Universitat Rovira i Virgili

# EL ROL DE LOS HOMININOS EN LA FORMACIÓN DE CONJUNTOS ARQUEO-PALEONTOLÓGICOS AL AIRE LIBRE: LA MINA Y EL FORN (BARRANC DE LA BOELLA, LA CANONJA, TARRAGONA) Y TORRALBA (TORRALBA DEL MORAL, SORIA)

## Antonio Pineda Alcalá

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**Antonio Pineda Alcalá**

## TESIS DOCTORAL

Dirigida por
**Dra. Palmira Saladié Ballesté**

UNIVERSITAT ROVIRA i VIRGILI

A mis padres,

Antonio Pineda Alcalá

# EL ROL DE LOS HOMININOS EN LA FORMACIÓN DE CONJUNTOS ARQUEO-PALEONTOLÓGICOS AL AIRE LIBRE: LA MINA Y EL FORN (BARRANC DE LA BOELLA, LA CANONJA, TARRAGONA) Y TORRALBA (TORRALBA DEL MORAL, SORIA)

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Departamento de Historia e Historia del Arte

UNIVERSITAT ROVIRA i VIRGILI

Tarragona
2018

**UNIVERSITAT ROVIRA i VIRGILI**

HAGO CONSTAR que el presente trabajo, titulado "El rol de los homininos en la formación de conjuntos arqueo-paleontológicos al aire libre: la Mina y el Forn (Barranc de la Boella, la Canonja, Tarragona) y Torralba (Torralba del Moral, Soria)", que presenta Antonio Pineda Alcalá para la obtención del título de Doctor, ha sido realizado bajo mi dirección en el Departamento de Historia e Historia del Arte de esta Universidad.

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I STATE that the present study, entitled "The role of hominins in the formation of archaeo-palaeontological open-air assemblages: la Mina and el Forn (Barranc de la Boella, la Canonja, Tarragona) and Torralba (Torralba del Moral, Soria)", presented by Antonio Pineda Alcalá for the award of the degree of Doctor, has been carried out under my supervision at the Department of History and History of Art of this University.

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Abril, 2018
April 2018

La Directora de la Tesis Doctoral

Doctoral Thesis Supervisor

Dra. Palmira Saladié Ballesté

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La ilustración de la portada ha sido diseñada por Domingo López, con el asesoramiento de Antonio Rosas.

# Resumen

Los conjuntos incluidos en la presente Tesis Doctoral son la Mina y el Forn, en el Barranc de la Boella, y Torralba. Se trata de depósitos al aire libre, formados en contextos fluvio-deltaicos. En el registro arqueológico es frecuente encontrar acumulaciones formadas en depósitos sedimentarios al aire libre. Estos depósitos pueden contener evidencias de la actuación de homininos (industria lítica y marcas de corte y percusión) y carnívoros (mordeduras, huesos digeridos, coprolitos…). Tradicionalmente, estas evidencias han sido utilizadas para considerar a homininos y carnívoros como los principales agentes acumuladores y modificadores de la mayoría de estos conjuntos.

Mediante los preceptos de la Zooarqueología y la Tafonomía hemos pretendido establecer el papel de homininos y carnívoros en los tres yacimientos investigados. La mala de conservación de las superficies óseas ha limitado la preservación de modificaciones tafonómicas superficiales de origen antrópico, si las hubiere. Ante esta carencia, hemos requerido del uso de los perfiles anatómicos para caracterizar la naturaleza de las acumulaciones óseas estudiadas e identificar el rol de los grupos de homininos en la formación y modificación de dichas acumulaciones. Además, hemos pretendido comprender cómo se integran estas acumulaciones en el espacio macro-regional en el que las poblaciones de homininos del Pleistoceno inferior y medio desarrollaban sus actividades.

Debido al contexto paleoecológico en el que estos se enmarcan, deben ser entendidos como sitios de tránsito, que no necesariamente de actividad, que formarían parte del espacio en el que estos grupos se integrarían y desarrollarían el conjunto de sus actividades.

Los análisis aplicados han evidenciado contextos de diferente competencia inferida en los diferentes conjuntos del Barranc de la Boella. La tendencia observada apunta a una mayor presencia de homininos en los niveles de elevada competencia inferida, en los que la actividad de los grupos carnívoros también es mayor. En Torralba, por otro lado, se han documentado contextos de baja y moderada competencia inferida con escasa actividad antrópica.

Las evidencias de procesado de las carcasas animales son pocas en los tres conjuntos estudiados. En ningún caso se ha definido un origen antrópico a dichas acumulaciones, que serían el resultado de la acumulación de eventos independientes en los que el papel de los homininos se relacionaría con las prácticas de merodeo y forrajeo en estos territorios.

El principal, aunque posiblemente no el único, elemento determinante para la presencia de un grupo de forrajeadores pleistocenos en un determinado espacio vendría dado por la presencia de recursos de interés. El riesgo de depredación de carnívoros parece no ser determinante. Estas observaciones atestiguan las capacidades de adaptación de las poblaciones homininas a diferentes tipos de ecosistemas.

# Abstract

The assemblages studied in this doctoral thesis are from la Mina and el Forn, in the Barranc de la Boella, and Torralba. These are open-air sites, formed in fluvial-deltaic contexts. In the archaeological record, it is common to find accumulations formed in open-air sedimentary deposits. These deposits may contain evidence of the presence of hominins (lithic industry and cut and percussion marks) and carnivores (tooth-marks, digested bones, coprolites, etc.). Traditionally, this evidence has been used to suggest that hominins and carnivores were the main accumulating and modifying agents of most of these assemblages.

Through the precepts of Zooarchaeology and Taphonomy, we attempted to establish the role of hominins and carnivores in the three sites under study. The poor conservation of the bone surfaces has affected the preservation of superficial anthropogenic taphonomic modifications, if any were present. In response to this lack of evidence, we have used anatomical profiles to characterize the nature of the bone accumulations studied and to identify the role of hominin groups in the formation and modification of these accumulations. In addition, we have tried to understand how these accumulations are integrated into the macro-regional space in which the populations of hominins of the Lower and Middle Pleistocene undertook their activities.

Due to the paleoecological context in which they are framed, these sites should be understood as transit sites, not necessarily sites of activity, which would form part of the space to which these groups belonged and in which they carried out all their activities.

The applied analyses have demonstrated contexts of differing levels of competition inferred in the assemblages of the Barranc de la Boella. The observed tendency points to a greater presence of hominins in the levels of high inferred competition, in which carnivore activity is also greater. In Torralba, on the other hand, contexts of low and moderate inferred competition with scarce anthropic activity have been documented.

Evidence of animal carcass processing is scarce in the three assemblages studied. No evidence has been uncovered that would attribute an anthropic origin to these accumulations, which would have resulted from independent events in which the role of the hominins was related to the practices of marauding and foraging in these territories.

The main, although possibly not the only, factor determining the presence of a group of Pleistocene foragers in a specific space would be the presence of resources of interest. The risk of carnivore predation does not seem to have been a deterrent. These observations attest to the capabilities of hominin populations to adapt to different types of ecosystems.

# Índice de contenido

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# Índice de figuras y tablas

# Capítulo 1. Introducción

Los trabajos pioneros que investigadores como Behrensmeyer (1975; 1978; 1983) o Hill (1979a; 1979b) desarrollaron en la sabana africana permitieron poner el foco de atención en las concentraciones óseas pleistocenas formadas en espacios abiertos e hicieron de la sabana un marco referencial para la reconstrucción de las dinámicas paleoecológicas que pudieron darse en este tipo de contextos. En un espacio en el que la tendencia natural es la dispersión y no la acumulación, debemos entender las concentraciones de fósiles como el resultado de la participación de procesos dinámicos (agentes biológicos, corrientes hídricas, coluviones…) de transporte y deposición de elementos hacia un mismo lugar (Domínguez-Rodrigo y de la Torre, 1999).

Entre estos procesos, se ha demostrado la capacidad de agentes físicos, como las corrientes de agua, de formar acumulaciones (Hanson, 1980). No obstante, los agentes físicos no parecen estar detrás de las grandes acumulaciones óseas pleistocenas, que presentan los marcadores típicos descritos para acumulaciones formadas por carnívoros y homininos (p.e. Hugues, 1954; Kruuk y Turner, 1967; Mech, 1970; Sutcliffe, 1970; Kruuk, 1972; Schaller, 1972; Hill, 1980; 1983; 1984; 1989; Maguire et al., 1980; Skinner et al., 1980; 1986; 1998; Binford, 1981; 1988; Brain, 1981; Klein y Cruz-Uribe, 1984; Binford et al., 1986; Kerbis-Peterhans, 1990; Cruz-Uribe, 1991; Skinner y van Aarde, 1991; Stiner, 1991; Lam, 1992; Domínguez-Rodrigo, 1994; 1995; Fosse, 1995; Martín y Borrero, 1997; Mills y Gorman, 1997; de Ruiter y Berger, 2000; Pickering, 2002; Brugal y Fosse, 2004; Lacruz y Maude, 2005; Fernandez et al., 2006; Montalvo et al., 2007; Pokines y Kerbis Peterhans, 2007; Fernandez y Guadelli, 2008; Lansing et al., 2009; Yravedra et al., 2011; 2012; Stiner et al., 2012; Rodríguez-Hidalgo et al., 2013; 2015; Arriaza y Domínguez-Rodrigo, 2016; Borrero et al., 2018; Saladié et al., *in press*). Precisamente, las acumulaciones generadas por estos agentes han generado una intensa literatura durante más de cuatro décadas, con el objetivo de caracterizarlas y establecer criterios que permitan su correcta identificación en el registro arqueológico.

En este sentido, se han podido identificar concentraciones fósiles pleistocenas en espacios abiertos atribuidas a los grupos humanos (Domínguez-Rodrigo et al., 2010c). Otras concentraciones fósiles en estos contextos, no obstante, resultan de la acumulación de sucesivos eventos independientes durante periodos prolongados de tiempo, en los que no encontramos un actor acumulador principal (Binford, 1983). En este tipo de concentraciones es frecuente encontrar evidencias de la presencia de las poblaciones homininas, en forma de industria lítica y señales de procesado de las carcasas, aunque estas últimas tienden a ser escasas o estar ausentes en muchas ocasiones (p.e. Barba y Domínguez-Rodrigo, 2007; Domínguez-Rodrigo y Barba, 2007a; 2007d; Bunn et al., 2010; Domínguez-Rodrigo et al., 2010b; Yravedra et al., 2017b). Dichas concentraciones se enmarcan dentro del espacio, entendido en un sentido regional y macro-regional, en el que los grupos de cazadores-recolectores se desenvuelven y desarrollan las múltiples actividades de su día a día, entre las que para nosotros reciben un especial interés las relacionadas con la subsistencia. Debemos adentrarnos en la caracterización y el conocimiento de estos conjuntos, para reconstruir las dinámicas de las poblaciones de homininos pleistocenas, así como sus capacidades para desenvolverse en diferentes medioambientes. Desde una perspectiva zooarqueológica, la capacidad de adquisición de recursos o la adaptación a la presencia de otros predadores aparecen como temas destacados.

Los yacimientos incluidos en la presente Tesis Doctoral son el Barranc de la Boella (Tarragona) y Torralba (Soria). Ambos representan contextos paleoecológicos que comparten algunos aspectos en común: se trata de yacimientos al aire libre, formados en contextos fluvio-deltaicos en los que la presencia de los grupos humanos está claramente atestiguada a través de la industria lítica, pero en el que las evidencias de actividad antrópica sobre las carcasas de animales son escasas.

El Barranc de la Boella es un yacimiento en el que se viene interviniendo desde el año 2007. Los trabajos de excavación se han centrado en la Unidad II, datada en torno a un millón de años de antigüedad, y afectan a tres catas penecontemporáneas: Pit 1, la Mina y el Forn, que forman parte de una misma secuencia estratigráfica. Los primeros estudios tafonómicos (Saladié et al., 2008) ya apuntaban a la identificación de un *butchering site*, un único evento de aprovechamiento de una carcasa de mamut en la Pit 1, interpretación ratificada en trabajos posteriores (Vallverdú et al., 2014b; Mosquera et al., 2015). Las otras dos áreas excavadas en el Barranc de la Boella, la Mina y el Forn, han sido las incluidas en la presente Tesis Doctoral. Ya durante los trabajos de excavación se percibió que, a diferencia de la Pit 1, en estos conjuntos nos encontrábamos ante acumulaciones con una mayor variabilidad taxonómica, un menor componente antrópico y una mayor presencia de carnívoros como agentes acumuladores.

Las intervenciones en el yacimiento de Torralba se iniciaron hace más de un siglo de la mano de Enrique de Aguilera y Gamboa, XVII Marqués de Cerralbo. Hasta la fecha, se ha intervenido en tres períodos de excavación distintos, dirigidos por Cerralbo (1909-1913), Howell (1961-1963) y Alfredo Pérez-González y Manuel Santonja (1994-1999). El yacimiento, datado en torno a 200 ka de antigüedad (N. Mercier, en Santonja et al., 2014), se convirtió desde un primer momento, junto con el vecino yacimiento de Ambrona, en un enclave privilegiado para la defensa de las capacidades cinegéticas de los homininos del Pleistoceno medio, considerados como responsables de las concentraciones de elefante excavadas en ambos conjuntos (p.e. Aguilera y Gamboa, 1913a; Butzer, 1965; Howell, 1966). Estas hipótesis fueron cuestionadas posteriormente por otros investigadores (p.e. Binford, 1981; 1987; Shipman y Rose, 1983b; Villa et al., 2005) que cuestionaron el rol activo de los grupos de homininos en las acumulaciones. Para este trabajo se han revisado los materiales procedentes de las excavaciones clásicas de Torralba (períodos Cerralbo y Howell) depositados en el Museo Arqueológico Natural de Madrid (MAN), el Museo Nacional de Ciencias Naturales de Madrid (MNCN-CSIC) y el Museo Numantino de Soria (MNS).

Los principales objetivos que nos proponemos abordar en esta investigación son: 1) Caracterizar la naturaleza de las acumulaciones óseas estudiadas; 2) Identificar el rol de los grupos de homininos en la formación y modificación de dichas acumulaciones; 3) Comprender cómo se integran estas acumulaciones en el espacio macro-regional en el que las poblaciones de homininos del Paleolítico inferior desarrollaban sus actividades.

La hipótesis de partida que planteamos sugiere un escaso rol de los grupos de homininos en la formación de los conjuntos estudiados. Debido al contexto paleoecológico en el que estos se enmarcan, deben ser entendidos como sitios de tránsito, que no necesariamente de actividad, que formarían parte del espacio en el que estos grupos se integrarían y desarrollarían el conjunto de sus actividades.

Esta Tesis Doctoral ha sido estructurada en 10 capítulos. Este capítulo, el primero de ellos, es la presentación de la Tesis, en la que se introduce el marco de referencia en el que ésta se inserta, así como los objetivos y las hipótesis de nuestra investigación. El segundo capítulo supone un estado del arte de todos aquellos aspectos que posteriormente serán desarrollados a lo largo del trabajo. En él, se definen los conceptos sobre los que se ha trabajado, haciendo hincapié en los procesos de acumulación y formación de conjuntos osteológicos al aire libre, presentándose el estado de la cuestión a cerca de la movilidad regional de los grupos de cazadores-recolectores actuales y la problemática en torno a la equifinalidad en los estudios tafonómicos y sus implicaciones a la hora de realizar inferencias zooarqueológicas y comportamentales de los grupos de homininos del Paleolítico inferior. En el capítulo 3 se presentan los conjuntos arqueológicos analizados en esta Tesis Doctoral: el Barranc de la Boella y Torralba. Se muestra el contexto geológico, litoestratigráfico y cronológico de ambos conjuntos; se expone la historia de las intervenciones y se presenta el registro arqueo-paleontológico documentado hasta la fecha.

Los capítulos cuarto y quinto comprenden el marco metodológico de nuestra investigación. En el capítulo 4 se presentan los métodos utilizados durante los trabajos que forman parte de la Tesis Doctoral. Debido a que se trata de una Tesis por compendio de artículos, en cada uno de ellos ya encontramos la correspondiente sección en la que se detallan los materiales y métodos empleados. A pesar de ello, en este capítulo se expone el conjunto de métodos de análisis zooarqueológico y tafonómico utilizados en los diferentes trabajos que componen nuestra investigación. El capítulo 5 comprende las experimentaciones llevadas a cabo con el objetivo de esclarecer los problemas de equifinalidad a la hora de identificar marcas de corte en conjuntos antiguos, con superficies óseas alteradas. Éstos se presentan en dos artículos, uno publicado y otro en revisión, en la revista *Journal of Archaeological Science* y han sido aplicados para resolver la problemática del conjunto faunístico del Barranc de la Boella.

En los capítulos sexto y séptimo se incluyen los artículos científicos en los que se exponen los resultados obtenidos durante el desarrollo de la Tesis Doctoral. En el capítulo 6 se exponen los resultados obtenidos para el conjunto del Barranc de la Boella, con tres artículos publicados en las revistas *Quaternary International* y *Palaeogeography, Palaeoclimatology, Palaeoecology* (2). En el capítulo 7 se presenta un manuscrito en revisión en la revista *Archaeological and Antrhopological Sciences*, en el que se presentan los resultados obtenidos tras el análisis de los materiales del yacimiento de Torralba. En el capítulo 8 se incluye una discusión general. Al igual que ocurre con los materiales y métodos, cada manuscrito incluido en esta Tesis Doctoral incluye una discusión específica, en las que se discuten los procesos de formación de los conjuntos arqueo-paleontológicos de los diferentes yacimientos y el rol desempeñado por los grupos de homininos y los carnívoros en cada caso, así como la problemática metodológica a la hora de analizar conjuntos con superficies óseas alteradas y los peligros de hacer inferencias erróneas en este tipo de conjuntos. El octavo capítulo no pretende ser una síntesis de las ya mencionadas discusiones; se presenta una discusión general, con la que se pretende ahondar sobre el rol desempeñado por los grupos humanos en estos contextos abiertos, comprendidos dentro de una escala de movilidad regional en la que estos grupos habrían desarrollado sus actividades. El capítulo 9 recopila las conclusiones a las principales hipótesis que hemos planteado en el presente trabajo, donde se define un escaso rol de los grupos de homininos en la formación de ambos depósitos, en los que su presencia, sin embargo, es indiscutible y se enmarca en el desarrollo de las prácticas de forrajeo que estos grupos llevarían a cabo en entornos de elevada presencia de recursos. Finalmente, en el último capítulo, el 10, se presentan las perspectivas de futuro surgidas de esta investigación.

## 1. Introduction

The pioneering works that researchers such as Behrensmeyer (1975; 1978; 1983) and Hill (1979a; 1979b) conducted in the African savanna have allowed us to focus attention on Pleistocene bone concentrations formed in open spaces, and made the savannah a frame of reference for the reconstruction of the paleoecological dynamics that could have occurred in this type of context. In a space where the natural tendency is dispersion as opposed to accumulation, we must understand the concentrations of fossils as the result of the participation of dynamic processes (biological agents, water currents, colluvial, etc.) resulting from the transport and deposition of elements in a single place (Domínguez-Rodrigo and de la Torre, 1999).

These processes include the demonstrated ability of physical agents such as water currents to form accumulations (Hanson, 1980). However, such physical agents do not seem to be behind large Pleistocene bone accumulations, which have been described mostly as the result of the intervention of carnivores and hominins (e.g. Hugues, 1954; Kruuk and Turner, 1967; Mech, 1970; Sutcliffe, 1970; Kruuk, 1972; Schaller, 1972; Hill, 1980; 1983; 1984; 1989; Maguire et al., 1980; Skinner et al., 1980; 1986; 1998; Binford, 1981; 1988; Brain, 1981; Klein y Cruz-Uribe, 1984; Binford et al., 1986; Kerbis-Peterhans, 1990; Cruz-Uribe, 1991; Skinner and van Aarde, 1991; Stiner, 1991; Lam, 1992; Domínguez-Rodrigo, 1994; 1995; Fosse, 1995; Martín and Borrero, 1997; Mills and Gorman, 1997; de Ruiter and Berger, 2000; Pickering, 2002; Brugal and Fosse, 2004; Lacruz and Maude, 2005; Fernandez et al., 2006; Montalvo et al., 2007; Pokines and Kerbis Peterhans, 2007; Fernandez and Guadelli, 2008; Lansing et al., 2009; Yravedra et al., 2011; 2012; Stiner et al., 2012; Rodríguez-Hidalgo et al., 2013; 2015; Arriaza and Domínguez-Rodrigo, 2016; Borrero et al., 2018; Saladié et al., *in press*). Indeed, the accumulations generated by these agents have been intensely addressed in the literature for more than four decades, in an effort to characterize them and establish criteria that would allow their correct identification in the archaeological record.

It has been possible to attribute some Pleistocene fossil concentrations in open spaces to human groups (Domínguez-Rodrigo et al., 2010c). Other fossil concentrations in these contexts, however, have resulted from the accumulation of successive independent events over prolonged periods of time, in which no main accumulating actor can be determined (Binford, 1983). In this type of concentration, it is not uncommon to find evidence of the presence of hominin populations, in the form of lithic industry and signs of carcass processing, although the latter tend to be scarce or absent in many cases (e.g. Barba and Domínguez-Rodrigo, 2007; Domínguez-Rodrigo and Barba 2007a; 2007d; Bunn et al., 2010; Domínguez-Rodrigo et al., 2010b; Yravedra et al., 2017b). This type of concentration is framed within the environment in which it is found and must be understood in a regional and macro-regional sense, in which groups of hunter-gatherers conducted the multiple activities of their daily lives, among which those related to subsistence are of particular interest to us. It is important to improve upon our characterization and knowledge of these assemblages in order to reconstruct the dynamics of Pleistocene hominin populations, as well as their ability to inhabit different environments. The ability of these hominin groups to acquire resources and adapt to the presence of other predators are of central importance to their study from a taphonomic and zooarchaeological perspective.

This doctoral thesis focuses on the assemblages from the Barranc de la Boella (Tarragona) and Torralba (Soria) sites. Both represent paleoecological contexts that share some aspects in common: they are open-air sites, formed in fluvial-deltaic contexts in which the presence of human groups is clearly documented through lithic industry, but in which the evidence of anthropic activity on the carcasses of animals is scarce.

Excavation work has been underway at Barranc de la Boella since 2007, and has focused on Unit II, dated to approximately one million years old. The excavations have affected three penecontemporary areas: Pit 1, la Mina and el Forn, which are part of the same stratigraphic sequence. The first taphonomic studies (Saladié et al., 2008) indicated the presence of a butchering site, a single event involving the exploitation of a mammoth carcass in Pit 1, an interpretation that was supported in later works (Vallverdú et al., 2014b; Mosquera et al., 2015). The other two areas excavated in the Barranc de la Boella, la Mina and el Forn, have also been included in this doctoral thesis because during the excavation work, it was perceived that these accumulations included greater taxonomic variability, a less intense anthropic component, and a greater presence of carnivores as accumulative agents than in Pit 1.

Interventions at the Torralba site began more than a century ago, conducted by Enrique de Aguilera y Gamboa, the 17th Marquis of Cerralbo. To date, it has undergone three different excavation periods, led by Cerralbo (1909-1913), Howell (1961-1963) and Alfredo Pérez-González and Manuel Santonja (1994-1999). The deposit, dated to around 200 ka (N. Mercier, in Santonja et al., 2014), along with the neighboring site of Ambrona, immediately became a valuable resource in the defense of the hunting capacities of Middle Pleistocene hominins, initially considered responsible for the concentrations of elephant remains excavated at both sites (e.g. Aguilera y Gamboa, 1913; Howel, 1966; Butzer, 1971). These hypotheses were subsequently challenged by other researchers (e.g. Binford, 1981; 1987; Shipman and Rose, 1983b; Villa et al., 2005) who questioned the active role of hominin groups in the accumulations. This doctoral thesis includes the study of the materials from the classic Torralba excavations (Cerralbo and Howell periods) deposited in the Museo Arqueológico Natural de Madrid (MAN), Museo Nacional de Ciencias Naturales de Madrid (MNCN-CSIC) and Museo Numantino de Soria (MNS).

The main objectives of this research are: 1) To characterize the nature of the bone accumulations studied; 2) To identify the role of the groups of hominins in the formation and modification of said accumulations; 3) To understand how these accumulations were integrated into the macro-regional space in which the hominin groups of the Lower Paleolithic conducted their activities.

Our initial hypothesis suggests that hominin groups played a limited role in the formation of the studied assemblages. Due to the paleoecological context in which these sites are framed, they should be understood as spaces of transit, not necessarily of activity, that would have been part of the space in which these groups existed and carried out all their daily activities.

This doctoral thesis is structured in 10 chapters. The present chapter represents the introduction, which establishes the frame of reference for the sites under study as well as the objectives and hypotheses of our research. The second chapter describes the state of the art of all the aspects that will later be developed throughout this study. In this chapter, these issues and concepts are defined, and data is presented about the accumulation and formation processes of archaeological deposits in open-air contexts, the regional mobility of hunter-gatherer groups, and the issue of equifinality in taphonomic studies and its implications when making zooarchaeological and behavioral inferences regarding the hominin groups of the Lower Paleolithic. The archaeological assemblages from the Barranc de la Boella and Torralba analyzed in this doctoral thesis are presented in chapter 3. The geological, lithostratigraphic and chronological context of both sites is described as are the history of the archaeological interventions and the archaeo-paleontological record documented to date.

The fourth and fifth chapters comprise the methodological framework of our research. Chapter 4 contains the methods used during the research for this doctoral thesis. As this thesis consists of a compendium of articles, we present the sections of those articles in which the materials and methods are described. We present a compendium of the zooarchaeological and taphonomic methods applied during the analysis of the materials. Chapter 5 includes the experiments conducted with the aim of clarifying the problems of equifinality when identifying cut marks at ancient sites with altered bone surfaces. These are presented in two articles, one published and one under review in the *Journal of Archaeological Science* and have been applied to solve the problems of the faunal bone surfaces from the Barranc de la Boella.

The sixth and seventh chapters contain the scientific articles in which the results obtained during the development of this doctoral thesis are included. Chapter 6 presents the results obtained for the Barranc de la Boella through three articles published in the journals *Quaternary International* and *Palaeogeography, Palaeoclimatology, Palaeoecology* (2). In Chapter 7, an under review manuscript is presented from the journal *Archaeological and Anthropological Sciences*, in which the results obtained after the analysis of the materials from the Torralba site are presented. A general discussion is included in chapter 8. As with the materials and methods, each manuscript included in this doctoral thesis includes a specific discussion which addresses the formation processes of the archaeo-paleontological assemblages of the Barranc de la Boella and Torralba and the role played by the hominin groups and carnivores in each case, as well as the methodological problems involved in analyzing accumulations with altered bone surfaces and the dangers of making erroneous inferences in these types of accumulations. The eighth chapter does not attempt to summarize the aforementioned discussions, but rather a general discussion is presented, which seeks to delve into the role played by human groups in these open contexts, included within a scale of regional mobility in which these groups would have undertaken their daily activities. Chapter 9 consists of the conclusions to the main hypotheses that we pose in this paper. It defines the limited role played by the hominin groups in the formation of the three deposits, while affirming their indisputable presence, which should be understood in the framework of the foraging activities that these groups would have conducted in environments with abundant resources. Finally, in the final chapter, we present the implications for future studies arising from this research.

# Capítulo 2. Marco teórico

*The chief problem of this branch of science is the study of the transition (in all its details) of animal remains from the biosphere into the lithosphere, i.e., the study of a process in the upshot of of* [sic] *which the organisms pass out of the different parts of the biosphere and, being fossilized, become part of the lithosphere* (Efremov, 1940: 85). La rama de la ciencia a la que Efremov hace referencia es la actuopaleontología, rama de la paleontología que estudia los organismos fósiles comparándolos con organismos vivos similares. Efremov se sirvió de esta frase para plantear un problema que afectaba no solo a la actuopaleontología, sino a todas aquellas ramas derivadas de la Geología que se encargaban del estudio de los organismos vivos del pasado: la carencia de información sobre los procesos de enterramiento y fosilización de los organismos y, por ende, los procesos de formación de los yacimientos arqueo-paleontológicos.

A partir de esta premisa Efremov definió, en ese mismo trabajo, la Tafonomía, una disciplina derivada de las ciencias geológicas cuyo estudio radica en las leyes del enterramiento. El término *Tafonomía* deriva, precisamente, de los términos griegos *taphos* (enterramiento) y *nomos* (ley) y es, según su definición, el estudio de un proceso cuyo resultado final es que los restos de los organismos que sucumben en las diversas partes de la biosfera, una vez fosilizados, se convierten en parte de la litosfera (Efremov, 1940). Las principales preocupaciones de Efremov se centraban en el momento y en la manera en la que se producía un sesgo en el registro fósil. En este sentido, la Tafonomía debería servir para entender los diversos procesos que afectaban a un animal desde el momento de su muerte, haciendo hincapié en los procesos ocurridos durante *la transición de un animal de la biosfera a la litosfera* ya que, según Efremov (1953) era en este momento cuándo se producía el mayor sesgo de la muestra.

Efremov no es, en realidad, el primero en prestar atención sobre el origen de las acumulaciones faunísticas pretéritas, si bien es cierto que su trabajo supuso un antes y un después en la materia. Algunos trabajos (Cadée, 1990; Lyman, 1994: 12-33; Yravedra, 2006: 25-35) han intentado sintetizar el origen y desarrollo historiográfico de aquellos que, desde comienzos del siglo XIX y hasta inicios del siglo XX, empezaron a prestar atención a la fauna presente en el registro arqueo-paleontológico, que acabaron suponiendo un punto de partida para una disciplina que no ha parado de desarrollar nuevos marcos conceptuales, teóricos y metodológicos desde entonces, siempre basados en el concepto uniformitarista de la naturaleza (Simpson, 1970).

Dart (1957; 1971) es quién intenta por primera dar explicaciones conductuales a las concentraciones fósiles pleistocenas (Brain, 1981; Lyman, 1994). Establecerá la denominada "*cultura osteodontokerática*" (Dart, 1957) para dar explicación a los tafotipos que encuentra en diversas cuevas surafricanas como Makapansgat o Sterkfontein y dotará de un origen antrópico a las acumulaciones y modificaciones óseas presentes en dichas cavidades.

Las hipótesis de Dart fueron cuestionadas desde un primer momento (Le Gros Clark, 1957; Straus, 1957; Washburn, 1957). Washburn (1957) fue el primero en observar que las hienas también transportaban elementos esqueléticos y formaban acumulaciones óseas en sus cubiles. La comparación de los perfiles esqueléticos con el registro de las mencionadas cavidades le llevará a defender que las hienas habrían sido los principales agentes acumuladores y los australopitecinos, parte de sus presas.

Brain (1981) también cuestionó el origen antrópico de las concentraciones fósiles de las cuevas surafricanas, implicando a los carnívoros como principales agentes acumuladores. La importancia de las aportaciones de Brain reside, precisamente, en el uso del actualismo para la caracterización e interpretación de las acumulaciones fósiles, mediante la concepción de un marco teórico a través del estudio de la etología de los carnívoros africanos actuales, en el desierto del Kalahari.

Por otra parte, a inicios de la década de los ’70 nos encontramos con los trabajos de Isaac (1971; Isaac y Crader, 1981) y Mary Leakey (Leakey, 1971) en la zona del Rift, en los yacimientos de Olduvai y Koobi Fora. Estos trabajos supusieron un primer intento de diferenciar y caracterizar las distintas acumulaciones arqueo-paleontológicas, entendiendo estos conjuntos como distintos espacios en los que los grupos humanos habrían desarrollado diferentes actividades (p.e. *home bases*, *butchering sites*…), llegando a establecer las características propias de la *humanidad* que habrían definido la conducta humana (Leakey, 1971; Isaac, 1976; Isaac, 1978).

Al tiempo que Brain se encuentra haciendo sus estudios en el desierto del Kalahari, encontramos a Binford (1978b; 1980; 1981; 1983) desarrollando estudios actualistas, que buscaban también establecer marcos metodológicos para entender las acumulaciones del pasado. Aunque tal y como confiesa (Binford, 1983), no tenían noticia el uno del otro, sus propuestas tuvieron resultados paralelos. Ambos sembraron las bases de los estudios zooarqueológicos. Las propuestas de Binford fueron uno de los impulsos más importantes junto a las propuestas de David L. Clarke (p.e. 1968) para la Arqueología Procesual, o *New Archaeology*. Para Binford la arqueología debía considerarse una rama de la antropología y tratarse como una ciencia. De este modo y mediante el uso del método científico, se podrían establecer generalizaciones a partir de las conclusiones obtenidas (Binford, 1983).

Además, introducirá la necesidad del uso de la estadística en las investigaciones zoo-arqueológicas y dará por primera vez verdadera importancia al concepto de espacio en Arqueología (Binford, 1978b). Binford defenderá la importancia de entender el concepto de espacio en un sentido doméstico (p.e. la caracterización y diferenciación de las que denominará *drop zone* y *toss zone*) (Binford, 1978a) pero también en un sentido amplio, remarcando la necesidad de conocer el marco regional en el que las comunidades de cazadores-recolectores se integran y realizan el conjunto de sus actividades (Binford, 1978b; 1980). Binford también planteará la necesidad de contar una Teoría de Alcance Medio en Arqueología, que permita la construcción de marcos referenciales en contextos actuales que nos permitan desarrollar analogías para descifrar el registro arqueológico (Binford, 1983).

Inspirados en la línea de pensamiento de la Arqueología Procesual, a mediados de la década de los ’70 nació la corriente de la Arqueología Conductual (*Behavioral Archaeology*) de la llamada “Escuela de Arizona”, con los trabajos de Schiffer y colegas (Schiffer, 1976; 1983; 1987; LaMotta y Schiffer, 1999), considerados extensión o superación de la *New Archaeology* (Jiménez Jáimez, 2008). La Arqueología Conductual entiende la arqueología como el estudio de la relación existente entre el comportamiento humano y la cultura material (Schiffer, 1976), haciendo hincapié en el estudio de la formación del registro arqueológico y en los procesos acumulativos y erosivos que en él intervienen (Schiffer, 1976; 1983; 1987; LaMotta y Schiffer, 1999). Estos investigadores definen la existencia de un contexto sistémico en el que los procesos acumulativos se verían continuamente afectados por procesos erosivos (p.e. tareas de limpieza y mantenimiento de un sitio, o recuperación y reutilización de objetos). Como consecuencia, entienden que la cultura material que acabaría formando parte del contexto arqueológico sería el resultado de continuos procesos de acumulación y erosión que se repiten hasta llegar a la fase de abandono (Schiffer, 1976; LaMotta y Schiffer, 1999). Esta fase y los momentos inmediatamente anteriores serían, salvo excepciones, los que quedarían finalmente representados en el conjunto arqueológico (Stevenson, 1985).

Para los arqueólogos conductualistas, los restos arqueológicos dejan de ser escombros si se aplica a su estudio el método inductivo; es decir, proponen la extracción de conclusiones a partir de los datos particulares (Schiffer, 1983; 1987). En las tendencias actuales sabemos que la extracción de leyes o generalidades es imposible, precisamente por la influencia de la diversidad de la conducta humana. Aun así, la necesidad del uso del método científico en la descripción de las señales tafonómicas es imprescindible para el correcto análisis e interpretación de los conjuntos.

Desde la Tafonomía se han intentado reconstruir los procesos de formación, tanto de acumulación como de depleción, de los conjuntos arqueológicos, para la comprensión de la conducta de las diferentes especies homininas del pasado y así comprender en qué ambientes desarrollaron estas actividades. Para ello usamos proxies como el reconocimiento de las señales tafonómicas (Binford, 1981; Potts y Shipman, 1981; Shipman, 1981a; Shipman y Rose, 1983a; Olsen y Shipman, 1988; Bello y Soligo, 2008; Bello et al., 2009; Domínguez-Rodrigo et al., 2009a; 2017; Merrit, 2012; *in press*; Pineda et al., 2014; Mate-González et al., 2015; *in press*; Palomeque-González et al., 2017; Braun et al., *in press*; Courtenay et al., *in press*), los perfiles anatómicos (Marean y Spencer, 1991; Marean et al., 1992; Blumenschine y Marean, 1993; Capaldo, 1997; Faith y Behrensmeyer, 2006; Domínguez-Rodrigo y Organista, 2007; Faith et al., 2007; Egeland, 2008; 2014; Saladié et al., 2014) o las edades de muerte (Hillson, 1996; Bunn y Pickering, 2010; Marín et al., 2017), por poner algunos de los ejemplos más relevantes. Todo ello en un momento en que en nuestros estudios el problema creciente de la equifinalidad tafonómica es cada vez más palpable (Domínguez-Rodrigo y Barba, 2006; 2007c; Domínguez-Rodrigo et al., 2009a; 2010a; 2017; Pineda et al., 2014; Domínguez-Rodrigo y Alcalá, 2016; Domínguez-Rodrigo Sahle et al., 2017; Yravedra et al., 2017a).

Identificar correctamente una modificación tafónomica y relacionarla con un agente es el objetivo de la interpretación tafonómica para, en la medida de lo posible, establecer su relación con la conducta humana o de otros seres vivos del entorno de los propios homininos. Gifford-Gonzalez (1991) defiende que, desde un punto uniformitarista de la materia, existe una relación entre los agentes causales, actores y efectores y las señales que producen. Sin embargo, uno de los principales problemas es que los efectos físicos de diferentes actores pueden superponerse y acabar creando un mismo patrón (Lyman, 1987; 1994; Gifford-Gonzalez, 1991). Lyman (1987) lo describe como un problema de equifinalidad, el cual genera dificultades para establecer relaciones actor-señal y de realizar las subsecuentes interpretaciones tafonómicas y zooarqueológicas. Según Gifford-Gonzalez (1991) el problema viene dado porque un suceso causal especifico puede darse en circunstancias completamente diferentes, incluyendo diferentes actores y ambientes. Siguiendo la premisa de Shipman (1981a) de que sólo los aspectos distintivos pueden ser considerados como diagnósticos, nosotros sólo podemos atribuir una señal a un agente causal, actor o efector siempre que se demuestre que no puede atribuirse a ningún otro.

