Aitzbitarte III, IV	GRAV	2	184		88	73	2	5		354	2.7	25	7	X
Aitzbitarte III, Va	GRAV		103		43	53	4	8		211	2.9	36	10	X
Aitzbitarte III, Vb sup	GRAV		53		9	65				127	2.3	0	0	X
Aitzbitarte III, Vbmid	GRAV	12	51		22	70		3		158	3.1	0		X
Aitzbitarte IV, 4	SOL	2	9	3	62	101	0	2	0	179	2.3	0	6	
Altamira, (1924) Magd.	IM											0	6	
Altamira, (1981) Magd.	IM											0	15	
Altamira, lower	SOL											0	7	
Amalda, IV	SOL	2	9	134	503	144	1	1	5	799	2.2	38	8	X
Amalda, V	SOL	8	9	172	1022	94		1	18	1324	1.6	23	4	X
Amalda, VI	GRAV	101	99	236	2769	274	2	17	3	3501	1.6	36	5	X
Arlanpe, II	SOL		1		3	2				6	2.6	0	0	
Arlanpe, III	SOL		0	40	5	6		1		52	1.6	0	13	
Buxu, SecD3	SOL		0		50	13				63	1.5	0		
Chufín, A/1	SOL		0	104	11	105				220	2.2	0	0	
Coimbre B, 1 & 2 (old?)	UM	8	4	722	57	560	0	31	1	1383	2.3	0		
Coimbre B, 1a	UM	11	9	1182	127	278		33	2	1837	1.8	4	4	X
Coimbre B, 1b/c	UM	8	20	1881	258	393		11	3	2890	1.8	10	3	X
Coimbre B, 2	MM	4	5	195	30	35		6		282	1.9	0	6	
Coimbre B, 4	LM	5	16	254	20	76				376	1.8	9	0	
Coimbre B, 6	GRAV	6	47	46		24				124	3.1	22	0	
Cueto de la Mina, B	UM	3	4	38	2	34	1	3		85	2.7	0		
Cueto de la Mina, E	SOL	44	14	44	2	169	1	2	1	277	2.4	16	6	X
Cueto de la Mina, H	GRAV	48	1	1		2	1		2	55	1.3	0	10	

Site, Level	Period	HORSE (NISP)	BOS/BISON (NISP)	IBEX (NISP)	CHAMOIS (NISP)	RED DEER (NISP)	REINDEER (NISP)	ROE DEER (NISP)	WILD BOAR (NISP)	SUM NISP (ungulate prey)	I.SimpInd	Ranking by Age	Ranking by Species	Seasonality
Ekain, V	UM		3	20	1	71		1		96	1.7	0	10	X
Ekain, VI	FM		3	160	9	47	4	2		225	1.8	40	10	X
Ekain, VII	LM	6	9	81	8	650		9		763	1.4	0		X
Ekain, VIII	SOL		4	14	75	54		5	1	153	2.7	0	13	X
El Castillo, 6 inf	UM		8	24	30	57		1	2	122	3.1	0	3	
El Castillo, 8	LM		143	14	151	755		11	47	1121	2.0	0	0	
El Horno, 1	UM	2	0	246	1	37		0	0	286	1.3	0	0	
El Horno, 2	UM	5	0	661	3	162		2	1	834	1.5	0	10	X
El Juyo, 4	LM	42	44	23		1662		49	2	1822		0	9	
El Juyo, 6	LM	19	2	37		1462		27	1	1548	1.1	0	6	
El Juyo, 7	LM	2	1			140		9		152	1.2	0	14	
El Mirón, 102	UM		0	52	8	112		20	3	195	2.4	62		
El Miron, 102.1	FM			7	3	16		5	1	32		50	0	
El Miron, 102.2	FM			9	2	19		2		32		67	0	
El Miron, 104	UM	1		86	1	89				177		50	0	
El Miron, 104.2	UM			2		3				5		0	38	
El Miron, 104.3	UM					1				1		0	17	
El Miron, 105	UM			18		24				42		60	0	
El Mirón, 106	UM	4	0	211	13	228		2	1	459	2.2	53	36	X
El Miron, 106.1	UM					49		1		50		44	13	
El Mirón, 108	MM	1	2	1096	62	1524				2685	2.0	59	11	X
El Mirón, 11	UM		0	79	2	80		27	1	189	2.7	55	0	X
El Mirón, 11.1	FM		0	31	1	31		2		65	2.2	88	0	X
El Miron, 11.2	FM			11	1	11		1		24		20	0	
El Mirón, 12	UM	3	0	33		24		6		66	2.5	38	0	
El Mirón, 121	SOL			44	13	63				120	2.4	56	6	
El Mirón, 122	SOL		2	75	3	67				147	2.1	50	3	
El Miron, 123	SOL			12	2	7						0	6	
El Mirón, 124	SOL	1		30	9	24				64	2.6	63	3	
El Mirón, 125	SOL			25	3	14				42	2.1	63	0	
El Miron, 126	SOL			8	9	14						17	0	
El Mirón, 127	SOL			7		7				14	2.0	60	0	
El Mirón, 128	EUP			69	7	40				116	2.1	57	0	
El Mirón, 129	EUP			26	1	8				35	1.7	33	0	
El Miron, 13	MM	4		21	7	15				47		67	0	
El Mirón, 130	MP	2		54	10	15				81	2.0	43	0	
El Mirón, 14	MM		0	117	1	56		9	3	186	2.0	38	14	
El Mirón, 15	LM	1	0	500	9	339				849	2.0	25	0	
El Mirón, 16	LM	3	1	627	4	347				982	1.9	41	0	
El Mirón, 17--10	LM	8	8	987	11	875	1	3		1893	2.1	41	38	
El Mirón, 17--12	LM	10	8	734	4	772		3		1531	2.1	44	0	
El Mirón, 17--6	LM	3	1	364	4	142		3		517	1.8	38	0	
El Mirón, 17--8	LM	6	22	938	12	693		1		1672	2.1	28	0	
El Mirón, 18	IM	1		28		14				43	1.9	40	0	
El Mirón, 19	IM			9		2				11	1.4	0	0	
El Mirón, 20	IM			3		1				4	1.6	0	0	

Site, Level	Period	HORSE (NISP)	BOS/BISON (NISP)	IBEX (NISP)	CHAMOIS (NISP)	RED DEER (NISP)	REINDEER (NISP)	ROE DEER (NISP)	WILD BOAR (NISP)	SUM NISP (ungulate prey)	I.SimpInd	Ranking by Age	Ranking by Species	Seasonality
El Mirón, 21	IM			4		5				9	2.0	0	0	
El Mirón, 306	FM	1	1	26	8	63		14	1	114	2.6	46	0	X
El Mirón, 308	UM		0	20	7	21				48	2.6	57	25	X
El Mirón, 504	LM	7		386	5	214				612	1.9	17	0	
El Pendo, II	FM	9	16	16	5	427		5	2	480	1.3	67	9	X
El Pendo, II a+b	UM	7	12	10		299		1	1	330	1.2	0	12	X
El Pendo, II c+d	LM	2	12	26		343		4	1	388	1.3	50	7	X
Ermittia, III	MM	1	1	234	9	20	4	1	6	276	1.4	22	13	
Ermittia, V	SOL	1	0	74	31	19	4	2	1	132	2.6	35	10	
Erralla, III-I	FM	5	4	132	65	48	4	3		261	2.8	0	10	
Erralla, V	LM	1	1	2375	3	198	1	2		2581	1.2	0	3	
Hornos de la Peña, C	SOL	254	27	32	98	150		13	0	574	3.3	16	4	X
La Fragua, 4	UM		5	114	1	79		13	7	219	2.5	0	27	X
La Lastrilla, X	SOL		0	7		56				63	1.2	0		
La Paloma, 4	FM	1	1	9	7	597				615	1.1	42	0	X
La Paloma, 8	LM	41	10	11	20	1738	1	2		1823	1.1	19	1	X
La Riera, 1	GRAV	116	62	18	4	161		2		363	3.0	0	4	X
La Riera, 1	GRAV											36		
La Riera, 19 (top,bottom)	LM	7	0	372	1	1323		2		1705	1.5	42		X
La Riera, 4	SOL	24	8	425	0	216	0	0	0	673	2.0	31	0	X
La Riera, 7	SOL	31	5	548	18	1557	0	31	0	2190	1.8	0	7	X
La Riera, 8	SOL	9	2	513	0	1172	0	10	0	1706	1.8	37	10	X
La Riera, 15	SOL	7	2	235	20	1000	0	7	0	1271	1.5	24	3	X
La Riera, 16	SOL	2	1	260	7	797	0	2	0	1069	1.6	33	2	X
La Riera, 17	SOL	1	1	96	0	223	0	0	0	321	1.7	38	0	X
La Riera, 19/20	UM	1	0	163	1	706	0	0	0	871	1.4	38	5	X
La Riera, 21-23	UM	17		156		983	2	6	2	1166	1.4	33	17	X
La Riera, 24	UM	8	0	350	8	431	5	23	0	825	2.2	48	10	X
La Riera, 26	UM	2	0	130	13	407	0	43	3	598	1.9	0	24	X
La Riera, 27 (lower)	UM	9	12	131	45	586	0	45	16	844	2.0	32	19	X
Laminak II, 9 y 4	UM											0	38	
Las Caldas, Sala II, II-VI	MM	10	0	36		65				111	2.2	50	0	X
Las Caldas, Sala II, IV	MM	70	2	1010	292	1671		1		3046	2.4	15	4	X
Las Caldas, Sala II, IX	MM	980	7	1479	303	3729	1	20		6519	2.5	23	13	X
Las Caldas, Sala II, VII	MM	115	7	1600	304	2980		8		5014	2.2	16	3	X
Las Caldas, Sala II, VIII	MM	389	9	382	215	1112	1	27		2135	2.9	20	14	X
Morín, 5a	GRAV	30	29	8	3	373		94	1	538	1.9	25	23	
Perro, 2c	UM											20	6	
Rascaño, 2	FM	7	0	557	7	67			2	640	1.3	46	5	X
Rascaño, 3	LM	4	1	510	2	26				543	1.1	29	0	
Rascaño, 4a	LM	1	1	673		63				738	1.2	17	0	X
Rascaño, 5	LM	5	2	1313		113				1433	1.2	24	0	X
Rascaño, 7	GRAV		0	9		1				10	1.2	0	0	
Ruso, III	SOL	478	46	63	8	1278		21	1	1895	1.9	39	10	
Santimamiñe, Almp	FM	3	3	76	1	61	1	5	1	151	2.4	38		X
Santimamiñe, Csn-Camr	LM	1	0	9	13	255	1			279	1.2	57		X

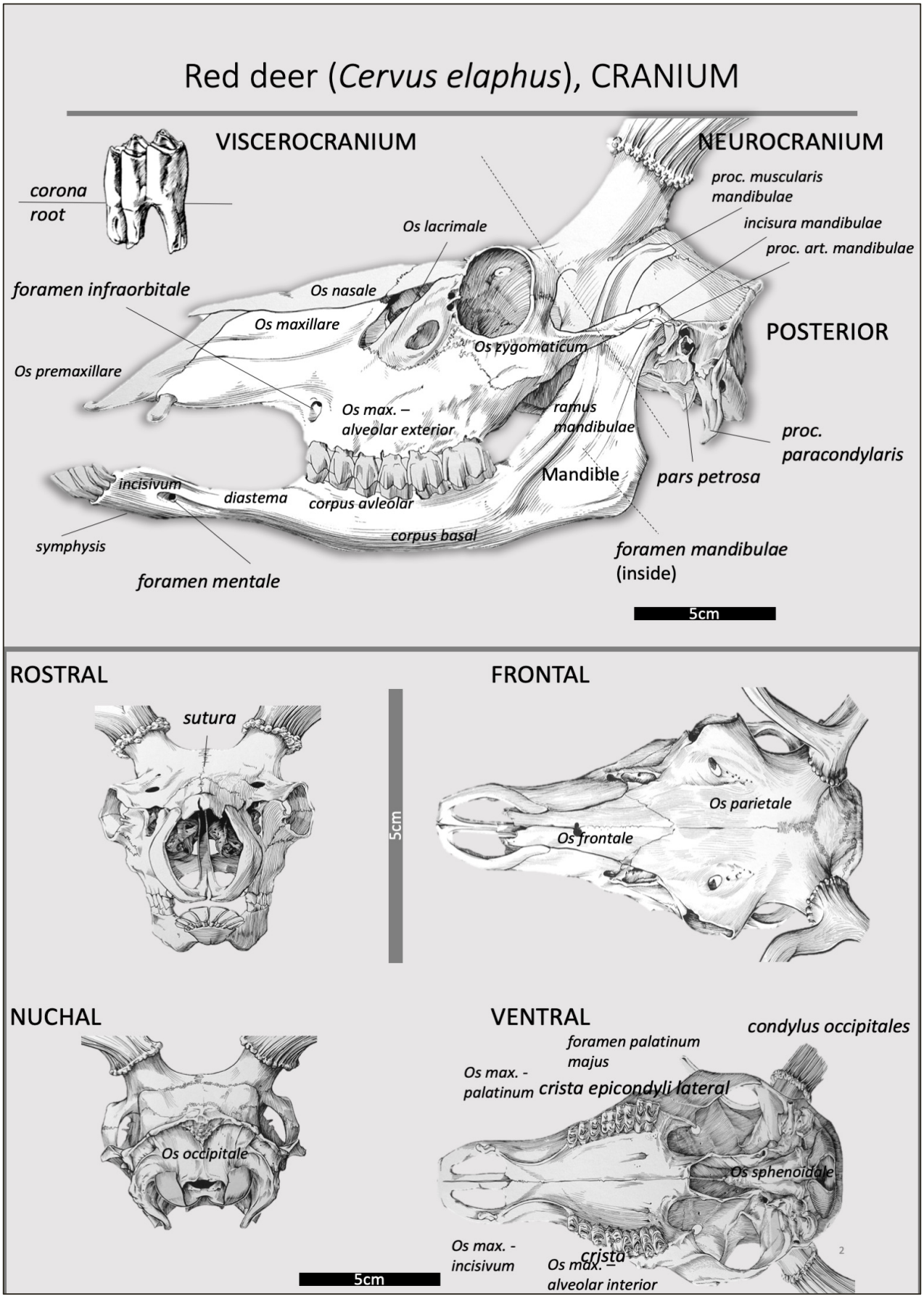
Site, Level	Period	HORSE (NISP)	BOS/BISON (NISP)	IBEX (NISP)	CHAMOIS (NISP)	RED DEER (NISP)	REINDEER (NISP)	ROE DEER (NISP)	WILD BOAR (NISP)	SUM NISP (ungulate prey)	I.SimpInd	Ranking by Age	Ranking by Species	Seasonality
Santimamiñe, Slnc	FM	1	15	52		83		17	1	169	2.8	38		X
Tito Bustillo, 1a	LM	62	19	126	17	836		3		1063	1.6	26	4	X
Tito Bustillo, 1b/ XIIC	UM	51	14	172	40	1062	1			1340	1.5	29	0	X
Tito Bustillo, 1c	MM	36	7	151	19	1222				1435	1.4	35	0	X
Tito Bustillo, 2	LM	3	6	10	4	418				441	1.1	25	0	X
Urtiaga, D	FM	29	16	545	245	1002	46	226	24	2133	3.2	32	16	X
Urtiaga, F	LM	8	20	112	73	557	12	43	0	825	2.1	0	20	X
Zatoya, II b	FM	2	0	66	56	268			78	470	2.6	58	26	
Zatoya, IIb am	GRAV	9	1	6	67	46			4	133	2.6	20	9	

Appendix I Anatomical location of landmarks in skeletal elements

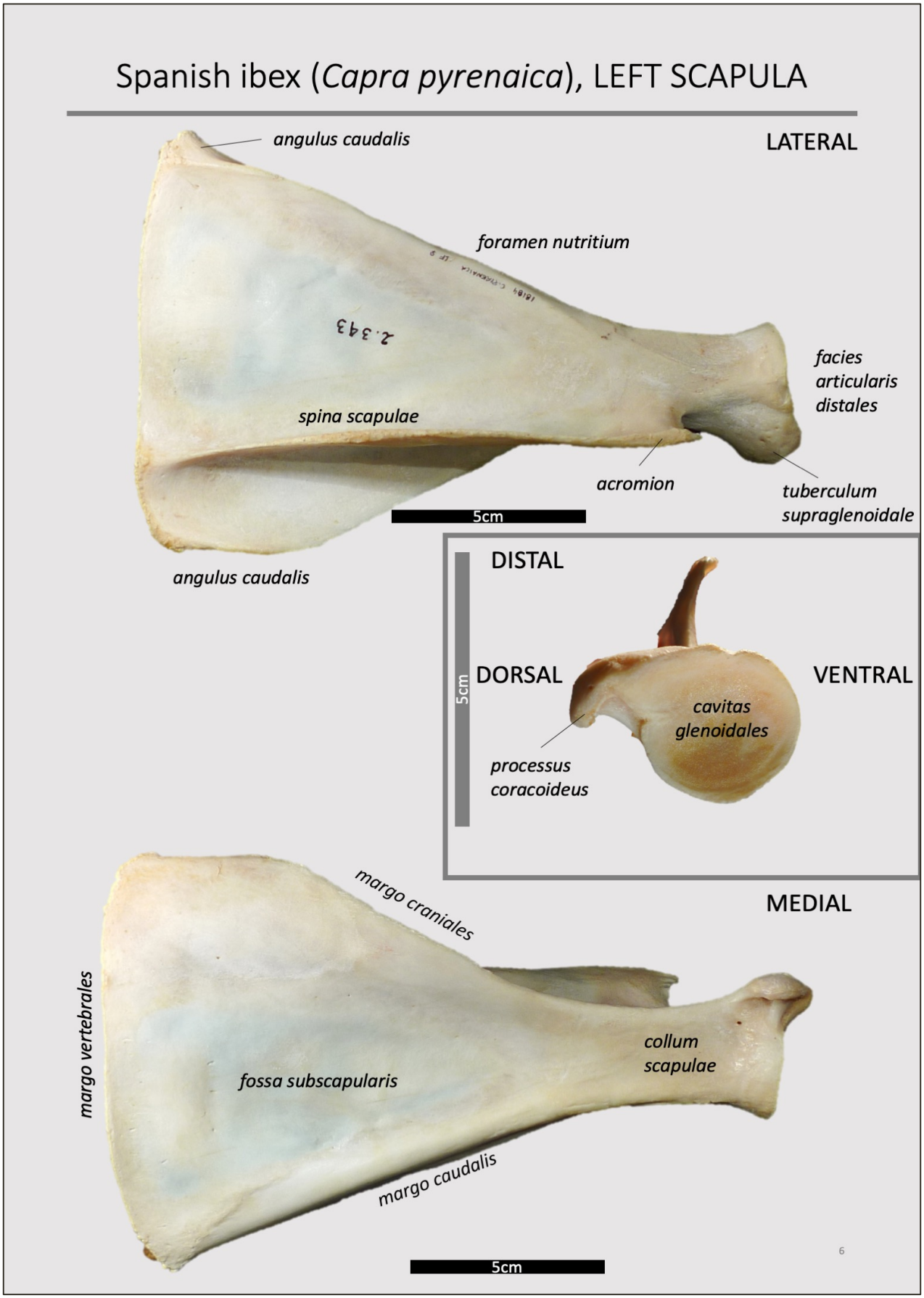
Appendix I includes illustration a of anatomical position of landmarks that were used for archeological identification as well as for estimating MNE and MNI.