Enmarcada dentro de este contexto, una parte importante de nuestra literatura científica se ha generado para intentar solventar estos problemas de equifinalidad. En concreto, las marcas de corte han sido el sujeto principal de muchos de estos trabajos. En un primer momento, los trabajos se centraron en su caracterización morfológica, para ayudar a su correcta identificación (Binford, 1981; Potts y Shipman, 1981; Shipman, 1981a; 1981b; Shipman y Rose, 1983b; Olsen y Shipman, 1988) y a su diferenciación con estrías producidas por otros procesos físicos, como el trampling (Binford, 1981; Shipman, 1981b; Bromage, 1984; Andrews y Cook, 1985; Behrensmeyer et al., 1986; Olsen y Shipman, 1988; Fiorillo, 1991). A partir de aquí, se derivaron trabajos que intentaban relacionar las marcas de corte con actividades de carnicería concretas (Binford, 1981; Nilssen, 2000), con la herramienta y/o materia prima usadas (Walker y Long, 1977; Greenfield, 2006; Christidou, 2008; Domínguez-Rodrigo et al., 2009a; de Juana et al., 2010) y con el objetivo de secuenciar el acceso de homininos y carnívoros a las carcasas dentro del llamado "*debate caza* vs *carroñeo*" (Binford, 1981; 1988; Bunn, 1981; 1982; Shipman, 1981a; Wilson, 1982; Shipman y Rose, 1983a; Binford et al., 1985; Blumenschine, 1986; 1987; 1988; 1989, 1991; 1995; Bunn y Kroll, 1986; Marean, 1989; Selvaggio, 1994b; Capaldo, 1995; 1997; Domínguez-Rodrigo, 1996; 1997a; 1997b; 1999c; 2002; Domínguez-Rodrigo y Pickering, 2003). En estos momentos nos encontramos ante trabajos que vuelven a mostrarse críticos con los criterios empleados para su correcta identificación (Domínguez-Rodrigo et al., 2009a; 2010a; 2017; Pineda et al., 2014; Domínguez-Rodrigo y Alcalá, 2016; Sahle et al., 2017) puesto que todavía nos enfrentamos a problemas de subjetividad y, en consecuencia, de equifinalidad a la hora de identificar estas estrías (Domínguez-Rodrigo et al., 2017; Sahle et al., 2017). La correcta o incorrecta identificación de las marcas de corte puede conllevar a cambios de paradigma. Por ejemplo, ¿usaron los homininos previos a *Homo* elementos con bordes cortantes para ayudarse en los procesos de carnicería hace 3.3 Ma, como sugirieron McPherron y colegas (2010)? ¿O bien se trata de una incorrecta identificación de las estrías, que serían en realidad producidas por el trampling (Domínguez-Rodrigo et al., 2010a; Domínguez-Rodrigo y Alcalá, 2016)? Esta problemática nos conduce irremediablemente a la necesidad de rechazar la hipótesis alternativa de que estas estrías son producidas por cualquier otro proceso o agente, antes de aceptar su origen antrópico (Domínguez-Rodrigo y Alcalá, 2016). Por y para ello se siguen desarrollando nuevos métodos y técnicas para identificar dichas marcas y poder correlacionarlas con el comportamiento humano (Bello y Soligo, 2008; Bello et al., 2009; Domínguez-Rodrigo et al., 2009a; 2017; Merrit, 2012; *in press*; Pineda et al., 2014; Palomeque-González et al., 2017; Braun et al., *in press*; Mate-González et al., *in press*; Courtenay et al., *in press*).

En paralelo, se han desarrollado los estudios respecto a la equifinalidad en las modificaciones de los carnívoros (Selvaggio, 1994a; Domínguez-Rodrigo y Barba, 2006; Delaney-Rivera et al., 2009; Andrés et al., 2012; Rodríguez-Hidalgo et al., 2013; Saladié et al., 2013b; Domínguez-Rodrigo et al., 2015a; Arriaza et al., 2017; Yravedra et al., 2017a). Aunque, en este caso, la literatura científica ha sido menos intensa al respecto, probablemente debido a que su identificación macroscópica es más común. Shipman (Shipman, 1981a) estableció los criterios que caracterizaban las a las mordeduras y que han sido empleados durante más de dos décadas paran la identificación de dichas modificaciones, amparados en la validez de su identificación por parte de los tafónomos (Blumenschine, 1986). Sin embargo, trabajos posteriores han puesto en entredicho la validez de estas identificaciones (Domínguez-Rodrigo y Barba, 2006), demostrando que la acción de hongos y bacterias puede producir modificaciones que podrían mimetizarse con las mordeduras de carnívoros, poniendo en entredicho la validez de los criterios utilizados hasta la fecha en su identificación. Otros trabajos han intentado caracterizar morfológicamente las mordeduras producidas por diferentes carnívoros (p.e. Selvaggio, 1994a; Delaney-Rivera et al., 2009; Andrés et al., 2012; Rodríguez-Hidalgo et al., 2013; Saladié et al., 2013b), e incluso las caracterización de las mordeduras humanas (p.e. Turner II, 1983; White, 1992; Andrews y Fernández-Jalvo, 2003; Cáceres et al., 2007; Landt, 2007; Lloveras et al., 2008; Delaney-Rivera et al., 2009; Fernández-Jalvo y Andrews, 2011; Saladié et al., 2013a; Romero et al., 2016) para su correcta identificación y así evitar los problemas de equifinalidad derivados de una identificación errónea (Sahle et al., 2017). En los últimos años, se han desarrollado trabajos que recurren a nuevas herramientas como la micro-fotogrametría y la morfometría geométrica para cumplir este cometido (Arriaza et al., 2017; Yravedra et al., 2017a).

En definitiva, nos encontramos ante una corriente de revisión de los criterios metodológicos que han sido empleados para definir el rol de homininos y carnívoros como agentes modificadores de los conjuntos fósiles y para inferir las correspondientes pautas conductuales. Esta puede enmarcarse en el Neo-procesualismo (Domínguez-Rodrigo, 2008) que, aunque tiene sus raíces en el Procesualismo, también muestra una postura crítica con él. Apostamos, como lo hicieron los primeros procesualistas (Biberson, 1968; Clarke, 1968; Flannery, 1969), por la necesidad de justificar todas las interpretaciones a través del realismo científico, aunque debemos declararnos incapaces de llevar a cabo una reconstrucción holística de la cultura de los homininos pleistocenos (Domínguez-Rodrigo, 2008; Domínguez-Rodrigo et al., 2017). Nos encontramos ante la intención de realizar reconstrucciones etnoarqueológicas, entrando en los sistemas sociales y culturales en la medida de lo posible, integrando el conocimiento del entorno natural en el que grupos homininos forrajeadores pretéritos, desde finales del Plioceno a inicios del Holoceno, habitaron; un entorno que incuestionablemente ofreció abundantes riesgos, pero también los recursos para garantizar su supervivencia y evolución.

### 2.1. Procesos de acumulación de restos y origen de las acumulaciones arqueologías al aire libre: importancia de los estudios actualistas

Desde el nacimiento de la Arqueología Procesual, el actualismo se ha convertido en uno de los pilares básicos para el sustento de nuestras investigaciones, puesto que supone el pilar base que nos permite realizar analogías para acercarnos al comportamiento de los grupos de homininos del pasado y conocer sus roles en la formación de los depósitos arqueológicos. El actualismo parte de la premisa teórica en la que se asienta el uniformitarismo, según la cual la observación directa de elementos del presente es la clave mediante la cual podemos acercarnos al pasado, ya que nos permite establecer hipótesis sobre lo que habría sucedido (Simpson, 1970). No obstante, debemos ser conscientes de los riesgos que entraña la mala aplicación de las asunciones uniformitaristas y de las analogías defectuosas (Simpson, 1970; Lawrence, 1971).

Nosotros entendemos el término *analogía* según la definición de Bunge (1981), recientemente puesta en boga por Domínguez-Rodrigo y colegas (2017). Bunge entiende que el razonamiento más analógico en la ciencia ocurre en estructuras sistémicas dinámicas. Estas estructuras dependen de la interacción ajustada de tres componentes: composición (colección de los componentes en alguno de los dos sistemas), estructura (relación de esos componentes con cada sistema) y ambiente (determina como los componentes del sistema interactúan). A partir de ello, Bunge (1981) determina que dos sistemas pueden ser sustancialmente análogos (cuando comparten los mismos componentes), estructuralmente análogos (cuando comparten estructuras similares) o ambientalmente análogos (cuando sus contextos son similares). No todos los razonamientos analógicos son igualmente válidos, por lo que establece grados en estas analogías (sustanciales, estructurales y ambientales) y determina el *grado de analogía total*, como una media del grado de las analogías sustancial, estructural y ambiental compartidas entre dos sistemas (Bunge, 1981). Se requiere, por tanto, la presencia de sistemas verdaderamente análogos para aplicar este tipo de inferencias, ya que el uso de marcos de referencia ampliamente divergentes conllevaría a una interpretación errónea de los conjuntos fósiles y del comportamiento de los grupos de homininos (Domínguez-Rodrigo et al., 2017).

Gifford-González (1991) cuestiona los fallos derivados del uso de analogías formales, en las que las relaciones estipuladas se basan exclusivamente en semblanzas de cualidades formales. Defiende la importancia del uso de analogías relacionadas, ya que los enlaces entre el origen y el contexto, por un lado, y los criterios relevantes de semblanzas, por el otro, son sistémicos y basados causalmente (Gifford-González, 1991).

La sabana africana se ha convertido en el marco referencial para los arqueólogos que centran sus trabajos en el comportamiento desempeñado por los grupos humanos plio-pleistocenos en espacios abiertos (Maguire et al., 1980; Brain, 1981; Blumenschine, 1986; Cruz-Uribe, 1991; Domínguez-Rodrigo, 1994;, 1995; 1999a; Capaldo, 1997; Pickering, 2002; Brugal y Fosse, 2004; Faith y Behrensmeyer, 2006; Faith et al., 2007; Pokines y Kerbis Peterhans, 2007; Egeland et al., 2008; Prendergast y Domínguez-Rodrigo, 2008; Pante et al., 2012; Egeland, 2014; Pante et al., 2015; Arriaza y Domínguez-Rodrigo, 2016). No debemos obviar que algunos elementos de los diferentes ambientes pueden haber variado, como por ejemplo la densidad de carnívoros (Van Valkenburgh, 2001) o sus propias pautas comportamentales (Shipman, 1981a; Gifford-González, 1991), por lo que las analogías entre la sabana africana y los ecosistemas pleistocenos deben hacerse cautelosamente. Uno de los errores más comunes es la llamada *ecología transferida* (Lawrence, 1971), que consiste en atribuir a ecosistemas pasados características propias de los ecosistemas modernos en base a pocos puntos de características físicas en común entre ambos ecosistemas.

Un segundo problema derivado del uniformitarismo y del uso de analogías es el ya mencionado problema de la equifinalidad. De acuerdo a Shipman (1981a), sólo los aspectos distintivos pueden ser considerados como diagnósticos a la hora de usar analogías para interpretar el registro pretérito, si bien es cierto que en ocasiones un efecto que en sí mismo podría no ser diagnóstico, puede pasar a serlo si forma parte de un conjunto de efectos o modificaciones (Saladié et al., *in press*).

Uno de los primeros temas de estudio fue la dispersión de carcasas y elementos esqueléticos en estos espacios, enmarcado dentro del ya mencionado debate sobre el posible origen antrópico de las acumulaciones de yacimientos como Olduvai o Koobi Fora. Behrensmeyer (1975; 1978) estudió la deposición de los huesos en espacios abiertos y describió su descomposición y destrucción como parte natural de un proceso de reciclaje en el que la supervivencia y posterior fosilización de los huesos acabaría dependiendo de la intensidad de los procesos que incidiesen y de un enterramiento previo a su destrucción (Behrensmeyer, 1978). Los primeros trabajos (Hill, 1979a; 1979b; Behrensmeyer y Boaz, 1980; Behrensmeyer, 1983) ya evidenciaron la disposición de los restos a dispersarse en los espacios abiertos pues, como describen Domínguez-Rodrigo y de la Torre (1999: 16) "*la tendencia natural* [de las concentraciones óseas] *es la dispersión y no la concentración, ya que los huesos de un animal, tras su muerte, suelen desaparecer por la acción de agentes físicos y biológicos o, los que perduran, se dispersan debido a los mismos responsables*".

Teniendo en cuenta esta premisa, las concentraciones fósiles deben ser entendidas como el resultado de la actividad de agentes y/o procesos de acumulación de restos, que acaban dando lugar a la formación del registro arqueológico. Estos procesos se dividen en dos grupos: procesos dinámicos y procesos estáticos. Para Domínguez-Rodrigo y de la Torre (1999), los procesos estáticos se corresponden con deposiciones naturales de carcasas, por depredación, muertes naturales o catastróficas, mientras que los procesos dinámicos engloban a aquellos agentes, tanto físicos como biológicos, que transportan materiales. Excepcionalmente podemos encontrar conjuntos que sean consecuencia de procesos estáticos, como por ejemplo los *butchering/kill sites* que podrían haber muerto de manera natural o mediante depredación. Sin embargo, Domínguez-Rodrigo y de la Torre (1999) determinan que las acumulaciones al aire libre son propiciadas por procesos dinámicos. Entre los procesos dinámicos, homininos y carnívoros han sido descritos como los mayores agentes acumuladores de carcasas de macromamíferos y han centrado un volumen muy importante de la literatura al respecto (Hugues, 1954; Kruuk y Turner, 1967; Mech, 1970; Sutcliffe, 1970; Kruuk, 1972; Schaller, 1972; Hill, 1980; 1983; 1984; 1989; Maguire et al., 1980; Skinner et al., 1980; 1986; 1998; Binford, 1981; 1988; Brain, 1981; Klein y Cruz-Uribe, 1984; Binford et al., 1986; Kerbis-Peterhans, 1990; Cruz-Uribe, 1991; Skinner y van Aarde, 1991; Stiner, 1991; Lam, 1992; Domínguez-Rodrigo, 1994; 1995; Fosse, 1995; Martín y Borrero, 1997; Mills y Gorman, 1997; de Ruiter y Berger, 2000; Pickering, 2002; Brugal y Fosse, 2004; Lacruz y Maude, 2005; Fernandez et al., 2006; Montalvo et al., 2007; Pokines y Kerbis Peterhans, 2007; Fernandez y Guadelli, 2008; Lansing et al., 2009; Yravedra et al., 2011; 2012; Stiner et al., 2012; Rodríguez-Hidalgo et al., 2013; 2015; Arriaza y Domínguez-Rodrigo, 2016; Borrero et al., 2018; Saladié et al., *in press*, por poner algunos ejemplos). Es cierto que otros agentes biológicos como los grandes roedores también generan acumulaciones de materiales (Brain, 1981). Además, determinados agentes físicos también pueden generar acumulaciones óseas. Se ha descrito, por ejemplo, la capacidad de las corrientes hídricas para generar dichas acumulaciones, en las que factores como la energía de la corriente o la densidad de los restos transportados acaban influyendo en la composición resultante (Hanson, 1980).

El nivel de transporte y de la subsecuente acumulación de restos óseos por parte de los carnívoros viene marcado por la posición que el animal ocupa en la cadena trófica y de la capacidad de defensa de sus presas ante otros predadores, aunque también intervienen otros factores como el tipo de hábitat o el grado de disponibilidad de recursos (Domínguez-Rodrigo, 1994). Los leones, por ejemplo, ocupan el eslabón más alto de la cadena trófica. Las interpretaciones tradicionales sugieren que esta posición jerárquica les permite consumir a sus presas en el lugar de adquisición y sin transporte de carcasas (Schaller, 1972; Domínguez-Rodrigo, 1994; 1995; 1999a). Sin embargo, los leones ejemplifican la posible variabilidad de la conducta de los gremios de carnívoros, ya que recientemente Arriaza y colegas (2016) han descrito una acumulación originada por estos actores. Los otros félidos que ocupan la sabana, guepardos y leopardos, desplazan a sus presas a lugares seguros: los guepardos suelen transportarlas a zonas de arbusto o hierbas altas, sin llegar a formar acumulaciones (Domínguez-Rodrigo, 1994), mientras que leopardos suelen trasladarlas sistemáticamente a árboles o cuevas, para su posterior consumo (Brain, 1981; Domínguez-Rodrigo, 1994; 1999b; de Ruiter y Berger, 2000; Van Valkenburgh, 2001). El transporte repetido a un mismo árbol puede acabar formando pequeñas acumulaciones óseas (Brain, 1981), aunque sólo el uso repetido de cavidades acaba formando acumulaciones óseas importantes (Domínguez-Rodrigo, 1994; de Ruiter y Berger, 2000). El puma, aunque lejos de la sabana africana, también ha sido descrito como un agente acumulador (Martín y Borrero, 1997; Montalvo et al., 2007; Stiner et al., 2012; Borrero et al., 2018).

Por otra parte, los cánidos tienden a realizar un consumo rápido en el lugar de aprehensión o cercano al mismo, debido a su adaptación para el consumo rápido de presas o carroña (Kruuk y Turner, 1967; Mech, 1970; Domínguez-Rodrigo, 1995; 1998). Cuando realizan transporte de alimentos, éste puede limitarse a la regurgitación de carne, con escaso aporte de elementos esqueléticos (Domínguez-Rodrigo, 1998).

Múltiples estudios intentan establecer criterios que permitan describir las acumulaciones formadas por hienas, principalmente la hiena manchada (*Crocuta crocuta*) (Hugues, 1954; Sutcliffe, 1970; Kruuk, 1972; Skinner et al., 1980; 1986; 1998; Brain, 1981; Kerbis-Peterhans, 1990; Skinner y van Aarde, 1991; Lam, 1992; Fosse, 1995; Mills y Gorman, 1997; de Ruiter y Berger, 2000; Pokines y Kerbis Peterhans, 2007; Lansing et al., 2009; Saladié et al., *in press*) y diferenciarlas de las producidas por los grupos humanos (Hill, 1980; 1983; 1984; 1989; Maguire et al., 1980; Brain, 1981; Klein y Cruz-Uribe, 1984; Binford et al., 1986; Binford, 1988; Kerbis-Peterhans, 1990; Cruz-Uribe, 1991; Gifford-González, 1991; Stiner, 1991; Pickering, 2002; Brugal y Fosse, 2004; Lacruz y Maude, 2005). En la actualidad, los perfiles anatómicos, taxonómicos, de edad, y las modificaciones superficiales son los elementos utilizados para identificar al agente acumulador (p.e. Gifford-González, 1991; Stiner, 1991; Pickering, 2002; Egeland et al., 2008; Saladié et al., *in press*). Otros elementos como la presencia de coprolitos de hiena o de huesos digeridos pueden ayudar a definirlos (Pickering, 2002). Estos criterios, no obstante, están sujetos a historias tafonómicas y procesos post-deposicionales que habrían afectado a los conjuntos arqueo-paleontológicos y que los habrían dotado de una alta variabilidad (Pickering, 2002; Egeland et al., 2008; Prendergast y Domínguez-Rodrigo, 2008; Saladié et al., *in press*).

Además de los actores descritos, debemos tener en cuenta las especies extinguidas, de las que se han identificado acumulaciones de extintos tigres dientes de sable (*Homotherium serum*) (Marean y Ehrhardt, 1995) y de la hiena gigante, *Pachycrocuta brevirostris* (Arribas y Palmqvist, 1999).

En espacios abiertos, también podemos encontrar otro tipo de contextos que son el resultado de la acumulación sucesiva de eventos independientes en los que no encontramos un actor protagonista en la formación de los depósitos. Binford (1983) caracterizó la actividad desarrollada alrededor de una charca, describiendo la multiplicidad de eventos que ocurren en ese espacio. Herbívoros y carnívoros desarrollan parte de su actividad en este entorno, en el que los carnívoros desempeñan un rol activo en la modificación de estos conjuntos sin asumir un papel protagonista en la acumulación de los mismos (Binford, 1983). En entornos Plio-Pleistocenos los homininos serían un agente que se sumaría y que circularía en estos espacios con abundantes recursos (y de diferente índole) durante el desarrollo de actividades de forrajeo (Binford, 1980; Delson, 2007).

Binford (1980) propuso que estas actividades de forrajeo acabarían dando lugar a acumulaciones en forma de palimpsestos. Estos palimpsestos serían consecuencia de la continua deposición de múltiples eventos de acumulación en la que el conjunto de agregados (bióticos y abióticos) que los conformaban estarían relacionados espacialmente, pero en los que las relaciones temporales no existirían o serían imposibles de determinar (Bailey, 2008). Excepcionalmente, entre estos conjuntos se han podido individualizar algunos eventos, en base a elementos como la correlación estratigráfica de los restos, la identificación de remontajes anatómicos y la homogeneidad de las modificaciones (Domínguez-Rodrigo et al., 2010b; Pineda et al., 2017a). La mayor parte de los yacimientos arqueológicos, no obstante, deben ser entendidos como palimpsestos, aunque excepcionalmente podamos encontrarnos ante conjuntos formados por un único episodio (Bailey, 2007; 2008), como el aprovechamiento de un caballo descrito en Boxgrove (Roberts y Parfitt, 1999) o de una carcasa de mamut recientemente descrito en la Pit 1 del Barranc de la Boella (Vallverdú et al., 2014b; Mosquera et al., 2015).

Bailey (2007; 2008) propuso una descripción de los palimpsestos según su carácter y la relación espacial y/o temporal entre sus agregados, como fuente para la obtención de información temporal que contienen. La clasificación propuesta es:

- ❖ *Palimpsesto real*: palimpsestos en el sentido estricto del término, en el que solo se preservan rastros de la última actividad realizada.
- ❖ *Palimpsesto acumulativo*: representa episodios sucesivos de deposición, que permanecen superpuestos entre sí sin pérdidas (acusadas) de información, aunque las evidencias se encuentren re-elaboradas de manera que no sea posible individualizar los constituyentes originales.
- ❖ *Palimpsesto espacial*: una mezcla de episodios segregados espacialmente, en el que las relaciones temporales son borrosas y difíciles de individualizar.
- ❖ *Palimpsesto temporal*: conjunto de materiales y objetos que forman parte de un mismo depósito espacial, pero en el que se representan eventos temporalmente diferenciados.

Los conjuntos al aire libre tienden a encajar, salvo excepciones, en la definición de palimpsestos espaciales (Bailey, 2008). En estos momentos nos encontramos ante la necesidad de identificar estos conjuntos. Su correcta caracterización contribuirá a nuestro entendimiento de las dinámicas existentes en el espacio macro-regional (de acuerdo a la concepción de Binford (Binford, 1978b; 1980) en el que se movían los grupos de homininos del Pleistoceno.

Uno de los primeros acercamientos al concepto del espacio en arqueología Prehistórica vino de la mano de los trabajos de Mary Leakey en la Garganta de Olduvai. Leakey (1971) a través de los distintos depósitos excavados en Olduvai propuso la existencia de cuatro tipos de yacimientos o acumulaciones: a) suelos de ocupación o *living floors*; b) yacimientos matadero (*butchering* o *kill sites*): c) yacimientos en contextos fluviales; y d) depósitos de dispersión vertical. Posteriormente, Isaac llevará a cabo un trabajo similar, clasificando los yacimientos plio-pleistocenos en diferentes *tipos*, basándose en la presencia, ausencia o co-ocurrencia de industria lítica y huesos en los yacimientos de Koobi Fora (Isaac, 1978; Isaac y Crader, 1981): a) Tipo A, formados por restos líticos en el que los huesos son poco abundantes; b) Tipo B, formados por industria asociada a los restos de un único mega-herbívoro (proboscídeos, hipopótamos o rinocerontes); y c) Tipo C, formados por artefactos líticos asociados a abundantes restos faunísticos.

Estos trabajos representan el intento de entender las relaciones espaciales existentes entre los materiales que forman un mismo conjunto y clasificar los conjuntos en base a dichos elementos (Leakey, 1971; Isaac, 1978; Isaac y Crader, 1981). Binford criticó estas tipologías y, especialmente, las interpretaciones que de estos conjuntos se derivan (Binford, 1983). La idea que tenía Binford de los homininos carroñeros estaba en total desacuerdo con la posibilidad de que estos transportasen elementos y por tanto generasen acumulaciones visibles desde un punto de vista arqueológico. Desde esta perspectiva, un carroñeo marginal no dispone de excedentes que transportar, ni compartir, contrariamente a las ideas expuestas por Isaac sobre el reparto no solo de alimentos, sino también de tareas de subsistencia (Isaac, 1978).

Sin embargo, Binford, tras sus estudios de los patrones de comportamiento de los esquimales Nunamiut, remarcó la necesidad de conocer las estrategias de movilidad territorial de los cazadores-recolectores (Binford, 1978b; 1980; 1982) para comprender los modelos de asentamiento y explotación de los recursos de los grupos humanos de finales del Paleolítico Medio (Binford, 1983).

Binford (1980) propone distinguir entre movilidad residencial y movilidad logística. La movilidad residencial caracteriza a los grupos *foragers* e implica el desplazamiento de todo el grupo de cazadores-recolectores hacia las fuentes de recursos críticos, que deben estar disponibles durante todo el año. La movilidad logística, contrariamente, implica el desplazamiento de una parte especializada del grupo hasta la fuente de recursos críticos situados en torno a un núcleo central, en el que se almacenan los recursos, que no estarían disponibles todo el año; esta estrategia caracterizaría a los grupos *collectors* (Binford, 1980). Además de los patrones de movilidad, Binford (1982) describe diversas áreas de movimiento y captación de recursos alrededor del núcleo central de campamento, entre las que se incluyen el área de búsqueda y el área logística (lugares de captación de recursos, con diferencias en la distancia y en la duración de las expediciones) o el *extended range* (área de la que suelen tener un control y un conocimiento de los recursos, aunque no estén dentro del rango de observación).

Otro modelo de movilidad es el propuesto por Woodburn (1991), que clasifica los sistemas económicos de los grupos nómadas según los tipos de movilidad. Por un lado, grupos de retorno inmediato (*inmediate return*), que practican la búsqueda diaria de recursos para el consumo inmediato y que se relacionan a las sociedades de bandas; por otro lado, grupos de retorno retardado (*delayed return*), que practican desplazamientos de más de una noche fuera de la zona residencial, con el almacenamiento y consumo no-inmediato de recursos, asociadas a sociedades no igualitarias.

Estos modelos muestran la importancia de la movilidad entre los grupos de cazadores-recolectores dentro de grandes territorios. Según Binford (1983), exceptuando a algunos grupos de zonal tropicales, los cazadores recolectores actuales pueden disponer de un área de dominio del medio ambiente de 300.000 km$^2$. Dentro de este vasto territorio hay zonas de mayor actividad y dónde encontramos las áreas residenciales y diferentes tipos de yacimientos ocupacionales y asentamientos ocupacionales, pero también zonas de paso. Según Binford (1983), yacimientos aislados pueden estar interconectados y formar complejos ocupacionales.

Esta movilidad también se ha documentado en grupos subtropicales *collectors,* como los Hadza, y *foragers*, como los Aché (Jones, 1983; 1993; Lee, 1998; Marlowe, 2010). Estas actividades acaban generando contextos arqueológicos de acumulación, que pueden clasificarse en *residenciales* y *no-residenciales* (Binford, 1976) y que pueden tener mayor o menor visibilidad arqueológica.

Binford también describe diferentes usos de un mismo emplazamiento en diferentes momentos, lo que aporta una mayor variabilidad al registro depositado. Así, un campamento de caza de verano, en el que las ocupaciones son cortas y de pocos individuos, puede ser usado como campamento residencial en otra época del año, donde se asentaría todo el grupo, en un periodo más largo en el que se desarrollan tareas diversas (Binford, 1982).

De hecho, la visibilidad en el registro arqueológico suele depender de la existencia de patrones de repetición a largo plazo de dichas actividades en un mismo espacio (Binford, 1982). Este concepto es definido como redundancia espacial (*spatial redundancy*) por Brooks y Yellen (1987), que lo catalogan con 5 aspectos: 1) es un factor clave para la creación de grandes concentraciones de escombros, a una escala regional; 2) las áreas reocupadas tienen más posibilidades de entrar a formar parte del registro arqueológico; 3) la redundancia espacial y la congruencia de actividades vienen condicionadas por una combinación de factores organizativos y ambientales; 4) es más probable que los espacios dedicados a actividades de aprovisionamiento, como los lugares de caza por emboscada, se asocien a la redundancia que los campamentos al aire libre; 5) las actividades que se derivan de esta redundancia espacial estarán desproporcionalmente representadas en el registro arqueológico.

Una de las principales aportaciones de estos trabajos es la importancia de considerar todos los yacimientos como parte de un sistema más amplio; esto es, un territorio conocido y controlado por parte de estos grupos. En nuestro caso, nuestros conjuntos deben ser entendidos como elementos integrados en este sistema, aunque debido a su naturaleza de lugares de tránsito nos encontramos ante sucesivos eventos independientes que somos incapaces de individualizar. Sin embargo, sabemos que los homininos del Pleistoceno inferior ya muestran una movilidad regional relacionada con la captación de alimentos, en entornos que albergan gran cantidad de recursos y que acaban siendo de atracción para otros depredadores (Domínguez-Rodrigo, 2001; Egeland, 2014; Saladié et al., 2014).

Diversos trabajos han demostrado las posibilidades de inferir los niveles de competencia en un entorno paleoecológico, así como la presión entre predadores (Marean y Spencer, 1991; Marean et al., 1992; Blumenschine y Marean, 1993; Capaldo, 1997; Faith y Behrensmeyer, 2006; Domínguez-Rodrigo y Organista, 2007; Faith et al., 2007; Egeland, 2008; 2014). La competencia es una interacción entre individuos, provocada por la existencia de un recurso requerido por ambos agentes, que conduce a una reducción en la supervivencia, crecimiento y/o reproducción de al menos algunos de los individuos o grupos (Begon et al., 2006). La competencia por los recursos puede tener lugar de dos maneras: directamente, cuando diversos consumidores se dirigen al mismo recurso al mismo tiempo; o indirectamente, cuando existen diversos consumidores que utilizan el mismo recurso a lo largo del tiempo (Faith y Behrensmeyer, 2006).

Para Capaldo (1997), la presencia de huesos largos enteros sería indicativo de una baja presión entre predadores, que les llevaría a abandonar elementos nutritivamente no explotados en su totalidad. Los trabajos de Faith y Behrensmeyer (2006) y Faith y colegas (2007) describieron como cambios en la densidad de poblaciones de grandes carnívoros (hienas y leones) en Amboseli (Kenia) podían verse reflejados en la representación esquelética de elementos y porciones que sobrevivan el proceso de saqueo por parte de los carnívoros machacadores de huesos. En condiciones óptimas, estos carnívoros tienden a acceder a los elementos esqueléticos que les reportan un mayor contenido nutritivo en menos esfuerzo, mientras que en momentos de elevada competencia los carnívoros machacadores de huesos tienden a consumir todas las partes esqueléticas posibles, con independencia de la densidad mineral y el aporte nutritivo, de manera que en los contextos de elevado saqueo se documenta una ausencia de correlación entre los elementos conservados y su densidad (Palmqvist y Arribas, 2001; Faith et al., 2007). Trabajos posteriores (Domínguez-Rodrigo y Organista, 2007; Egeland, 2008) también han documentado que la supervivencia de determinados elementos esqueléticos es una herramienta útil para acercamos a los niveles de saqueo y competencia en un determinado entorno, estableciendo modelos teóricos para su aplicación a contextos arqueológicos. Estas aproximaciones han permitido sustentar las capacidades de los grupos de homininos de sobrevivir en entornos altamente competitivos ya en cronologías tempranas (Domínguez-Rodrigo, 2001; Domínguez-Rodrigo et al., 2007; Egeland, 2008; 2014; Saladié et al., 2014; Pineda et al., 2015; 2017a).

# Capítulo 3. Áreas de estudio

## *3.1.* El Barranc de la Boella

### *3.1.1. Contexto geográfico y geológico*

El Barranc de la Boella se localiza en el extremo noreste de la Península Ibérica, en la localidad de la Canonja, a 3 km de la ciudad de Tarragona y 6 km de la actual costa mediterránea (Fig. 3.1). Tanto el Barranc de la Boella como el Barranc de Quart proceden de los contrafuertes paleozoicos de Castellver, de Almoster y de la Selva del Camp y llegan al mar por medio de la playa de la Pineda o del Francolí (Bataller y Vilaseca, 1923).

En la descripción del Plioceno y el Cuaternario aluvial de la provincia de Tarragona, el área que engloba Reus y Tarragona se caracteriza por tierras rojas arcillosas con gravas angulosas de pizarras procedentes de los torrentes que tienen la cabecera en el macizo de Prades. Estos depósitos se estratifican al llegar a la zona de Vila-seca, la Canonja y Constantí, con conglomerados cementosos amarillentos, arenas gruesas blancas y tierras grises arenosas en nichos regulares y poco extensos (Vallverdú et al., 2008).

El conjunto del Barranc de la Boella tiene relación con el valle fluvial antecedente del actual tramo final del valle del Francolí. Entre la Autopista A7 (término de Els Antigons) y el Mas de la Boella, se puede observar como la terraza de 50 m del río Francolí erosiona los depósitos de la paleoriera, mientras que junto a la Autovía Reus-Tarragona (N-420), los depósitos de la paleoriera están incididos en la terraza de 60 m. Pese a no tener una cartografía adecuada a la escala de sus afloramientos, los depósitos pleistocenos del Barranc de la Boella pertenecen en parte a una paleoriera incidida en las terrazas fluviales de más de 50 m. Esta paleoriera desembocaría en la finca de la Boella de la Canonja. Este tramo final antecedente del valle del Francolí se limita al este, por el relieve estructural del semigraben miocénico de les Gavarres, desde Constantí en dirección NNW-SSE hacia la playa de la Pineda y por el oeste por el glacis que cubre la depresión con una dirección W-E, desde Reus a la Selva del Camp hacia el semigraben de les Gavarres (Vallverdú et al., 2008; 2014b).

### *3.1.2. Litoestratigrafía y dataciones*

El Barranc de la Boella presenta una secuencia litoestratigráfica de 9 m de potencia nombradas I-VI de base a techo, descritas en detalle en Vallverdú et al (2014b) (Fig. 3.2). Esta estratigrafía es el resultado del relleno de un valle incidido en la terraza de + 60 m del río Francolí. La unidad I contiene superposiciones discordantes en un estrato de clastos neógenos en 1.5 m de gravas gruesas de esquisto clasto-soportadas imbricadas, bien estratificadas con y sin fangos rojizos azoicos. El grueso del material arqueopaleontológico del barranco se concentra en diversos niveles arqueo-paleontológicos identificados en la unidad II. Esta unidad presenta una secuencia homogénea de 2 m con arenas y gravas pobremente estratificadas, característica de los depósitos de flujos de masa subaérea y subacuática (Vallverdú et al., 2014b). Según se describe en Vallverdú et al. (2014a: 290)“[…] *en su base dominan los lechos mal estratificados formados por clastos del tamaño grava media de esquistos soportados por una matriz de arenas gris verde*“ y en su techo “*los lechos de arenas y gravas* […] *están impregnados por segregaciones criptocristalinas amarillentas en banda a techo de la unidad y también por fangos lechos*

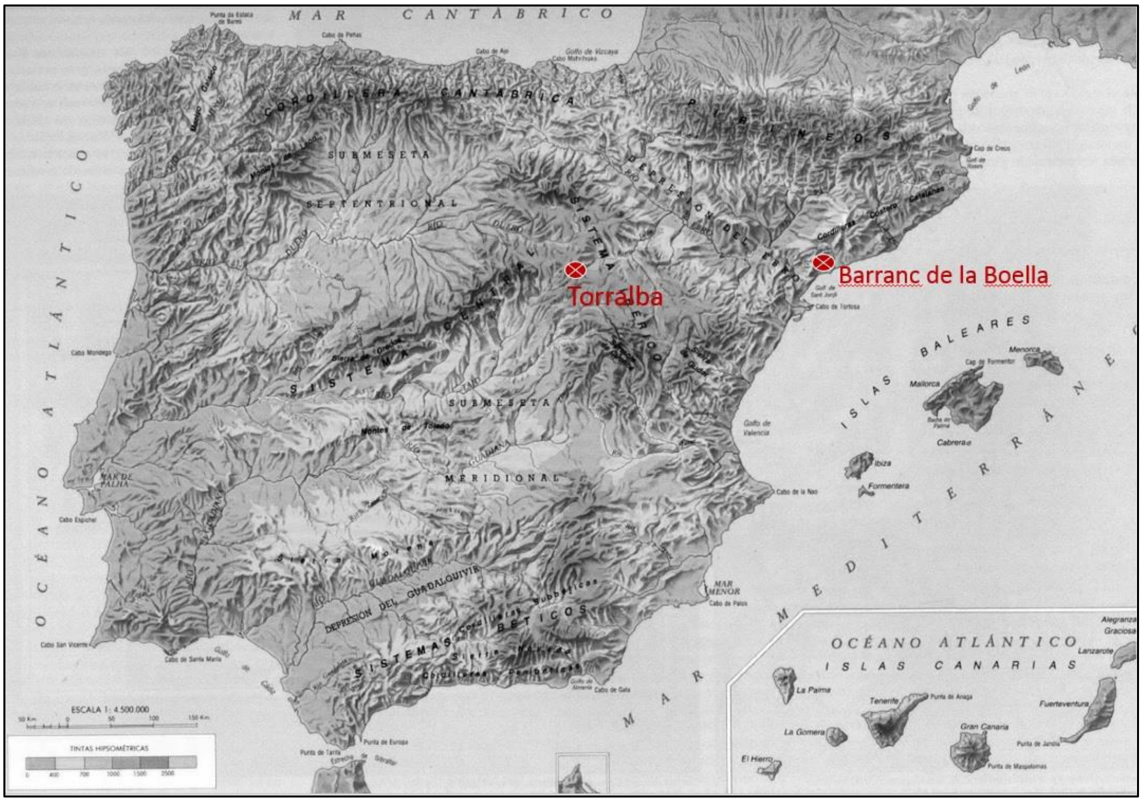

**Figura 3. 1.** Mapa de situación del Barranc de la Boella y Torralba en el marco de la Península Ibérica.

*laminados carbonosos* […]". La unidad III se compone de fangos verdosos masivos manchados de rojo en 2 m de potencia, con alguna discontinuidad sugerida por cantos o gravillas. La unidad IV, que llega a alcanzar los 2 m de potencia, está formada por fangos arenosos verdes interestratificados con surcos y pequeños canales rellenos de grava y con rizomas de carbonato de calcio en su techo en LM. La unidad V está formada por barros masivos de hasta 3 m de espesor. La unidad VI está formada por 2 m de lechos horizontales de gravas y arenas rojo-amarillentas (Vallverdú et al., 2014b).