Plates will appear according their anatomical order in body parts:

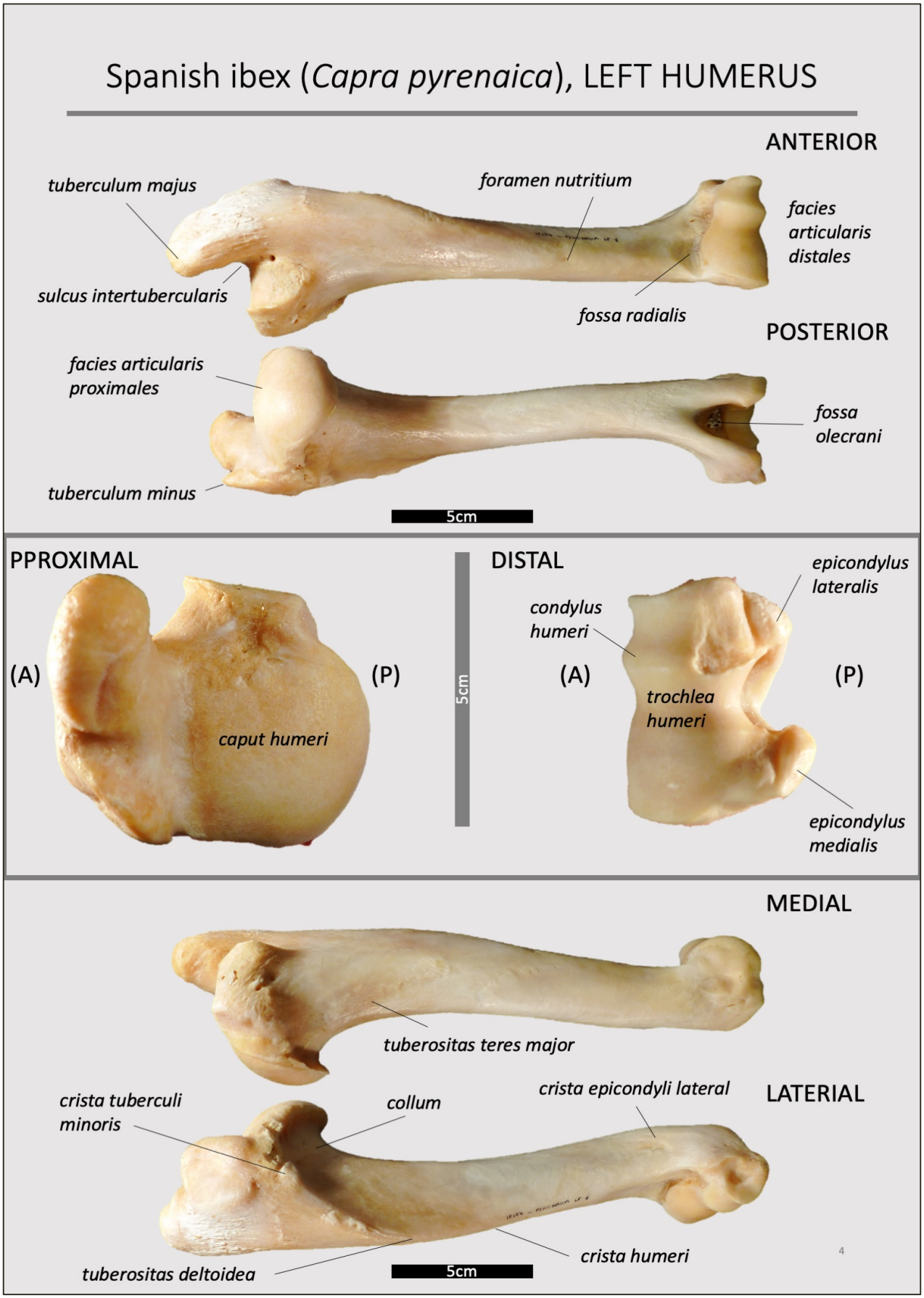
- Appendix Figure I.1 shows head of Spanish ibex (*Capra pyrenaica*)
- Appendix Figure I.2 shows shoulder of Spanish ibex (*Capra pyrenaica*)
- Appendix Figure I.3shows humerus of Spanish ibex (*Capra pyrenaica*)
- Appendix Figure I.4 shows radius of Spanish ibex (*Capra pyrenaica*)
- Appendix Figure I.5 shows pelvis of Spanish ibex (*Capra pyrenaica*)
- Appendix Figure I.6 shows femur of Spanish ibex (*Capra pyrenaica*)
- Appendix Figure I.7 shows tibia of Spanish ibex (*Capra pyrenaica*)
- Appendix Figure I.8 shows metapodia of Spanish ibex (*Capra pyrenaica*)
- Appendix Figure I.9 shows phalanges of Spanish ibex (*Capra pyrenaica*)
- Appendix Figure I.10 shows vertebrae of Spanish ibex (*Capra pyrenaica*)



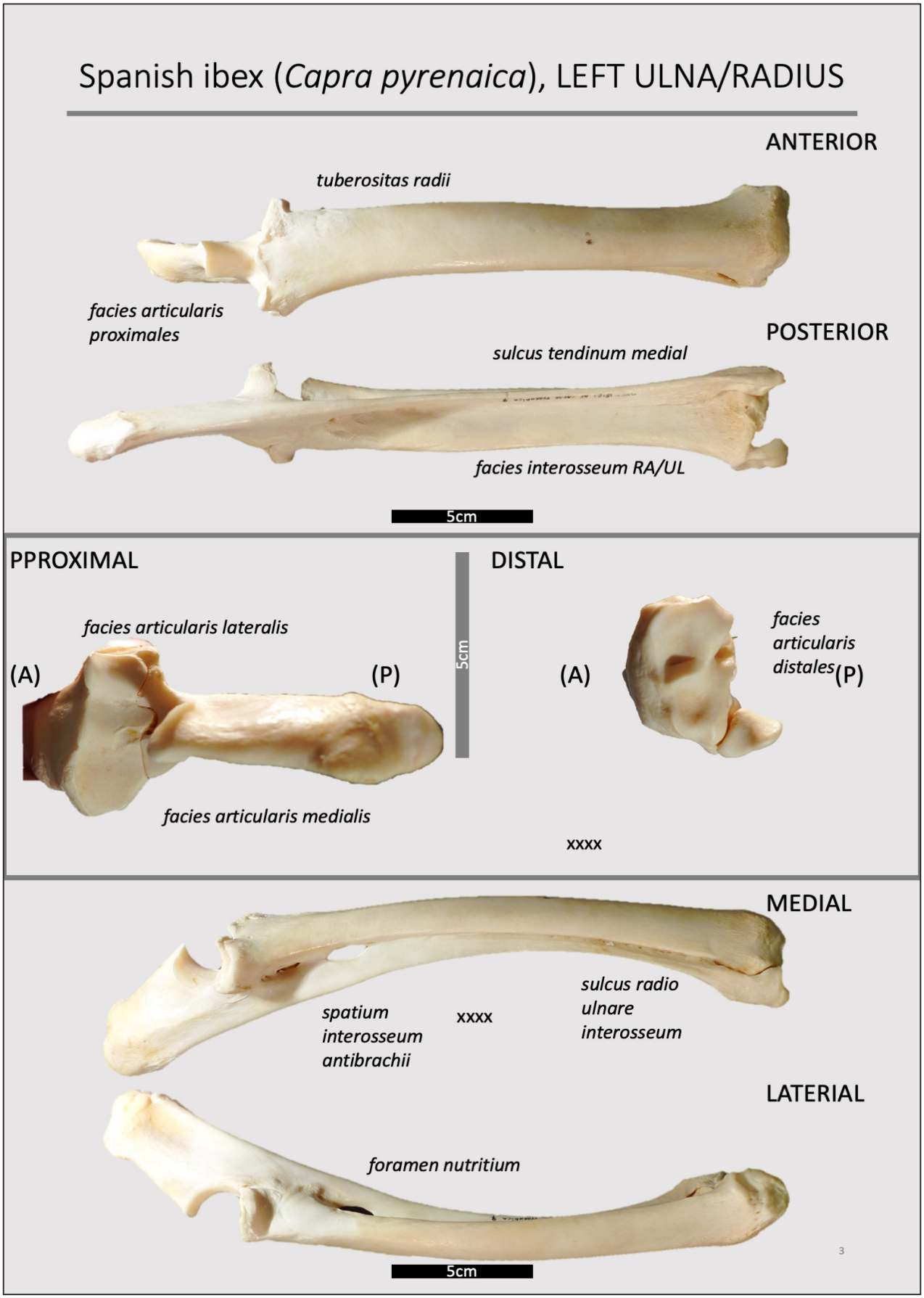
Appendix Figure I.1: Landmarks on cranial skeletal remains shown on red deer cranium. Illustrations were adapted and modified from Pales and Lambert (PALES & LAMBERT 1971).



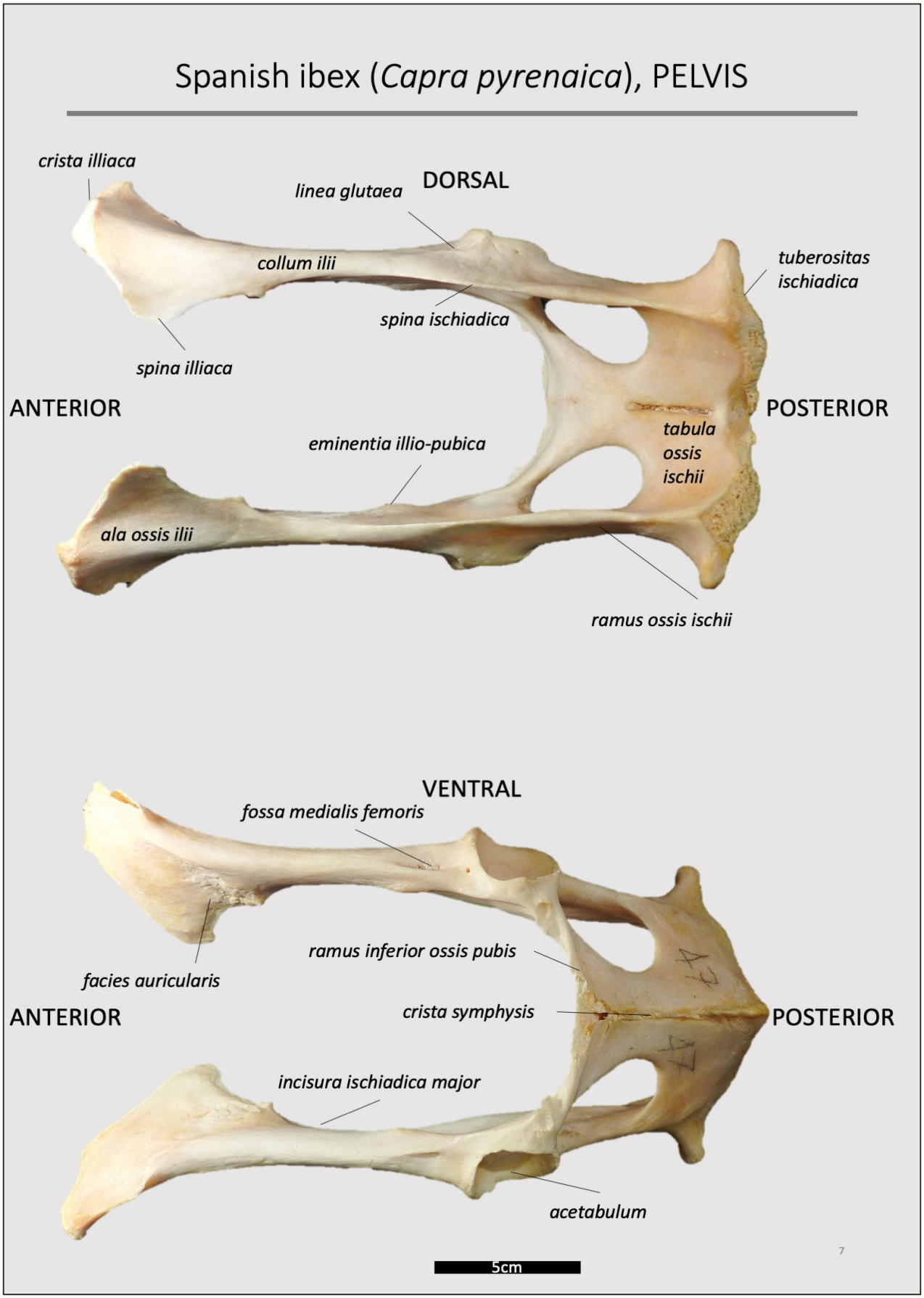
Appendix Figure D.2: Skeletal morphology and landmarks on scapula from Spanish ibex (*Capra pyrenaica*). Photographs (by JMG) show items from the Bioarchaeological reference collection.



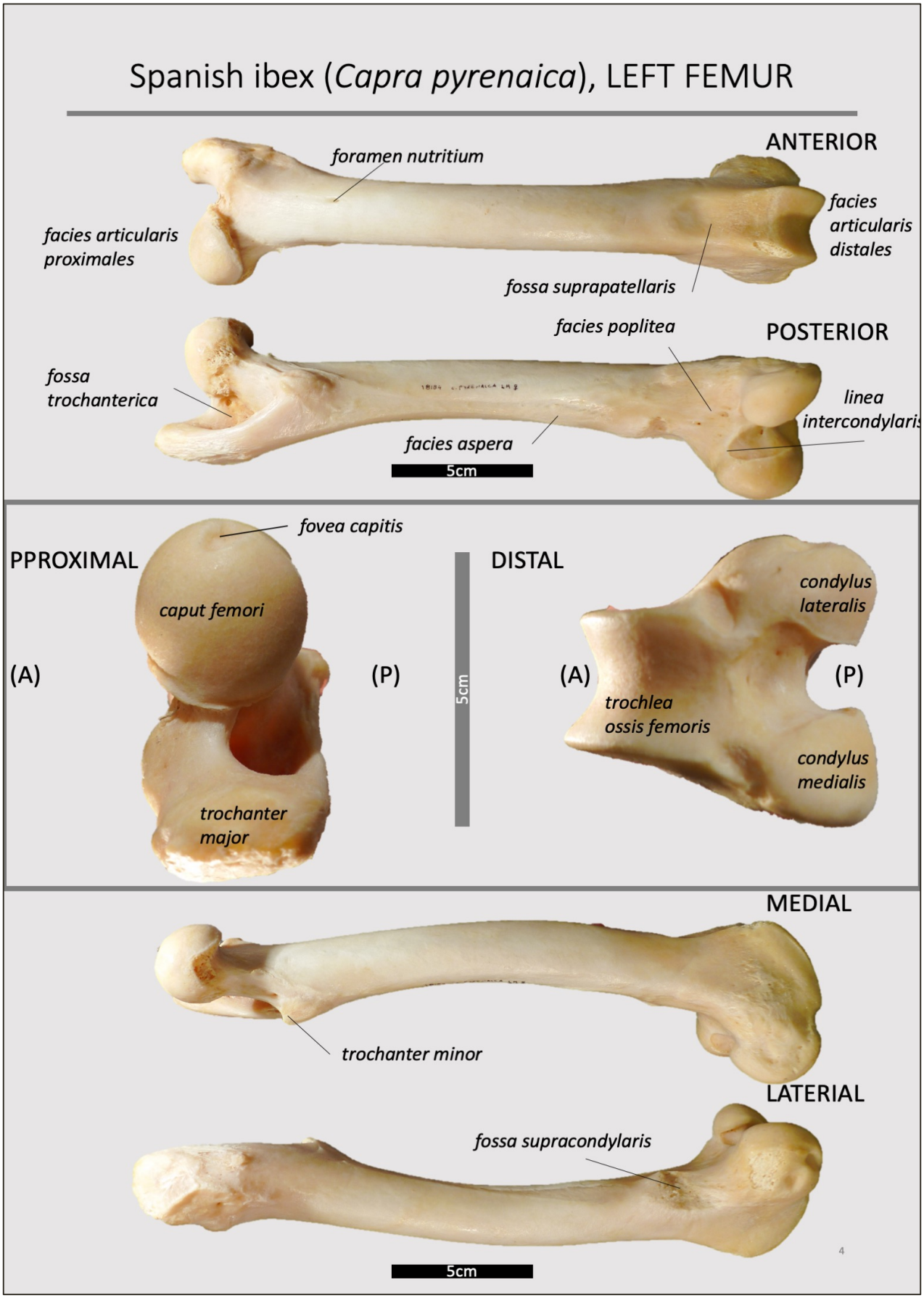
Appendix Figure I.3: Skeletal morphology and landmarks on humerus from Spanish ibex (*Capra pyrenaica*). Photographs (by JMG) show items from the Bioarchaeological reference collection.



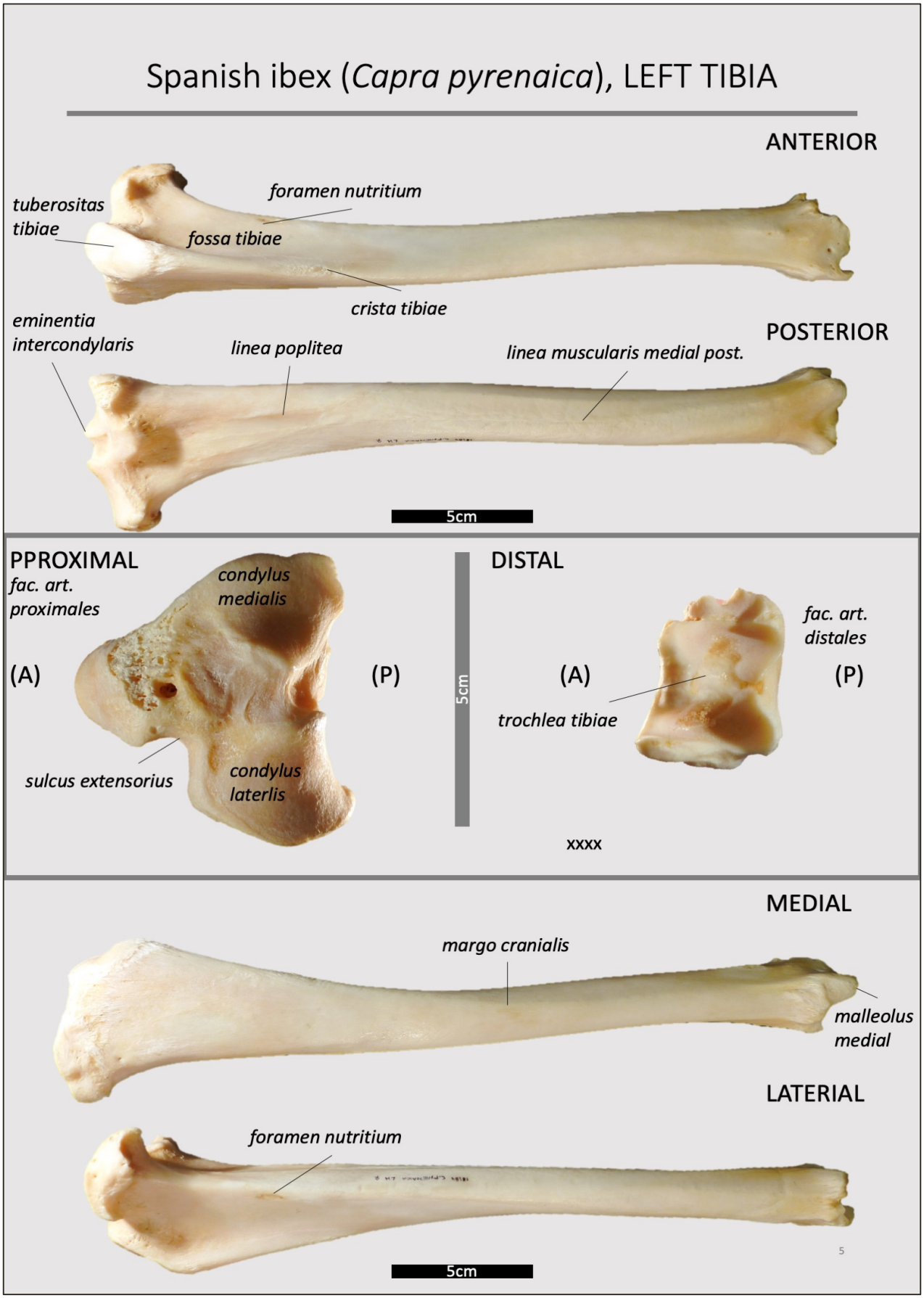
Appendix Figure I.4: Skeletal morphology and landmarks on radio and ulna from Spanish ibex (*Capra pyrenaica*). Photographs (by JMG) show items from the Bioarchaeological reference collection.