La identificación de especies como *Mammuthus meridionalis*, *Hippopotamus antiquus* o *Mimomys savini* en la unidad II ya permitió sugerir una cronología mínima de 700 Ka en los primeros trabajos preliminares que se desarrollaron (Saladié et al., 2008; Vallverdú et al., 2008). Posteriormente, los trabajos de paleomagnetismo han determinado la existencia de polaridad negativa en las unidades I, II y III, con el cambio a polaridad normal identificado en la base de la unidad IV (Vallverdú et al., 2014b). En este sentido, la bioestratigrafía identificada en la unidad II (Lozano-Fernández et al., 2014; Vallverdú et al., 2014b) ha permitido correlacionar la polaridad magnética negativa de las unidades I, II y III con el chron Matuyama, que se extiende hasta los 780 Ka, habiéndose identificado la inversión Matuyama-Brunhes en la base de la unidad IV (Vallverdú et al., 2014b).

Lozano-Fernández y colegas (2014) pudieron afinar con mayor precisión la biocronología del nivel 2 del Barranc de la Boella, a través del Índice de Diferenciación del Esmalte (*enamel differentiation index*, *SDQ*) de los m1 de los arvicolinos recuperados en el conjunto: *Mimomys savini* y *Victoriamys chalinei*. El grosor medio del esmalte les ha permitido establecer una horquilla cronológica que se situaría entre 900 y 780 Ka. A su vez, su comparación con el registro de arvicolinos de los conjuntos del Pleistoceno inferior de la Península Ibérica les permitió sugerir que este nivel se encontraría cercano a los 900 Ka, donde se ubica la base de esta biozona. Paralelamente, los resultados del análisis de los núclidos cosmogénicos de diversas muestras obtenidas en la unidad II han permitido establecer un lapso preciso de tiempo en torno a 960-781 Ka para la unidad II del Barranc de la Boella (Vallverdú et al., 2014b) confirmando las fechas de Pleistoceno inferior propuestas previamente a partir de estudios biocronológicos.

### *3.1.3. Historia y desarrollo de las intervenciones e investigaciones*

Para conocer el primer documento en el que se mencionan hallazgos de restos arqueo-paleontológicos en el Barranc de la Boella tenemos que remontarnos hasta la memoria explicativa de la primera serie de la cartografía

1:50.000 del IGME, dirigida por Agustí Martín en 1933, en la que se describe la identificación en el barranco de restos de *Rhinoceros* sp., *Cervus* sp., *Equus caballus* y *Helix* sp. y se presenta como parte de un registro de edad pliocena.

Dos décadas más tarde, el Dr. Salvador Vilaseca publicará la presencia de abundantes restos líticos cerca del barranco, en contexto estratigráfico dentro de unos grandes regatos próximos a la actual ubicación del aeropuerto de Reus, en un yacimiento que el propio Vilaseca denominó "la Boella" (Vilaseca, 1973). El Dr. Vilaseca describió un conjunto representado por "*cerámica protohistórica y e industria lítica de carácter arcaico a unos 1.5 m de profundidad*" (Vallverdú et al., 2014a: 289). Posteriormente, será el propio Vilaseca quién aportó nuevos datos sobre el potencial del barranco, aludiendo al hallazgo de cinco artefactos de sílex y pizarra "atípicos" (según Vilaseca, cuatro de ellos de origen dudoso) junto a algunos restos fósiles de *Elephas (Archidiskodon) meridionalis* (Vilaseca, 1973).

El hallazgo fortuito de dos defensas de elefante por parte del Dr. Vallverdú en 2007 llevó a la realización de una excavación de carácter preventivo en la Cala 1, con el objetivo de recuperar las mencionadas piezas. La intervención, que afectó a 15 m², se llevaría a cabo entre abril y junio de ese mismo año. El primer descubrimiento de piezas dentarias de proboscídeos y el posterior hallazgo de herramientas en sílex acabarían por demostrar el potencial arqueopaleontológico del barranco (Vallverdú *et al*., 2008; 2014a).

Las excavaciones programadas anuales se iniciaron a partir del año 2008 dentro del proyecto *Evolució paleoambiental i poblament prehistòric a les comarques dels rius Francolí, Gaià, Siurana i rieres del Camp de Tarragona*. Ese mismo año se iniciaron los sondeos en una nueva zona (Cala 2 o la Mina) a la vez que se preparó y abrió la superficie de una tercera (Cala 3 o el Forn). A partir de 2009 la excavación se centró en estas dos catas, con la continuación de los sondeos en la Mina y el inicio de la excavación sistemática en el Forn. Los trabajos de excavación en el Forn continuaron hasta su finalización tras la campaña de 2013, momento en que se cerró la excavación en esta cata. Los trabajos de excavación en extensión en la Mina se iniciaron en 2011 y continúan hasta la actualidad, con excepción del año 2012.

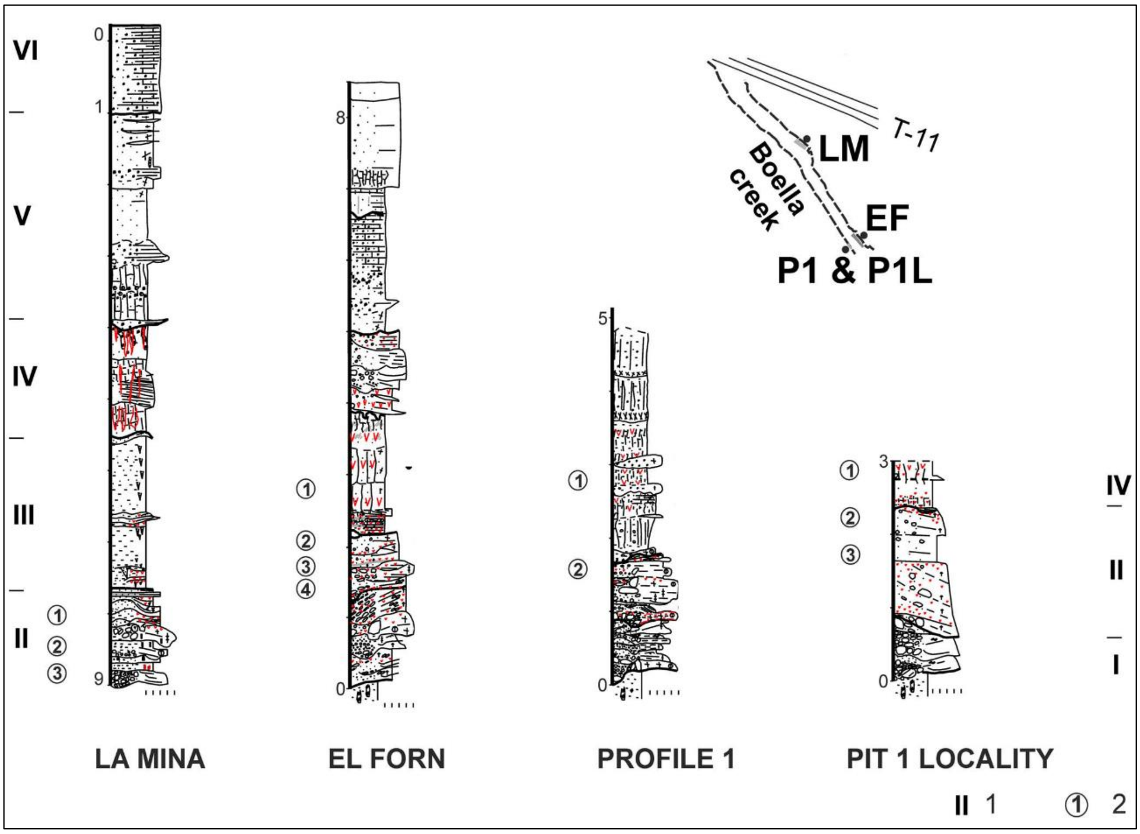

**Figura 3. 2.** Distribución de los yacimientos en el Barranc de la Boella. Se muestran las unidades litoestratigráficas (1) y los niveles arqueo-paleontológicos (2) de los yacimientos y del perfil 1. Extraído y modificado de Vallverdú et al. (2014b).

### *3.1.4. Yacimientos del Barranc de la Boella*

#### *3.1.4.1. Cala 1 (Pit 1)*

Los trabajos en la Cala 1 o Pit 1 (P1), anteriormente llamada *Centre de Convencions*, se iniciaron en el año 2007, tras el ya mencionado hallazgo fortuito de cuatro defensas de *Mammuthus meridionalis* pertenecientes a la Unidad II: un par en el nivel II.2 y otro en el nivel II.3. La intervención, de carácter preventivo, se llevó a cabo en una superficie de 15 m$^2$ y permitió la recuperación de las ya mencionadas defensas. Además, en el nivel II.2 se recuperaron otros restos de proboscídeo y 125 artefactos líticos (Saladié et al., 2008; Vallverdú et al., 2008; 2014b).

El estudio de los restos arqueo-paleontológicos recuperados en el nivel II.2 fue presentado por Mosquera y colegas (2015). Se trata de un conjunto monoespecífico, en el que los restos de *Mammuthus meridionalis* (n=485) representan el 99% de los especímenes identificados. Se corresponden, principalmente, con restos craneales y dentales, aunque algunos elementos post-craneales (p.e. fragmentos de costilla y vertebra y una escápula) también han sido identificados. La fracturación es elevada en todo el conjunto y generalmente asociada a procesos post-deposicionales; sin embargo, dos defensas, cuatro molares y una escapula fueron recuperados casi completos. Cuatro fragmentos craneales de *Dama* cf. *vallonetensis* y un molar de *Equus sp.* completan el registro faunístico (Vallverdú et al., 2014b; Mosquera et al., 2015).

El registro tecnológico se compone de 125 artefactos, mayoritariamente se trata de lascas, lascas fragmentadas y fragmentos de lasca (n=103), al que se le suman tres percutores, siete *cobbles* usados como *percussion materials*, tres núcleos, ocho lascas retocadas y un gran formato, un pico de esquisto (Vallverdú et al., 2014b; Mosquera et al., 2015; Mosquera et al., 2016).

**Figura 3. 3.** Superficie de excavación del nivel II.2 de la Pit 1. Año 2007.

El conjunto recuperado en el II.2 (Fig. 3.3) ha sido identificado como un *butchering site* (según describe Isaac, 1978), un único evento de aprovechamiento de la carcasa de un mamut por un grupo de homínidos, reflejo de una actividad antrópica especializada y una resolución temporal breve (Mosquera et al., 2015; Vallverdú et al., 2014b). La identificación de dos posibles marcas de corte sobre dos costillas podría confirmar el acceso de los homininos a grandes masas de carne de megaherbívoros, aunque su relación con la muerte del animal no ha podido ser establecida. La muerte del animal se habría producido *in situ* o muy cerca del lugar de deposición, y tres hipótesis han sido barajadas al respecto: a) estos grupos habrían aprovechado la carcasa de un mamut muerto por causas naturales; b) el animal fue activamente cazado por los grupos humanos; c) el animal atrapado es embarrancado en una zona fangosa, cazado y procesado por los grupos humanos, una escena relativamente común en este tipo de ambientes, según describen Bunn y Ezzo (1993).

En el año 2016, tras ocho campañas sin intervención en la Cala 1, se retomaron los trabajos de excavación con el objetivo de recuperar la superficie excavada en el año 2007 y continuar con las investigaciones.

#### *3.1.4.2. Cala 2 o la Mina*

Los trabajos arqueológicos en la Mina se iniciaron durante la campaña de 2008. La excavación afectó a 9 m$^2$ y permitió el hallazgo de 133 restos faunísticos, 29 restos de industria lítica y ocho coprolitos. Los trabajos de excavación de los años posteriores han revelado que la Mina es, a día de hoy, la excavación más prolífera del barranco, con cerca de 1000 restos entre fauna, industria lítica y coprolitos (Pineda et al., 2015; 2017a; 2017b; Mosquera et al., 2016) en un área excavada que supera los 40 m$^2$ (Fig.3.4).

Cuatro niveles arqueoestratigráficos han sido identificados hasta la fecha en la Mina, siendo el nivel 2 el más rico en abundancia de restos faunísticos y líticos (Pineda et al., 2015; 2017a). El nivel 3 ha sido identificado como una letrina de hienas (Pineda et al., 2017b) en la que abundan los coprolitos (n=208) y en la que restos líticos también han sido documentados, aunque escasean los restos óseos. Las últimas campañas de excavación han permitido destapar el techo del nivel 4, aunque no ha sido excavado todavía. Los análisis preliminares apuntan a la presencia

**Figura 3. 4.** Trabajos de excavación en el yacimiento de la Mina. Año 2017.

de restos de gran tamaño y una fuerte actividad de carnívoros en el nivel.

#### *3.1.4.3. Cala 3 o el Forn*

Los trabajos de excavación en la Cala 3, también llamada el Forn (EF), se iniciaron en el año 2008 y afectaron, en un primer momento, a una superficie de 12 $m^2$. Los primeros trabajos se realizaron sobre los niveles arqueo-paleontológicos 1 y 2. En el nivel 1 se recuperaron algunos restos de fauna, principalmente de cérvido, junto con una única herramienta de piedra: un núcleo de sílex. En el nivel 2, contrariamente, se recuperaron más restos de fauna (principalmente cérvidos, caballos e hipopótamos) y diversas herramientas de piedra sobre esquisto, cuarzo y sílex.

En posteriores campañas la superficie de excavación se amplió hasta los 68 $m^2$ (Fig. 3.5). En la unidad litoestratigráfica II, se han identificado seis niveles arqueológicos (EF2-7) (Rosas et al., 2015). El nivel arqueológico 1 se sitúa dentro de la unidad III. La excavación en extensión se ha centrado entre los niveles 1 y 4. En estos cuatro niveles se han encontrado restos paleontológicos (fundamentalmente de équidos, cérvidos e hipopótamos) y restos de industria lítica (mayoritariamente realizadas sobre sílex y esquisto, aunque también se documenta el uso de cuarzo, cuarcita, arenisca y granito). En la base de la unidad II, donde se encuentran los niveles inferiores (EF5-7), la intervención se realizó a través de un sondeo durante la campaña de 2013. Los restos hallados permitieron identificar niveles paleontológicos con una muy baja densidad de materiales. La intervención en el Forn se cerró tras la campaña de 2013, una vez se alcanzó la base de la Unidad II.

### *3.1.5. El registro fósil del Barranc de la Boella*

Los restos fósiles localizados en los diferentes yacimientos que conforman el Barranc de la Boella se distribuyen mayoritariamente en la unidad II y, en menor medida, en la III. (Lozano-Fernández et al., 2014; Vallverdú et al., 2014b; Mosquera et al., 2015; 2016; Pineda et al., 2015; 2017a; 2017b).

Los micromamíferos son, en general, poco abundantes. *Mimomys savini* y *Victoriamys chalinei* son las dos especies más representadas, aunque también se han recuperado un incisivo de *Crocidura* sp. y una ulna de *Talpa* sp. (Lozano-Fernández et al., 2014). El registro de macromamíferos, contrariamente, sí que ha aportado una mayor variedad taxonómica (Vallverdú et al., 2014b; Pineda et al., 2015; 2017a). Los ungulados son el grupo más abundante, habiéndose identificado la presencia de *Mammuthus meridionalis*, *Hippopotamus antiquus*, *Stephanorhinus* cf. *hundsheimensis*, *Megaloceros savini*, *Cervus elaphus*, *Dama* cf. *vallonetensis*, *Equus* sp., Bovini y *Sus* sp. Entre los carnívoros destacan los restos de *Ursus* sp. Otros carnívoros han sido identificados, aunque mediante escasos restos: *Panthera* cf. (onca) *gombaszoegensis*, *Canis* cf. *mosbachensis*, *Vulpes* sp. y *Lynx* sp. También ha sido identificado un canino de primate, *Macaca sylvanus* (florentina), *Castor* sp., así como restos de tortuga, lepóridos y aves (Pineda et al., 2015; 2017a). Se ha documentado también una falange de un félido de talla grande. El estudio paleontológico, inédito hasta el momento, sugiere que se trata de un león.

El entorno paleoecológico inferido en el Barranc de la Boella podría corresponderse al de un ecosistema con grandes masas de agua, como atestigua la elevada presencia de especies acuáticas (*Hippopotamus antiquus*, *Castor* sp. o *Mimomys savini*), con zonas abiertas y, presumiblemente, cercano a zonas de bosque de ribera, pues también se han identificado taxones que habitan estos espacios cerrados, como el macaco o el jabalí. En este contexto inferido convergerían una amplia variedad de recursos cárnicos, vegetales, agua y materias primas para la fabricación de herramientas, que podrían estar

**Figura 3. 5.** Extensión de la excavación en el Forn. Año 2012.

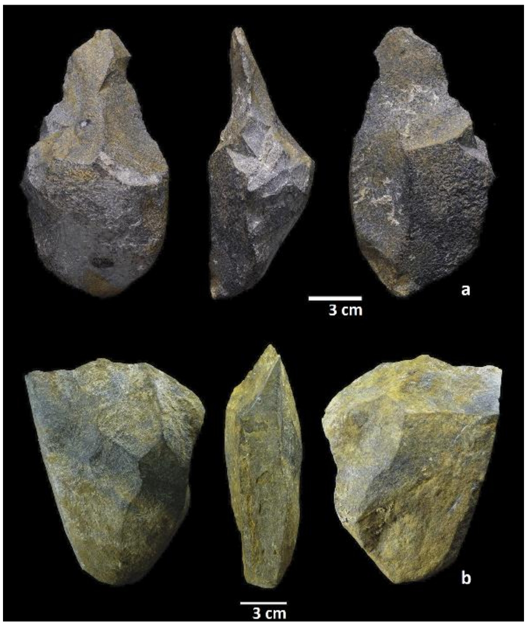

**Figura 3. 6.** Grandes formatos recuperados en el Barranc de la Boella. a) Pico sobre lasca de esquisto recuperado en el nivel II.2 de la Pit 1; b) hendedor sobre lasca espesa de esquisto recuperado en el nivel II.2 de el Forn. Modificado de Mosquera et al. (2016).

al alcance de las poblaciones de homininos que lo habitaron, como es descrito en Pineda et al. (2017b).

El registro lítico recuperado en los diferentes conjuntos del barranco es también amplio. El conjunto más significativo proviene del nivel 2 de la Cala 1, compuesto por 125 herramientas fabricadas en sílex, mayoritariamente, aunque también se han recuperado herramientas en esquisto, cuarzo, arenisca, granito y cuarcita. El conjunto se compone de tres percutores, siete cantos fracturados, tres núcleos de explotación unipolar y, en ocasiones, centrípeta; 45 lascas y 37 lascas fracturadas y fragmentos de lascas. Ocho de las lascas están retocadas, siendo todas muescas y denticulados. Finalmente, una herramienta de gran formato ha sido documentada: un pico sobre una lasca de esquisto (Fig. 3.6a) (Vallverdú et al., 2014b; Mosquera et al., 2015).

En la Mina, se han hallado 79 restos de industria, incluyendo dos percutores de arenisca y cuarzo y nueve cantos fracturados. Tres *choppers* sobre esquisto, un *chopping tool* sobre pórfido, dos núcleos de sílex, 25 lascas y 21 fragmentos de lascas y lascas fragmentadas completan el registro lítico del conjunto (Fig. 3.7). En el Forn, por su parte, se han recuperado 104 objetos: tres percutores, 11 cantos y cantos fracturados, un núcleo unipolar de cuarzo y un grupo de artefactos en sílex, que incluye siete núcleos, 46 lascas, 14 lascas fragmentadas y seis retocadas (denticulados). También se han localizado un hendedor sobre lasca espesa de esquisto (Figura 3.6b.), un *chopping tool* de cuarcita, dos *choppers*, una posible hacha de mano en esquisto y un pico fabricado en granito (Vallverdú et al., 2014b; Mosquera et al., 2016).

En un sentido amplio, los tres conjuntos presentan un registro tecnológico similar, en cuanto a la composición, los métodos de talla y el uso diferencial de materias primas de origen local (Mosquera et al., 2016). La principal diferencia es la presencia de dos herramientas de gran formato (*large-cutting tools*) en el Forn y la Pit 1, ausente en la Mina. Este registro tecnológico ha servido para establecer la llegada del Achelense más antiguo de Europa en cronologías cercanas al millón de años (Vallverdú et al., 2014b; Mosquera et al., 2015; 2016).

## *3.2.* Torralba

### *3.2.1. Contexto geográfico y geológico*

El yacimiento arqueo-paleontológico de Torralba se encuentra situado en la divisoria de las cuencas hidrográficas del Duero, el Tajo y el Ebro, en la localidad de Torralba del Moral (término municipal de Medinaceli), al sur de la provincia de Soria, en una zona de paso estratégica entre las tierras altas de la Meseta y el valle del Jalón (Fig. 3.1.) (Santonja et al., 2005b; 2014). Las coordenadas del punto central del yacimiento son 41º 8’ 13’’ N, 20º 30’ 9’’ W, y se ubica a 1113 ms.n.m. (Falguères et al., 2006).

Pérez-González y colegas (1997) sitúan el yacimiento en el poljé de Conquezuela, desarrollado en una estructura anticlinal, parcialmente fallada en el extremo noreste, que presenta diferentes terrazas de época pleistocena, así como superficies de corrosión neógenas. El

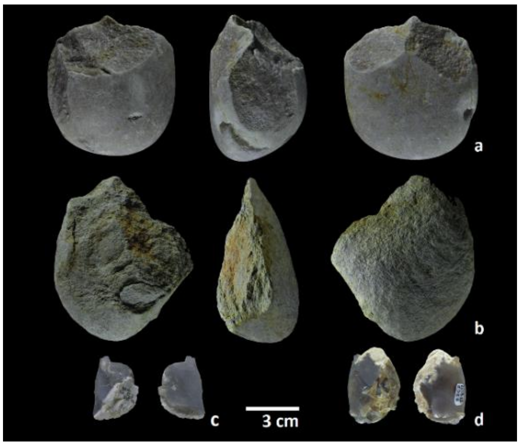

**Figura 3. 7.** Conjunto lítico recuperado en la Mina. a) *chopper-core* de cuarcita; b) *chopper* de esquisto; c-d) lascas de sílex. Modificado de Mosquera et al. (2016).

relleno cuaternario se compone principalmente de depósitos de pendiente detrítica y margas de origen lacustre.

Los primeros trabajos geológicos fueron llevados a cabo por Butzer en la década de los ‘60 (Butzer, 1965; Freeman y Butzer, 1966), quién llevó a cabo estudios de la zona circundante, llamada “Meseta Caliza” entre Soria y Guadalajara, el altiplano en el que contactan el Sistema Central y el Sistema Ibérico (Aguirre, 2005). Butzer acabó considerando el yacimiento de Torralba como peri-contemporáneo al yacimiento de Ambrona, ubicado a sólo 3 km de distancia y considerado parte de una misma secuencia estratigráfica (Butzer, 1965), si bien es cierto que posteriores revisiones han descartado que pudiera considerarse una única secuencia (Pérez-González et al., 1997). Dataciones numéricas han permitido documentar que el yacimiento de Ambrona sería considerablemente más antiguo que Torralba (Falguères et al., 2006).

### *3.2.2. Litoestratigrafía y dataciones*

Los depósitos cuaternarios de Torralba se asientan sobre arcillas rojas y yesos del Keuper y depósitos carbonatados Triásico-Jurásicos (Santonja et al., 2014). Tal y como afirman estos investigadores, la única estratigrafía detallada del yacimiento es la que proporcionó Butzer (1965), correspondiente a la sección N-S del yacimiento (Fig. 3.8). Es descrita como un perfil compuesto que empieza con facies cluvionares rojas depositadas sobre el ya mencionado Keuper, de hasta 3-4 metros de espesor, que desaparecen hacia el norte. Por encima, encontramos “*un depósito de arenas grises en las que se intercalan facies de gravas angulosas y subangulosas de composición carbonatada, con tamaños de 1-3 cm de eje mayor y un espesor de 1 m* (Santonja et al., 2014: 527). A techo, encontramos una unidad muy continua de marga gris-verdosa algo más arenosa en la base, con una potencia que llega a alcanzar 2 m. Finalmente, sobre esas facies de carácter lacustre somero encontramos, superpuesto, un depósito aluvionar-coluvionar rojo cuyo grosor oscila entre 0 y 1.5 m (Butzer, 1965; Santonja et al., 2014).

De esas facies fluviales de arenas y gravas es de donde provendrían mayoritariamente los restos recuperados durante los primeros trabajos de excavación del marqués de Cerralbo y de Howell (Santonja et al., 2014). Por entonces, el yacimiento arqueo-paleontológico de Torralba era considerado contemporáneo al ya mencionado yacimiento de Ambrona, para los que se atribuía una misma época de formación de los depósitos en un mismo contexto: la orilla de un mismo lago (Butzer, 1965). Sin embargo, en la actualidad podemos garantizar que esas inferencias no se ajustan a la realidad. Las dataciones numéricas obtenidas hasta la fecha sugieren una cronología cercana a 200 ka para Torralba, obtenida mediante OSL (N. Mercier, en Santonja et al., 2014). Así mismo, la correlación morfológica de los depósitos pleistocenos de Torralba podría equipararse con una terraza situada a +20-25 m del inmediato Alto Henares, datado entre 220-240 ka, según se presenta en Howell et al. (1995). Torralba, por tanto, quedaría englobada dentro del MIS 7 (243-192 ka) y sería más reciente que el yacimiento de Ambrona, datado por series de ESR/U en torno a 350 ka (Falguères et al., 2006).

### *3.2.3. Historia y desarrollo de las intervenciones e investigaciones*

El origen de los trabajos arqueológicos en el yacimiento de Torralba se remonta a 1888, cuando las obras de instalación de una tubería en las inmediaciones de la antigua estación ferroviaria de Torralba dejaron al descubierto restos de proboscídeos de época pleistocena (Santonja et al., 2005b; 2014). Fue a partir de

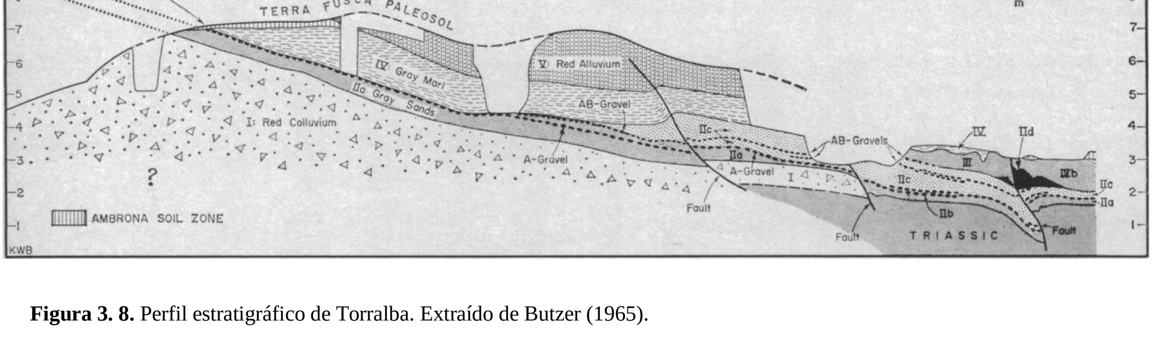

**Figura 3. 8.** Perfil estratigráfico de Torralba. Extraído de Butzer (1965).

estos descubrimientos que Enrique de Aguilera y Gamboa, XVII marqués de Cerralbo, inició los primeros trabajos de excavación entre 1909 y 1913 (Fig. 3.9). Los escritos que dejó Cerralbo (Aguilera y Gamboa, 1911; 1913a; 1913b) no han podido ser consultados para este trabajo y las referencias que de ellos se presentan han sido siempre a través de una fuente secundaria. Estos escritos son, a juicio de Santonja y colegas (2014), muy precisos. En ellos se especifica que "*el yacimiento se encontraba en el extremo y detrás de la estación del mismo nombre* […] *en el punto en que se que* [sic] *separaba la vía de Soria (1913a, 279), exactamente a la altura del km 156, tercer hectómetro (1911, 16; 1913b, 3)*" (Santonja et al., 2014: 7). En total, Cerralbo llevó a cabo seis campañas de excavación y, aunque en sus escritos señala que intervino en 200 m$^2$ (Aguilera y Gamboa, 1911), los trabajos posteriores de Howell y colegas (1962) evidenciaron que Cerralbo abrió aproximadamente unos 2000 m$^2$, aunque quizá no fueron excavados en su totalidad.

Los trabajos de excavación de Cerralbo aportaron más de 600 restos de fauna, mayoritariamente elefante (n=525), además de caballo (n=86), bovino (n=37) y rinoceronte (n=3), junto a 552 herramientas líticas (Aguirre, 2005). Las interpretaciones que Cerralbo obtuvo le llevaron a hablar de *la más antigua estación humana de Europa* (Aguirre, 2005: 7), reflejo de la caza de manadas de elefantes por parte de un grupo humano que presumiblemente se habría establecido al borde de un antiguo lago (Santonja et al., 2014). Cerralbo se apoyó en la identificación de ocho puntas de defensa de mamut que parecían presentar evidencias de fracturación intencional y de nueve restos de madera que podrían presentar trazas de manufactura o cortes (Aguirre, 2005).

Tras finalizar los trabajos el marqués de Cerralbo, la intervención arqueológica en dicho yacimiento se paralizó durante más de cuatro décadas hasta que, a partir de 1960, Howell retomó las excavaciones. Debe mencionarse que Howell también intervino en Ambrona durante este período. Ese mismo año realizó una campaña de prospección de Torralba y posteriormente realizó tres campañas de excavación entre 1961 y 1963, con un equipo formado por científicos de la talla de K. Butzer, E. Aguirre, P. Biberson o L. G. Freeman, entre otros (Aguirre, 2005; Santonja et al., 2005a; 2014). En 1961, Howell empezó limpiando la superficie excavada por Cerralbo y prospectó mediante catas los límites de la excavación, cuya extensión llegó a dibujar en 5000 m$^2$ (Fig. 3.9) (Aguirre, 2005). Quizá uno de los mayores logros

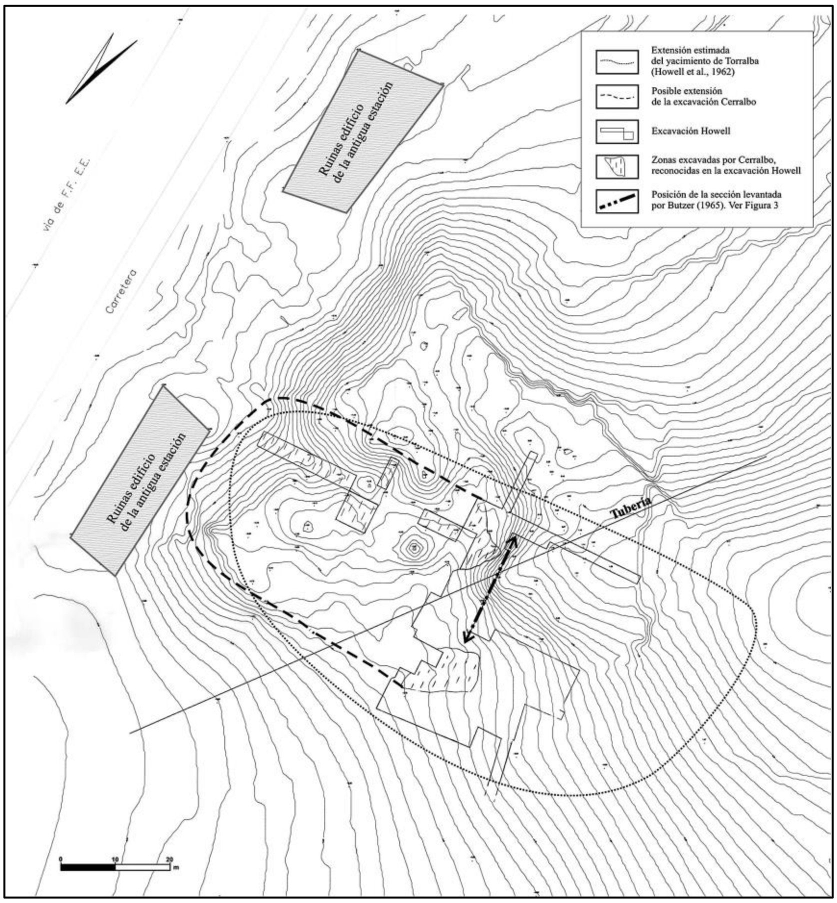

**Figura 3. 9.** Límite de las áreas excavadas por Cerralbo (1911-1913) y Howell (1961-1963). Extraído de Santonja et al. (2014).

de esta fase de excavaciones fue la descripción de la geología de Torralba y del entorno que realizó Butzer (Butzer, 1965; Freeman y Butzer, 1966).

Más de 2000 restos faunísticos fueron recuperados en Torralba durante este período. El elefante vuelve a ser el taxón más representado, junto a caballos, ciervos, bovinos y rinocerontes, así como algunos restos de carnívoro (Biberson, 1968; Aguirre, 2005). De estas campañas de excavación también derivaron dos estudios de la tecnología lítica: Biberson (1964) y Freeman (1975), quienes atribuyeron la tecnología a un Achelense medio y antiguo, respectivamente, y quienes defendieron la existencia de industria en hueso (Aguirre, 2005; 11), aunque es una evidencia cuestionada desde un primer momento (Klein, 1987). Recientemente, Domínguez-Rodrigo (2005) revisó los restos depositados en el Museo Arqueológico Nacional (MAN), descartando el origen antrópico de los artefactos, cuya morfología atribuyó a la acción de los carnívoros machacadores de huesos.

Desde entonces, los trabajos en los yacimientos de Torralba y Ambrona han continuado de manera intermitente. En Ambrona, Howell y Freeman continuaron excavando entre 1980 y 1983, sin llegar a intervenir en Torralba. Entre 1990 y 2000, Alfredo Pérez-González y Manuel Santonja desarrollaron un nuevo proyecto. Durante este período, Rafa Mora lideró los trabajos de excavación en Torralba (1994-1999), aunque de manera más limitada (Santonja et al., 2005b; 2014). Los trabajos de campo durante este tiempo consistieron en la realización de más de 20 sondeos preliminares, principalmente enfocados en controlar el grado de conservación del yacimiento para evaluar el potencial para futuras excavaciones. Paralelamente, se puso a punto la documentación topográfica del entorno con el objetivo de poder integrar los datos planimétricos y fotográficos de la localidad excavada por Cerralbo y Howell (Santonja et al., 2005a). Entre 1998 y 1999, se excavó un área situada en la parte NE del yacimiento, una zona cercana a las ruinas de la antigua estación ferroviaria y, por ende, contigua a la zona excavada originalmente por el marqués de Cerralbo (Santonja et al., 2005a).

En la actualidad, los trabajos de excavación en Ambrona se han retomado desde el año 2013, bajo la dirección del Dr. Alfredo Pérez-González y del Dr. Rafael Mora, en campañas de excavación ininterrumpidas hasta la fecha, aunque no se ha llegado a intervenir en Torralba.

### *3.2.4. El registro fósil de Torralba*

Al hablar del registro fósil de Torralba debemos mencionar, en primer lugar, a uno de los problemas que afectan a todos los conjuntos procedentes de excavaciones clásicas: el sesgo en el registro recuperado. Villa (1990) hace referencia a ello en su revisión de los materiales de dicho yacimiento, donde explica una pérdida de los restos más pequeños (óseos y líticos), como consecuencia de la ausencia de un triado sistemático durante los trabajos de excavación.

Un segundo problema es la ausencia de un lugar para el depósito y la conservación de los materiales, que ha comportado la dispersión de los materiales en diferentes centros, en algunos casos todavía sin un registro específico de los depósitos. Según Aguirre (2005), los materiales procedentes de las excavaciones antiguas Torralba y Ambrona estaban repartidos principalmente en el Museo Arqueológico Nacional (MAN) y el Museo Nacional de Ciencias Naturales (MNCN), ambos en Madrid, así como en el Museo Celtibérico (MC) y El Museo Numantino (MNS) de Soria, además de algunas piezas expuestas en el Museo Británico de Londres y en Museo Peabody de Yale o el Museo de Historia Natural de Washington. Esta amplia distribución de los materiales, sumada a la mencionada ausencia de un listado definitivo de los mismos, también supone una limitación a la hora de describir el registro fósil.

De época de Cerralbo se obtuvieron más de 600 restos faunísticos, principalmente de elefante, caballo, bóvido y rinoceronte, estudiados por Harlé (1910) con el objetivo de conocer la representación específica y poder hacer inferencias sobre la biocronología y la paleoclimatología del lugar (Aguirre, 2005). El propio Aguirre destaca la identificación de *Elephas meridionalis* y *Rhinoceros etruscus*, que les llevaron a ubicar este yacimiento en cronología de Pleistoceno inferior. Estos materiales serían revisados por Adam (1961), quién identificaría al proboscídeo de Torralba como *Elephas antiquus* y al rinoceronte como *Stephanorhinus hemitoechus* (Aguirre, 2005; Sesé y Soto, 2005).

Como ya se ha comentado con anterioridad, las interpretaciones que Cerralbo obtuvo le permitieron hablar de *la más antigua estación humana de Europa* (Aguirre, 2005: 7), entendiendo el registro de Torralba como una acumulación antrópica, consecuencia de actividades cinegéticas desarrolladas (Santonja et al., 2014).

La lista faunística fue revisada y ampliada con las excavaciones de Howell y colegas

(1963). De esta época tenemos nuevas asignaciones específicas, como el elefante, que pasa a ser identificado como *Palaeoloxodon antiquus*, o la identificación del león (*Panthera leo fossilis*). También se descarta que el gran bóvido representado sea *Bos primigenius*, siendo referido como *Bos* sp. aff. *trocheros* (Howell et al., 1963; Aguirre, 2005), si bien es cierto que hoy es considerado como *Bos antiquus* (Aguirre, 2005; Fuentes, 2005) .

Howell et al. (1963) también mencionan diversos fragmentos óseos que fueron identificados como herramientas talladas en piedra por Biberson (procedentes de la excavación de los años 60') y Aguirre (de las colecciones de Cerralbo depositadas en el MAN) (Aguirre, 2005). Estos artefactos fueron sujeto de debate durante más de cuatro décadas. No obstante, ya se ha comentado que una reciente revisión de los "artefactos en hueso" depositados en el MAN ha demostrado que los tafotipos representados serían producto de la actividad de un carnívoro machacador de huesos (Domínguez-Rodrigo, 2005).