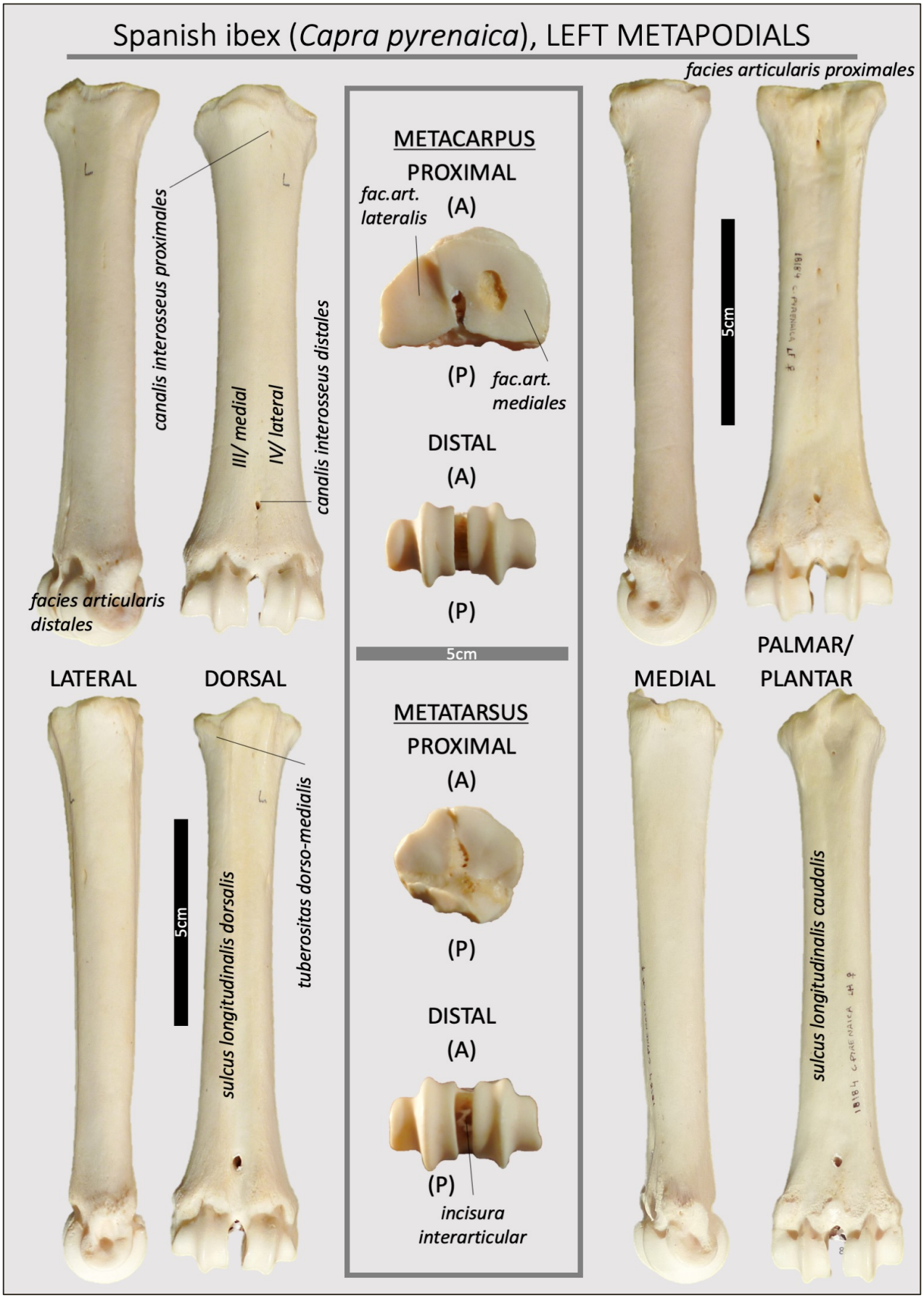
Appendix Figure I.5: Skeletal morphology and landmarks on pelvis from Spanish ibex (*Capra pyrenaica*). Photographs (by JMG) show items from the Bioarchaeological reference collection.



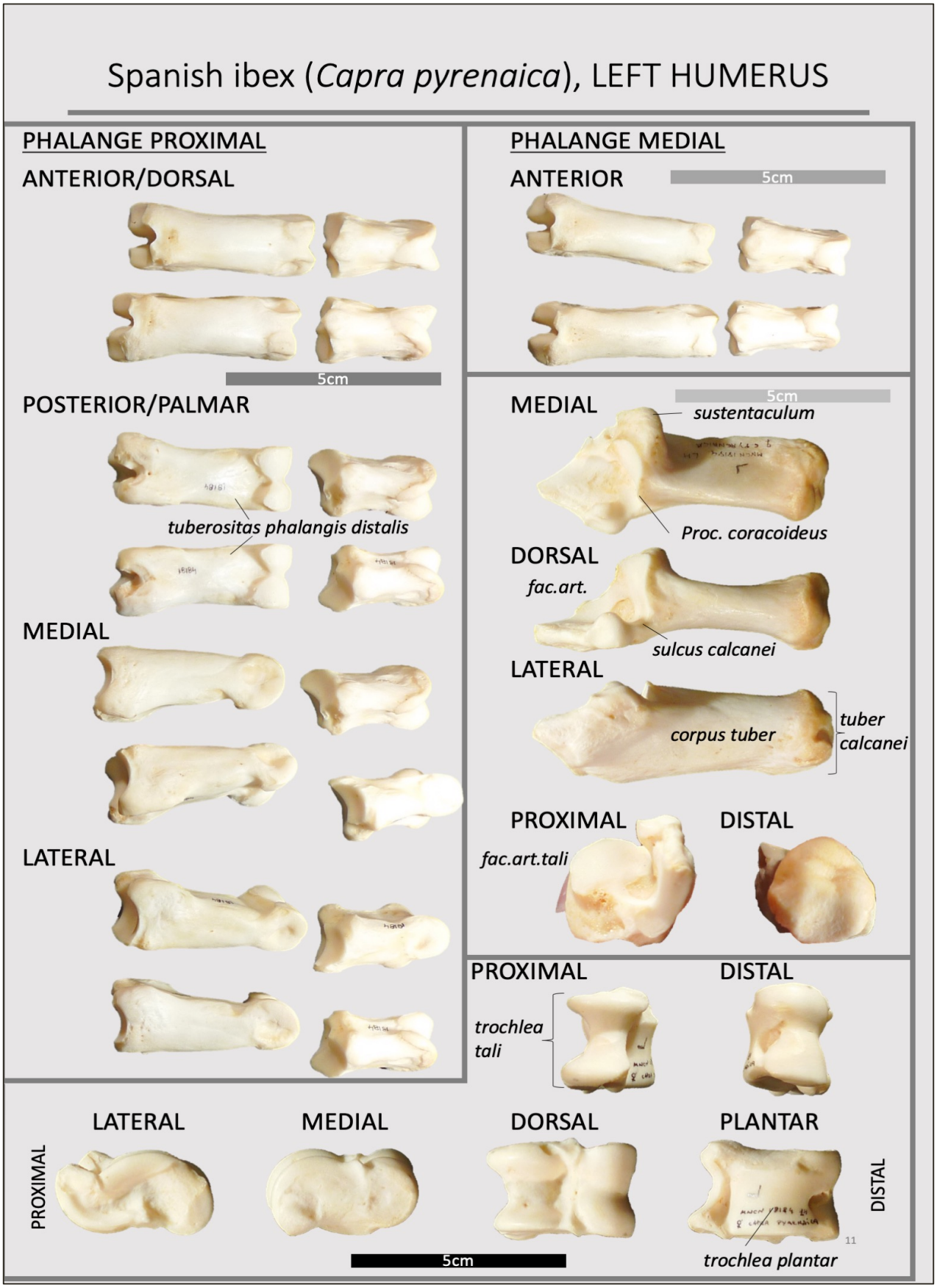
Appendix Figure I.6: Skeletal morphology and landmarks on femur from Spanish ibex (*Capra pyrenaica*). Photographs (by JMG) show items from the Bioarchaeological reference collection.



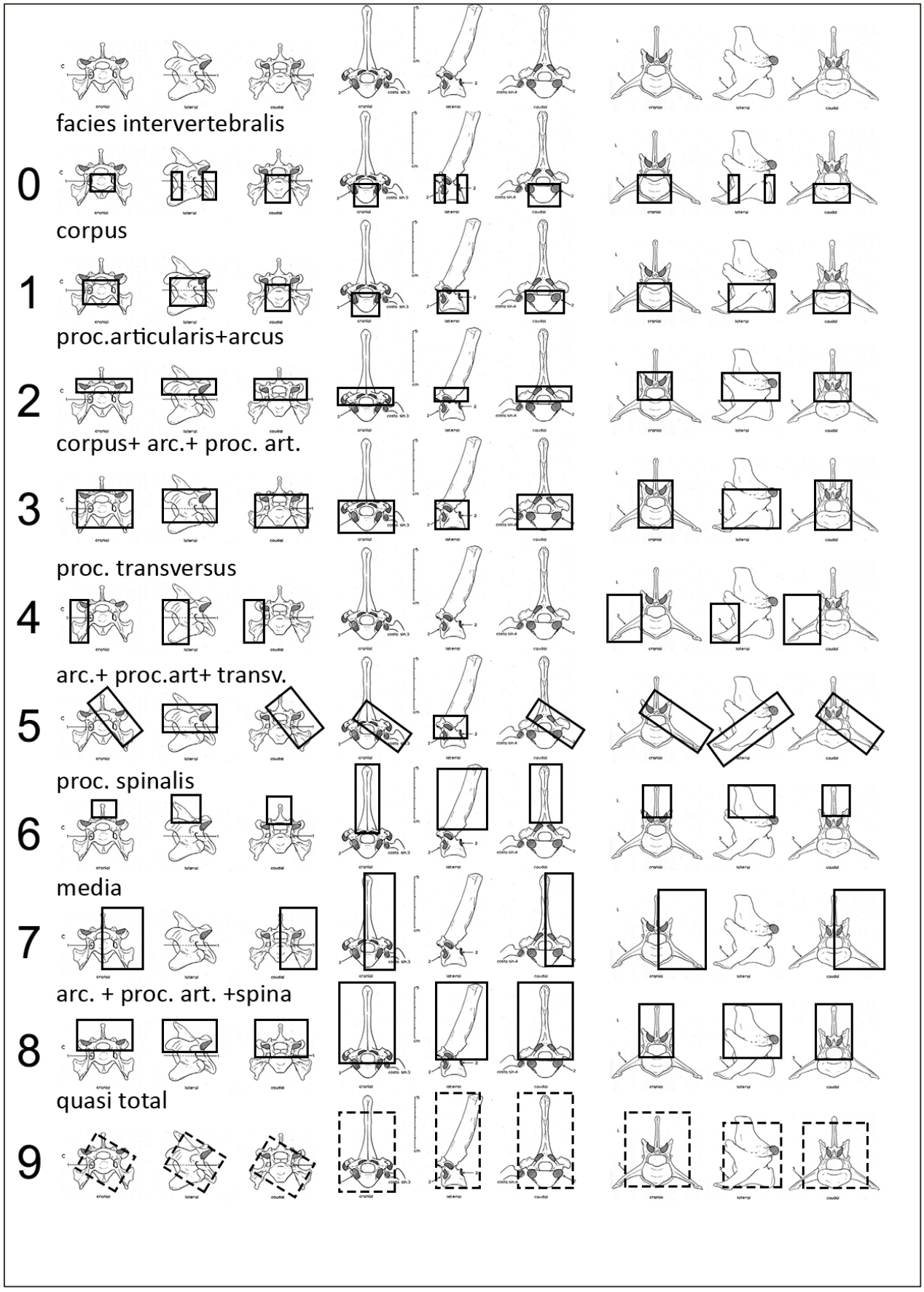
Appendix Figure I.7: Skeletal morphology and landmarks on tibia from Spanish ibex (*Capra pyrenaica*). Photographs (by JMG) show items from the Bioarchaeological reference collection.



Appendix Figure I.8: Skeletal morphology and landmarks on metapodia from Spanish ibex (*Capra pyrenaica*). Photographs (by JMG) show items from the Bioarchaeological reference collection.



Appendix Figure I.9: Skeletal morphology and landmarks on talus, calcaneus, phalange proximal and medial from Spanish ibex (*Capra pyrenaica*). Photographs (by JMG) show items from the Bioarchaeological reference collection.



Appendix Figure I.10: Skeletal morphology and landmarks on cervical (left), thoracic (middle) and lumbar (right) vertebrae. Illustrations were adapted and modified from (SCHMID 1972).

Appendix J References
Appendix J.1 Appendix Bibliography

AGUIRRE, M. (2012): Ocupaciones gravetienses de Antoliñako koba: Aproximación preliminar a su estratigrafía, cronología e industrias. – In: Pensando el Gravetiense: nuevos datos para la región cantábrica en su contexto peninsular y pirenaico. – pp. 216–228, (Ministerio de Educación, Cultura y Deporte).

ALTUNA, J. (1972): Fauna de mamíferos de los yacimientos prehistóricos de Guipúzcoa: con catálogo de los mamíferos cuaternarios del Cantábrico y del Pirineo Occidental. – San Sebastian (Sociedad de Ciencias Naturales Aranzadi).

ALTUNA, J. (1990): La cueva de Amalda (Zestoa, País Vasco): ocupaciones paleolíticas y postpaleolíticas. – 276 pp. San Sebastián (Editorial Eusko Ikaskuntza).

ALTUNA, J. (1992): Dataciones de radiocarbono para el Perigordiense Superior del País Vasco. – *Munibe*, **44**: 31–32.

ALTUNA, J., BALDEÓN, A. & MARIEZKURRENA, K. (eds) (1985): Cazadores magdalenienses en la cueva de Erralla (Cestona – País Vasco). – 193 pp. (Sociedad de Ciencias Aranzadi).

ALTUNA, J. & MARIEZKURRENA, K. (1984): Bases de subsistencia de origen animal en el yacimiento de Ekain (CAPITULO VIII). – In: El yacimiento prehistórico de la Cueva de Ekain (Deba, Guipúzcoa). Sociedad de Estudios Vascos, Serie B. – pp. 211–280,.

ALTUNA, J. & MERINO, J.M. (1984): El yacimiento prehistórico de la cueva de Ekain (Deba, Guipúzcoa). – 351 pp. .

ÁLVAREZ-ALONSO, D. (2007): Cantabrian Lower Magdalenian. Chronology context and structure. – *Munibe*, **58**: 127–142.

ÁLVAREZ-ALONSO, D. (2014): Olivo cave (Llanera). A new Magdalenian site in the center of Asturias. – *NAILOS. Estudios Interdisciplinares de Arqueología*, **1**: 181–192.

ÁLVAREZ-ALONSO, D., YRAVEDRA, J., ÁLVAREZ-FERNÁNDEZ, E., CALVO, A., CARRAL, P., IRIARTE-CHIAPUSSO, M.J., JORDÁ PARDO, J.F., SESÉ, C., UZQUIANO, P. & ARRIZABALAGA, Á. (2017): Subsistencia, movilidad y adaptación al medio de los cazadores-recolectores gravetienses en el sector occidental de la región cantábrica: la cueva de Coímbre (Asturias). – *Trabajos de Prehistoria*, **74**/1: 47. doi: 10.3989/tp.2017.12183.

ÁLVAREZ-ALONSO, D., YRAVEDRA, J., JORDÁ PARDO, J.F. & ARRIZABALAGA, A. (2016): The Magdalenian sequence at Coímbre cave (Asturias, Northern Iberian Peninsula): Adaptive strategies of hunter–gatherer groups in montane environments. – *Quaternary International*, **402**: 100–111. doi: 10.1016/j.quaint.2015.09.084.

ARIAS-CABAL, P. & SUÁREZ, C.P. (1995): Excavaciones arqueológicas en Arangas, Cabrales (1991-1994): las Cuevas de los Canes, el Tíu Llines y Arangas. – In: Excavaciones Arqueológicas en Asturias 1991-1995, 3. – pp. 79–92, Oviedo (Servicio de Publicaciones Principado de Asturias).

BARANDIARÁN-MAESTU, I. (1995): Los establecimientos de cazadores de la Prehistoria de Navarra. Del Paleolítico medio a inicios del Neolítico. – *Cuadernos de Arqueología de la Universidad de Navarra*, **3**: 53–84.

BARANDIARÁN-MAESTU, I. (1996): Le Paléolithique supérieur au Pays Basque et dans le bassin de l'Ebre (1990-1995). – In: Le Paléolithique supérieur européeen: Bilan quinquennal 1991-1996 ; [Congrès de Forli, Sept. 1996]. – pp. 319–322,.

BARANDIARÁN-MAESTU, I., FREEMAN, L.G., GONZÁLEZ-ECHEGARAY, J. & KLEIN, R.G. (eds) (1985): Excavaciones en la Cueva Del Juyo. – Madrid (Dirrecion general de bellas Artes, Archivos y Bibliotecas).

BERNALDO DE QUIRÓS, F. (1982): Los inicios del Paleolítico superior cantábrico. Edición: 1. – 347 pp. Madrid (Ministerio de Educación, Cultura y Deporte. Área de Cultura).

BINFORD, L.R. (1981): Bones: ancient men and modern myths. – 320 pp. New York (Academic Press).