Respecto a la tecnología lítica, ya las excavaciones de Cerralbo aportaron un elevado número de restos que él mismo clasificó como Achelense o Achelense evolucionado, a pesar de que Aguirre (2005) afirma que no se conoce estudio de la tecnología de esta primera fase de excavación (Fig. 3.10). Estos materiales fueron estudiados por Howell (en Howell et al., 1963) junto con los materiales recuperados en las primeras campañas de excavación que él mismo dirigió. En este trabajo, Howell describe diversas categorías tipológicas (de bifaces, hendedores, picos, raederas, raspadores, puntas, perforadores, protoburiles, núcleos, cantos tallados y diversos tipos de lascas) de herramientas talladas principalmente en cuarcita, pero también en caliza, pedernal, sílex, jaspe y lidita, de origen local (Aguirre, 2005). Howell acaba clasificando el conjunto de Torralba como Achelense antiguo o medio inferior (Howell et al., 1963).

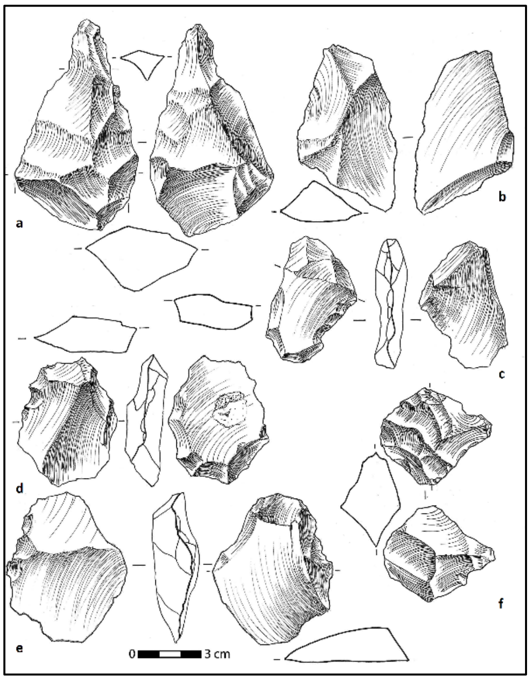

**Figura 3. 10.** Industria de Torralba procedente del período Cerralbo. A) punta de bifaz; b-e) lascas de talla de bifaz; f) núcleo discoidal bifacial. Modificado de Sánchez-Cervera et al. (2015).

Trabajos posteriores (Carbonell et al., 1987; Santonja y Villa, 1990; González Echegaray y Freeman, 1998) han debatido sobre la industria de Torralba y su encaje en el Pleistoceno medio peninsular. Recientemente, Sánchez-Cervera y colegas (2015) han revisado las colecciones líticas de las excavaciones de Cerralbo y Howell, depositadas en los ya mencionados Museo Numantino, Museo Nacional de Ciencias Naturales y Museo Arqueológico Nacional. En total, 552 piezas de época de Cerralbo y 977 procedentes de las excavaciones de los años 60', una industria que estos investigadores encuadran en el tecnocomplejo Achelense, siendo, a la luz de las nuevas dataciones (Santonja et al., 2014), unos de los últimos Achelenses identificados en el sur de Europa. También destacan la presencia de elementos tecnológicos *progresivos*, que les abren la puerta a plantear la necesidad de testar si en los niveles de Torralba existirían tradiciones tecnológicas encuadrables en el Paleolítico Medio (Sánchez-Cervera et al., 2015), como han sido identificadas en el vecino yacimiento de Ambrona (Santonja y Pérez-González, 2010).

De época de Cerralbo, también se tiene constancia de la recuperación de elementos de origen vegetal. Santonja y colegas (2005b) mencionan la documentación que el marqués de Cerralbo hizo de posibles restos de madera recuperados en Torralba (Aguilera y Gamboa, 1911). Se documentaron más de una treintena de restos que, aunque despertaron el interés del propio Cerralbo (Santonja et al., 2005b), no fueron estudiados hasta la década de los 60', a manos del propio Howell (Howell et al., 1962; Howell, 1966). Éste estudió los materiales depositados en el MAN y destacó la presencia de trazas de origen antrópico en nueve de ellos, así como evidencias de fuego (Santonja et al., 2005). Estos materiales han sido recientemente revisados por Postigo-Mijarra y colaboradores (2017), identificado los restos como pertenecientes a pino (*Pinus* cf. *sylvestris*), llegando a descartar evidencia alguna de procesado antrópico de los mismos, que en todos los casos tendrían un origen natural (Postigo-Mijarra et al., 2017).

De época de Howell también se tiene documentada la recuperación de 77 fragmentos de madera entre 1962 y 1963, junto a restos de carbones e improntas vegetales (Santonja et al., 2005a) que fueron mayoritariamente identificados como pino, aunque también se identificó un resto de abedul y otro de sauce o álamo (Freeman, 1975; Santonja et al., 2005b). Sin embargo, estos restos se encuentran en paradero desconocido y no se tienen nuevos datos hasta la fecha (Santonja et al., 2005a).

#### *3.2.4.1. Interpretaciones sobre el registro fósil de Torralba*

Ya hemos comentado que las primeras interpretaciones del conjunto fósil de Torralba dadas por el marqués de Cerralbo (Aguilera y Gamboa, 1913a) postulaban que los depósitos de Torralba eran el resultado de la caza especializada de elefantes por parte de los grupos humanos que se habrían asentado en zonas lacustres cercanas a estos depósitos. Siguiendo la línea de interpretaciones planteada por Cerralbo, Howell y los miembros de su equipo interpretaron el conjunto de Torralba como el resultado de la caza organizada de los grupos humanos del Pleistoceno Medio, quienes habrían conducido a las manadas de animales hacia barrizales donde habrían sido matadas, descuartizadas y preparadas para el consumo (Howell et al., 1962; Howell, 1966; Biberson, 1968; Freeman y Howell, 1982).

Estas interpretaciones fueron discutidas a partir de los años 80’ (Binford, 1981; Binford, 1987; Shipman y Rose, 1983b; Klein, 1987; Villa, 1990). Nuevos estudios tafonómicos vinieron a destacar la naturaleza paleontológica del sitio y plantearon nuevas interpretaciones acordes con los planteamientos metodológicos que se desarrollaban en el momento.

En el primer capítulo de *Bones, ancient men and modern myths*, Binford (1981) cuestionó por primera vez el origen antrópico de los depósitos de Torralba. Para Binford, el bajo número de individuos documentados en Torralba y el bajo número de restos líticos en los niveles llamados *ocupacionales* no se corresponderían, precisamente, con el número de restos esperables en zonas de ocupación. Acorde con sus interpretaciones, nos encontraríamos ante depósitos con un origen natural en el que el rol desempeñado por los grupos humanos sería escaso (Binford, 1981; 1987). Todas estas interpretaciones se apoyaron en los resultados obtenidos de la revisión de las marcas de corte que Shipman y Rose (1983b) llevaron a cabo. Según estas investigadoras, solo 12 restos (1% del total) presentaban marcas de corte indiscutibles, de los cuales solo cinco estaban sobre restos de elefante; un porcentaje tan bajo apoyaría la idea de Binford (1981) de un rol marginal de los grupos humanos, aunque estas investigadoras no descartan la posibilidad que procesos de abrasión pudieran haber borrado marcas de origen bioestratinómico presentes en las superficies óseas (Shipman y Rose, 1983b). Para Binford, además, la abundancia de denticulados y muescas, cuya función él asocia al reaprovechamiento de despojos cárnicos, evidenciaría un acceso secundario a las carcasas por parte de los grupos humanos (Binford, 1987).

La respuesta a estas nuevas interpretaciones vino dada de la mano del equipo de Howell y Freeman, quienes habían reanudado las excavaciones en Ambrona. El análisis de los nuevos materiales de Ambrona y la revisión de las colecciones antiguas (Freeman y Howell, 1982; Howell y Freeman, 1982) les llevó a reafirmarse en sus interpretaciones. Se basaron en elementos como el perfil catastrófico de muerte de los elefantes de Ambrona, las evidencias de uso de las herramientas para actividades de carnicería, las evidencias de carnicería sobre los huesos o la presencia de fragmentos de defensa de mamut trabajados.

Pese al intento del Howell y Freeman de mantener la hipótesis de la caza de elefantes, trabajos posteriores siguieron cuestionando el origen antrópico de dichas acumulaciones (Klein, 1987; Villa, 1990; Domínguez-Rodrigo, 1998; Yravedra, 2000; Villa et al., 2005). Villa (1990) también destacará la presencia de fenómenos post-deposicionales como la abrasión y problemas derivados de las excavaciones antiguas (como la ausencia de cribado y recuperación de los restos más pequeños). El escenario que encontramos en Torralba no permite hacer inferencias sobre los modelos de procesamiento de recursos cárnicos por parte de estos grupos humanos pleistocenos (Villa, 1990; Domínguez-Rodrigo, 1998; Yravedra, 2000; Villa et al., 2005).

# Capítulo 4. Metodología

En el capítulo introductorio de la presente Tesis Doctoral hemos mencionado que este trabajo se presenta en forma de Tesis por compendio de artículos científicos. Cada uno de ellos contiene la correspondiente sección metodológica, en la que se sintetizan, específicamente, los métodos de análisis empleados en cada trabajo. No obstante, en aras de claridad y de otorgar cohesión a los diferentes trabajos, en esta sección presentamos una compilación del conjunto de métodos zooarqueológicos y tafonómicos utilizados durante el análisis de los conjuntos osteológicos que forman parte de nuestra investigación. Excepcionalmente, el análisis de los coprolitos de hiénido requirió del uso de métodos de análisis específicos para tales sujetos de estudio. Estos métodos fueron detalladamente explicados en el correspondiente artículo, por lo que hemos prescindido de su inclusión en este capítulo.

## 4.1. Identificación anatómica y taxonómica

La construcción de los perfiles anatómicos y taxonómicos deviene una herramienta clave en nuestras investigaciones, ya que las inferencias que se vayan a realizar de los conjuntos parten de los resultados de esta parte del análisis (Pickering et al., 2003). Para la identificación del material incluido en la presente Tesis Doctoral se ha recurrido al uso de las diferentes colecciones de referencia osteológica depositadas en el *Institut Català de Paleoecologia Humana i Evolució Social (IPHES)*, así como a toda una serie de atlas de anatomía comparada (Pales y Lambert, 1971; 1981; Schmid, 1972; Barone, 1976; Hillson, 1996; 2005; Varela y Rodríguez, 2004; France, 2009).

La identificación de los restos se ha llevado a cabo mediante la identificación de los puntos de referencia (*landmarks*) presentes en los fragmentos óseos, siempre dependiente del estado de conservación de cada uno de ellos. De los elementos identificados anatómicamente se ha precisado la zona, la porción, la cara y el lado (derecho o izquierdo) del elemento representado.

Sin embargo, problemas derivados de la fragmentación de algunos restos o de la ausencia de *landmarks* han comportado la presencia de restos indeterminados. Estos restos son útiles para completar el estudio de las asociaciones fósiles ya que nos pueden aportar información complementaria respecto a los perfiles esqueléticos (Marean y Kim, 1998; Bartram y Marean, 1999; Pickering et al., 2003). Se ha recurrido a la adscripción de los mismos en categorías anatómicas y taxonómicas, en la medida en que ésta ha sido posible de realizar, para complementar el estudio incluyendo también estos restos.

En relación al tipo de hueso, los restos no identificados anatómicamente se han clasificado en huesos largos, huesos planos y huesos articulares o irregulares (Huguet et al., 1999; Saladié et al., 2011). Los huesos largos están formados por una diáfisis, dos metáfisis y dos epífisis; poseen una cavidad medular bien desarrollada y se componen, mayoritariamente, por tejido cortical en las diáfisis y por tejido esponjoso en las epífisis. Estos huesos se corresponden a los miembros del esqueleto apendicular proximal (húmero y fémur), medial (radio, ulna, tibia y fíbula), distal (metapodios) y las falanges. Los huesos planos son los huesos del esqueleto craneal (cráneo y mandíbula), axial postcraneal (costillas y vértebras), escápulas y coxales. Se caracterizan por la casi ausencia de cavidad medular y por el poco espesor de la parte cortical del hueso y, en el caso de las vértebras, se componen mayoritariamente de tejido esponjoso. Finalmente, los huesos articulares o irregulares son huesos de morfología irregular, con varias facetas articulares. Carecen de cavidad medular y su interior está compuesto por un tejido esponjoso muy denso y compacto. Son los carpales y tarsales y los huesos sesamoideos, entre los que se incluyen las patellas. Dada su morfología, esta categoría puede incluir fragmentos epifisarios de huesos largos y planos, así como fragmentos de cuerpos vertebrales.

También se ha recurrido al uso de las tallas de peso para clasificar los restos no identificados taxonómicamente, en relación a los pesos de animales en vida (Huguet et al., 1999; Saladié et al., 2011). Se han tenido en cuenta las tallas de peso descritas por Saladié y colegas (2011) para los taxones europeos a partir de las propuestas metodológicas de Bunn (1982) y Bunn y Ezzo (1993) para especies africanas. Saladié y colegas establecen 5 categorías de peso: a) talla muy pequeña (<10 kg); b) talla pequeña (10-100 kg); c) talla media (100-300 kg); d) talla grande (300-1000 kg); y e) talla muy grande (>1000 kg). Los taxones incluidos en cada categoría de peso varían en función de los yacimientos estudiados. En los diferentes artículos que componen los capítulos de Resultados se presentan las especies incluidas en cada caso.

## 4.2. Determinación de edad de muerte de los individuos

La determinación de la edad de muerte de los individuos analizados se ha llevado a cabo a partir de la erupción y el grado de desgaste de los dientes, siguiendo la propuesta metodológica de Stiner (1990), que establece tres grupos de edad: juveniles, adultos primos y seniles. Excepcionalmente, el grado de osificación y epifisación de los huesos (Schmid, 1972; Barone, 1976) ha sido utilizado para determinar la edad de muerte de algunos individuos.

## 4.3. Cuantificación e índices de densidad mineral

Los Índices de cuantificación utilizados son el Número de especímenes (NSP), el Número de Especímenes Identificados (NISP), el Número Mínimo de Elementos (NME), el Número Mínimo de Individuos (NMI) y la Unidad Mínima de Animales (*Minimal Animal Unit*-MAU) (Binford, 1984; Grayson, 1984). Cada uno de estos índices nos aporta informaciones diferentes, pero a la vez complementarias y, en conjunto, nos permiten organizar y contabilizar adecuadamente nuestros materiales.

La cuantificación del conjunto empieza con el recuento total del NSP. Este índice incluye la totalidad del registro (huesos, dientes y astas), tanto los restos identificados anatómica y/o taxonómicamente como los no identificados. A partir del NSP podemos obtener el NISP, que incluye el total de restos identificados anatómica y taxonómicamente.

Mediante el NISP se puede calcular el NME. Éste hace referencia al número mínimo de elementos (restos) que pueden individualizarse dentro del conjunto. Existen diferentes métodos para calcular el NME (p. e. Bunn et al., 1988; Marean y Spencer, 1991; Stiner, 1994; Saladié et al., 2011). En este trabajo se ha tenido en cuenta la zona, la cara, el lado, el rango de edad de muerte estimado del animal al que pertenecen los restos y el número de veces que el elemento se repite en un esqueleto. En este estudio, se han identificado las diferentes porciones de un hueso mediante un sistema numérico que divide los huesos en 5 porciones (Saladié et al., 2011) (Figura 4.1). Por un lado, en los huesos largos, las porciones 1 y 5 se corresponden con las epífisis proximal y distal del hueso, respectivamente; la porción 3 se corresponde con la zona medial de la diáfisis y las porciones 2 y 4 con las regiones proximal y distal de la diáfisis, respectivamente. Por otro lado, en los huesos planos también se ha identificado de manera similar, siendo el número 1 la región proximal del hueso y el número 5 la región distal, aunque teniendo en cuenta la mayor variabilidad morfológica que presentan.

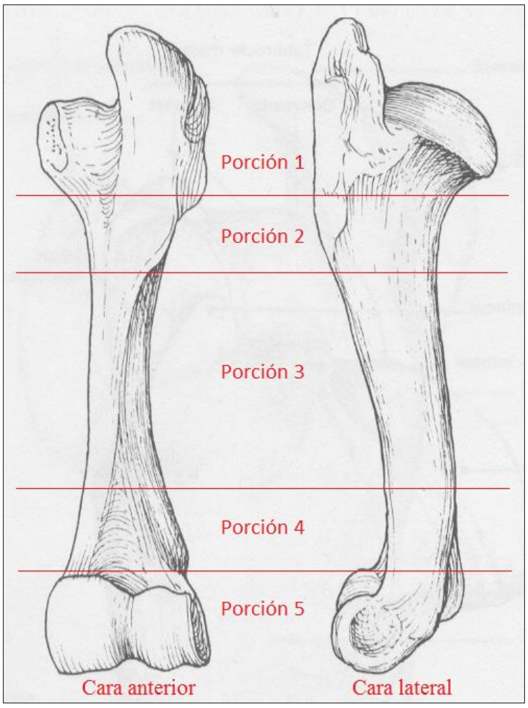

**Figura 4. 1.** Nomenclatura utilizada en la descripción de las porciones y caras de los fragmentos óseos de huesos largos. Modificado a partir de Barone (1976).

El NME nos ha permitido establecer el NMI. Éste intenta acercarse al número de animales existentes en el conjunto fósil, aunque no debe entenderse como un valor real sino como una aproximación. Su cálculo permite valorar la abundancia relativa de los diferentes taxones presentes en el conjunto y la cantidad de biomasa que representan. En el presente trabajo se ha establecido según el elemento anatómico más representado, diferenciando el lado (izquierdo o derecho) y el grupo de edad. En la mayoría de los casos se han utilizado las piezas dentarias para establecer el NMI, ya que han sido, generalmente, los elementos más representados y los que han permitido diferenciar los grupos de edad con mayor precisión.

Para el estudio ha sido necesaria la caracterización de la representación esquelética del conjunto. En el presente trabajo se ha aplicado el MAU (Binford, 1978b), cuya fórmula es:

$$MAU = \frac{\text{NME}}{\text{Número de elementos por esqueleto}}$$

Por tal de normalizar el MAU (%MAU) en una escala del 1 al 100 se aplica la siguiente fórmula:

$$\%MAU = \frac{\text{MAU} * 100}{\text{MAU máximo del conjunto}}$$

El cálculo del %MAU ha permitido conocer la representación esquelética y valorar el sesgo de la muestra. Éste puede estar motivado por causas bioestratinómicas y/o fosildiagenéticas (en función a la densidad de los restos), producidas durante la formación del yacimiento (Lyman, 1994). Diferentes trabajos sobre la densidad de los huesos de animales actuales nos permiten valorar los fenómenos de conservación diferencial presentes en los yacimientos arqueológicos: Binford (1978a) para los animales de talla pequeña y media y Emerson (1990) para los de talla grande.

## 4.4. Fragmentación y fracturación

La fragmentación y fracturación óseas son comunes en los yacimientos arqueológicos. Ambos términos hacen referencia a un proceso de origen tafonómico por el cual un resto da lugar a otro. No obstante, la significación de ambos términos es distinta, ya que el primero se debe a procesos físico-químicos, mientras que el segundo es por la acción de carnívoros u homininos, es decir, con fines generalmente alimenticios. Los orígenes de la fragmentación se deben a diferentes agentes y procesos, tanto bioestratinómicos como fosildiagenéticos. Todos los autores coinciden en que el principal condicionante es el estado del hueso en el momento de la fracturación (fresco o seco) (Bunn, 1983; Villa y Mahieu, 1991).

Los huesos frescos presentan una elevada plasticidad que favorece la deformación y hace que la fuerza del impacto se distribuya por las líneas de colágeno del hueso, absorbiendo el golpe. Sólo cuando el hueso recibe una elevada presión sufre una rotura, que se manifiesta desde la zona de presión hasta las epífisis a través de las líneas de debilidad del hueso. Contrariamente, los huesos secos son quebradizos. Al ser sometidos a presión, la fuerza se expande a través de la microestructura mineral, formando grietas perpendiculares al eje longitudinal de las fibras de colágeno. Estas diferencias de las propiedades físicas son las que condicionan la morfología de la fractura resultante.

En este sentido encontramos el Índice de Fragmentación (Bunn, 1983; Villa y Mahieu, 1991), que valora la proporción conservada de la sección y de la longitud de los huesos largos en relación a los huesos originales completos. Este método consiste en la asignación de un valor numérico en relación a una medida ósea. Respecto a la longitud del hueso, el número 1 indicaría la conservación de menos de ¼ parte; el número 2 indicaría entre $^1/_4$ y $^1/_2$; el número 3 indicaría la conservación de entre $^1/_2$ y $^3/_4$ partes; y el número 4 correspondería a la conservación íntegra o de más de $^3/_4$ partes de la longitud (Figura 4.2). Respecto a la sección del hueso, el número 1 correspondería a menos de $^1/_3$ parte del total; el número 2 indicaría la conservación de entre $^1/_3$ y $^2/_3$ partes; y el número 3 correspondería a la conservación íntegra o de más de $^2/_3$ partes de la sección (Figura 4.3).

Villa y Mahieu (1991) también introdujeron el análisis de la delineación (longitudinal, transversal o curva), el ángulo (recto, oblicuo o mixto) y la superficie (suave o irregular) de los paños de fractura para determinar el estado del hueso en el momento de su fragmentación.

De esta manera, Villa y Mahieu (1991) concluyen que los huesos fracturados en fresco presentan ángulos oblicuos, obtusos y agudos. El perfil se presenta curvo, espiral y helicoidal apuntado en forma de "V" y la textura de los bordes de fractura es suave. Contrariamente, los huesos fragmentados en seco se caracterizan por ángulos rectos, por perfiles transversales y por una textura suave.

Villa y Mahieu (1991) también establecen características diagnósticas que permiten atribuir el origen de las fracturas a la fracturación en fresco hecha o realizada por carnívoros o homininos. Éstas son tratadas en los capítulos correspondientes.

## 4.5. Modificaciones tafonómicas producidas por carnívoros y homininos

Son muchos los agentes que pueden actuar sobre los restos durante la formación del yacimiento. Estas modificaciones se clasifican en modificaciones bioestratinómicas, producidas previamente al enterramiento de los restos, y modificaciones fosildiagenéticas, producidas tras el enterramiento de los mismos. En la fase bioestratinómica se incluyen todas aquellas modificaciones provocadas por carnívoros y homininos en la fase nutritiva de las carcasas (Capaldo, 1997), durante el aprovechamiento de las mismas con fines alimenticios.

### *4.5.1. Modificaciones producidas por carnívoros*

Los carnívoros son capaces de generar grandes acumulaciones y de producir modificaciones sobre la superficie de los huesos (p.e. Hugues, 1954; Kruuk y Turner, 1967; Mech, 1970; Sutcliffe, 1970; Kruuk, 1972; Schaller, 1972; Hill, 1980; 1983; 1984; 1989; Maguire et al., 1980; Skinner et al., 1980; 1986; 1998; Binford, 1981; 1988; Brain, 1981; Klein y Cruz-Uribe, 1984; Binford et al., 1986; Kerbis-Peterhans, 1990; Cruz-Uribe, 1991; Skinner y van Aarde, 1991; Stiner, 1991; Lam, 1992; Domínguez-Rodrigo, 1994; 1995; Fosse, 1995; Martín y Borrero, 1997; Mills y Gorman, 1997; de Ruiter y Berger, 2000; Pickering, 2002; Brugal y Fosse, 2004; Lacruz y Maude, 2005; Fernandez et al., 2006; Montalvo et al., 2007; Pokines y Kerbis Peterhans, 2007; Fernandez y Guadelli, 2008; Lansing et al., 2009; Yravedra et al., 2011; 2012; Stiner et al., 2012; Rodríguez-Hidalgo et al., 2013; 2015; Arriaza y Domínguez-Rodrigo, 2016; Borrero et al., 2018; Saladié et al., *in press*). En este sentido, es importante conocer las características que permiten documentar la presencia de actividad de carnívoros.

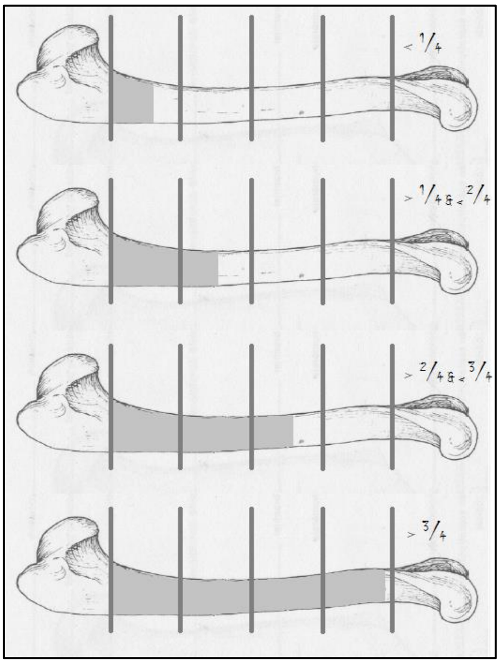

**Figura 4. 2.** Representación del Índice de Fragmentación de Bunn (1983) respecto a la longitud de los huesos largos. Modificado a partir de Barone (1976).

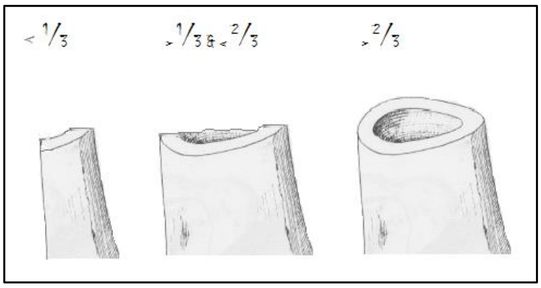

**Figura 4. 3.** Representación del Índice de Fragmentación de Bunn (1983) respecto a la sección de los huesos largos. Modificado a partir de Barone (1976).

Las mordeduras son el tipo de modificación más comúnmente identificado en el registro fósil. Éstas se producen con el contacto de los dientes de los carnívoros sobre la superficie de los huesos durante la extracción de los tejidos blandos o durante la fracturación de los huesos para la extracción y el consumo de la médula (Binford, 1981). Las modificaciones producidas por carnívoros han sido descritas en diversos trabajos (p.e. Bonnichsen, 1973; Haynes, 1980; 1983; Maguire et al., 1980; Binford, 1981; Brain, 1981). En nuestros conjuntos se han identificado las siguientes modificaciones producidas por carnívoros:

- ❖ *Surcos*: Se caracterizan por la sección en forma de "U" con un fondo plano, rugoso, áspero e irregular y, normalmente, se localizan en las diáfisis de los huesos largos de forma transversal al eje longitudinal. Se producen cuando, en un intento de arrancar la carne adherida al hueso, el consumidor arrastra la cúspide del diente sobre la superficie del hueso.
- ❖ *Depresiones*: Estas marcas presentan una morfología circular y, en ocasiones, el tejido cortical puede estar presente en el interior de la depresión. Suelen localizarse en las epífisis y en los extremos de la diáfisis de los huesos largos. Las depresiones se producen cuando el tejido óseo colapsa bajo la presión del diente en el intento de fracturar los huesos.

- *Furrowing*: El *furrowing* se produce cuando los extremos de los huesos son mordidos y el tejido esponjoso es consumido, dando lugar a las pérdidas de tejido esponjoso. Por otro lado. el vaciado es el resultado de un *furrowing* muy intensivo. Para su gradación hemos seguido los criterios descritos por Saladié y colegas (2013b), quienes lo clasifican entre leve, intermedia y fuerte según la intensidad de tejido esponjoso perdido.
- *Vaciados*: Mordisqueo continuo de las epífisis para eliminarlas y poder acceder al consumo de la médula.
- *Chupeteo*: Cánidos y hiénidos acostumbran a chupetear los huesos. Durante el proceso, la fricción de la lengua provoca el redondeo y pulido de las zonas que, generalmente, se localizan en los extremos de los restos.
- *Pitting*: El *pitting* o mordisqueo se caracteriza por la presencia de abundantes depresiones de pequeño tamaño y poca profundidad en los extremos de los restos. A menudo se asocian al chupeteo.
- *Bordes crenulados*: Son el resultado de la penetración de los dientes en los huesos planos y la destrucción de un área del borde que es igual a la superficie del área del diente.
- *Cilindros diafasarios*: Son el resultado de la extracción de las epífisis para el consumo de la médula ósea.
- *Huesos digeridos*: Los ácidos gástricos alteran los huesos que han sido ingeridos y regurgitados por los carnívoros. Los huesos digeridos presentan superficies porosas y con pequeñas cúpulas, consecuencia de la acción corrosiva de los propios ácidos.
- *Fracturas acanaladas*: Ocurren cuando el hueso se dispone de manera perpendicular a la boca y se ejerce la suficiente presión. El resultado son fracturas de tabletas en la diáfisis longitudinal respecto al eje sagital del hueso.
- *Fracturas en espiral*: Son el resultado de la aplicación de la fuerza de los dientes sobre las diáfisis de los huesos enteros. Suelen estar acompañadas de surcos y depresiones en las diáfisis.

Lo cierto es que distintos carnívoros pueden llegar a producir modificaciones similares, especialmente en lo que respecta a las mordeduras (Haynes, 1983; Selvaggio, 1994b). Éstas pueden producirse sobre el tejido cortical grueso, el tejido cortical fino y el tejido esponjoso. Muchos autores coinciden en la importancia de las dimensiones de las mordeduras como elemento para la identificación del carnívoro. Sin embargo, estos datos deben tomarse con mucha precaución, ya que diferentes carnívoros pueden llegar a hacer mordeduras de similares dimensiones, especialmente en el caso de los surcos (Selvaggio, 1994b; Domínguez-Rodrigo y Piqueras, 2003). Diversos trabajos apuntan a que el ancho de las depresiones producidas sobre tejido cortical es el que menos problemas de equifinalidad presenta (Saladié et al., 2011; Andrés et al., 2012). Las dimensiones de las depresiones han sido comparadas con datos actualistas (Selvaggio, 1994b; Delaney-Rivera et al., 2009; Andrés et al., 2012; Rodríguez-Hidalgo et al., 2013; Saladié et al., 2013b; Sala et al., 2014). Andrés y colegas (2012) plantean la necesidad de un mínimo de 30 mediciones para dotar de significancia estadística los resultados de las comparaciones. En nuestros conjuntos éstas se han comparado aun cuando el número de depresiones era <30 en muchos casos, dada la información descriptiva que aportan.

Los datos relativos a las dimensiones de las mordeduras deben apoyarse en el análisis de las características propias del conjunto y la etología de los diferentes tipos de carnívoros. La combinación de ambos factores nos puede acercar a una aproximación más eficaz del carnívoro (o los carnívoros) que han intervenido (Capaldo, 1997). Este investigador concluye que es importante tener en cuenta, por un lado, el comportamiento etológico de cada carnívoro y, por otro lado, las características de la presa (tamaño, edad y elementos esqueléticos).

### *4.5.2. Modificaciones producidas por homininos*

Las modificaciones de origen antrópico sobre las superficies óseas son la evidencia más directa del consumo antrópico de las carcasas. En este sentido, es necesario conocer las características que permiten documentar la presencia de actividad antrópica.

Las marcas de corte son las modificaciones más características de la actividad antrópica y las que más literatura han generado (p.e. Walker y Long, 1977; Binford, 1981; Potts y Shipman, 1981; Shipman, 1981a; Shipman y Rose, 1983a; Olsen y Shipman, 1988; Nilssen, 2000; Bello y Soligo, 2008; Bello et al., 2009; Domínguez-Rodrigo et al., 2009a; 2010a: 2017; de Juana et al., 2010; Merrit, 2012; *in press*; Palomeque-González et al., 2017; Yravedra et al., 2017a; Braun et al., *in press* Mate-González et al., *in press*; Courtenay et al., *in press*). Se producen durante los diferentes procesos de carnicería cuando, de manera accidental, la herramienta utilizada entra en contacto con el hueso. Son estrías alargadas, generalmente rectilíneas, de dimensiones variables y con una sección transversal. Se han diferenciado cuatro tipos de marcas de corte, en función al movimiento utilizado y al proceso de carnicería en el que han sido realizadas (Binford, 1981; Potts y Shipman, 1981; Shipman, 1981a; Shipman y Rose, 1983a; Domínguez-Rodrigo et al., 2009a):

- ❖ *Incisiones*: Estrías finas de dimensiones variables, realizadas en un movimiento continuo en el mismo sentido del eje longitudinal del borde de la herramienta. Pueden aparecer aisladas o en grupo. Generalmente la disposición suele ser oblicua, aunque no siempre es así.
- ❖ *Raspados*: Marcas largas y amplias, con microestriación interna. Aparecen a lo largo del eje longitudinal del hueso y se producen cuando la herramienta entra en contacto con el hueso en dirección perpendicular al movimiento de la mano.
- ❖ *Aserrados*: incisiones cortas, profundas, concentradas y superpuestas, generalmente de manera transversal. Son el resultado de una acción repetitiva durante la cual la herramienta siempre está en contacto con el hueso.
- ❖ *Tajos*: Marcas cortas, profundas y amplias con una sección en “V” muy marcada. Se producen al dar un golpe seco sobre el hueso con la herramienta, generalmente para cortar los elementos más duros, como los tendones.

Domínguez-Rodrigo et al. (2009a) definieron una serie de variables que caracterizaban las marcas de corte y podían ser útiles para su correcta identificación: trayectoria recta, orientación oblicua o perpendicular al eje longitudinal del hueso, presencia de barbas, morfología mayoritariamente en forma de “V”, simetría, presencia de *shoulder effect* y de microestriación interna.

Estos criterios, no obstante, deben tomarse con cautela. La simetría de las estrías, por ejemplo, depende de la inclinación de la herramienta en el momento en el que ésta contacta con el hueso (Bello y Soligo, 2008). Sabemos que otros criterios diagnósticos como el *shoulder effect* o la microestriación interna también pueden identificarse en estrías de trampling, dificultando la diferenciación de ambas señales (p.e. Shipman y Rose, 1983a; Oliver, 1984; Behrensmeyer et al., 1986; Domínguez-Rodrigo et al., 2009a).

Lo cierto es que en estos momentos seguimos careciendo de un método científico que permita la correcta identificación de marcas de corte evitando cualquier subjetividad en el análisis (Domínguez-Rodrigo et al., 2017). Trabajos recientes plantean el uso de la morfometría geométrica (Yravedra et al., 2017a) o el uso de *softwares* estadísticos para su correcta identificación (Palomeque-González et al., 2017). En la presente investigación, hemos limitado la identificación de estrías en superficies bien conservadas, en las que las características más comúnmente identificadas en las marcas de corte estaban presentes (Domínguez-Rodrigo et al., 2010a), reduciendo en la medida de lo posible el grado de subjetividad analítica. Así mismo, hemos recurrido al desarrollo de dos experimentaciones con el fin de caracterizar e identificar estas marcas en superficies mal preservadas, como ocurre en nuestros conjuntos (ver capítulo 5).

#### *4.5.2.1. La fracturación antrópica*

Al igual que los carnívoros, los homininos fracturan los huesos con el objetivo de consumir la médula ósea. La técnica más habitual es la fracturación directa, ya sea activa o pasiva. La fracturación directa activa consiste en el golpeo del hueso contra un objeto fijo. Contrariamente, la fracturación directa pasiva consiste en la fijación del hueso para ser golpeado con un percutor (Noe-Nygaard, 1977). En ocasiones también se pueden fracturar los huesos menos resistentes mediante el peeling (o fractura por flexión). El resultado es un astillamiento irregular y fibroso en los extremos de las fracturas (White, 1992).

Existen elementos diagnósticos que permiten atribuir la fracturación de los restos a la actividad antrópica, descritos en diversos trabajos (Binford, 1981; Brain, 1981; Blumenschine y Selvaggio, 1988). Su presencia y ubicación aportan información sobre el rol desempeñado por los homininos. En nuestros conjuntos hemos podido identificar:

- ❖ *Estigmas de percusión*: Hundimientos de forma circular u ovalada que se producen debido a la compactación del tejido óseo al producirse un impacto sin la fuerza suficiente como para que se produzca la fracturación del hueso. Se caracterizan por la presencia de microsurcos y microestriaciones en su interior. Blumenschine y Selvaggio (1988) atribuyen su aparición a una ligera desviación del objeto utilizado como percutor en el momento de golpear.
- ❖ *Impactos de percusión*: Hundimiento del área cortical del hueso en la que se produce la mayor intensidad del golpe,

provocando una muesca en el borde de fractura del hueso. Blumenschine y Selvaggio (1988) destacan la presencia de microestrías concéntricas o paralelas en las fibras de colágeno que se sitúan en el punto de impacto.

- *Contragolpes*: Fracturas situadas en la cara opuesta al punto de impacto, producidas como resultado de la colocación del hueso sobre un yunque en el momento del impacto.
- *Conos de percusión*: Pequeñas extracciones del tejido óseo que se desprenden del área de impacto en el momento de la fracturación. En su mayor parte están formados por tejido medular y, en ocasiones, presentan restos de la pared cortical. Su morfología es cónica. Suelen presentar un bulbo y un talón, tal y como ocurre con las lascas de piedra que se producen durante la elaboración de las herramientas de industria lítica. Los carnívoros también pueden provocar conos de percusión. Sólo la presencia de estigmas permite atribuirlos claramente a la acción antrópica.
- *Esquirlas parasitarias*: Conos de percusión que no han acabado de desprenderse del punto de impacto.
- *Extracciones medulares*: Pequeñas extracciones de tejido óseo que, a diferencia de los conos de percusión, se producen en un área cercana al punto de impacto. La cara medular del hueso suele presentar negativos, como consecuencia del propio desprendimiento. Es necesario identificar estigmas de percusión para asignarlos a la actividad antrópica.
- *Extracciones corticales*: Pequeños desprendimientos de tejido cortical que se producen durante la fracturación del hueso. Como resultado del desprendimiento, aparecen negativos en la cara cortical del hueso. Al igual que se ha mencionado en los casos anteriores, la localización de estigmas de percusión es necesaria para identificarlas de las producidas por los carnívoros.

## 4.6. Intensidad del saqueo y competencia entre predadores

El impacto que ejercen los carnívoros sobre un conjunto osteológico, incluyendo la selección, el transporte, la modificación y/o la destrucción de los elementos es definido como saqueo (*ravaging*) (Binford, 1981; Marean y Spencer, 1991). Las propuestas para medir con precisión los niveles de saqueo de los carnívoros sobre los conjuntos y poder realizar inferencias paleoecológicas relacionadas con el grado de competencia entre predadores o la selección de hábitats son diversas (Marean y Spencer, 1991; Blumenschine y Marean, 1993; Faith y Behrensmeyer, 2006; Domínguez-Rodrigo y Organista, 2007; Faith et al., 2007; Egeland, 2008). Diversos índices han sido propuestos para cumplir con estos objetivos.

Domínguez-Rodrigo y Organista (2007) han establecido tres ratios (a partir del NME) para medir el saqueo de carnívoros sobre el conjunto. El saqueo se define como el impacto o la destrucción de los conjuntos por parte de los carnívoros, ya sea por el transporte de algunos restos, por su fracturación o su destrucción durante el consumo (Binford, 1981; Marean y Spencer, 1991). Las ratios planteadas son las siguientes:

- *Axial:appendicular bones ratio*: Teniendo en cuenta que los miembros del esqueleto axial son los primeros en desaparecer con la intervención de un gran carnívoro sobre los restos, esta ratio se calcula mediante la siguiente fórmula:

  $$ratio = \frac{\text{NME esq. axial (sin sacro ni v. caudales)}}{\text{NME esqueleto apendicular}}$$

  Un resultado cercano a 0 implica un saqueo prácticamente completo del esqueleto, con una elevada desaparición de los elementos axiales. Contrariamente, una ratio cercana a 4.25 implica una buena representación del esqueleto axial y, en consecuencia, la ausencia de saqueo.
- *Femur-tibia ratio*: Esta ratio parte de la base que los huesos menos densos (como los fémures) tienden a desaparecer más rápido que otros huesos más densos (como las tibias) en contextos de alto saqueo. Se obtiene mediante la siguiente fórmula:

  $$ratio = \frac{\text{NME fémures}}{\text{NME tibias}}$$

  Una ratio cercana a 0 implica un alto saqueo, mientras que una ratio cercana a 1 se relacionaría con su ausencia. Esta ratio sólo es aplicable a conjuntos donde no ha habido fracturación antrópica previa a la acción de los carnívoros.
- *(proximal humerus + distal radius):(distal humerus + proximal radius) ratio*: Teniendo en cuenta que el extremo proximal del húmero y el extremo distal del radio son menos densos que los extremos opuestos, éstos tienden

> a desaparecer en contextos de alto saqueo. Se calcula mediante la siguiente fórmula:
>
> $$ratio = \frac{\text{húmero proximal} + \text{radio distal}}{\text{húmero distal} + \text{radio proximal}}$$
>
> Al igual que en la ratio anterior, un resultado cercano a 0 implica un alto saqueo, mientras que su ausencia se ve reflejada en una ratio cercana a 1. Esta ratio sólo es aplicable en aquellos conjuntos con fracturación antrópica previa al acceso de los carnívoros a las carcasas.

Se ha aplicado un modelo teórico en el que la ratio *axial:appendicular bones* ha sido relacionada con la ratio *(proximal humerus + distal radius):(distal humerus + proximal radius)*, como sugieren Domínguez-Rodrigo y Organista (2007) para conjuntos con intervención antrópica (Figura 4.4.).

La ratio epífisis:diáfisis, sumada a la frecuencia de marcas de mordedura (Blumenschine y Marean, 1993), ha sido utilizada para conocer los diferentes grados de competencia en los conjuntos. Según Blumenschine y Marean (1993), grados de baja competencia se ven reflejados en una baja ratio y una elevada frecuencia de mordeduras; esto es debido a que, en estos contextos, las hienas (los carnívoros estudiados por estos investigadores) consumen sus presas *in situ*, destruyendo las epífisis y produciendo mordeduras sobre los restos. Contrariamente, en contextos de alta competencia las hienas transportan diversos elementos a lugares seguros para su consumo. En estos casos, aunque la desaparición de las epífisis sigue siendo elevada y la ratio epífisis:diáfisis sigue siendo baja, la frecuencia de mordeduras sobre los restos es mucho menor.

La ratio epífisis:diáfisis se ha calculado mediante la división del número de epífisis por el número de diáfisis (a través del NISP). El resultado, que oscila entre 0 y 2, determina si se han dado contextos de saqueo (cuando el resultado es cercano a 0) o si, por el contrario, el impacto de los carnívoros es inferior (resultado cercano a 2) (Lyman, 1994).

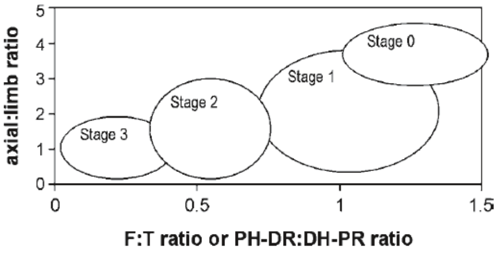

**Figura 4. 4.** Modelo desarrollado por Domínguez-Rodrigo y Organista (2007) para estimar el saqueo sobre un conjunto.

La correlación del %MAU de las epífisis de los huesos largos con su densidad mineral, acorde a las propuestas metodológicas de Faith y Behrensmeyer (2006) y Faith y colegas (2007) también ha sido calculada. En situaciones de baja competencia, los carnívoros tienden a consumir exclusivamente los huesos con mayor contenido graso (menos densos), lo que comporta una alta correlación entre la representación esquelética y la densidad mineral. En situaciones de alta competencia los carnívoros consumen ambos tipos de huesos, dando como resultado una muy baja correlación entre ambos elementos (Faith y Behrensmeyer, 2006; Faith et al., 2007).

El cálculo del porcentaje de cambio de las epífisis también nos aporta datos sobre el grado de competencia entre predadores. El porcentaje de cambio se ha calculado siguiendo a Marean y Spencer (1991) y modificado por Domínguez-Rodrigo y colegas (2002). Éste se calcula mediante la siguiente fórmula:

$$\%\ cambio = \frac{\text{NME previo } saqueo - \text{NME tras } saqueo}{\text{NME previo } saqueo} * 100$$

Altos valores del porcentaje de cambio indicarían cambios considerables y baja precisión en la abundancia original de los elementos (Marean y Spencer, 1991). Domínguez-Rodrigo et al. (2002) lo elaboran basándose en el NME total:

$$= \frac{\text{NME epíf. esperado según NME total} - \text{NME tras saqueo}}{\text{NME epif. esperado según NME total}} * 100$$

Domínguez-Rodrigo et al. (2002) parten de la base de que cada elemento tuvo originalmente una diáfisis y dos epífisis. El número total de fragmentos epifisarios en el conjunto es presumiblemente mayor al que se asume, pero el trabajo con epífisis completas de acuerdo al NME da una estimación mínima que permite algunas interpretaciones.

Egeland (2008) ha establecido un modelo teórico para medir la competencia entre carnívoros de manera similar al modelo establecido por Domínguez-Rodrigo y Organista (2007), calculando la relación entre la ratio huesos axial:apendicular y la ratio epífisis: diáfisis (Figura 4.5.). Su cálculo ha sido aplicado en el presente estudio. Según Egeland (2008), los contextos de baja competencia reflejarán un alto índice en ambas ratios, mientras que los contextos de alta competencia presentarán ratios cercanas a 0.

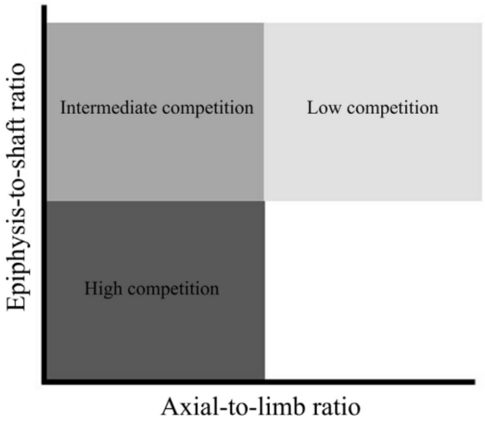

**Figura 4. 5.** Modelo establecido por Egeland (2008) para conocer el grado de competencia en el acceso a las carcasas de un conjunto en base a la correlación de la ratio epífisis:diáfisis y la ratio esqueleto axial:apendicular.

## 4.7. Modificaciones subaéreas y fosildiagenéticas

### *4.7.1. Meteorización (weathering)*

La meteorización (*weathering*) se define como el proceso mediante el cual los componentes microscópicos orgánicos e inorgánicos originales de los huesos se separan de otros y se destruyen por los agentes físicos y químicos que operan sobre los huesos *in situ*. Puede producirse sobre la superficie o en los suelos, entendiéndose que la descomposición y la destrucción de los huesos de los vertebrados forma parte del proceso natural de reciclado de los nutrientes (Behrensmeyer, 1978).

Este proceso se produce por la descomposición del colágeno y la destrucción de la proteína hidroxapatita por parte de microorganismos, en una superposición de reacciones controladas por el agua, el ácido, el oxígeno y el calcio contenido en los huesos y suelos (White y Hannus, 1983). La pérdida del tejido graso es la que, en última instancia, permite la aparición de agrietamientos longitudinales.

En un trabajo experimental llevado a cabo en el Amboseli Park (Kenia), Behrensmeyer estudió cómo la meteorización afecta a los diferentes tipos de hueso de macromamíferos (superiores a 5 kg) en relación al tiempo de exposición. Behrensmeyer acabó estableciendo un total de seis estadios de meteorización diferentes según el tiempo y la intensidad en qué los agentes atmosféricos habían afectado a los huesos (Behrensmeyer, 1978) (Tabla 4.1). A raíz de esta experimentación, acabó sugiriendo que eran los cambios de temperatura y humedad los agentes responsables de la meteorización de los restos. A mayor prolongación de la exposición de los huesos a estos cambios, según Behrensmeyer, mayor será la meteorización de los restos. En consecuencia, el proceso de formación de los conjuntos será, necesariamente, más prolongado (Behrensmeyer, 1978). Lyman y Fox defenderán que los grados de meteorización de los huesos de un yacimiento no necesariamente aportan información sobre la duración del proceso de formación de los conjuntos. Alegando que en la formación de un yacimiento nos encontramos ante diferentes “tiempos tafonómicos”, estos investigadores concluyen que la correlación entre el grado de meteorización y el tiempo de formación de los conjuntos no es necesariamente válida (Lyman y Fox, 1989; Lyman, 1994).

Posteriores estudios han demostrado que los cambios en la temperatura y humedad, la incidencia de los rayos solares o los ciclos de hielo y deshielo también afectan a los huesos expuestos en superficie, agravando notablemente la meteorización de los restos (Tuross et al., 1989; Junod y Pokines, 2014; Fernández-Jalvo y Andrews, 2016).

**Tabla 4. 1.** Estadios de meteorización descritos por Behrensmeyer (1978).

| *Estadio* | *Años* | *Características del weathering* |
|---|---|---|
| *0* | 0-1 | Sin modificaciones. |
| *1* | 0-3 | Grietas paralelas a la estructura fibrosa (longitudinal) de los huesos largos. Fracturas en mosaico en las epífisis. |
| *2* | 2-6 | Lascados concéntricos asociados a las fracturas. Pérdida de cortical. |
| *3* | 4-15+ | Superficie del hueso áspera y textura fibrosa. Meteorización sólo hasta 1-1.5 cm de profundidad. Bordes de fractura redondeados. |
| *4* | 6-15+ | Superficie del hueso áspera y fibrosa. Astillas ligeramente pegadas. La meteorización penetra en las cavidades. Se abren grietas. |
| *5* | 6-15+ | Debilitación mecánica del hueso *in situ*. Astillamiento. |

Otros factores como las diferentes densidades de los restos (y de las diferentes porciones de un mismo hueso) o las diferencias taxonómicas condicionan el proceso de meteorización (Lyman y Fox, 1989). Lyman plantea la necesidad de ejecutar experimentos en los que estas variables puedan ser controladas y así conocer cómo estas diferencias influyen en dicho proceso. Por otro lado, las condiciones microambientales también influyen en el grado de meteorización, aunque no se conoce con exactitud qué factores son los que influyen en dicha gradación. Sin embargo, este investigador defiende que los restos que se encuentran en una misma unidad estratigráfica deben haberse depositado en las mismas condiciones medioambientales (o en condiciones muy similares) (Lyman, 1994). No obstante, no podemos olvidar que un conjunto fósil puede ser el resultado de la práctica de uno o varios agentes acumuladores, que pueden haber adquirido o depositado los restos en diferentes momentos y fases de meteorización, de manera que el hecho de que un conjunto presente diversos grados de modificación no tendría por qué estar ligado a cambios microambientales.

### *4.7.2. Abrasión hídrica*

La abrasión es una alteración física que produce la eliminación de los bordes y/o superficies de un material a causa de una erosión mecánica. Ésta puede producirse con los restos en superficie o en el sustrato. En concreto, el contacto del hueso con el agua y las partículas sedimentarias que ésta conlleva es el que produce la abrasión (p.e. Shipman, 1981a; Behrensmeyer et al., 1989; Gifford-Gonzalez, 1989; Fernández-Jalvo, 1992; Lyman, 1994; Cáceres, 2002). Esta alteración se presenta en forma de redoneo y pulido de los restos. El redondeo se produce por la fricción de las partículas sedimentarias contenidas en el agua con los bordes y superficies de los restos (Shipman, 1981a). El pulido se atribuye a la abrasión de las partículas transportadas por el agua, provocando muescas y la pérdida de láminas superficiales y dando rugosidad a la superficie (Bromage, 1984).

Lyman cita a Brain como uno de los primeros tafónomos en remarcar la abrasión no antrópica de los restos, en un trabajo en 1967 (Lyman, 1994) donde destacó el redondeo y pulido de unos restos depositados en sedimentos arenosos que habían sido pisoteados por cabras y humanos. Al parecer, los restos presentaban el redondeo y pulido de las superficies, que podría confundirse con abrasiones de origen antrópico (Lyman, 1994). Más allá de este trabajo, fue Shipman (1981a) una de las primeras investigadoras en estudiar este proceso. Shipman introducirá una variable a tener en cuenta: las diferencias anatómicas y taxonómicas de los restos y acabará estableciendo tres categorías, según el grado de abrasión: Grado 1) presencia de bordes angulosos y superficie no alterada; Grado 2) presencia de abrasión moderada y redondeo de los bordes de fractura; Grado 3) presencia de abrasión fuerte y redondeo de los bordes de fractura y pulido de la superficie.

Estas variables serán ampliadas en trabajos posteriores. Elementos como el tamaño y el tipo de las partículas sedimentarias, la presencia de tejidos blandos en el hueso, el estado del hueso (fresco, seco, meteorizado, fósil…) y el tiempo de abrasión influyen en el grado de abrasión (Fernández-Jalvo, 1992; Andrews, 1995; Fernández-Jalvo y Andrews, 2003; 2016; Gaudzinski-Windheuser et al., 2010; Rabinovich et al., 2012). La dinámica sedimentaria de cada yacimiento (que incluye aspectos como la energía del agua, el tipo de sedimento que transporta y las características topográficas del terreno) también influye en el grado de abrasión (Cáceres, 2002).

Cáceres (2002) ha destacado que ambas alteraciones (redondeo y pulido) no tienen por qué presentarse sobre un mismo resto y, en caso de hacerlo, no tienen por qué hacerlo en el mismo grado. Ante esta premisa, ha establecido diferentes grados de alteración (Tabla 4.2). En el presente trabajo se ha seguido aplicado el método propuesto por Cáceres (2002). A los restos se les ha asignado un grado específico de redondeo y pulido. Dado que la asignación a un grado no siempre es clara, en caso de duda se ha asignado el grado de alteración más elevado.

**Tabla 4. 2.** Grados de redondeo y pulido descritos por Cáceres (2002).

| **Redondeo (R)** | **Grado** | **Pulido (P)** |
|---|---|---|
| Restos con bordes angulosos, sin redondeo. | **0** | Restos con superficie mate. |
| Redondeo en bordes anatómicos y de fracturas. Apreciable microscópicamente (entre 18 y 50 aumentos). | **1** | Fina capa que afecta a los bordes de fractura. Apreciable microscópicamente (entre 18 y 50 aumentos). |
| Afecta a determinadas partes del hueso. Apreciable macroscópicamente. | **2** | Superficie brillante (macroscópicamente). A nivel microscópico, aparecen zonas pulidas (a modo de placas) y bordes brillantes. |
| El redondeo afecta a todo el hueso. Puede perderse la morfología original del resto. | **3** | Hueso completamente pulido. Superficie claramente brillante (a nivel macroscópico). |

No podemos obviar que esta alteración de las superficies puede afectar a las señales tafonómicas. Algunos estudios han destacado cómo la abrasión de los restos puede crear, borrar o alterar estas marcas (Shipman y Rose, 1983b; Behrensmeyer et al., 1989; Gaudzinski-Windheuser et al., 2010; Rabinovich et al., 2012) y producir cambios en la morfología de los restos (Cáceres, 2002; Fernández-Jalvo y Andrews, 2003; 2016; Gaudzinski-Windheuser et al., 2010; Rabinovich et al., 2012).

### *4.7.3. Pisoteo (trampling)*

El trampling o pisoteo puede definirse cómo el proceso de fricción entre las partículas del sedimento y los huesos, causado por el tránsito de animales u homininos por la superficie o por el contacto del hueso con el sedimento durante su consumo por parte de los carnívoros, por poner algunos ejemplos. El trampling puede causar modificaciones en la superficie de los restos arqueológicos, su fracturación o su dispersión.

Algunos autores (Andrews y Cook, 1985; Fiorillo, 1991; Kos, 2003; Stuart y Larkin, 2010) han realizado observaciones sobre conjuntos arqueológicos para conocer los efectos que el trampling puede producir. Sin embargo, gran parte de los estudios se basan en la experimentación para realizar este tipo de inferencias (Villa y Courtin, 1983; Gifford-Gonzalez et al., 1985; Behrensmeyer et al., 1986; Olsen y Shipman, 1988; Nielsen, 1991; Blasco et al., 2008; Domínguez-Rodrigo et al., 2009a; 2017; Eren et al., 2010; Benito-Calvo et al., 2011).

Los huesos sometidos a trampling pueden presentar estriaciones sobre la superficie. Caracterizar estas estriaciones y diferenciarlas de las marcas de corte producidas durante el procesado de las carcasas por parte de los homininos es importante a la hora de realizar posteriores interpretaciones.

Muchos autores consideran que las estrías producidas por el trampling pueden presentarse aisladas o agrupadas y paralelas entre sí, sin ningún tipo de patrón de localización y/o distribución sobre los elementos esqueléticos (Behrensmeyer et al., 1986; Olsen y Shipman, 1988; Domínguez-Rodrigo et al., 2009a). No obstante, Andrews y Cook (1985) han sugerido que estas marcas se presentan, generalmente, en las diáfisis y en los cuellos de los huesos largos, pero nunca en las facetas articulares. Según Andrews y Cook, esta ubicación las diferencias de las marcas de corte, localizadas en los cuellos y en las facetas articulares, y de las marcas de mordedura, distribuidas por toda la superficie de los huesos (Andrews y Cook, 1985). Fiorillo (1991) también sugirió que estas marcas tienden a localizarse en las diáfisis de los huesos.

Tradicionalmente se han descrito una serie de características que permiten diferenciar las estrías de trampling de otras marcas, como las marcas de corte (Andrews y Cook, 1985; Behrensmeyer et al., 1986; Olsen y Shipman, 1988; Domínguez-Rodrigo et al., 2009a). Olsen y Shipman las caracterizan por presentar una sección plana, por la ausencia de un patrón de localización y de distribución y por su trazo fino, superficial y carente de microestriación interna (Olsen y Shipman, 1988). Sin embargo, recientes trabajos parecen discrepar en algunos de estos aspectos. Domínguez-Rodrigo et al., (2009a) han determinado que las marcas producidas por pisoteo también tienden, por ejemplo, a presentar microestriación interna. Como ya se ha comentado previamente, nos encontramos en un momento en el que los criterios que permiten diferenciar estas estrías de las marcas de corte están siendo revisados (Domínguez-Rodrigo et al., 2009a; 2017), por lo que la adscripción de estas marcas a un proceso debe realizarse con mucha cautela.

Behrensmeyer y colegas (1986) también destacan que estas marcas pueden ser muy variables, debido, principalmente, a que segundas marcas pueden llegar a provocar nuevas abrasiones que son capaces de eliminar la morfología y la micro-estriación interna originales. En este sentido, destacan que una marca de corte que después es sometida a este proceso llega a ser indistinguible de una marca de trampling, algo que ya había apuntado Oliver (1984). Además, apuntan a que esto puede producirse en cuestión de minutos, como también señalan Shipman y Rose (1983b) y Bromage (1984). Factores como el contexto sedimentario, la angulosidad de las partículas más grandes o la intensidad del trampling influyen en el grado en que estas marcas aparecen (Olsen y Shipman, 1988).

Además de las estriaciones, el trampling puede provocar la fracturación los restos (Andrews y Cook, 1985; Kos, 2003; Stuart y Larkin, 2010; Blasco et al., 2008). Ciertos trabajos parecen sugerir que la fracturación se produce sobre los huesos secos y meteorizados (Olsen y Shipman, 1988; Kos, 2003; Stuart y Larkin, 2010), pudiendo asociarse también descamaciones (Kos, 2003), pequeñas muescas en las fracturas de los ángulos oblicuos (Blasco et al., 2008) o el pulido de la superficie (Olsen y Shipman, 1988) de los restos. Domínguez-

Rodrigo y colegas (2009a) han sugerido que la asociación con el pulido no siempre aparece. Por otro lado, Yellen (1991) ha sugerido que los huesos planos o cilíndricos tienen una mayor tendencia a fracturarse que los esféricos.

El trampling también se ha demostrado como un proceso que puede producir la dispersión vertical (Villa y Courtin, 1983; Andrews y Cook, 1985; Gifford-Gonzalez et al., 1985; Nielsen, 1991; Eren et al., 2010; Benito-Calvo et al., 2011) y horizontal (Olsen y Shipman, 1988; Yellen, 1991; Eren et al., 2010) de los restos, así como su reorientación (Villa y Courtin, 1983; Eren et al., 2010; Benito-Calvo et al., 2011).

### *4.7.4. Modificaciones de origen bioquímico*

Por modificaciones de origen bioquímico entendemos todas aquellas modificaciones producidas por hongos y bacterias sobre los restos óseos, principalmente sobra las superficies de los mismos (Domínguez-Rodrigo y Barba, 2007b).

Las modificaciones producidas por la acción de las raíces (*root-etching*), principalmente en forma de disolución de las superficies, han sido frecuentemente documentadas en el registro arqueológico y han sido el sujeto de estudio de múltiples trabajos (Behrensmeyer, 1978; Morlan, 1980; Binford, 1981; Andrews y Cook, 1985; Hesse y Wapnish, 1985; Cook, 1986; Grayson, 1988; Piepenbrink, 1989; Andrews, 1990; Fernández-Jalvo, 1992; White, 1992; Lyman, 1994; Cáceres, 2002; Fernández-Jalvo y Marín-Monfort, 2008; Willis et al., 2008).

Behrensmeyer (1978) planteó que la disolución de los ácidos asociada al crecimiento y decrecimiento de las raíces y hongos que se encuentran en contacto directo con la superficie de los restos era la causante de estas modificaciones. Sin embargo, según otros investigadores (Morlan, 1980; Grayson, 1988), la corrosión es debida a los ácidos segregados por los hongos, en asociación a las plantas en proceso de descomposición.

Fernández-Jalvo (1992), por su parte, también considera que estas modificaciones no se producen por la acción de las raíces en sí mismas, sino por la acción de hongos (Mychorrizae) y bacterias (Rhozhobium), importantes en la absorción y transferencia del fósforo de los huesos a la raíz (Fernández-Jalvo, 1992). Parece ser que esta es la idea más aceptada en la actualidad. Sin embargo, se habla de modificaciones producidas por raíces desde una perspectiva amplia para hacer referencia a este tipo de alteraciones (Lyman, 1994).

Las raíces pueden provocar varios tipos de alteraciones sobre la superficie de los restos, siendo las vermiculaciones las modificaciones más características. En general, se definen como estrías sinuosas, anchas, alargadas, superficiales y con una sección en forma de “U”, que aparecen en forma detrítica y que pueden afectar a una parte o la totalidad de los restos (Behrensmeyer, 1978; Binford, 1981; Hesse y Wapnish, 1985; Cook, 1986; Fernández-Jalvo, 1992; Lyman, 1994).

Según Cook (1986), estas marcas presentan, microscópicamente, corrosión en su interior. En ocasiones, puede venir acompañadas por cambios en la coloración, siendo el surco más oscuro que el resto de la superficie según Binford (1981), o pudiendo también ser algo más claro, tal y como apunta Morlan (1980). Este investigador también destaca que, en ocasiones, los surcos pueden presentarse de manera muy superficial y alrededor de la estría puede aparecer un cambio de coloración hacia tonos oscuros (Morlan, 1980).

Algunos investigadores han destacado que estas estriaciones pueden llegar a confundirse con marcas de carácter antrópico (Binford, 1981; Hesse y Wapnsih, 1985; Andrews y Cook, 1985; Willis et al., 2008), si bien es cierto que Lyman (1994) defiende que son fácilmente diferenciables. Según Andrews (1990), la corrosión producida por las raíces también puede llegar a confundirse con la corrosión provocada por el pH del sedimento o incluso por la acción de los carnívoros. Sin embargo, este investigador destaca que la superficie del resto afectada por las raíces presenta estas acanaladuras dendríticas características del crecimiento de la raíz, algo que los otros agentes no producen (Andrews, 1990). Domínguez-Rodrigo y Barba (2006; 2007d) han descrito una serie de rasgos que servirían para diferenciar las mordeduras de los surcos producidos por la acción de hongos y bacterias. Las mordeduras tienden a presentar una morfología recta y una anchura homogénea, con descamación y exfoliación a ambos lados del surco y, generalmente, una orientación perpendicular u oblicua al eje longitudinal del hueso. Las marcas de origen bioquímico, contrariamente, tienden a presentar morfología irregular y cambios en la anchura del surco; se orientan, frecuentemente, paralelas al eje longitudinal del hueso y la presencia de exfoliaciones o descamaciones se distribuye aleatoriamente a lo largo del surco (Domínguez-Rodrigo y Barba, 2006; 2007d).

Además de estrías y surcos, las raíces pueden llegar a crear perforaciones sobre los restos (Andrews, 1990), llegando incluso a fracturarlos (Behrensmeyer, 1978; Andrews y Cook, 1985;

Andrews, 1990). La acción de hongos también puede llegar a producir perforaciones sobre los restos óseos (Marchiava et al., 1974).

Existen discrepancias sobre el momento en que raíces y líquenes empiezan a actuar sobre los huesos. Lyman (1994) considera que hay musgos y líquenes que pueden afectar a los huesos previamente a su entierro y Cook (1986) afirma que se producen durante el proceso de enterramiento. Contrariamente, Fernández-Jalvo y Marín-Monfort (2008) defienden que las raíces de las plantas no afectan a los huesos frescos y que, además, necesitan más de dos años para ser visibles sobre el hueso.

Lo cierto es que estas marcas aportan información y son indicativas de un entorno que permite el crecimiento de plantas (Lyman, 1994). Según White (1992), la localización de estas marcas en los paños de fractura o en la cara interna de un resto también es indicativo de una fracturación previa a la acción de las raíces y, posiblemente, previa a la deposición de las mismas. Esta idea se apoya en la premisa de Cook (1986), quién defiende que la actuación de raíces y, especialmente, de líquenes necesita de un tiempo de exposición relativamente largo.

### *4.7.5. Alteración química: óxido de manganeso*

La presencia de restos óseos que presentan una coloración negra de la superficie (parcial o total) es frecuente en los conjuntos arqueológicos pleistocenos. En muchos casos, esta coloración es debida a la carbonización de los restos (Brain, 1981; Lyman, 1994) aunque otros procesos diagenéticos pueden llevar a pigmentar las superficies de manera similar.

La presencia de materiales carbonáceos (como el hollín de las antorchas o el alquitrán) (Hill, 1982) o la acumulación de guano de ratas y murciélagos (Shahack-Gross et al., 2004) pueden provocar el ennegrecimiento de las superficies de los restos orgánicos. Así mismo, la precipitación de Óxido de Manganeso (IV), también llamado Dióxido de Manganeso, suele ser el agente causante de la coloración negra de los restos faunísticos.

La precipitación de óxidos de manganeso se produce por bacterias que se desarrollan en ambientes húmedos y aerobios con un Ph neutro o cercano a neutro (Potter y Rossman, 1979; Fernández-Jalvo, 1992). Estas bacterias acaban produciendo la pigmentación oscura de las superficies, tras el uso de los restos orgánicos como alimentos (Cáceres, 2002). Ésta puede darse en diversos ambientes: en el barniz desértico (en regiones áridas y semi-áridas), en la superficie o grietas de las rocas y asociada a ríos, cuevas o glaciares (Potter y Rossman, 1979). La difracción de rayos X (Potter y Rossman, 1979), la espectroscopia infrarroja (Potter y Rossman, 1979) o la espectroscopia de rayos X (McKeown y Post, 2001) han sido técnicas utilizadas para la identificación mineralógica de los óxidos de manganeso.

Existen múltiples trabajos centrados en la presencia de este tipo de óxidos en yacimientos ubicados en sistemas kársticos (Hill, 1982; Cáceres, 2002; López-González et al., 2006; Michel et al., 2006; Marín-Arroyo et al., 2008). Sin embargo, la presencia de óxidos de manganeso en conjuntos arqueo-faunísticos al aire libre no ha sido tan estudiada. Conocer cómo estos óxidos actúan en este tipo de conjuntos es importante para discernir correctamente el origen de estas pigmentaciones.

### *4.7.6. Roturas y deformaciones*

Una vez los restos se encuentran enterrados, éstos pueden verse afectados por factores como el peso, la contracción o la compactación de los sedimentos, que pueden provocar la deformación y/o fractura de los mismos.

Para Lyman (1994), la deformación de un resto se refiere a su distorsión; es decir, el cambio en un elemento esquelético de la localización espacial de dos (o más) puntos anatómicos en relación a un tercero. El tipo y el grado de deformación de los restos pueden ser muy variados y dependen tanto de factores intrínsecos como de factores extrínsecos (Shipman, 1981a; Lyman, 1994). Los factores intrínsecos incluyen la morfología original del resto, su grado de elasticidad y la orientación en los planos horizontal y vertical de la parte esquelética que está siendo deformada (Lyman, 1994). Los factores extrínsecos, por su parte, se relacionan con las características de los sedimentos: tamaño y partículas sedimentarias, que pueden provocar mineralización, intercambios químicos o disolución (Shipman, 1981a; Lyman, 1994).

Shipman también destaca que la deformación no se produce exclusivamente de fuera hacia adentro, ya que la entrada de pequeñas partículas sedimentarias en el interior de los huesos puede provocar una deformación desde el interior (Shipman, 1981a).

La deformación prolongada de un resto puede llevar a su fragmentación. Ésta tiende a producirse en las zonas de mayor debilidad del resto (debilidad que puede ser de origen anatómico o estar relacionada con procesos sufridos previamente) (Fernández-Jalvo, 1992). En general, los huesos secos (carentes de elasticidad) son los que acaban por fragmentarse tras recibir una mayor presión de la que pueden resistir. Villa y Mahieu (1991) han desarrollado un método para identificar el estado del hueso en el momento de su fragmentación a través del análisis de los paños de fractura. Según estos investigadores, las fragmentaciones de origen diagenético se caracterizarían por presentar ángulos rectos, perfiles transversales y una textura suave o irregular. Además, los diferentes fragmentos tendrían a localizarse cercanos entre sí (o incluso en contacto), presentando superficies cóncavas o convexas (Villa y Mahieu, 1991).

# Capítulo 5. Aproximaciones experimentales

En esta sección se presentan dos aproximaciones experimentales con el objetivo de solventar los problemas de equifinalidad en la identificación de estrías superficiales en las superficies óseas del Barranc de la Boella. Éstas se presnetan en forma de dos artículos, uno publciado y otro en proceso de revisión, en la revista *Journal of Archaeological Science.*

**Artículo 1:** Pineda, A., Saladié, P., Vergès, J. M., Huguet, R., Cáceres, I. y Vallverdú, J. (2014). Trampling *versus* cut marks on chemically altered surfaces: an experimental approach and archaeological application at the Barranc de la Boella site (la Canonja, Tarragona, Spain). *Journal of Archaeological Science* 50: 84-93

**Artículo 2:** Pineda, A., Cáceres, I., Saladié, P., Huguet, R., Rosas, A. y Vallverdú, J. (enviado). Tumbling effects and its application to archaeological deposits: the case of Barranc de la Boella (Tarragona, Spain). *Journal of Archaeological Science*.

In this section, we present two experimental approaches with the aim to solve equifinallity problems during the analysis of Barranc de la Boella bone surfaces. These experimental approaches are presented in two papers, one of them is already published and the other one is submitted, into *Journal of Archaeological Science*.

**Paper 1:** Pineda, A., Saladié, P., Vergès, J. M., Huguet, R., Cáceres, I. y Vallverdú, J. (2014). Trampling *versus* cut marks on chemically altered surfaces: an experimental approach and archaeological application at the Barranc de la Boella site (la Canonja, Tarragona, Spain). *Journal of Archaeological Science* 50: 84-93

**Paper 2:** Pineda, A., Cáceres, I., Saladié, P., Huguet, R., Rosas, A. y Vallverdú, J. (submitted). Tumbling effects and its application to archaeological deposits: the case of Barranc de la Boella (Tarragona, Spain). *Journal of Archaeological Science*

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# Trampling *versus* cut marks on chemically altered surfaces: an experimental approach and archaeological application at the Barranc de la Boella site (la Canonja, Tarragona, Spain)

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ABSTRACT

Several studies have attempted to identify diagnostic criteria for distinguishing between evidence of trampling and cut marks, two common modifications at archaeological sites. These studies have brought to light, with relative precision, the features that identify and differentiate the two types of modifications. However, few studies differentiate these modifications after they have been affected by other factors. Chemical alteration, related to lixiviated sediments, is documented in a relatively high number of archaeological sites. Following the criteria established by Domínguez-Rodrigo et al. (2009), the aim of this paper is to know if diagnostic criteria that would allow modifications resulting from trampling to be differentiated from cut mark modifications are preserved, after undergoing chemical alterations. The results have been applied to unidentified marks located on faunal skeletal remains from the La Mina site, at the Barranc de la Boella (Tarragona, Spain), the surfaces of which have been heavily modified by the lixiviation of the sediments. The data suggest that chemically altered marks lose the diagnostic criteria necessary for correct identification. The unidentified marks discovered on remains from la Boella could not be verified as cut or trampling marks and therefore cannot be considered in future zooarchaeological and taphonomical studies.

## 1. Introduction

Trampling is defined as the friction process occurring between sedimentary particles and bones caused by hominin and/or animal transit over the surface or by carnivore consumption, in addition to other processes. Trampling can cause modifications on the surfaces of archaeological bones, give rise to fractures and contribute to the dispersion of an assemblage.

Some researchers (Andrews and Cook, 1985; Fiorillo, 1991; Kos, 2003; Stuart and Larkin, 2010) have described the effects of trampling at archaeological sites. However, other studies have employed experimentation to make inferences about this phenomenon (Villa and Courtin, 1983; Gifford-González et al., 1985; Behrensmeyer et al., 1986; Olsen and Shipman, 1988; Nielsen, 1991; Holen, 2006; Blasco et al., 2008; Domínguez-Rodrigo et al., 2009; Eren et al., 2010; Benito-Calvo et al., 2011).

Bones subjected to trampling can present striae over the entire surface. It is important to characterize these striae and differentiate them from cut marks generated during hominin butchering tasks in order to make valid subsequent interpretations (Behrensmeyer et al., 1986; Domínguez-Rodrigo et al., 2009).

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Macroscopically, trampling tends to present features that allow them to be differentiated from other striae (Andrews and Cook, 1985; Behrensmeyer et al., 1986; Olsen and Shipman, 1988; Domínguez-Rodrigo et al., 2009). According to Olsen and Shipman (1988), modifications caused by trampling are characterized by a U-shaped section, the absence of a location and distribution pattern, and a thin, shallow stroke lacking internal microstriation. However, current works seem to disagree with this description in some aspects. Domínguez-Rodrigo et al. (2009) determined that trampling striae also tend to present internal microstriation.

Behrensmeyer et al. (1986) also highlighted the variability of trampling marks, mainly because second striae can give rise to new abrasions capable of destroying the original morphology of marks and their internal microstriations. They suggest that a cut mark subjected to trampling could become indistinguishable from a trampling mark alone, as Oliver (1984) suggested previously. This process can occur in just a few minutes, as also indicated by Shipman and Rose (1983) and Bromage (1984). Factors such as sedimentary context, angularity of the larger particles and trampling intensity also influence the degree to which these marks appear (Olsen and Shipman, 1988).

The problem appears when bone surfaces have been altered and the diagnostic criteria that characterize the two types of striae (trampling and cut marks) have disappeared or been altered.

Some works have described the effects of diagenesis on bone surfaces. Effects of lichens, algae and fungi over bones surfaces have been well synthetized (Fernándeez-Jalvo, 1992; Fernández-Jalvo et al., 2002). Fungi are the most studied organic agent causative of chemical alterations. Piepenbrink's studies (1989) showed their ability for dissolve or break down bone tissue. Fungi capacity for produce perforations on bones have also been displayed (Marchifava et al., 1974).

Root-etching effects on bone surfaces have also been described (Behrensmeyer, 1978), although Fernándeez-Jalvo (1992) has defended fungi (*Mycorrhizae*) and bacteria (*Rhizobium*) action as causative of root-etching modification. Roots may overlap, create new striae and remove previous striae (Andrews and Cook, 1985; Andrews, 1990).

Most experimental works have elaborated diagnoses using rather static frameworks, in which single-agent processes have been modeled independently and the resulting morphologies and diagnostic criteria have been used as if they were static byproducts. For this reason, some authors have suggested marks interpretation should be limited to well-preserved bone surfaces or portions of those assemblages where bone preservation maintains the original properties of the cortical surface (Domínguez-Rodrigo et al., 2010). In point of fact, marks modification is the result of multiple-process agents (Behrensmeyer et al., 1986). Marks metamorphoses through dynamic biostratinomic processes have recently been further championed by Gaudzinski-Windheuser et al. (2010).

Bones in contact with sediments below pH 4 can also be corroded (Andrews, 1990), on the ground and after burial (Fernández-Jalvo et al., 2002). Highly alkaline sediments may also corrode bone tissue during fossilization process (Fernández-Jalvo et al., 2002). Effects of soil chemistry is reflected as a corrosion located on bones portions that have in contact with sediments, although bones may roll and change their position, producing the corrosion of all bone surface (Fernándeez-Jalvo, 1992).