BOWMAN, S.E., AMBERS, J.C. & LEESE, M.N. (1990): Re-evaluation of British Museum radiocarbon dates issued between 1980 and 1984. – *Radiocarbon*, **32**/1: 59–79.

CARRETERO, J.M., QUAM, R.M., GÓMEZ-OLIVENCIA, A., CASTILLA, M., RODRÍGUEZ, L. & GARCÍA-GONZÁLEZ, R. (2015): The Magdalenian human remains from El Mirón Cave, Cantabria (Spain). – *Journal of Archaeological Science*, **60**: 10–27. doi: 10.1016/j.jas.2015.03.026.

CASTAÑOS, P. (1982): Estudio de los macromamíferos del yacimiento prehistórico de "Cueto de la Mina" (Asturias). – *Boletín del Real Instituto de Estudios Asturianos*, **36**/105: 43–86.

CORCHÓN-RODRÍGUEZ, M.S. (1995): Reflexiones acerca de la cronología del Magdaleniense cantábrico. Las dataciones 14C de la Cueva de Las Caldas (Asturias, España). – *Zephyrus*, **XLVIII**: 3–19.

CORCHÓN-RODRÍGUEZ, M.S. (1999): Solutrean and Magdalenian of the Western Cantabrian Coast: 14C (Calibrated) Datings and cronological framework. – *Zephyrus*, **52**: 3–32.

CORCHÓN-RODRÍGUEZ, M.S. (2002): El Tardiglaciar y la transición al Postglaciar en la Meseta Norte española: una visión de síntesis(reflexiones acerca de las investigaciones realizadas en los últimos 10 años en el territorio de Castilla-León). – *Zephyrus: Revista de prehistoria y arqueología*, **55**: 85–142.

COSTAMAGNO, S. & FANO, M.A. (2005): Pratiques cynégétiques et exploitation des ressources animales dans les niveaux du Magdalénien supérieur-final de El Horno (Ramales, Cantabrie, Espagne). – *PALEO. Revue d'archéologie préhistorique*, **17**: 31–56.

VON DEN DRIESCH, A. (1976): A guide to the measurements of bones from archaeological sites: as developed by the Institut für Palaeoanatomie, Domestikationsforschung und Geschichte der Tiermedizin of the University of Munich. – 172 pp. Harvard University (Peabody Museum Bulletin 1).

D'ERRICO, F. & VANHAEREN, M. (2002): Criteria for Identifying Red Deer (Cervus elaphus) Age and Sex from Their Canines. Application to the Study of Upper Palaeolithic and Mesolithic Ornaments. – *Journal of Archaeological Science*, **29**/2: 211–232. doi: 10.1006/jasc.2001.0687.

FERNANDEZ, H. (2001): Ostéologie comparée des petits ruminants eurasiatiques sauvages et domestiques (genres Rupicapra, Ovis, Capra et Capreolus): diagnose différentielle du squelette appendiculaire. – Diss.: Muséum d'histoire naturelle Genève (University of Geneva).

FERNÁNDEZ, M.M. & VILLA, A.M. (1992): Excavaciones arqeológicas en la cueva de la Güelga: campañas de 1989-1990. – In: – pp. 75–80, Oviedo (Servicio de Publicaciones Principado de Asturias).

GEILING, J.M. & MARÍN-ARROYO, A.B. (2015): Spatial distribution analysis of the Lower Magdalenian human burial in El Mirón Cave (Cantabria, Spain). – *Journal of Archaeological Science*, **60**: 47–56. doi: 10.1016/j.jas.2015.03.005.

GÓMEZ-OLIVENCIA, A., ARCEREDILLO, D., ÁLVAREZ-LAO, D.J., GARATE-MAIDAGAN, D., SAN PEDRO, Z., CASTAÑOS, P. & RIOS-GARAIZAR, J. (2013): New evidence for the presence of reindeer (Rangifer tarandus) on the Iberian Peninsula in the Pleistocene: an archaeopalaeontological and chronological reassessment. – *Boreas*: n/a–n/a. doi: 10.1111/bor.12037.

GONZÁLEZ-ECHEGARAY, J. (1980): El yacimiento de la cueva de El Pendo: Excavaciones (1953-1957). – 266 pp. Madrid (Editorial CSIC-CSIC Press).

GONZÁLEZ-ECHEGARAY, J. & BARANDIARÁN-MAESTU, I. (1981): El Paleolitico Superior de la Cueva del Rascaño (Santander). – 339 pp. Santander (Santilla del Mar (Santander): Centro de Investigacion y Museo de Altamira).

GONZÁLEZ-MORALES, M.R. & STRAUS, L.G. (2013): La ocupación gravetiense de la cueva de El Mirón (Ramales de la Victoria, Cantabria) y el contexto del arte paleolítico temprano de la cuenca del Asón. – In: DE LAS HERAS, C. (ed.): Pensando el Gravetiense: Nuevos datos para la región cantábrica en su contexto peninsular y pirenaico. – pp. 289–300, Santander (Museo Nacional y Centro de Investigación de Altamira).

HOYOS GÓMEZ, M. (1995): Paleoclimatología del Tardiglacial en la Cornisa Cantábrica basada en los resultados sedimentológicos de yacimientos arqueológicos kársticos. – In: El final del Paleolítico cantábrico. Universidad de Cantabria, Santander. – pp. 15–75, Santander (Universidad de Cantabria).

KLEIN, R.G., WOLF, C., FREEMAN, L.G. & ALLWARDEN, K. (1981): The use of dental crown heights for constructing age profiles of red deer and similar species in archaeological samples. – *Journal of Archaeological Science*, **8**/1: 1–31. doi: 10.1016/0305-4403(81)90010-8.

LÓPEZ QUINTANA, J.C. (ed) (2011): La cueva de Santimamiñe: revisión y actualización (2004-2006). – 446 pp. Bilbao (Diputación Foral de Bizkaia).

MAÍLLO FERNÁNDEZ, J.M., VALLADAS, H., CABRERA VALDÉS, V. & BERNALDO DE QUIRÓS, F. (2001): Nuevas dataciones para el Paleolítico superior de Cueva Morín (Villanueva de Villaescusa, Cantabria). – *Espacio Tiempo y Forma. Serie I, Prehistoria y Arqueología*, **14**: 145–150. doi: 10.5944/etfi.14.2001.4725.

MARÍN-ARROYO, A.B. (2010): Arqueozoología en el Cantábrico Oriental durante la transición Pleistoceno/Holoceno. La cueva del Mirón. - Archeozoology in the Eastern Cantabrian Region during the Pleistocene/ Holocene transition. El Mirón cave. – 685 pp. Santander (PUbliCan Universidad de Cantabria).

MARÍN-ARROYO, A.B. (2013): Human response to Holocene warming on the Cantabrian Coast (northern Spain): an unexpected outcome. – *Quaternary Science Reviews*, **81**: 1–11. doi: 10.1016/j.quascirev.2013.09.006.

MARÍN-ARROYO, A.B. & GEILING, J.M. (2015): Archeozoological study of the macromammal remains stratigraphically associated with the Magdalenian human burial in El Mirón Cave (Cantabria, Spain). – *Journal of Archaeological Science*, **60**/Supplement C: 75–83. doi: 10.1016/j.jas.2015.03.009.

MARÍN-ARROYO, A.B., GEILING, J.-M., JONES, J.R., GONZÁLEZ MORALES, M.R., STRAUS, L.G. & RICHARDS, M.P. (2018a): The Middle to Upper Palaeolithic transition at El Mirón Cave (Cantabria, Spain). – *Quaternary International*: online availiable. doi: 10.1016/j.quaint.2018.06.036.

MARÍN-ARROYO, A.B., GUTIÉRREZ-ZUGASTI, I., JONES, J.R., CUENCA SOLANA, D., LOPEZ-DÓRIGA, I., GEILING, J.M., GARCÍA-ESCÁRZAGA, A., SUÁREZ-REVILLA, R., NUÑEZ DE LA FUENTE, S., AGUDO PÉREZ, L., HIGUERO, A. & GONZÁLEZ-MORALES, M.R. (2019): Investigacion en el Laboratorio de Bioarqueologia del Instituo Internacional de Investigaciones Prehistóricas de Cantabria (IIIPC) - Universidad de Cantabria. – *Sautuola: Revista del Instituto de Prehistoria y Arqueología Sautuola*, **XX**: 349–369.

MARÍN-ARROYO, A.B., LANDETE RUIZ, M.D., VIDAL BERNABEU, G., SEVA ROMÁN, R., GONZÁLEZ-MORALES, M.R. & STRAUS, L.G. (2008): Archaeological implications of human-derived manganese coatings: a study of blackened bones in El Mirón Cave, Cantabrian Spain. – *Journal of Archaeological Science*, **35**/3: 801–813. doi: 10.1016/j.jas.2007.06.007.

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. (2018b): Chronological reassessment of the Middle to Upper Paleolithic transition and Early Upper Paleolithic cultures in Cantabrian Spain. – *PLOS ONE*, **13**/4: e0194708. doi: 10.1371/journal.pone.0194708.

MAROTO, J., VAQUERO, M., ARRIZABALAGA, Á., BAENA, J., BAQUEDANO, E., JORDÁ, J., JULIÀ, R., MONTES, R., VAN DER PLICHT, J., RASINES, P. & WOOD, R. (2012): Current issues in late Middle Palaeolithic chronology: New assessments from Northern Iberia. – *Quaternary International*, **247**: 15–25. doi: 10.1016/j.quaint.2011.07.007.

MOURE-ROMANILLO, J.A. & GONZÁLEZ-MORALES, M.R. (1988): El contexto del arte parietal. La tecnología de los artistas en la cueva de Tito Bustillo (Asturias). – *Trabajos de Prehistoria*, **45**: 19–49.