The chemical alteration of bones, usually caused by rinsing soluble sediments, is common in many assemblages. A high level of lixiviation leads to the greater alteration of surfaces and, consequently, a high alteration of superficial marks. This type of alteration was documented in the faunal remains of the ~ million-years-old Barranc de la Boella site, the surfaces of which have been heavily chemically modified and superficial marks are altered and, in some cases, undistinguishable.

Correct diagnosis of hominin activities by analyses of bone remains during the Lower Pleistocene is important to realized correct inferences about the role of hominins in these ancient chronologies. These studies required an accurate investigation of taphonomic process. Domínguez-Rodrigo et al. (2010) have shown as a cut mark misidentification produce wrong inferences about the behavior of the first hominins (McPherron et al., 2010).

The aim of this paper is to analyze chemically altered trampling and cut marks, and document the lost and preserved diagnostic criteria which can be used to differentiate between the two. Our results were applied during the analysis of the chemically altered superficial marks located on the remains recovered at the La Mina site (Barranc de la Boella). Although these marks present features similar to those expected in cases of trampling, some of those features seem to be related to cut marks. The correct identification of these marks is necessary in order to conduct valid future zooarchaeological and taphonomical studies (*in prep.*).

## 2. The Barranc de la Boella site

The Barranc de la Boella site is located in the north-eastern corner of the Iberian Peninsula, in the township of la Canonja (Tarragona, Spain) (Fig. 1). The gully has been a recognized archaeological and paleontological site since the first third of the twentieth century (Bataller, 1935). However, it was not until the seventies that Dr. Salvador Vilaseca discovered the paleontological potential of the site with the discovery of *Elephas meridionalis* remains (Vilaseca, 1973).

The Barranc de la Boella is an outdoor archaeopaleontological site whose formation is related to a deltaic sedimentary environment. Six lithostratigraphic units have been identified at 9 m thick sedimentary succession, fully described in Vallverdú et al. (2014). Lithostratigraphic unit II is the richest in remains. Unit II contains poorly stratified sand and gravel with a total thickness of 2 m (Vallverdú et al., 2014). Early studies dated this level at the Lower-Middle Pleistocene transition (0.78 Ma) (Saladié et al., 2008; Vallverdú et al., 2008). Recently, Lozano-Fernández et al. (2013) have suggested a chronology of less than a million years for these levels, based on the study of the micromammal remains recovered. Recent paleomagnetic and cosmogenic nucleides analysis confirms this hypothesis, suggesting a 0.96–0.78 Ma chronology for the unit II (Vallverdú et al., 2014).

Scheduled excavation began in the gully in 2007 at three different archaeological sites (Cata 1, El Forn and La Mina), although the actual work at the La Mina site started in 2008. Three archaeopaleontological levels have been differentiated at La Mina unit II, with over 900 faunal, coprolite and stone tool remains recovered. The paleoecological diversity of the assemblage seems to be typical of a landscape near ponds. *Cervus elaphus* is the most highly represented taxa, although *Dama* cf. *vallonetensis* and *Megaloceros* have been documented as well. Remains of *Equus* cf. *stenonis*, *Hippopotamus antiquus* and *Mammuthus meridionalis* have also been found. Among the carnivores, remains of *Ursus sp*., *Canis mosbachensis* and a medium-sized felid have been recovered, in addition to coprolites belonging to a hyenid. Further studies have being carried out currently.

## 3. Material and methods

Both archaeological and experimental remains were then analyzed using a binocular microscope (OPTECH HZ) at 60 increases. The cut marks were analyzed in accordance with the criteria established by Domínguez-Rodrigo et al. (2009). The

**Fig. 1.** Location of the Barranc de la Boella site in relation to western Europe (top, left) and the northeastern Iberian peninsula (top, center). Distribution of the different archaeological sites in the gully (right) and a view of the La Mina site (bottom).

trampling marks were analyzed and documented using the criteria established by Domínguez-Rodrigo et al. (2009) and other previous studies (Shipman and Rose, 1983; Oliver, 1984; Bromage, 1984; Andrews and Cook, 1985; Behrensmeyer et al., 1986; Olsen and Shipman, 1988; Fiorillo, 1991).

After experimentation process, the free software Paleontological Statistics (PAST) (Hammer et al., 2001) was used and a correspondence analysis was conducted in order to compare the data presented by Domínguez-Rodrigo et al. (2009) with the results of our study.

All processes were recorded using a Sony Cyber-shot DSC-R1 digital camera. Detailed photos were also taken the USB Digital Microscope DigiMicro scale 2.0, and an environmental scanning electron microscope (ESEM, FEI Quanta 600) was used to take photos and analyze striae in detail.

### 3.1. Archaeological material

A total of 691 remains have been recovered and analyzed from the La Mina site. Animals from different body weigh are represented, although medium (100–300 kg) (38.2%) and large-sized (300–1000 kg) (16.6%) carcass are the most represented. The anatomical representation shows a high variability. All skeletal parts are represented in the La Mina assemblage, although the shafts of large bones are the most preserved.

Both biostratinomic and diagenetic modifications were documented during the analysis of faunal remains. The analysis of trampling and unidentifiable marks included the location, distribution and microscopic features of every striae.

### 3.2. Experimental material

Four fresh large bones belonging to an adult *Bos taurus* (a humerus, a tibia and two femurae) were used in the experiment. Previous to the start of the experiment, the surfaces of the bones were analyzed and all marks were documented.

The first step was to reproduce the cut marks (Fig. 2A). All cut marks were made using a simple flint flake. These marks does not reproduce butchery marks because the presence and distribution of such marks can be distinct from the random pattering produced by taphonomic processes although the characteristics of any incision made are the same. Eleven marks were made on the shaft of the

**Fig. 2.** Different phases of the experimental series: reproduction of the cut marks (A) and partial burial of bones in plastic mesh for reproduce the effects of trampling at the Boella gully (B).

humerus: six on the anterior face and five on the posterior face. A total of fourteen marks were made on the tibia: four on the shaft of the anterior face, seven on the shaft of the posterior face and three on the crest of the medial face. Finally, thirteen marks were made on the shaft of one of the femurs: seven on the anterior face and six on the posterior face.

In all cases, the cut marks on the anterior surface of the shaft were made from the lateral side to the medial and from proximal to distal. The marks on the posterior face were always made from the medial face to the lateral side and from the proximal to the distal area. The marks on the tibia were made from the posterior face to the anterior and from the proximal to the distal area.

Generally, posterior to making the cut marks, the bones were fragmented using direct percussion with two granite hammers (with a smooth and rounded surface) on a limestone anvil (with a smooth and angled surface). With the second femur, however, the order of the process was inverted. The shaft was first fragmented with a radial into eight parts and afterward four cut marks were made on each part. This process allowed us to study the shaft, as many previously made marks were lost during the fracturing process. Next, all the remains were boiled in water for 30 min, washed by hand, and left to dry at room temperature.

The cut marks were analyzed in accordance with the criteria established by Domínguez-Rodrigo et al. (2009). However, the trajectory and orientation of the grooves were not taken into account in the experimental project, because the marks were not made during carcass processing. All cut marks were identified as incisions, defined as thin striae of variable dimensions, made in a continuous movement in the same direction as the longitudinal axis of the tool edge (Binford, 1981; Potts and Shipman, 1981).

After the cut mark analysis, the bones were buried for 34 days (25 December 2013–28 January 2014) at the Boella gully to reproduce trampling at sandy sediment with gravels, in an area where water currents are abundant. Bones were placed inside a mesh to avoid dispersal and subsequently covered with some sediment, which did not cover the mesh completely (Fig. 2B). When water currents occur, a friction process between bone and sandy particles and gravels is produced, reproducing trampling successfully.

After this process, the bones were removed and cleaned with water and left to dry at room temperature. Trampling marks were analyzed and documented using the criteria mentioned previously. Location and distribution of both trampling and cut marks were documented and photographed after each process, in order to differentiate both marks when were located at same bone specimen.

The last step was the chemical alteration of the remains. They were immersed in a solution of 5% hydrochloric acid with water, in two phases of 10 s each. This low combination (acid concentration and time) was selected because it allowed us to control the progress of the alteration. This low solution caused a slight alteration of the surfaces. As a result, the experimentally reproduced striae presented similar grades of damage to the striae located at the Barranc de la Boella site.

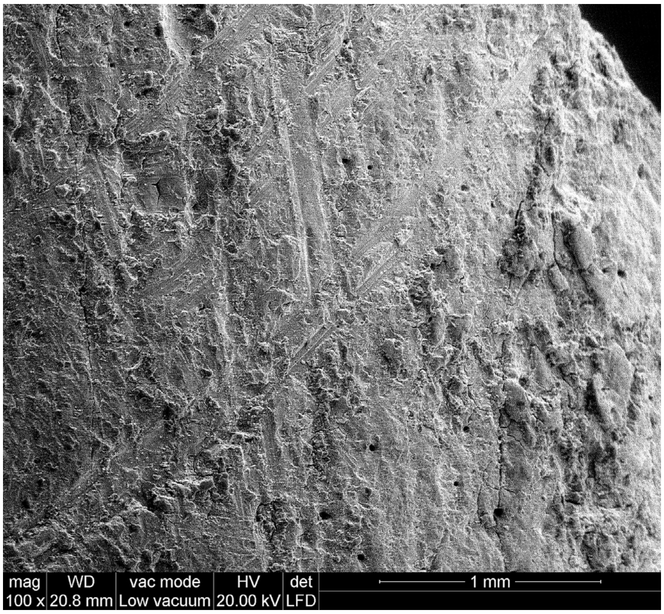

**Fig. 4.** Unidentified marks located on the surface of a long bone of a medium-sized carcass at the La Mina site. Photo taken with an environmental scanning electron microscope (ESEM).

At the first phase, all the experimental bones with both trampling and cut marks were immersed in the solution. After the immersion, the remains were analyzed and the changes in the marks were documented. Silicone molds were also made before each change using silicone in two components (Provil Novo). After this process, bones that still exhibited striae over the surface were immersed another time. Changes in the marks were also documented after the second phase of chemical alteration.

## 4. Results

### 4.1. Archaeological material

Sixteen unidentified marks were documented on five different bones: deer's jaw, femur (Fig. 3) and metatarsus, a long bone of a medium-sized animal and a rib of a very large animal. The marks

**Fig. 3.** Deer's femur from La Mina site. Two unidentifiable incisions are documented on the shaft.

are all superficial except one, which has a relatively greater depth. The marks tend to occur in parallel or sub-parallel to each other, with a U-shaped morphology and lacking (in most cases) internal microstriation. Other features (flaking, the shoulder effect, micro-abrasion, etc.) are also absent (Fig. 4).

On the other hand, 53 trampling striae have also been documented, distributed in 17 remains. Trampling tends to appear on different skeletal parts and body-sized categories. Generally appears as superficial striae, although one notch has also been documented. These marks have well preserved and properly identified.

All La Mina surface striae were analyzed following the criteria established by Domínguez-Rodrigo et al. (2009) (Table 1).

### 4.2. Experimental material

A total of 66 bone fragments were obtained. Seventy-one incisions were identified, distributed over 28 remains (42.4%) (Fig. 5). Sixty-four trampling-marks were identified on 26 remains (39.4%). The analysis of the cut and trampling marks was realized (after each phase) according to the criteria mentioned previously (Table 2).

In general, the experimental cut marks were characterized by a V-shaped cross-section, symmetrical walls (87.3%), and by the absence of barbs (73.2%) and the shoulder effect (84.5%). Flaking was present in 47.9% of the remains. Internal microstriation was documented in 45.1% of the cut marks. This consisted, in most cases, of continuous, straight striae on the walls of the groove. Furthermore, the experimental trampling marks were characterized by a tendency towards symmetry (78.1%) and by the absence of flacking (79.7%), barbs (95.3%) and the shoulder effect (100%). The morphology of the cross-sections was varied and only one mark (3.1%) had internal microstriation.

After being immersed in hydrochloric acid, most of the diagnostic features that had been previously identified were lost or altered, both in the trampling marks and cut marks (Fig. 6). After the first immersion in hydrochloric acid, the most superficial marks

**Table 1**
Criteria established by Domínguez-Rodrigo et al. (2009) for identifying and analyzing trampling and cut marks (columns 1–3) were used in the analysis of the La Mina surface striae (columns 4–5). Absolute and (percentage) data are presented.

| Features | | Trampling (Domínguez-Rodrigo et al., 2009) | Unretouched tool cut marks (Domínguez-Rodrigo et al., 2009) | Retouched tool cut marks (Domínguez-Rodrigo et al., 2009) | Trampling Boella site | Unidentified -marks Boella site |
|---|---|---|---|---|---|---|
| *Groove trajectory* | | | | | | |
| 1 | Straight | 75 (29.8) | 230 (93.5) | 102 (97.1) | 45 (84.9) | 18 (100) |
| 2 | Curvy | 42 (16.7) | 16 (6.5) | 0 (0) | 5 (9.4) | 0 (0) |
| 3 | Sinuous | 134 (53.4) | 0 (0) | 3 (2.9) | 3 (5.7) | 0 (0) |
| *Barb* | | | | | | |
| 4 | Present | 6 (2.4) | 25 (10.2) | 6 (5.7) | 1 (1.9) | 0 (0) |
| 5 | Absent | 245 (97.6) | 221 (89.8) | 99 (94.3) | 52 (88.1) | 18 (100) |
| *Mark orientation* | | | | | | |
| 6 | Parallel | 25 (9.9) | 1 (0.4) | 0 (0) | 0 (0) | 6 (33.3) |
| 7 | Perpendicular | 20 (8) | 96 (39) | 3 (2.9) | 13 (20.8) | 2 (11.1) |
| 8 | Oblique | 206 (82.1) | 149 (60.6) | 102 (97.1) | 40 (79.2) | 10 (55.6) |
| *Groove shape* | | | | | | |
| 9 | “V” | 10 (4) | 238 (96.7) | 6 (5.7) | 32 (60.4) | 6 (33.3) |
| 10 | “U” | 241 (96) | 8 (3.3) | 99 (94.3) | 21 (39.6) | 12 (66.7) |
| *Symmetry* | | | | | | |
| 11 | Symmetrical | 226 (90) | 212 (86.2) | 42 (40) | 49 (92.5) | 16 (88.9) |
| 12 | Asymmetrical | 25 (9.9) | 34 (13.8) | 63 (60) | 4 (7.5) | 2 (11.1) |
| *Shoulder effect* | | | | | | |
| 13 | Present | 15 (5.9) | 81 (32.9) | 78 (74.3) | 2 (3.8) | 2 (11.1) |
| 14 | Absent | 236 (94.1) | 165 (67.1) | 27 (25.7) | 51 (96.2) | 16 (88.9) |
| *Flacking on shoulder* | | | | | | |
| 15 | Present | 7 (2.7) | 36 (14.6) | 54 (51.4) | 3 (5.7) | 3 (11.7) |
| 16 | Absent | 244 (97.3) | 210 (85.4) | 51 (48.6) | 50 (94.3) | 15 (88.3) |
| *Extent of flacking* | | | | | | |
| 17 | Long | 2 (0.7) | 0 (0) | 12 (11.4) | 0 (0) | 0 (0) |
| 18 | Short | 5 (1.9) | 36 (14.6) | 42 (40) | 3 (5.7) | 3 (11.7) |
| 19 | Absent | 244 (97.2) | 0 (0) | 51 (48.6) | 50 (94.3) | 15 (88.3) |
| *Overlapping striae* | | | | | | |
| 20 | Present | 203 (80.3) | 12 (4.9) | 0 (0) | 18 (34) | 11 (61.1) |
| 21 | Absent | 48 (19.7) | 234 (95.1) | 105 (100) | 35 (66) | 7 (38.9) |
| *Internal microstriation* | | | | | | |
| 22 | Present | 188 (75) | 190 (77.2) | 105 (100) | 2 (3.8) | 0 (0) |
| 23 | Absent | 63 (25) | 56 (22.8) | 0 (0) | 51 (96.2) | 18 (100) |
| *Microstriation trajectory* | | | | | | |
| 24 | Continuous | 169 (67.3) | 190 (100) | 105 (100) | 2 (100) | – |
| 25 | Discontinuous | 82 (37.2) | 0 (0) | 0 (0) | 0 (0) | – |
| *Shape microstriations trajectory* | | | | | | |
| 26 | Straight | 140 (82.8) | 190 (100) | 105 (100) | 2 (100) | – |
| 27 | Irregular | 29 (17.2) | 0 (0) | 0 (0) | 0 (0) | – |
| *Location of microstriations* | | | | | | |
| 28 | Walls | 7 (2.9) | 180 (94.7) | 3 (2.9) | 1 (50) | – |
| 29 | Bottom | 219 (87.1) | 0 (0) | 93 (88.6) | 0 (0) | – |
| 30 | Both | 25 (10) | 10 (5.3) | 9 (8.6) | 1 (50) | – |
| *Microabrasion* | | | | | | |
| 31 | Absent | 1 (0.4) | 6 (2.4) | 0 (0) | 0 (0) | 0 (0) |
| 32 | Present | 250 (99.6) | 240 (97.6) | 105 (100) | 53 (100) | 18 (100) |

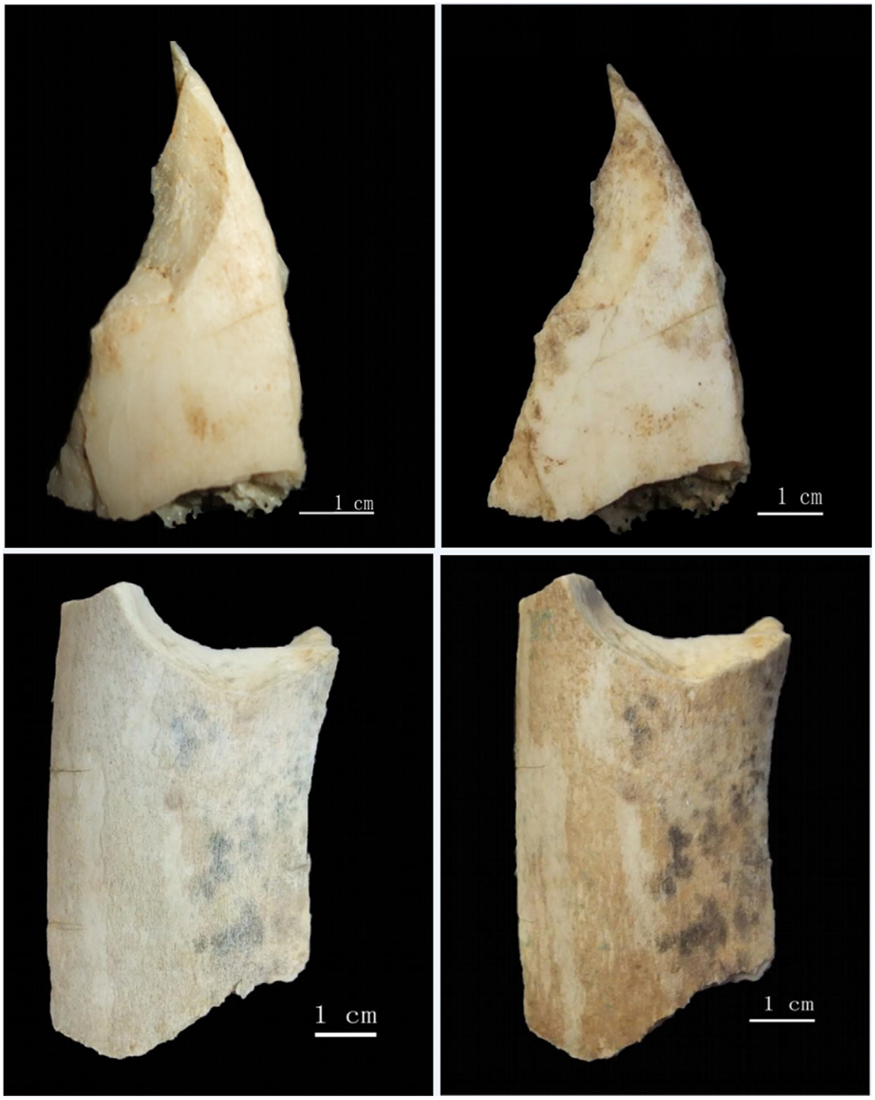

**Fig. 5.** Two experimental bones before (left) and after (right) the chemical alteration process. Alteration of the surfaces is detectable macroscopically.

disappeared (36% of trampling and 2.8% of the cut marks). Among the cut marks, the most significant alteration was the loss of internal microstriation in 87.5% of the marks and the increase in flaking by 26.6%. The disappearance of the microabrasion, a decrease in the presence of barbs and a slight increase in the asymmetry of the marks was also documented. Among the trampling marks, a remarkable increase in flaking was documented after the initial chemical treatment (246.2%), from 20.3% of flacking prior alteration to 62.3% after the first phase of alteration.

After the second immersion, a loss of cortical tissue was noted in the remains. As a result, a marked lack of features such as flaking, the shoulder effect and barbs was documented. Furthermore, internal microstriation was lost in both trampling marks and cut marks (Fig. 7). All marks were completely altered and an increase in the porosity of the bone surface (Fig. 8) was detected.

In sum, after chemical alteration, most of the criteria established in previous works (Shipman and Rose, 1983; Oliver, 1984; Bromage, 1984; Andrews and Cook, 1985; Behrensmeyer et al., 1986; Olsen and Shipman, 1988; Fiorillo, 1991; Domínguez-Rodrigo et al., 2009) for distinguishing between evidence of trampling and cut marks have been lost or modified when chemical alteration occurs. For this reason, these criteria should be used in assemblages (or part of assemblages) with optimal preservation, but not when chemical modification is detected. They should be dropped, though, when chemical modification is detected.

## 5. Discussion

The chemical alteration generally caused by the lixiviation of sediments affects bone remains and is present in many archaeological sites. This type of alteration is documented in the faunal remains of the Barranc de la Boella site, altering different striae located on the surface of the bones and hindering their correct identification. The validity of future zooarchaeological and taphonomical studies will depend on a clear understanding of how different marks respond to chemical alteration.

In this paper, trampling marks and cut marks were subjected to chemical alteration. An analysis of those marks allowed us to identify the diagnostic criteria that are lost, the elements that are preserved and, in this case, the degree to which the marks are modified after exposure to certain chemical processes.

**Table 2**
Analysis and comparison of the experimental trampling and cut marks in the different phases of alteration, in accordance with the criteria established by Domínguez-Rodrigo et al. (2009). Groove trajectory and mark orientation are not established because these parameters were not measurable in the experimental work. Absolute and (percentage) data are presented.

| | Feature | Phase 0 | | Phase 1 | | Phase 2 | |
|---|---|---|---|---|---|---|---|
| | | Experimental trampling | Experimental cut marks | Experimental trampling | Experimental cut marks | Experimental trampling | Experimental cut marks |
| | Number of marks | 64 | 71 | 41 | 69 | 40 | 67 |
| *Barb* | | | | | | | |
| 4 | Present | 3 (4.7) | 19 (26.8) | 2 (4.9) | 11 (15.9) | 1 (2.5) | 1 (1.5) |
| 5 | Absent | 61 (95.3) | 52 (73.2) | 39 (95.1) | 58 (84.1) | 39 (97.5) | 66 (98.5) |
| *Groove shape* | | | | | | | |
| 9 | “V” | 30 (46.9) | 62 (87.3) | 20 (48.8) | 60 (87) | 20 (50) | 59 (88.1) |
| 10 | “U” | 34 (53.1) | 9 (12.7) | 21 (51.2) | 9 (13) | 20 (50) | 8 (11.9) |
| *Symmetry* | | | | | | | |
| 11 | Symmetrical | 50 (78.1) | 62 (87.3) | 24 (58.5) | 54 (78.3) | 24 (60) | 53 (79.1) |
| 12 | Asymmetrical | 14 (21.9) | 9 (12.7) | 17 (41.5) | 15 (21.7) | 16 (40) | 14 (20.9) |
| *Shoulder effect* | | | | | | | |
| 13 | Present | 0 (0) | 11 (15.5) | 0 (0) | 9 (13) | 0 (0) | 8 (11.9) |
| 14 | Absent | 64 (100) | 60 (84.5) | 41 (100) | 60 (87) | 40 (100) | 59 (88.1) |
| *Flacking on shoulder* | | | | | | | |
| 15 | Present | 13 (20.3) | 34 (47.9) | 32 (78) | 43 (62.3) | 6 (15) | 21 (31.3) |
| 16 | Absent | 51 (79.7) | 37 (52.1) | 9 (22) | 26 (37.7) | 34 (85) | 46 (68.7) |
| *Extent of flacking* | | | | | | | |
| 17 | Long | 1 (0.9) | 0 (0) | 16 (39) | 16 (23.2) | 1 (2.5) | 2 (3) |
| 18 | Short | 12 (18.8) | 34 (47.9) | 16 (39) | 27 (39.1) | 5 (12.5) | 19 (28.4) |
| 19 | Absent | 51 (79.7) | 37 (52.1) | 9 (22) | 26 (37.7) | 34 (85) | 46 (68.7) |
| *Overlapping of striae* | | | | | | | |
| 20 | Present | 17 (26.6) | 9 (12.7) | 11 (26.8) | 9 (13) | 10 (25) | 8 (11.9) |
| 21 | Absent | 47 (73.4) | 62 (87.3) | 30 (73.2) | 60 (87) | 30 (75) | 59 (88.1) |
| *Internal microstriation* | | | | | | | |
| 22 | Present | 1 (1.6) | 32 (45.1) | 1 (2.4) | 4 (5.8) | 0 (0) | 0 (0) |
| 23 | Absent | 63 (98.4) | 39 (54.9) | 40 (97.6) | 65 (94.2) | 40 (100) | 67 (100) |
| *Trajectory of microstriation* | | | | | | | |
| 24 | Continuous | 1 (100) | 26 (81.3) | 1 (100) | 1 (25) | – | – |
| 25 | Discontinuous | 0 (0) | 6 (18.7) | 0 (0) | 3 (75) | – | – |
| *Shape microstriation trajectory* | | | | | | | |
| 26 | Straight | 1 (100) | 31 (96.9) | 1 | 4 (100) | – | – |
| 27 | Irregular | 0 (0) | 1 (3.1) | 0 | 0 (0) | – | – |
| *Location of microstriations* | | | | | | | |
| 28 | Walls | 1 (100) | 30 (93.8) | 1 (100) | 4 (200) | – | – |
| 29 | Bottom | 0 (0) | 0 (0) | 0 (0) | 0 (0) | – | – |
| 30 | Both | 0 (0) | 2 (6.2) | 0 (0) | 0 (0) | – | – |
| *Microabrasion* | | | | | | | |
| 31 | Absent | 61 (95.3) | 71 (100) | 41 (100) | 69 (100) | 40 (100) | 67 (100) |
| 32 | Present | 3 (4.7) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |

In general, the trampling reproduced experimental results in the most superficial striae, causing the disappearance of 36% of the cut marks in the first phase of alteration. Although some studies have argued that the trampling tends to occur more superficially (Olsen and Shipman, 1988), the fact is that the depth of the cut marks mainly depends on the force exerted by the tool at the time contact occurs (Bello and Soligo, 2008). In this work, the most superficial cut marks also disappeared after the first phase of alteration.

Many of the features established by Domínguez-Rodrigo et al. (2009) as a means of differentiating between the two types of marks (internal microstriation, microabrasion, the shoulder effect, etc.) decreased quantitatively after the first phase of experimentation, and disappeared completely (or almost completely) after the second phase. The highest degree of variation was noted in the amount of flaking documented in the two mark types. After the first phase, flaking increased in both types of marks and tended to extend only short distances. Conversely, it decreased after the second phase, especially on the trampling marks. This is because the acid attacks the outer bone layers (eternal circumferential system), causing an initial alteration of these layers, and thus increasing the frequency of flaking. After the second immersion, these layers eventually either partially or completely disappear, thus causing part of the flaking to disappear as well.

Prior to the chemical alteration phase, the experimental cut marks were similar to the cut marks described by Domínguez-Rodrigo et al. (2009), based on the presence of internal microstriation (mainly regular, continuous and localized on the walls), the presence of the shoulder effect and in the limited effect of microabrasion. The trampling defined by Domínguez-Rodrigo et al. (2009) featured a morphology characterized by a U-shaped cross-section, overlapping striae and irregular, discontinuous microstriation at the base of the groove.

Correspondence analysis (Fig. 9) showed a clear grouping among the chemically altered remains (including archaeological remains), and this grouping was far more significant than that of the remains that had not been altered.

In addition, correspondence analysis also suggests a direct statistical relationship between the marks documented on the archaeological remains of the Boella site, all the chemically altered experimental marks, and the trampled marks in the stage prior to chemical alteration. The absence of microabrasion, internal microstriation and the shoulder effect and the presence of extended flaking are correlating features among these different marks.

The data suggest that trampling and cut marks progressively lose the characteristic elements that define and differentiate them when affected by chemical alteration. Statistically, the differences are slight. The morphology of the cross-section (Potts and Shipman, 1981) seems to be one of the features that is least affected by chemical alteration. However, this feature cannot be used to differentiate between the types of marks, because trampling marks can appear as having either a V-shape or a U-shape, as found in the data presented by Domínguez-Rodrigo et al. (2009) and in this work. Also, the symmetry of the walls seems to be little affected by chemical alteration. However, Bello and Soligo (2008) noted that the symmetry of the cut marks depends on the inclination of the tool (in relation to the bone surface) at the time contact occurs, so both morphologies are relevant. Chemical alteration ultimately produces highly altered grooves, hindering the correct identification of mark type.

All these criteria have been considered in the analysis of different types of marks on a selection of skeletal remains from the Boella site. The marks analyzed did not present features that allowed the designation of anthropic or mechanical origin, even when considering the possible morphological variations related to the chemical alteration of the bone surface established within this experiment. Diagnostic criteria have not been documented on marks located at the archaeological material, as occurs at experimental marks chemically altered, becoming impossible their correct identification. Thus, this research support Domínguez-Rodrigo et al. (2010) suggestion that just well-preserved bone surfaces striae should be take into account to diagnosing hominin activities. Undistinguishable marks located at La Mina site may not be included in future zooarchaeological and taphonomical studies, as their designation as cut marks may lead to erroneous inferences (Behrensmeyer et al., 1986) about the behavior of one of the earliest groups of hominins that inhabited the Iberian Peninsula. The development of subsequent experimental work will more precisely clarify the origin of these marks.

## 6. Conclusions

In this study, trampling and cut marks were reproduced and subjected to chemical alteration. The analysis documented how these marks respond to alteration and showed that in both types of mark much of the diagnostic criteria that would allow researchers to distinguish between them was lost and/or modified after chemical alteration.

In general, marks tend to preserve the symmetry and the shape of the cross-section after alteration. However, features as micro-striation, barbs and the shoulder effect tend to gradually disappear as the modifying process progresses. These results suggest that zooarchaeological inferences based on cut marks analysis should be made on well-preserved bones surfaces only.

The application of these results to marks located on five bone remains from the La Mina site (Barranc de la Boella) suggests that the diagnostic elements are modified to such a degree as to greatly hinder the correct identification of mark type subsequent to chemical alteration. Therefore, these marks cannot be taken into account in zooarchaeological and taphonomical studies, as they may lead to misinterpretations of the behavior of these hominin groups.

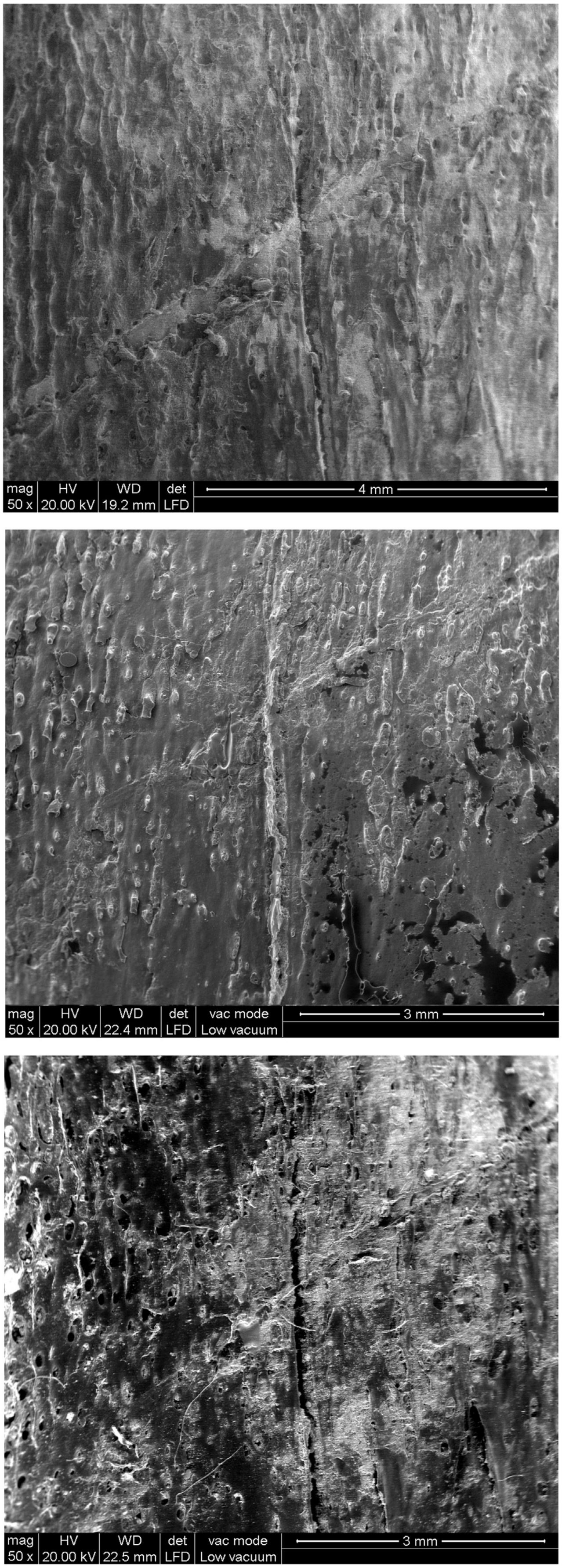

**Fig. 6.** A cut mark (lengthwise) and a trampling mark (oblique) at three different phases of the experiment: before chemical alteration (top), after the first phase (center) and after the second phase (bottom). Photos after the first alteration were taken from a mold. The negative image has been digitally inverted. Photos were taken with an environmental scanning electron microscope (ESEM).

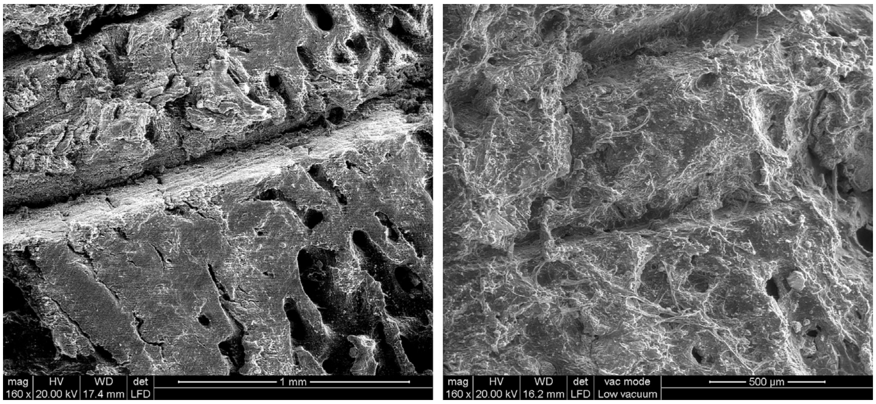

**Fig. 7.** Cut marks at the beginning (left) and end (right) of the experimental process. Internal microstriations and microabrasion were lost after chemical alteration. Photos were taken with an environmental scanning electron microscope (ESEM).

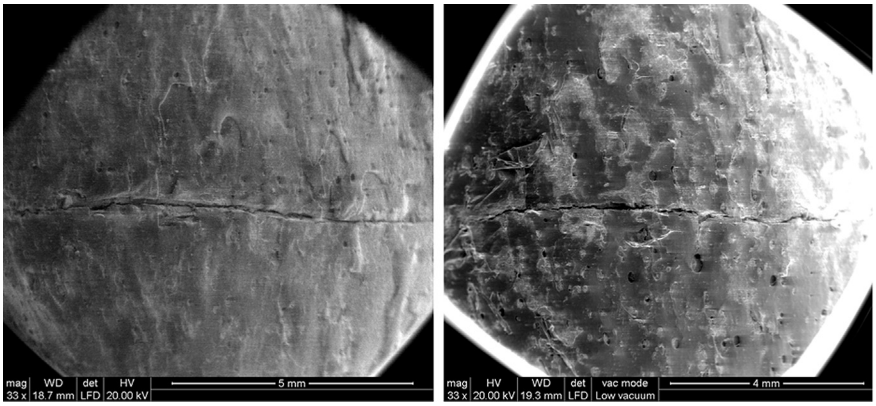

**Fig. 8.** A cut mark at the beginning (left) and end (right) of the experimental process. The second image shows the alteration to the cut mark and the increase in porosity of the bone surface. Photos were taken with an environmental scanning electron microscope (ESEM).