MUÑOZ FERNANDEZ, E. & MONTES BARQUIN, R. (2007): Arqueologia y arte rupestre paleolitico en las cavidades de El Cuco o Sobera y La Lastrilla. – 278 pp. Castro Urdiales (Concejalia de Medioambiente y Patrimonio arqueologico).

MUÑOZ, M., SANCHEZ GOÑI, M.F. & UGARTE, F.M. (1990): El entorno geo-ambiental del yacimiento arqueológico de Kurtzia. – *Munibe*, **41**: 107–115.

NODDLE, B. (1974): Ages of epiphyseal closure in feral and domestic goats and ages of dental eruption. – *Journal of Archaeological Science*, **1**/2: 195–204. doi: 10.1016/0305-4403(74)90042-9.

ONTAÑÓN-PEREDO, R. (2003): Sols et structures d'habitat du Paléolithique supérieur, nouvelles données depuis les Cantabres: la Galerie Inférieure de La Garma (Cantabrie, Espagne). – *L'Anthropologie*, **107**/3: 333–363. doi: 10.1016/S0003-5521(03)00037-2.

PALES, L. & LAMBERT, C. (1971): Atlas ostéologique pour servir à l'identification des mammifères du quaternaire: Herbivores. – 177 pp. Paris (Éditions du Centre national de la recherche scientifique).

PÉREZ-RIPOLL, M. (1988): Estudio de la secuencia del desgaste de los molares de la «Capra pyrenaica» de yacimientos prehistóricos. – *Archivo de Prehistoria levantina*, **18**: 83–127.

RIOS-GARAIZAR, J., IRIARTE AVILÉS, E., GARATE-MAIDAGAN, D., GÓMEZ-OLIVENCIA, A. & SAN PEDRO CALLEJA, Z. (2008): Nuevos datos sobre la transición entre el Solutrense superior y el Magdaleniense inferior en la región cantábrica: la cueva de Arlanpe (Lemoa, Vizcaya). – *Sautuola: Revista del Instituto de Prehistoria y Arqueología Sautuola*, **14**: 95–104.

SAUQUÉ, V. & CUENCA-BESCÓS, G. (2013): The Iberian Peninsula, the last European refugium of panthera pardus linnaeus 1758 during the Upper Pleistocene. – *Quaternaire. Revue de l'Association française pour l'étude du Quaternaire*, **24**/1: 13–24. doi: 10.4000/quaternaire.6468.

SAUQUÉ, V., RABAL-GARCÉS, R., SOLA-ALMAGRO, C. & CUENCA-BESCÓS, G. (2014): Bone Accumulation by Leopards in the Late Pleistocene in the Moncayo Massif (Zaragoza, NE Spain). – *PLoS ONE*, **9**/3: e92144. doi: 10.1371/journal.pone.0092144.

SCHMID, E. (1972): Atlas of animal bones: for prehistorians, archaeologists and quaternary geologists = Knochenatlas: für Prähistoriker, Archäologen und Quartärgeologen. – 156 pp. Amsterdam-London-New York (Elsevier).

SCHMIDT, I., BRADTMÖLLER, M., KEHL, M., PASTOORS, A., TAFELMAIER, Y., WENINGER, B. & WENIGER, G.-C. (2012): Rapid climate change and variability of settlement patterns in Iberia during the Late Pleistocene. – *Quaternary International*, **274**: 179–204. doi: 10.1016/j.quaint.2012.01.018.

SERJEANTSON, D. (1998): Birds: a Seasonal Resource. – *Environmental Archaeology*, **3**/1: 23–33. doi: 10.1179/env.1998.3.1.23.

SERJEANTSON, D. (2009): Birds. – 486 pp. New York (Cambridge University Press).

SIMPSON, E.H. (1949): Measurement of Diversity. – *Nature*, **163**: 688–688.

SOTO, M.J. (2003): Cronología radiométrica, ecología y clima del paleolítico cantábrico. – 435 pp. Madrid (Ministerio de Educación, Cultura y Deporte).

STRAUS, L.G. (1992): Iberia before the Iberians: the Stone Age prehistory of Cantabrian Spain. – 360 pp. Albuquerque (University of New Mexico Press).

STRAUS, L.G. & CLARK, G.A. (eds) (1986): La Riera Cave: Stone age hunter-gatherer adaptations in northern Spain. – Arizona State University (Tempe).

STRAUS, L.G., GEILING, J.M. & GONZÁLEZ-MORALES, M.R. (2018): The Lower Magdalenian Osseous Industry from Level 17 in El Mirón Cave (Ramales De La Victoria, Cantabria): A Preliminary Overview. – *Zephyrvs*, **81**/0: 15–30. doi: 10.14201/zephyrus2018811530.

STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2003): El Miron Cave and the 14C Chronology of Cantabrian Spain. – *Radiocarbon*, **45**/1: 41–58.

STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2007): Further Radiocarbon Dates for the Upper Paleolithic of El Mirón Cave (Ramales de la Victoria, Cantabria, Spain). – *Radiocarbon*, **49**/3: 1205–1214.

STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2010): The Radiocarbon Chronology of El Mirón Cave (Cantabria, Spain): New Dates for the Initial Magdalenian Occupations. – *Radiocarbon*, **52**/1: 33–39.

STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2016): El Mirón Cave (Ramales, Cantabria, Spain) Date List V: Middle Paleolithic and Lower Magdalenian. – *Radiocarbon*, **58**/4: 943–945. doi: 10.1017/RDC.2016.84.

STRAUS, L.G. & GONZÁLEZ-MORALES, M.R. (2018): New Dates for the Solutrean and Magdalenian of Cantabrian Spain: El Miron and La Riera Caves. – *Radiocarbon*, **60**/03: 1013–1016. doi: 10.1017/RDC.2018.14.

STRAUS, L.G., GONZÁLEZ-MORALES, M.R. & CUENCA-SOLANA, D. (2015): The Magdalenian human burial of El Mirón Cave (Ramales de la Victoria, Cantabria, Spain): introduction, background, discovery and context. – *Journal of Archaeological Science*, **60**: 1–9. doi: 10.1016/j.jas.2015.02.018.

STRAUS, L.G., GONZÁLEZ-MORALES, M.R. & FANO, M.Á. (2006): The Upper Paleolithic record in the Asón river basin, eastern Cantabria (Spain): research & publications, 2000-2005. – In: NOIRET, P. (ed.): Le Paléolithique supérieur européen. Bilan quinquennal 1996-2001. – pp. 117–128, Liège (Université de Liège).

STRAUS, L.G., GONZÁLEZ-MORALES, M.R., GUTIÉRREZ-ZUGASTI, I. & IRIARTE-CHIAPUSSO, M.J. (2011): Further Solutrean evidence in El Mirón Cave (Ramales de la Victoria, Cantabria). – *Munibe*, **62**: 117–133.

STRAUS, L.G., GONZÁLEZ-MORALES, M.R., HIGHAM, T., RICHARDS, M. & TALAMO, S. (2015): Radiocarbon Dating the Late Upper Paleolithic of Cantabrian Spain: El Mirón Cave Date List IV. – *Radiocarbon*, **57**/1: 183–188. doi: 10.2458/azu_rc.57.18109.

STRAUS, L.G., GONZÁLEZ-MORALES, M.R., MARÍN-ARROYO, A.B. & IRIARTE-CHIAPUSSO, M.J. (2013): The human occupations of el Mirón cave (Ramales de la Victoria, Cantabria, Spain) during the Last Glacial Maximum/ Solutrean period. – *Espacio Tiempo y Forma. Serie I, Prehistoria y Arqueología*, **5**: 413–426.

STRAUS, L.G., GONZÁLEZ-MORALES, M.R., MARTÍNEZ, M.Á.F. & GARCÍA-GELABERT, M.P. (2002): Last Glacial Human Settlement in Eastern Cantabria (Northern Spain). – *Journal of Archaeological Science*, **29**/12: 1403–1414. doi: 10.1006/jasc.2001.0800.

STUCKENRATH, R. (1978): Dataciones de carbono 14. – In: Vida y muerte en Cueva Morin. Institución Cultural de Cantabria, Santander. – p. 215, Santander (Institución Cultural de Cantabria).

SZUMA, E. (2008): Geographic Variation of Tooth and Skull Sizes in the Arctic Fox *Vulpes* (*Alopex*) *lagopus*. – *Annales Zoologici Fennici*, **45**/3: 185–199. doi: 10.5735/086.045.0304.

UTRILLA, P. (1982): El yacimiento de las cueva de Abauntz (Arraiz, Navarra). – *Trabajos de Arqueología Navarra*, **2**: 203–345.

UTRILLA, P. (1996): La sistematización del Magdaleniense cantábrico: una revisión histórica de los datos. – In: MOURE-ROMANILLO, J.A. (ed.): "El hombre fósil" 80 años después - Homenaje a Hugo Obermaier. – pp. 211–248, Santander (Universidad de Cantabria).

UTRILLA, P., DOMINGO, R., MONTES, L., MAZO, C., RODANÉS, J.M., BLASCO, F. & ALDAY, A. (2012): The Ebro Basin in NE Spain: A crossroads during the Magdalenian. – *Quaternary International*, **272–273**: 88–104. doi: 10.1016/j.quaint.2012.04.024.

UTRILLA, P., MAZO, C. & DOMINGO, R. (2015): Fifty thousand years of prehistory at the cave of Abauntz (Arraitz, Navarre): A nexus point between the Ebro Valley, Aquitaine and the Cantabrian Corridor. – *Quaternary International*, **364**: 294–305. doi: 10.1016/j.quaint.2014.06.022.

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. – *Journal of Human Evolution*, **69**: 91–109. doi: 10.1016/j.jhevol.2013.12.017.

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