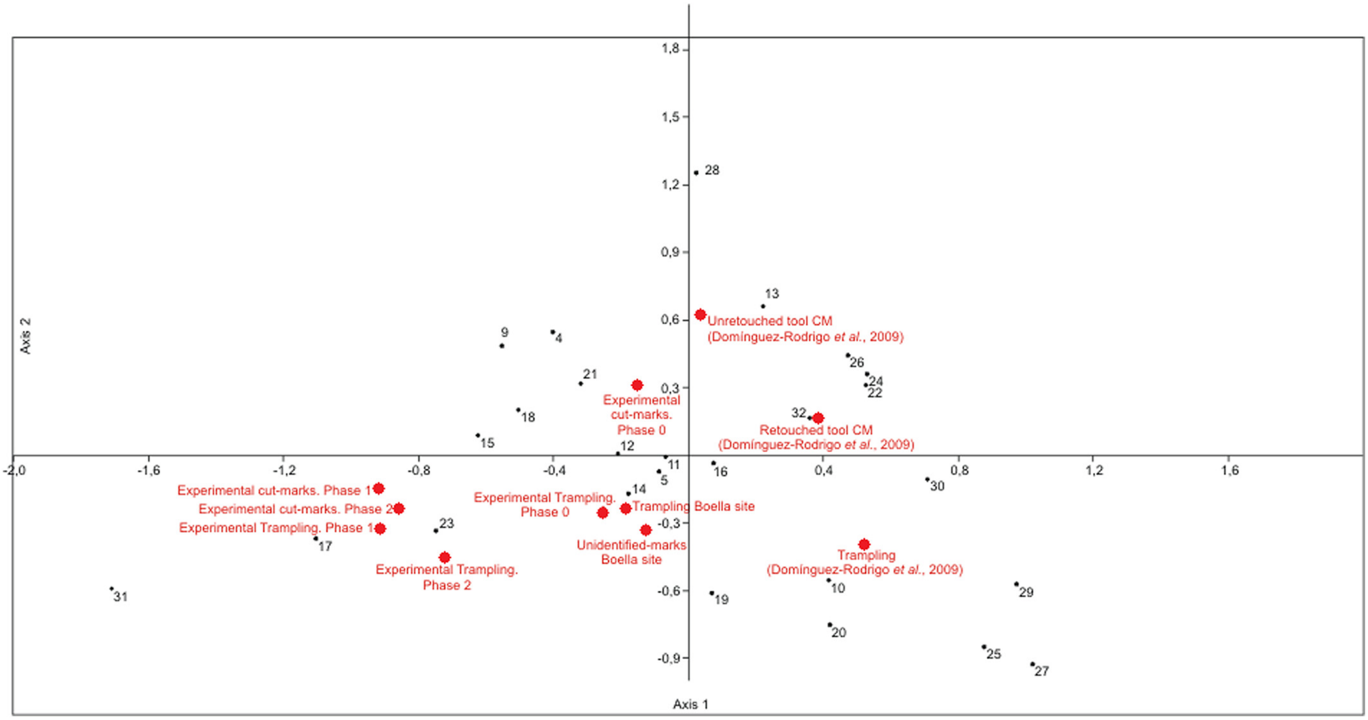

**Fig. 9.** Correspondence analysis in which data presented by Domínguez-Rodrigo et al. (2009) were combined with experimental and archaeological data. The trajectory and orientation of the grooves were not taken into account.

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# Tumbling effects and its application to archaeological deposits: the case of Barranc de la Boella (Tarragona, Spain)

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## Abstract

Tumbling is defined as a process in which hyper-concentrated flows alter bone remains, producing changes in their morphology and original structure. Although the process is well known, little experimental research has focused on describing the effects of this process on the surface modifications of bones for subsequent application to the fossil record. Water currents may have played an important role in the alteration of bone surfaces at Barranc de la Boella, which was formed in a deltaic fan context. Striae of undetermined origin have been documented on bones at the la Mina site and possible cut marks found on bones in the Pit 1 site. In our experimentation, fresh and dry bones with reproduced trampling striae and cut marks were exposed to tumbling in a tumbling machine, combining different types of movement and proportions of water to sediment. Observations were made after each of the five cycles of the modification process lasting 30′, 30′, 1h, 2h and 4h. Our results show the considerable disappearance of trampling striae, while most of the cut marks were preserved. Fresh bones underwent greater alteration than dry bones. Based on the results of this experiment, we propose an anthropic origin for the marks of Pit 1 and a natural origin (trampling) for the striae present in la Mina.

**Keywords:** cut marks, late Early Pleistocene, sequential experiments, taphonomy, trampling

## 1. Introduction

Traditionally, taphonomic studies of archaeological deposits, and especially actualistic and experimental studies, have been conducted through the study of single taphonomic processes in order to determine how a specific process affects the fossil record (Behrensmeyer, 1975; Haynes, 1980; 1983; Andrews and Cook, 1985; Hill, 1989; Domínguez-Rodrigo and Piqueras, 2003; Fernández-Jalvo and Andrews, 2003; Jans et al., 2004; Pickering and Egeland, 2005). Archaeo-paleontological deposits, however, are not the result of single taphonomic processes; they are the result of the accumulation of multiple processes that, because of their additive character, represent complex taphonomic histories. Behrensmeyer et al. (1986) proposed that the marks preserved on bone surfaces are the result of multiple processes that acted on the bones. Recently, Gaudzinski-Windheuser et al. (2010) and Rabinovich et al. (2012) emphasized the importance of studying taphonomic processes as accumulative and the difficulty in sequencing them. Precisely identifying, sequencing and understanding how a new process can affect previous modifications is now an essential factor for reconstructing the history of our assemblages.

These researchers developed an experimental series to determine how trampling and tumbling affect bones in order to interpret the taphonomic history of Gesher Benot Ya'aqov. They noted the alteration produced by these processes on the bone surfaces, highlighting the creation, modification and elimination of striae (Gaudzinski-Windheuser et al., 2010; Rabinovich et al., 2012). In addition, they showed that the striae produced or modified during the experimental process could mimic hominin- and carnivore-induced marks, demonstrating the importance of identifying the cessation time of biostratinomic processes for the identification and interpretation of the modifications on bone surfaces (Gaudzinski-Windheuser et al., 2010).

Due to their contribution to the study of human evolution, cut marks have been one of the most extensively studied taphonomic modifications, from a broad variety of perspectives, over the past few decades. Some of the most frequently studied topics include the origins of cut marks and their relationship to carcass-processing activities (Binford, 1981;1984; Crader, 1983; Blumenschine et al., 1994; Selvaggio, 1994; 1998; Capaldo, 1995; 1998; Nilssen, 2000; Domínguez-Rodrigo and Pickering, 2003; Domínguez-Rodrigo and Barba, 2006; Merrit, 2012; Galán and Domínguez-Rodrigo, 2013; Courtenay et al., 2017) and the type of tool used in the formation of the marks (Walker and Long, 1977; Greenfield, 2006; Christidou, 2008; de Juana et al., 2010), in addition to attempts to establish criteria that allow such marks to be accurately identified in comparison with other linear marks such as those caused by trampling (Shipman and Rose, 1983; Bello and Soligo, 2008; Bello et al., 2009; Domínguez-Rodrigo et al., 2009; 2010; 2017; Pineda et al., 2014; Sahle et al., 2017) . These studies have shown that processes of non-anthropic origin can produce striae with characteristics that have traditionally defined butchery marks (Behrensmeyer et al., 1986; Domínguez-Rodrigo et al., 2009; 2017; Gaudzinski-Windheuser et al., 2010; Rabinovich et al., 2012; Pineda et al., 2014). These equifinality problems are related to the presence of shared characteristics in different types of marks (Domínguez-Rodrigo et al., 2010) and to the fact that different striae, once altered, can become indistinguishable (Pineda et al., 2014). The incorrect identification of these striae can lead to erroneous inferences about the role that past human populations may have played with regard to animal communities (Domínguez-Rodrigo et al., 2010; Sahle et al., 2017). A recent work conducted by Domínguez-Rodrigo et al. (2017) has even revealed the subjectivity of the previously established criteria in the identification of cut marks (Domínguez-Rodrigo et al., 2009), highlighting the need to find an identification method in accordance with the principles of the scientific method. Domínguez-Rodrigo et al. (2009) also highlighted the importance of accompanying these works with images to support the validity of identifications.

This problem is especially relevant in the study of prehistoric populations and the early use of tools (Heinzelin et al., 1999; Domínguez-Rodrigo et al., 2010; McPherron et al., 2010; Harmand et al., 2015). Barranc de la Boella (BB) appears to fall within this context, chronologically situated in the European late Early Pleistocene (Vallverdú et al., 2014). At the la Mina site in BB, different marks of undetermined origin, in some respects similar to cut marks, have been identified on bone surfaces. Pineda et al. (2014) developed a sequential experiment in which cut marks and trampling striae were reproduced and subsequently chemically altered. The aim was to establish diagnostic criteria that would allow both types of marks to be accurately identified after chemical alteration for subsequent application to the archaeo-paleontological record of BB. However, the results did not reveal which agent could have produced the marks.

BB is described as a fluvio-deltaic assemblage in which deposits were formed by hyper-concentrated flows (according to the description by Benvenuti and Martini, 2009), which were determined in both sedimentological (Vallverdú et al., 2014) and taphonomic studies (Mosquera et al., 2015; Pineda et al., 2015; 2017a; 2017b). This may have contributed to the alteration of bone surfaces by means of abrasion. Abrasion is defined as a physical alteration produced by the polishing and rounding of edges and/or surfaces of a material due to mechanical erosion caused by contact with water and the sedimentary particles that it contains (Shipman, 1981; Behrensmeyer et al., 1989; Gifford-González, 1989; Cáceres, 2002; Fernández-Jalvo and Andrews, 2003; 2016). Multiple studies have shown that abrasion contributes to the creation, modification and elimination of superficial striae (Shipman and Rose, 1983; Behrensmeyer et al., 1989; Gaudzinski-Windheuser et al., 2010; Rabinovich et al., 2012) and the consequent general morphological changes (Cáceres, 2002; Fernández-Jalvo and Andrews, 2003; 2016; Gaudzinski-Windheuser et al., 2010; Rabinovich et al., 2012). It is for this reason that in this work we describe a sequential experiment in which trampling and cut marks were experimentally reproduced and subjected to tumbling. Our aim is to attempt to determine the source of the striae of questionable origin identified in BB and thus fill in the picture of its taphonomic history.

## 2. Barranc de la Boella (BB)

Barranc de la Boella (BB) is an archaeo-paleontological site located in the township of la Canonja (Tarragona) in the north-eastern corner of the Iberian Peninsula (Fig. 1a). BB is made up of a 9-meter sequence in which six litho-stratigraphic units have been identified. The archaeo-paleontological material is concentrated in Unit II. This unit consists of a 2-meter sequence of poorly stratified sands and gravels, characteristic of underwater hyper-concentrated deposits, dated by means of cosmogenic nucleoids to 960-781 Ka (Vallverdú et al., 2014). To date, the excavation work has been carried out in three different localities: Pit 1 (P1), la Mina (LM) and el Forn (EF). All three sites share the same stratigraphic sequence.

Work at P1 began in 2007 over a surface of 15 m$^2$ (Fig. 1b), which resulted in the recovery of two *Mammuthus meridionalis* tusks in level II.3, as well as a second pair of tusks in level II.2, associated with other proboscides remains and 125 lithic artifacts (Saladié et al., 2008; Vallverdú et al., 2014). The thorough study of the archaeo-paleontological assemblage of level II.2 has led to its interpretation as a butchering site (Mosquera et al., 2015). It is a monospecific assemblage, in which the remains of *Mammuthus meridionalis* represent 99% of the identified specimens. They correspond mainly to cranial and dental remains, although some post-cranial elements have also been identified, including two mammoth ribs with possible evidence of anthropic processing (cut marks).

The archaeological works at la Mina began in 2008. Today, LM is the most prolific excavation in the ravine, with about 2,000 faunal, lithic industry and coprolite remains uncovered in an excavated area exceeding 40 m$^2$ (Lozano-Fernández et al., 2014; Pineda et al., 2015; 2017a; 2017b; Mosquera et al., 2016) (Fig. 1c). The taxonomic list comprises 17 species of macro-mammals (Pineda et al., 2015; 2017b), in which medium-sized and large ungulates predominate, but also including various carnivores and the remains of a macaque. Clear evidence of anthropic processing of the animal carcasses is limited to four instances of bone breakage (Pineda et al., 2015), as the identification of possible cut marks has not been confirmed to date (Pineda et al., 2014).

The work at el Forn started in 2008 and has led to the documentation of seven archaeological levels, four of which (levels 1-4) contain most of the archaeo-paleontological record (Mosquera et al., 2016; Pineda et al., 2017b). The taxonomic composition is similar to that of LM, although some species absent in the first assemblage have been documented here: *Stephanorhinus hundseimiensis*, *Sus* sp. and *Castor* sp. (Pineda et al., 2017b). The presence of stone tools in levels 1 to 4 indicates the presence of human groups (Mosquera et al., 2016), although the processing of carcasses has only been noted in the breakage of two limb bones of medium-sized animals (between 100 and 300 kg) in level EF1 (Pineda et al., 2017b).

## 3. Material and methods

### *3.1. Experimental material*

Both cut and trampling marks were reproduced on fresh and dry bones for this experimental work. The raw material employed was quartzite, used as simple flakes for the reproduction of cut marks and as a hammer for the breakage of limb bones.

<u>Dry bones</u>: For the reproduction of trampling on dry bones, a femur and tibia of red deer (*Cervus elaphus*) recovered from the Bosque de

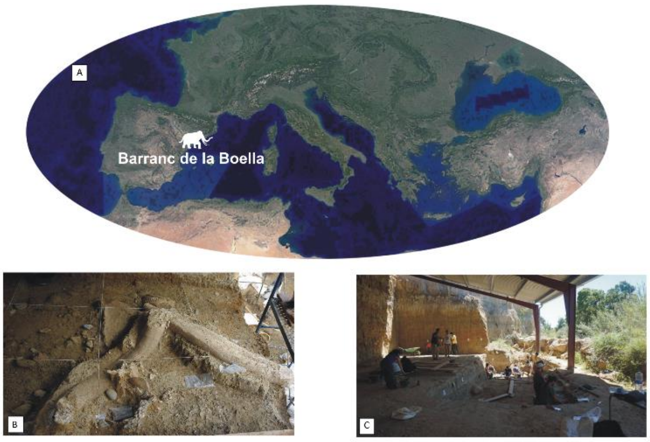

**Figure 1.** View of the Barranc de la Boella; a) Location of the Barranc de la Boella on the Iberian Peninsula and western Europe; b) View of Pit 1 excavation; c) View of la Mina excavation.

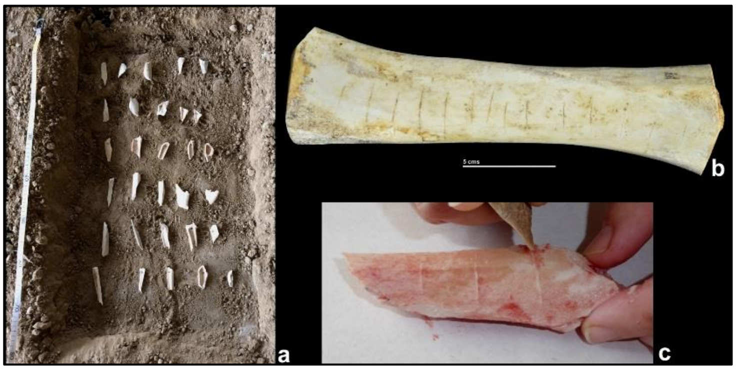

**Figure 2.** Different phases of reproduction of the experimental marks; a) Dry bone fragments during trampling process; b) Dry horse tibia with intentional cut marks; and c) Fresh bone with intentional cut marks made with quartzite flake used in the tumbling experiment.

Riofrío (Segovia, Spain) in the year 2000 (Cáceres et al., 2009; 2011) were broken. The bone fragments were first buried at Barranc de la Boella next to the LM excavation area at a depth of about 5 cm in sediment belonging to Unit II (made up of sands and gravels). The bone fragments were trampled for 30′ (Fig. 2a). After trampling, the fragments were recovered and analyzed. However, the paucity of marks obtained incited us to reproduce the trampling process in the laboratory with the same sediment. For the cut marks, a dry horse tibia (*Equus ferus caballus*) was used, on which experimental cut marks were reproduced in 2013, when it was fresh (Gené, 2013) (Fig. 2b). The bone was cut with a multitool (Dremel 3000) in portions containing between two and three cut marks.

Fresh bones: Two cow femora (*Bos taurus*) fractured by direct percussion were used. Twenty intentional cut marks were made on part of the sample, with between two and three marks on each fragment (Fig. 2c). The remaining fragments were subjected to a trampling process in the laboratory, as done with the dry bones.

Two fragments bearing a total of five cut marks and five bone fragments with trampling striae on their surfaces were used in each experimental turn. The bone fragments with both marks were distributed equally in eight experimental turns, in order to combine four variables (Table 1): a) bone state (fresh and dry); b) type of movement: unidirectional (83 revolutions per minute (rpm)) and bidirectional (70 rpm, with change in the direction of rotation every 23″ and pauses of 5″); c) proportion of water (distilled) to sediment consisting of sands (from Unit II of LM): one with four turns with 0.8 L of water and 0.2 kg of sediment (proportion 80%/20%) and another four with a proportion of 50%/50% (0.5 L of water and 0.5 kg of sediment); and d) exposure time. All the fragments were subjected to the abrasion process in a tumbling machine (KT-3010 SUPER-TUMBLER) for a total of eight hours, in different cycles: cycle 1 (30′), cycle 2 (30′), cycle 3 (1h), cycle 4 (2h) and cycle 5 (4h).

All marks were analyzed by a single researcher to reduce the subjectivity problems during the analysis. A binocular microscope (OPTECH HZ) at up to 60 magnifications was used before starting the experimental process and after the completion of each experimental cycle, exclusively following the descriptive criteria for the analysis of striae proposed by Domínguez-Rodrigo et al. (2009). The presence/absence of barbs, abrasions, shoulder effects and microstriations, the morphology of the cross-section (defined as V-narrow shaped (V) or V-open shaped (_/)) and symmetry (or asymmetry) of the striae were analyzed. The criteria of location and distribution of the marks (trajectory,

**Table 1.** Description of the different turns included in the experimental work and the different marks included in each case, according to the type of movement (unidirectional/bidirectional), the proportion of water to sediment (80%/20% or 50%/50%) and the state of the bone (fresh/dry).

| *Turn* | *Bone stage* | *Type of movement* | *Proportion of water and sediment* | *Nº fragments (nº cut marks)* | *Nº fragments (nº trampling)* |
|---|---|---|---|---|---|
| *1* | Dry | Bidirectional | 80%+20% | 2 (5) | 5 (11) |
| *2* | Dry | Unidirectional | 80%+20% | 2 (5) | 5 (15) |
| *3* | Dry | Bidirectional | 50%+50% | 2 (5) | 5 (13) |
| *4* | Dry | Unidirectional | 50%+50% | 2 (5) | 5 (7) |
| *5* | Fresh | Bidirectional | 80%+20% | 2 (5) | 5 (9) |
| *6* | Fresh | Unidirectional | 80%+20% | 2 (5) | 5 (10) |
| *7* | Fresh | Bidirectional | 50%+50% | 2 (5) | 5 (9) |
| *8* | Fresh | Unidirectional | 50%+50% | 2 (5) | 5 (8) |

orientation and superposition of striae) were not analyzed in the experimental materials due to the intentionality of the marks reproduced. F-tests were applied in order to detect statistical differences between experimental marks in each experimental cycle and in relation to each variable.

All reproduced striae (cut marks and trampling marks) were photographed with a digital microscope (Hirox Kh7800) at magnifications of 50x and 100x, before starting the experimentation and after the completion of each experimental cycle. All the results were treated statistically with the PAST software (Hammer et al., 2001).

### 3.2. Archaeological material

The archaeological materials considered in the present work come from the la Mina and Pit 1 sites (Barranc de la Boella). Twenty-one marks from la Mina were included in the analysis. Abraded faunal remains were identified in taphonomic studies (Pineda et al., 2015; 2017a; 2017b) through the polish of the surfaces and the rounding of the edges. The ambiguous striae are located mainly on the remains of medium-sized animals (mandible, humerus, femur and metatarsus of a cervid and a medium-sized limb bone) although they have also been identified on a bovine atlas and a rib of a very large animal (> 1,000 kg). Of these, 18 were already included in a previous experimental work (Pineda et al., 2014).

The study also considers three marks from Pit 1, which are located on three mammoth rib fragments. Taphonomic studies identified low percentages (<5%) of rounding and polishing. These marks were interpreted as possible cut marks, but only some features characteristic of cut marks (V-shaped morphology and the symmetry of the cross-section) were present (Mosquera et al., 2015).

## 4. Results

### 4.1. Experimental material

In this section, we will present the general results of the experimental process to reproduce the trampling and cut marks, as well as specific results based on the following variables: type of movement (unidirectional or bidirectional), bone state (dry or fresh) and proportion of water to sediment (80%/20% or 50%/50%), for both trampling and cut marks. Although five cycles of exposure and observation were completed, the results presented here are classified as cycle 0 (C0), cycle 1 (C1), cycle 3 (C3) and cycle 5 (C5), because no remarkable changes from the previous cycle were observed in cycles 2 or 4.

#### 4.1.1. Trampling

We analyzed 82 striae resulting from trampling (Table 2). At the beginning of the experimental session, these striae were characterized as symmetrical (59.8%), _/-shaped in cross-section (72%), and relatively presence in barbs (8.5%) and shoulder effect (18.3%).

After C1 (30'), 28% of the striae had disappeared, leaving 59 remaining. Few changes were recorded regarding the symmetry (57.6%) and the morphology of the section (_/-shaped = 72.9%). However, several important changes were detected with regard to the loss of other diagnostic criteria. After C3 (2h) the number of documented striae was 28 (34.1%). No notable changes were documented regarding the greater tendency to symmetry (82.1%), the morphology of the section (_/-shaped = 71.4%) or the absence of microabrasions (96.4%), but changes were detected with respect to microstriations (10.7%) and the total disappearance of barbs and shoulder effect.

After C5 (8h), four striae were preserved, meaning 4.9% of the marks survived. Diagnostic criteria were not preserved except for the _/-shaped cross-section (75%) and symmetry (75%) of the striae. This confirmed the progressive loss of diagnostic features when striae are submitted to abrasive processes. The percentage of cross-section morphology and symmetry can be linked to the final preserved striae.

##### 4.1.1.1. Type of movement: unidirectional or bidirectional

No statistically significant changes were detected (Table 3) when classifying striae by type of movement, unidirectional and bidirectional (Table 2). In both groups the striae and their features disappeared gradually as the experimentation progressed and the exposure time was extended. At first, a greater loss of striae subjected to bidirectional than unidirectional movement was documented (Table 2), which would indicate that the type of movement is a variable that can be identified in the initial stages of exposure (or in low-intensity currents), although this difference is not statistically proven (ANOVA, F=0.01, p=0.921). The percentages became more balanced as experimentation progressed.

**Table 2**. Diagnostic features described in each of the cycles of analysis of the experimental trampling. Global and disaggregated data are presented according to types of movement, bone states and proportions of water to sediment. Data presented in percentages, except the number of striae. *The data reflects the presence of these features. **As opposed to _/-shaped. *** As opposed to asymmetry.

| | Type of movement | | | | | | | | | | | | State of bone | | | | | | | | Proportion of water and sediment | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Global | | | | Unidirectional | | | | Bidirectional | | | | Dry | | | | Fresh | | | | 80%+20% | | | | 50%+50% | | | |
| | C0 | C1 | C3 | C5 | C0 | C1 | C3 | C5 | C0 | C1 | C3 | C5 | C0 | C1 | C3 | C5 | C0 | C1 | C3 | C5 | C0 | C1 | C3 | C5 | C0 | C1 | C3 | C5 |
| Number of striae | 82 | 59 | 28 | 4 | 40 | 32 | 17 | 2 | 42 | 27 | 11 | 2 | 46 | 33 | 13 | 0 | 36 | 26 | 15 | 4 | 43 | 35 | 14 | 1 | 31 | 24 | 14 | 3 |
| Striae preservation | 100 | 72 | 34.1 | 4.9 | 100 | 80 | 42.5 | 5 | 100 | 64.3 | 26.2 | 18.2 | 100 | 71.7 | 31.2 | 0 | 100 | 72.2 | 41.1 | 11.1 | 100 | 81.4 | 32.5 | 2.3 | 100 | 64.9 | 37.8 | 8.1 |
| Barbs* | 8.5 | 6.8 | 0 | 0 | 12.5 | 6.3 | 0 | 0 | 4.8 | 7.4 | 0 | 0 | 10.9 | 6.1 | 0 | - | 5.6 | 7.7 | 0 | 0 | 11.1 | 5.7 | 0 | 0 | 5.4 | 8.3 | 0 | 0 |
| Morphology (V-shaped)** | 28 | 27.1 | 28.6 | 25 | 40 | 34.4 | 23.5 | 0 | 16.7 | 18.5 | 36.4 | 50 | 26.1 | 30.3 | 46.2 | - | 30.6 | 23.1 | 13.3 | 25 | 31.1 | 31.4 | 28.6 | 0 | 24.3 | 20.8 | 28.6 | 33.3 |
| Symmetry*** | 59.8 | 57.6 | 82.1 | 75 | 57.5 | 40.6 | 76.5 | 50 | 61.9 | 77.8 | 90.9 | 100 | 39.1 | 36.4 | 61.5 | - | 86.1 | 84.6 | 100 | 75 | 51.1 | 37.1 | 64.3 | 0 | 70.3 | 87.5 | 100 | 100 |
| Shoulder effect* | 18.3 | 10.2 | 0 | 0 | 2.5 | 3.1 | 0 | 0 | 33.3 | 15.5 | 0 | 0 | 28.3 | 12.1 | 0 | - | 5.6 | 7.7 | 0 | 0 | 11.1 | 2.9 | 0 | 0 | 27 | 20.8 | 0 | 0 |
| Internal microstriation* | 32.9 | 22 | 10.7 | 0 | 3.5 | 18.8 | 5.9 | 0 | 28.6 | 25.9 | 18.2 | 0 | 43.5 | 27.3 | 15.4 | - | 19.4 | 15.4 | 6.7 | 0 | 33.3 | 14.3 | 7.1 | 0 | 32.4 | 33.3 | 14.3 | 0 |
| Microabrasion* | 22 | 0 | 3.6 | 0 | 17.5 | 0 | 0 | 0 | 26.2 | 7.4 | 9.1 | 0 | 37 | 0 | 0 | - | 2.8 | 0 | 0 | 0 | 22.2 | 0 | 0 | 0 | 21.6 | 8.3 | 7.1 | 0 |

### *4.1.1.2. Bone state: fresh or dry*

When analyzing the striae reproduced on fresh and dry bones separately, some initial differences were detected: a) we noted increased symmetry in fresh bones (84.6% versus 39.1%); and greater values of b) microabrasions (37%), microstriations (43.5%) and shoulder effect (28.3%) in dry bones (Table 2).

After C1 (30′) no differences were found in terms of symmetry, the presence of barbs, the morphology of the cross-section or microabrasions, whose values were similar to the baseline, regardless of the state of the bone. We did find differences based on bone state with regard to microstriations and shoulder effect. After two hours of tumbling (C3) the fresh bones (Fig. 3) lost a large part of the diagnostic criteria, while the dry bones (Fig. 4), although in low percentages, conserved microstriations, microabrasions and the shoulder effect. After C5 (8h) the striae preserved on fresh bones (11.1%) were only identified by the morphology of the cross-section (_/-shaped = 75%) and the symmetry (25%), while the totality of the striae on the dry bones had disappeared.

In summary, the morphological criteria were maintained without major changes regardless of the state of the bone, with differences in the conservation that would be related, mainly, to the disappearance of one striae or another. The diagnostic features disappeared more rapidly in fresh bones than in dry bones, especially in the initial (C1) and intermediate (C3) cycles. This could mean that the state of the bone could indeed influence the morphology of trampling striae, although these results are not statistically significant (Table 3). The main difference observed is that striae were not preserved on dry bones in C5, so the F-test could not be applied in that case.

### *4.1.1.3. Proportion of water to sediment: 80%/20% or 50%/50%*

Trampling striae subjected to tumbling in different proportions of water and sediment (80%/20% and 50%/50%) seem to behave similarly (Table 2). Trampling striae subjected to a greater proportion of water seem to lose diagnostic criteria more quickly, although no significant differences were documented in any case (Table 3). After C5, all striae had lost diagnostic criteria except for the morphology of the cross-section and the symmetry of the striae.

**Table 3.** F-test and p value applied in order to detect significant statistical differences between experimental trampling striae in each experimental cycle (C0, C1, C3 and C5) and in each variable (type of movement, bone state and proportion of water to sediment). *Test not done due to the absence of trampling marks in C5 on dry bones.

| | **Type of movement** | | | **State of bone** | | | **Proportion of water and sediment** | |
|---|---|---|---|---|---|---|---|---|
| | ANOVA, F | **(p)** | | **ANOVA, F** | **(p)** | | **ANOVA, F** | **(p)** |
| *C0* | 0,025 | 0,875 | **C0** | 0,628 | 0,443 | **C0** | 0,07 | 0,795 |
| *C1* | 0,01 | 0,921 | **C1** | 0,039 | 0,847 | **C1** | 0 | 1 |
| *C3* | 0,098 | 0,76 | **C3** | 0,017 | 0,898 | **C3** | 0,1 | 0,757 |
| *C5* | 0 | 0,552 | **C5** | - | -* | **C5** | 2,4 | 0,14 |

### *4.1.2. Cut marks*

Forty intentional cut marks were subjected to the tumbling process (Table 4). Initially, these cut marks were characterized by a predominance of symmetry (82.5%) and a V-shaped cross-section (85%), the low presence of microastriations (20%) and barbs (17.5%) and a complete absence of microabrasions. The shoulder effect was documented in 35% of these marks.

After 30′ of tumbling (C1), all cut marks were preserved. The diagnostic features generally showed lower values compared to the previous cycle, although the V-shaped morphology increased, as did the presence of microabrasions. After 2h of exposure to tumbling (C3) all cut marks were preserved and there were no changes in the percentage representation of the diagnostic criteria except for the decrease in microstriations (7.5%) and the increase in microabrasions (5%) and the total disappearance of barbs.

After 8h of experimentation (C5), six cut marks had disappeared, which means 85% survived the process. In general, the symmetry (82.3%) and the V-shaped morphology of the cross-section (97.1%) were conserved throughout the abrasive process. A substantial decrease in the shoulder effect was documented (14.7%) as well as the total disappearance of microstriations and microabrasions. As with trampling, the diagnostic criteria disappeared progressively as the experimentation progressed, albeit at a slower pace.

#### *4.1.2.1. Type of movement: unidirectional or bidirectional*

Some differences were observed during the analysis based on the type of movement to which the experimental cut marks were subjected (Table 4). However, the results of the F-test conclude that these differences were not statistically verified (Table 5). It should be noted

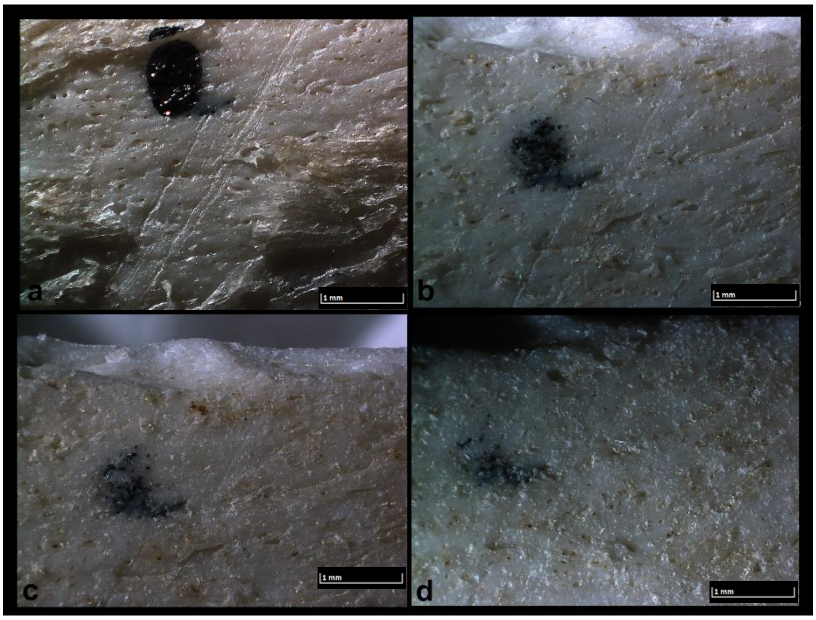

**Figure 3.** Trampling marks on fresh bone in different modification phases. a) trampling marks before tumbling process (C0); b) trampling marks after 30 minutes (C1); c) after 1 hour (C2); and e) after 2 hours (C3). The marks disappeared during C4 of tumbling. Images taken with HIROX KH-8700 at 50x.

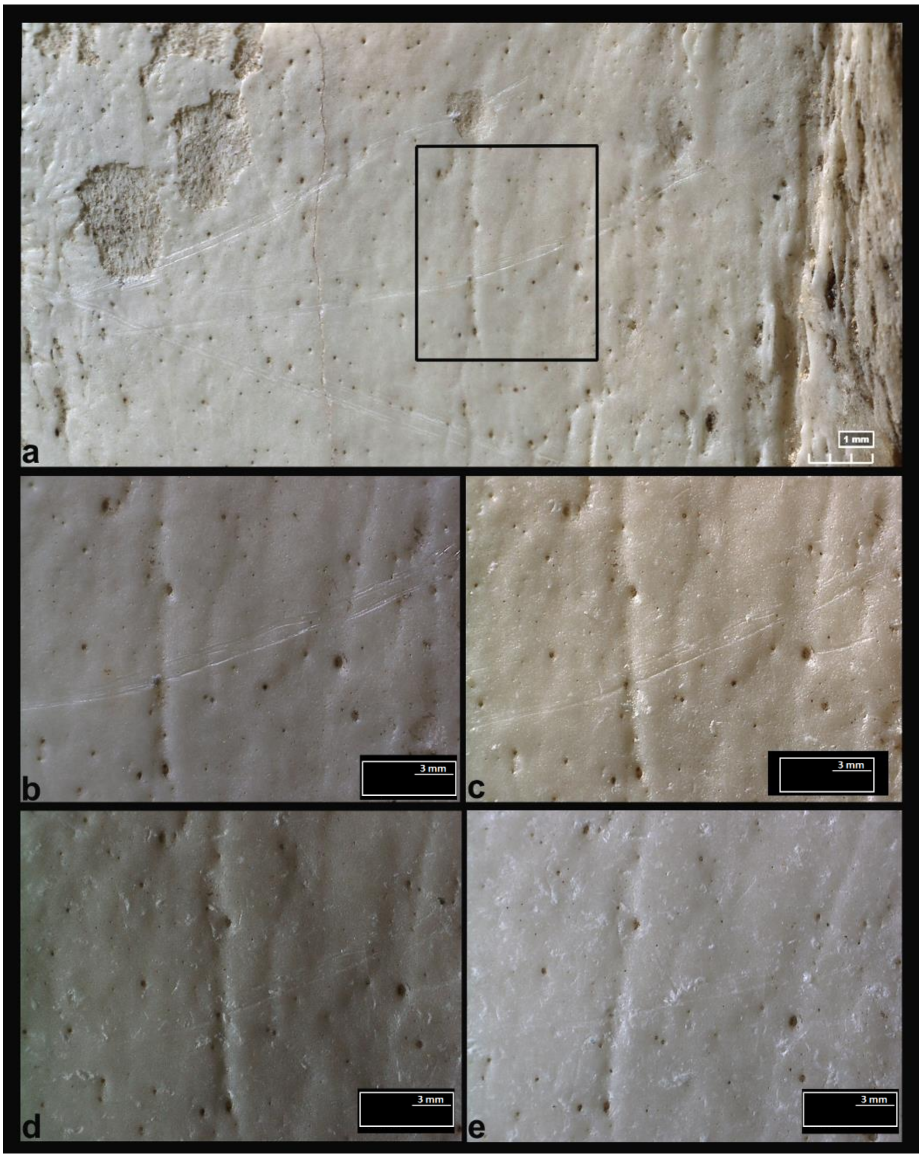

**Figure 4.** Trampling marks on dry bone in different modification phases. a) general view of trampling marks, the square shows the controlled area; b) controlled area before tumbling process (C0); c) after 30 minutes (C1); d) after 1 hour (C2); and e) after 2 hours (C3). The marks disappeared during C4 of tumbling. Images taken with HIROX KH-8700 at 50x.

that the non-preserved cut marks (n=6) were all subjected to unidirectional turns.

*4.1.2.2. Bone state: fresh or dry*

At the beginning of the experiment, the cut marks on the dry bones displayed a higher percentage of barbs, shoulder effect and microstriations than the cut marks on fresh bones (Table 4). After the modification process, the decrease in shoulder effect and the disappearance of microstriations and microabrasions was more evident on the fresh bones (Fig. 5) than on the dry ones (Fig. 6). In any case, these differences were not statistically proved (Table 5).

*4.1.2.3. Proportion of water to sediment: 80%/20% or 50%/50%*

Although differences were not statistically proved in relation to the proportion of water to sediment (Table 5) the disappearance of cut marks was higher among the bones subjected to tumbling in 80%/20% proportions, although the loss of the characteristics of the striae was very similar in both groups throughout the experimental process. All of the striations that disappeared belonged to the bones tumbled in a greater proportion of water (80%/20%).

**Table 4**. Diagnostic features described in each of the cycles of analysis of the experimental cut marks. Global and disaggregated data are presented according to types of movement, bone states and proportions of water to sediment. Data presented in percentages, except the number of striae. *The data reflects the presence of these features. **As opposed to _/-shaped. *** As opposed to asymmetry.

| | | | | | Type of movement | | | | | | | | State of bone | | | | | | | | Proportion of water and sediment | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Global | | | | Unidirectional | | | | Bidirectional | | | | Dry | | | | Fresh | | | | 80%+20% | | | | 50%+50% | | | |
| | C0 | C1 | C3 | C5 | C0 | C1 | C3 | C5 | C0 | C1 | C3 | C5 | C0 | C1 | C3 | C5 | C0 | C1 | C3 | C5 | C0 | C1 | C3 | C5 | C0 | C1 | C3 | C5 |
| Number of striae | 40 | 40 | 40 | 34 | 20 | 20 | 20 | 14 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 15 | 20 | 20 | 20 | 19 | 20 | 20 | 20 | 14 | 20 | 20 | 20 | 20 |
| Striae preservation | 100 | 100 | 100 | 85 | 100 | 100 | 100 | 70 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 75 | 100 | 100 | 100 | 95 | 100 | 100 | 100 | 70 | 100 | 100 | 100 | 100 |
| Barbs* | 17.5 | 12.5 | 0 | 0 | 35 | 15 | 0 | 0 | 5 | 10 | 0 | 0 | 20 | 15 | 0 | 0 | 15 | 10 | 0 | 0 | 30 | 25 | 0 | 0 | 5 | 0 | 0 | 0 |
| Morphology (V-shaped)** | 85 | 92.5 | 97.5 | 97.1 | 90 | 90 | 100 | 100 | 80 | 95 | 95 | 95 | 70 | 85 | 95 | 93.3 | 100 | 100 | 100 | 100 | 85 | 85 | 100 | 100 | 85 | 100 | 95 | 95 |
| Symmetry*** | 82.5 | 67.5 | 70 | 82.3 | 85 | 70 | 70 | 100 | 80 | 65 | 70 | 70 | 65 | 35 | 40 | 66.7 | 100 | 100 | 95 | 94.7 | 65 | 50 | 50 | 64.3 | 100 | 85 | 90 | 95 |
| Shoulder effect* | 35 | 30 | 30 | 14.7 | 45 | 35 | 35 | 7.1 | 25 | 25 | 25 | 20 | 45 | 45 | 45 | 26.7 | 25 | 15 | 15 | 5.3 | 10 | 5 | 5 | 7.1 | 60 | 55 | 55 | 20 |
| Microestriación* | 20 | 10 | 7.5 | 0 | 25 | 5 | 5 | 0 | 15 | 15 | 10 | 0 | 25 | 10 | 10 | 0 | 15 | 10 | 5 | 0 | 10 | 5 | 0 | 0 | 30 | 15 | 15 | 0 |
| Microabrasion* | 0 | 2.5 | 5 | 0 | 0 | 0 | 5 | 0 | 5 | 5 | 5 | 0 | 0 | 0 | 5 | 0 | 0 | 5 | 5 | 0 | 0 | 5 | 5 | 0 | 0 | 0 | 5 | 0 |

### 4.2. *Archaeological material*

A total of 24 striae of undetermined origin have been described and analyzed in the Barranc de la Boella assemblage (Table 6) (Fig. 7). Those from the la Mina site (n=21) have been described as straight (100%) and predominantly symmetrical (90.5%), oblique (61.9%) and with a _/-shaped cross-section (66.7%). The shoulder effect is discernable in two striae (9.5%) and no barbs, microabrasions or microstriations have been documented. The superposition of striae was documented in 54.4% of cases.

Three marks have been found on mammoth rib bones from the Pit 1 site. These striations are described as straight, oblique and V-shaped in all cases, and mostly symmetrical (66.7%). No barbs, shoulder effect, microabrasions, microstriations or striae superposition has been documented.

## 5. Discussion

This experimental process was conducted by reproducing cut and trampling marks, submitting them to mechanical alteration by water and sediment, and then analyzing them considering several different variables: type of movement (unidirectional or bidirectional), bone state (fresh or dry), proportion of water to sediment (80%/20% or 50%/50%), and exposure time (up to 8h).

The results show that cut marks survived better than trampling striae at the end of the experimental process. The morphology of the cross-section (predominantly V-shaped for the cut marks and _/-shaped for the trampling marks) and symmetry are the only two morphological variables that were conserved in all preserved striae. Only the cut marks also conserved the shoulder effect in some cases. Barbs, microstriations and microabrasions disappeared completely in both groups of striae. From a statistical perspective, the type of movement, the proportion of water to sediment and the bone state do not appear to differentially affect the marks.

Several studies have shown that the bone state variable intervenes in how abrasion affects bone remains (Cáceres, 2002; Fernández-Jalvo and Andrews, 2003; 2016; Thompson et al., 2011). Fernández-Jalvo and Andrews (2003) conducted an experiment in which fresh, dry, weathered and fossilized bones were subjected to tumbling in different sediments (fine and coarse sands, gravels and silts) to observe changes in general morphology and appearance (rounding and polishing). Their results showed that fresh bones, in general, tend to be little affected by

**Table 5**. F-test and p value applied in order to detect significant statistical differences between experimental cut marks in each experimental cycle (C0, C1, C3 and C5) and in each variable (type of movement, bone state and proportion of water to sediment).

| | **Type of movement** | | | **State of bone** | | | **Proportion of water and sediment** | |
|---|---|---|---|---|---|---|---|---|
| | **ANOVA, F** | **(p)** | | **ANOVA, F** | **(p)** | | **ANOVA, F** | **(p)** |
| *C0* | 0,193 | 0,668 | **C0** | 0,038 | 0,848 | **C0** | 0,264 | 0,617 |
| *C1* | 0 | 1 | **C1** | 0,094 | 0,764 | **C1** | 0,248 | 0,627 |
| *C3* | 0,004 | 0,952 | **C3** | 0,021 | 0,886 | **C3** | 0,346 | 0,895 |
| *C5* | 0 | 0,661 | **C5** | 0,229 | 0,64 | **C5** | 0,576 | 0,462 |

abrasion, except when exposed to a sandy matrix. We documented a greater preservation of marks (trampling and cut marks) reproduced on fresh bones, while no trampling striae on dry bones survived in C5. In contrast, the shoulder effect, documented in the cut marks after C5, was preserved in a higher percentage on dry bones than on fresh ones. This may be related to the use of sands in the experiment, which could have more intensely abraded the fresh bones, as described by Fernández-Jalvo and Andrews (2003).

To analyze the effect of the type of movement the striae are subjected to, we applied rotary movement in two direction modes: unidirectional and bidirectional. The reproduced effect would correspond to that produced by hyper-concentrated currents, based on the proportion of water to sediment (as described by Benvenuti and Martini, 2009). Thompson et al. (2011) submitted fresh, weathered, archaeological and fossil bones to a closed-loop, fine-sand experimental process to determine how abrasion occurs in relation to the modes of sediment transport: bedload, saltation and suspension. These researchers did not detect significant differences between fresh and archaeological bones when transported by bedload (Thompson et al., 2011). Bedload transport occurs in hyper-concentrated currents. In our experimental work, did not find significant differences between fresh and dry bones, although more marks were preserved on fresh bones than on dry bones.

Our results did not reveal statistical differences in relation to the type of movement, although we did observe a greater disappearance of cut marks in the bones subjected to unidirectional movement. This could be related

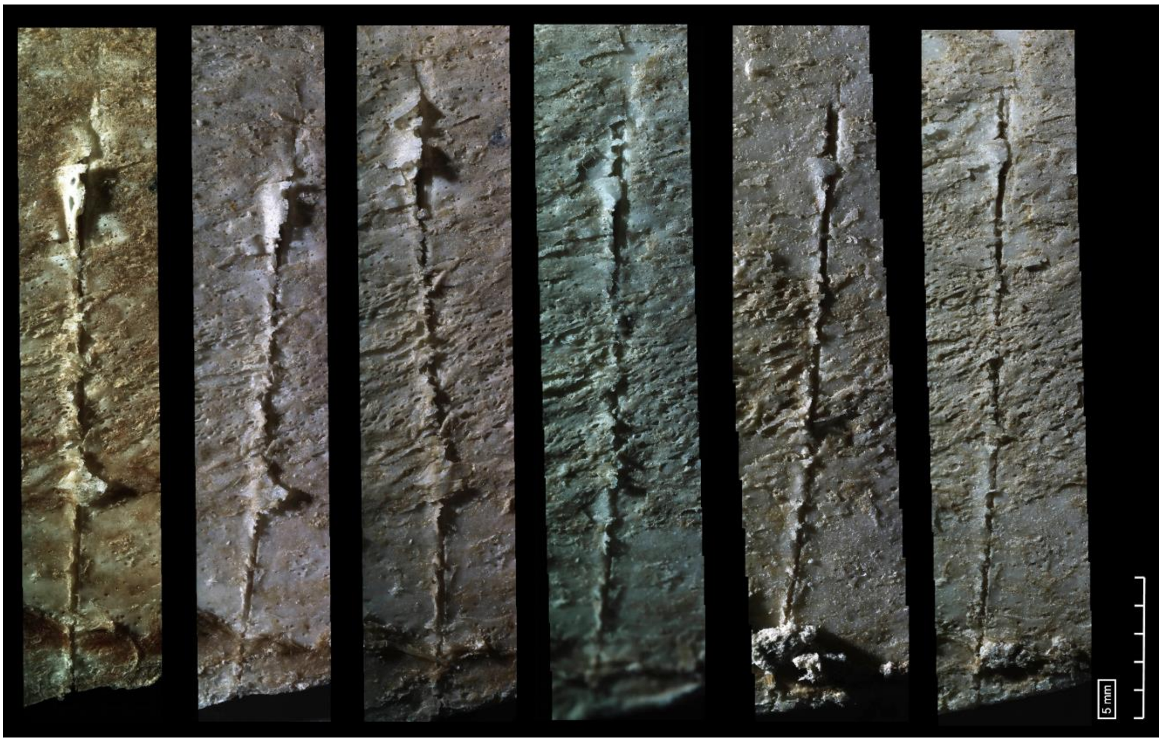

**Figure 5.** Cut mark on fresh bone in different modification phases. Left to right correspond to C0 to C5 (after 8 hours of tumbling). Images taken with HIROX KH-8700 at 50x.

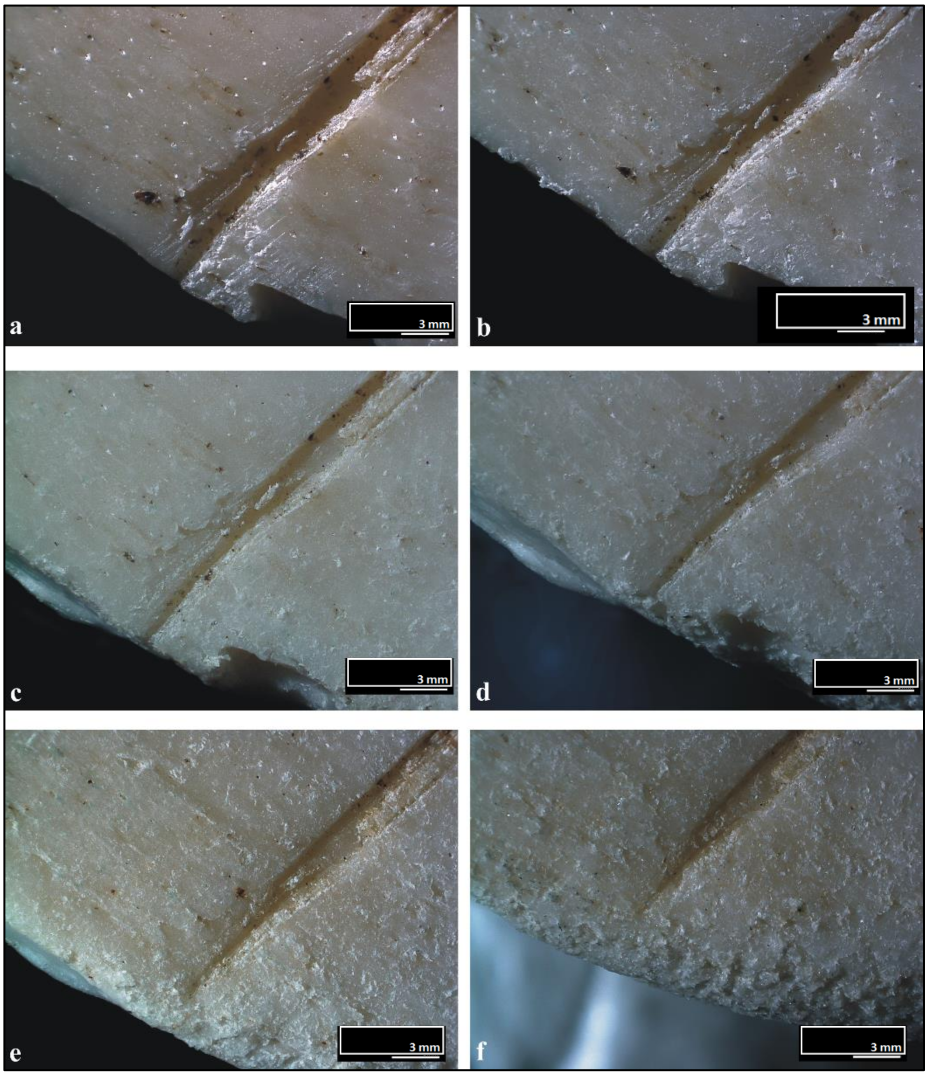

**Figure 6.** Detail of cut mark on dry bone in different modification phases. a) before tumbling; b) after 30 minutes (C1); c) after 1 hour (C2); d) after 2 hours (C3); e) after 4 hours (C4); and f) after 8 hours (C5). Images taken with HIROX KH-8700 at 50x.

to the fact that unidirectional movement involves a longer exposure time, as bidirectional involves pauses in the rotation. Experimental research conducted at Gesher Benot Ya'aqov has described how movement type affects the bones and the creation, modification and obliteration of superficial marks (Gaudzinski-Windheuser et al., 2010; Rabinovich et al., 2012). These researchers described different surface modifications on the bones according to the type of movement (unidirectional or multidirectional) the bones were exposed to, documenting a greater abrasion in bones and surfaces exposed to multidirectional movement, in which a correlation between the time of exposure and the level of abrasion was observed in the abovementioned studies. These works, therefore, agree that exposure time is a variable that influences the degree of modification of striae.

Differences in the proportion of water to sediment used were also described at Gesher Benot Ya'aqov experiments, where the bones underwent greater abrasion when exposed to sediment with a lower proportion of water in unidirectional movement (Gaudzinski-Windheuser et al., 2010; Rabinovich et al., 2012). We did not find statistical differences in relation to the proportion of water to sediment, although in our case, the striae and diagnostic criteria disappeared largely on bones subjected to a greater proportion of water.

**Table 6.** Diagnostic features described in faunal remains from the Barranc de la Boella sites la Mina and Pit 1. Data presented in percentages, except the number of striae. *The data reflects the presence of these features. **As opposed to _/-shaped. *** As opposed to asymmetry.

| | *La Mina (n=21)* | *Pit 1 (n=3)* |
|---|---|---|
| *Barbs** | 0 | 0 |
| *Morphology (V-shaped)*** | 33.3 | 100 |
| *Symmetry**** | 90.5 | 66.7 |
| Shoulder effect* | 9.5 | 0 |
| *Internal microstriation** | 0 | 0 |
| *Microabrasion** | 0 | 0 |

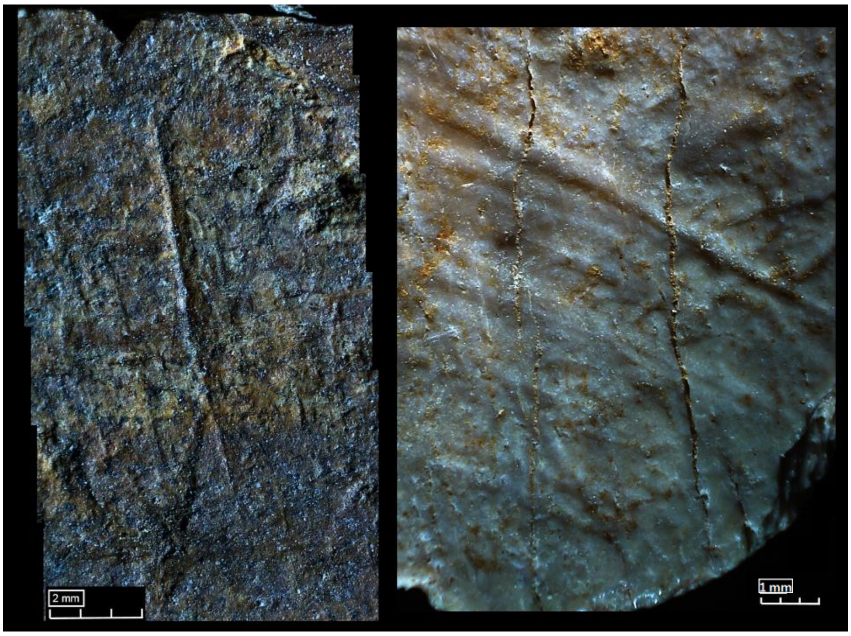

**Figure 7.** Marks from Pit 1 (left) and la Mina (right) sites, Barranc de la Boella. Images taken with HIROX KH-8700 at 50x.

In conclusion, our results show that the type of movement, the proportion of water to sediment and the state of the bone do not influence the differential alteration of surface marks, and that exposure time is the most influential variable in the alteration and disappearance of trampling striae and cut marks. Although the differences are not statistically proved, we documented a greater disappearance of marks on dry bones. Other types of sediment (e.g. clays or gravels) and other proportions of water should be applied in future research in order to experimentally reproduce the greatest possible variability with an aim to solving taphonomic problems.

The identification of striae similar to cut marks has been documented in archaeological sites for more than three decades (Behrensmeyer et al., 1986; Olsen and Shipman, 1988; Fiorillo, 1991; Heinzelin et al., 1999; Domínguez-Rodrigo et al., 2010; McPherron et al., 2010; Pineda et al., 2014; Harmand et al., 2015; Domínguez-Rodrigo and Alcalá, 2016; Sahle et al., 2017). The correct differentiation of cut marks and non-anthropogenic striae is necessary to draw accurate inferences related to the processing of animal resources by human groups (Domínguez-Rodrigo et al., 2010, 2017). It is especially important when working on ancient chronologies (Heinzelin et al., 1999; Domínguez-Rodrigo et al., 2010; Mcpherron et al., 2010; Domínguez-Rodrigo and Alcalá, 2016; Sahle et al., 2017) or when studying the earliest occupations of Europe (Martínez et al., 2010; Saladié et al., 2011; Espigares et al., 2013; Huguet et al., 2013), as is the case at Barranc de la Boella (Vallverdú et al., 2014).

As previously indicated, several striae of undetermined origin have been identified in the la Mina site (Pineda et al., 2014), as well as possible cut marks in the Pit 1 site (Mosquera et al., 2015) of Barranc de la Boella (BB), dated at around 1 Ma (Lozano-Fernández et al., 2014; Vallverdú et al., 2014). The BB has been described as an ecosystem rich in animal and plant resources, water and raw materials for tool production (Pineda et al., 2015, 2017b). Knowing the true origins of the striae observed on these fossils is important in order to establish the relationship of hominin groups with the fauna recovered in these assemblages and the role that hominins played in their formation.

Pineda et al. (2014) demonstrated that trampling and cut marks rapidly lose diagnostic criteria when exposed to chemical alteration, thus preventing the identification of their origin. The present work has shown that, unlike chemical alteration, mechanical alteration produced by abrasion does not always imply the total disappearance of the criteria, allowing the origin (cut marks or trampling) of the abraded marks to be identified.

A principal component analysis (PCA) was conducted for the purpose of viewing how the trampling and cut marks are distributed in relation to the morphological and diagnostic criteria described (Domínguez-Rodrigo et al., 2009), considering the different cycles of analysis of the striae before, during and after

**Table 7.** Diagnostic criteria described in both experimental and archaeological striae and used in PCA (Figure 8) (data as percentage).

| | *Barbs* | *Morphology (V-shaped)* | *Symmetry* | *Shoulder effect* | *Internal microstriation* | *Microabrasion* |
|---|---|---|---|---|---|---|
| *TR Cycle 0* | 8,5 | 28 | 59,8 | 18,3 | 32,9 | 22 |
| *TR Cycle 1* | 6,8 | 27,1 | 57,6 | 10,2 | 22 | 0 |
| *TR Cycle 3* | 0 | 28,6 | 82,1 | 0 | 10,7 | 3,6 |
| *TR Cycle 5* | 0 | 25 | 75 | 0 | 0 | 0 |
| *CM Cycle 0* | 17.5 | 85 | 82.5 | 35 | 20 | 0 |
| *CM Cycle 1* | 12.5 | 92.5 | 67.5 | 30 | 10 | 2.5 |
| *CM Cycle 3* | 0 | 97.5 | 70 | 30 | 7.5 | 5 |
| *CM Cycle 5* | 0 | 97.1 | 82.3 | 14.7 | 0 | 0 |
| *La Mina* | 0 | 33.3 | 90.5 | 9.5 | 0 | 0 |
| *Pit 1* | 0 | 100 | 66.7 | 0 | 0 | 0 |

experimentation. The striae described in the BB deposits at Pit 1 and la Mina were also included.

The descriptive criteria of the shoulder effect (presence and location of flacking) and microstriations (morphology, trajectory and location) were excluded from the PCA due to their relative paucity; therefore, only the presence or absence of these modifications was used, both in the experimental and the archaeological material (Table 7).

The PCA (Figure 8) shows a differential distribution between trampling striae and cut marks. Thus, while the experimental trampling and la Mina are located to the left of axis 1 (explaining 74.43% of inertia), the cut marks and the Pit 1 are located to the right of the axis. The experimental striae in initial phases of alteration are located in the upper part of axis 2 (explaining 15.792% of inertia), associated with barbs, microabrasions, microstriations and the shoulder effect, which tend to disappear; the advanced phases and the archaeological striae are on the lower part of the graph, associated with the symmetry and the morphology of the cross-section, which are the only recognizable criteria at the end of the experimental process. Pineda et al. (2014) also documented the greater survival of these variables in their work on chemical alteration. In our case, the trampling and cut marks present symmetry in approximately 60-80% of cases. However, it is in the morphology of the cross-section where the differences were observed: in the case of the cut marks, V-shaped cross-sections predominate (>90%) whereas in striae caused by trampling, _/-shaped cross-sections were the most common (>70%). Therefore, Pit 1 appears to be associated with cut marks in advanced stages of alteration, while la Mina is associated with highly altered trampling striae.

The fossils from both sites presented modifications related to the abrasion of the surfaces, which made it difficult in prior studies to identify the agent that may have produced the marks (Pineda et al., 2015; 2017b; Mosquera et al., 2015). In light of our results, the symmetrical and V-shaped morphology of the marks from Pit 1, interpreted as a butchering site of a mammoth carcass, can be confirmed as cut marks, as these are the features that experimentally survived the alteration process. In addition, as already indicated in Mosquera et al. (2015), their location on three rib fragments comports with the descriptions given by Crader (1983), which indicate that a greater number of marks are generated on these skeletal elements during the processing of proboscides. La Mina is a palimpsest formed by multiple events in which evidence of anthropogenic processing is scarce (Pineda et al., 2015, 2017b). The origin of the striae identified at this site could not be assigned in the previous work (Pineda et al., 2014). Now, these striae, predominantly symmetrical and with a _/-shaped cross-section, can be interpreted as resulting from trampling in view of the experimental results obtained.

When the state of the bone before alteration is considered, a clear distinction can be drawn between fresh and dry bones. As shown in Figure 9 (Table 8) the Pit 1 marks would correspond to freshly altered cut marks. Figure 10 (Table 9), related to bones subjected to trampling, also shows a clear differentiation between fresh and dry bones, suggesting the striae on the la Mina remains occurred on fresh bones. Both sets could have been affected by water currents after the deposition of the remains, when they were not yet in a dry state. These results would be in accordance with the sedimentological (Vallverdú et al., 2014) and taphonomic (Pineda et al., 2015; 2017b; Mosquera et al., 2015) data, suggesting the assemblages underwent rapid burial.

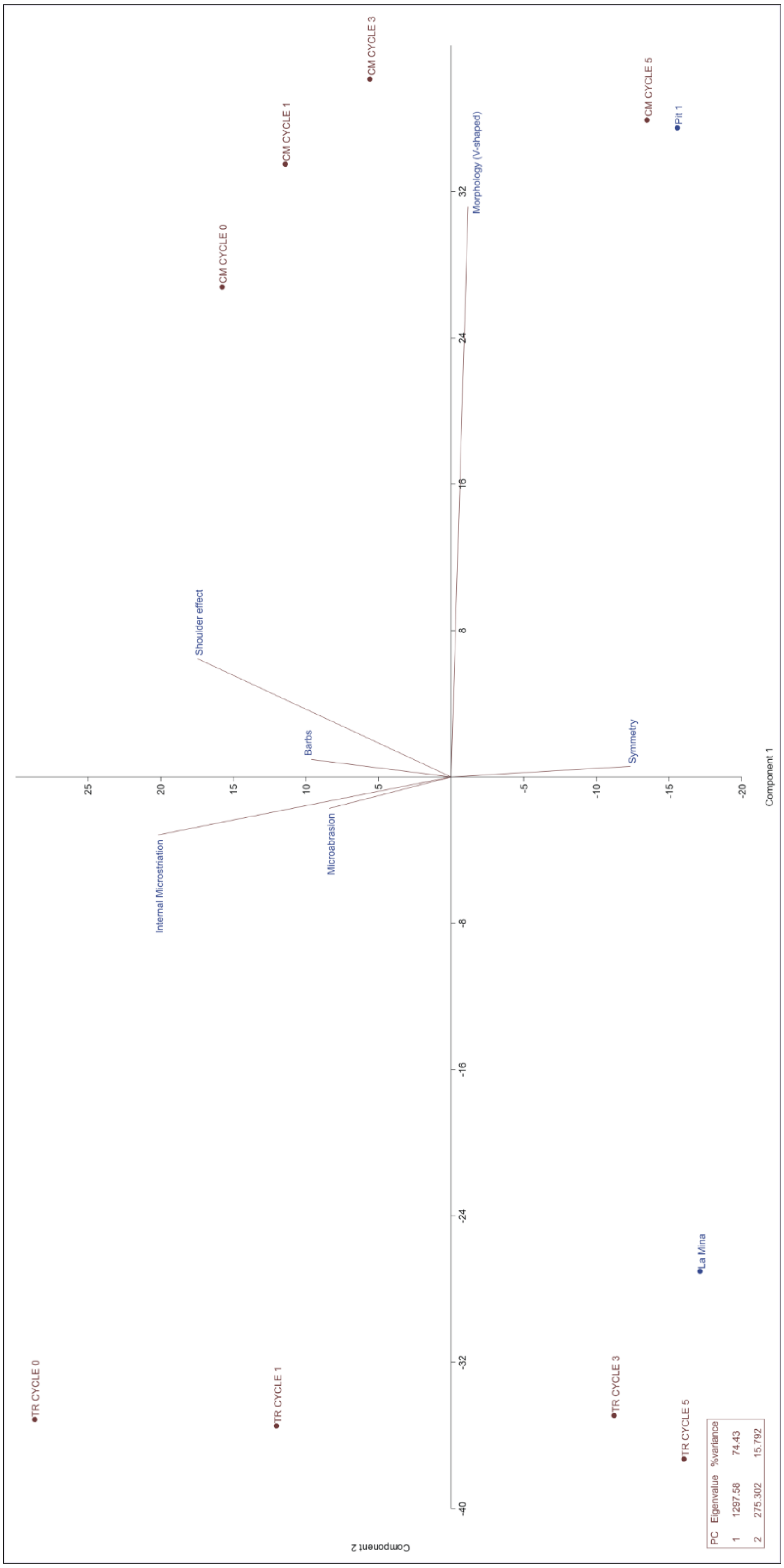

**Figure 8.** PCA distribution of the experimental trampling and cut marks and striae from la Mina and Pit 1 sites, in accordance with the analytic criteria. Data from Table 7.

**Table 8**. Diagnostic criteria described in the experimental cut marks on both dry and fresh bones and the cut marks identified at Pit 1 site (data as percentage).

| | *Barbs* | *Morphology (V-shaped)* | *Symmetry* | *Shoulder effect* | *Internal microstriation* | *Microabrasion* |
|---|---|---|---|---|---|---|
| *FR Cycle 0* | 15 | 100 | 100 | 25 | 15 | 0 |
| *FR Cycle 1* | 10 | 100 | 100 | 15 | 10 | 5 |
| *FR Cycle 3* | 0 | 100 | 95 | 15 | 5 | 5 |
| *FR Cycle 5* | 0 | 100 | 94,7 | 5,3 | 0 | 0 |
| *DRY Cycle 0* | 20 | 70 | 65 | 45 | 25 | 0 |
| *DRY Cycle 1* | 15 | 85 | 35 | 45 | 10 | 0 |
| *DRY Cycle 3* | 0 | 95 | 40 | 45 | 10 | 5 |
| *DRY Cycle 5* | 0 | 93,3 | 66,7 | 26,7 | 0 | 0 |
| *Pit 1* | 0 | 100 | 66.7 | 0 | 0 | 0 |

Table 9. Diagnostic criteria described in experimental trampling on both dry and fresh bones and the trampling marks identified at la Mina site (data as percentage).

| *Trampling* | *Barbs* | *Morphology (V-shaped)* | *Symmetry* | *Shoulder effect* | *Internal microstriation* | *Microabrasion* |
|---|---|---|---|---|---|---|
| *FR Cycle 0* | 5.6 | 30.6 | 86.1 | 5.6 | 19.4 | 2.8 |
| *FR Cycle 1* | 7.7 | 23.1 | 84.6 | 7.7 | 15.4 | 0 |
| *FR Cycle 3* | 0 | 13.3 | 100 | 0 | 6.7 | 0 |
| *FR Cycle 5* | 0 | 25 | 75 | 0 | 0 | 0 |
| *DRY Cycle 0* | 10.9 | 26.1 | 39.1 | 28.3 | 43.5 | 37 |
| *DRY Cycle 1* | 6.1 | 30.3 | 36.4 | 12.1 | 27.3 | 0 |
| *DRY Cycle 3* | 0 | 46.2 | 61.5 | 0 | 15.4 | 0 |
| *La Mina* | 0 | 33.3 | 90.5 | 9.5 | 0 | 0 |

## 6. Conclusions

The mechanical alteration (with water and sediment) of trampling and cut marks reproduced experimentally in this work has allowed us to determine the origin of the unidentified striae present on the remains from Pit 1 and la Mina deposits at Barranc de la Boella. Cut marks on the experimental materials demonstrated a higher survival rate after alteration than trampling marks, and some diagnostic criteria endured the experimental process better than others: the morphology of the cross-section (predominantly V-shaped), symmetry and, in some cases, the shoulder effect. Trampling striae mostly disappeared and those that survived only retained the morphology of the cross-section (predominantly _/-shaped) and symmetry. No statistical differences have been obtained regarding the type of movement, the proportion of water to sediment used and the state of the bone. However, marks on dry bones were altered more quickly than those on fresh bones.

The application of these results has allowed us to propose an origin for the striae found on the remains at la Mina and Pit 1. In the case of the la Mina striae, our results suggest that they should be considered trampling in an advanced phase of alteration. Furthermore, our results reaffirm the anthropogenic character of the marks described on the remains from Pit 1, in an advanced stage of modification. In both cases, the abrasive process took place on fresh bones. This work highlights the importance of understanding fossilization processes as cumulative and the usefulness of sequential experimentation to solve taphonomic problems.

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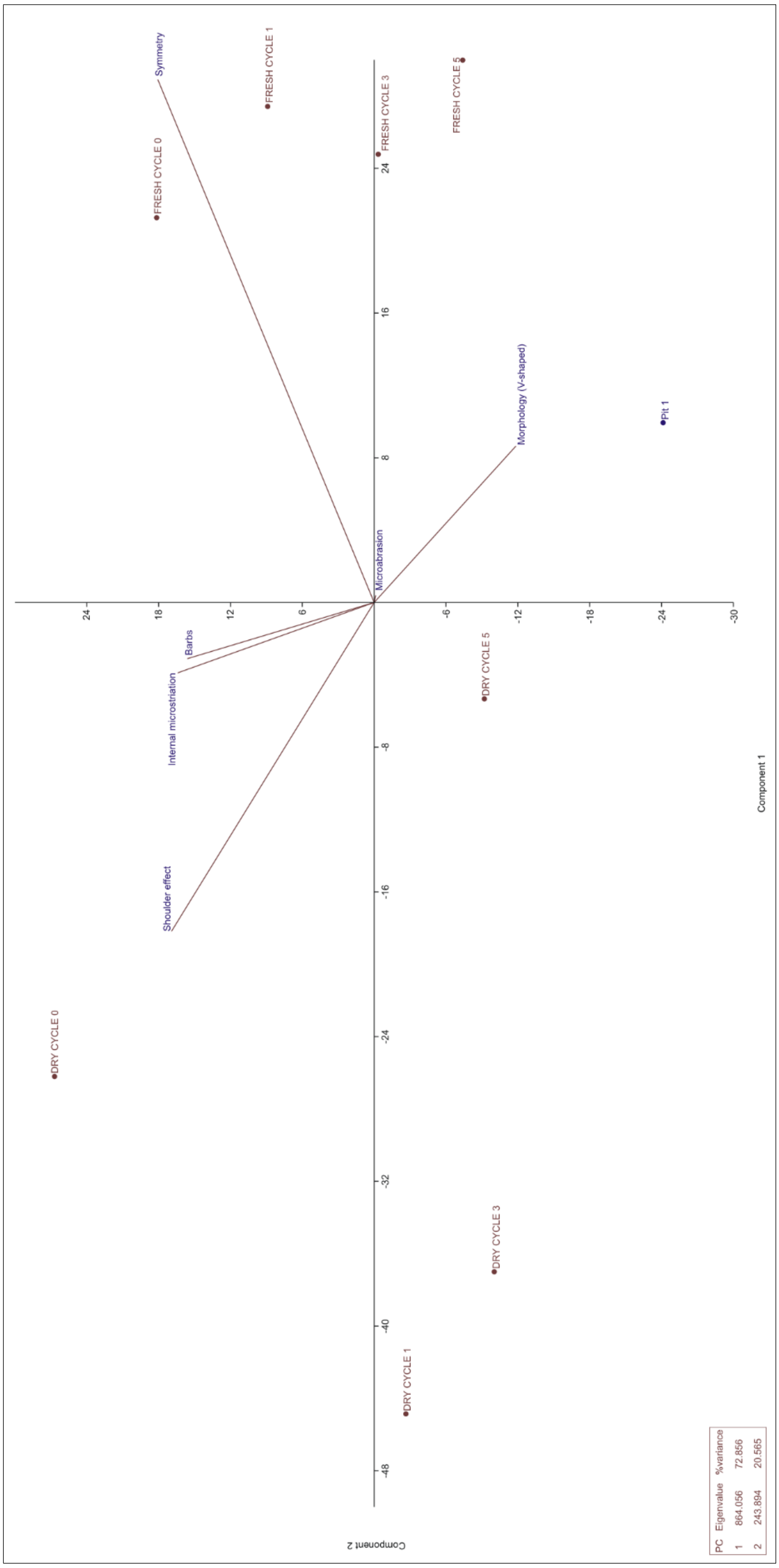

**Figure 9.** Distribution of the experimental cut marks reproduced on both fresh and dry bones and the Pit 1 cut marks, in accordance with the analytic criteria. Data from Table 8.

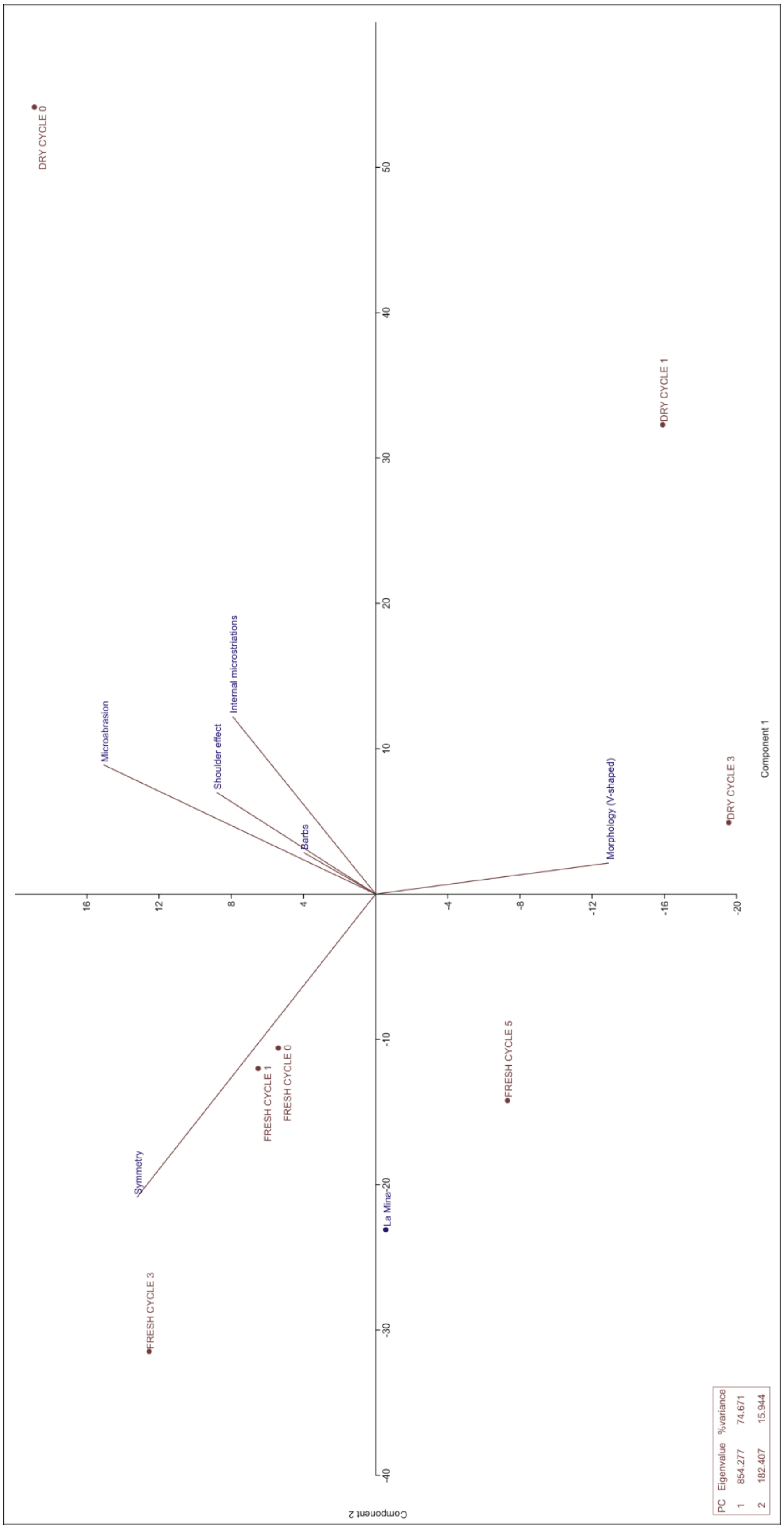

**Figure 10. Distribution** of the experimental trampling reproduced on both fresh and dry bones and La Mina trampling striae, in accordance with the analytic criteria. Data from Sup. Table 3.

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# Capítulo 6. La Mina y el Forn (Barranc de la Boella)

Los resultados obtenidos tras el análisis de los restos faunísticos de la Mina y el Forn (Barranc de la Boella) se presentan en tres artículos publicados en las revistas *Quaternary International* y *Palaeogeography, Palaeoclimatology, Palaeoecology* (2).

**Artículo 3:** Pineda, A., Saladié, P., Huguet, R., Cáceres, I., Rosas, A., García-Tabernero, A., Estalrrich, A., Mosquera, M., Ollé, A. y Vallverdú, J. (2015). Coexistence among large predators during the Lower Paleolithic at the site of La Mina (Barranc de la Boella, Tarragona, Spain). *Quaternary International* 388: 177-187

**Artículo 4:** Pineda, A., Saladié, P., Huguet, R., Cáceres, I., Rosas, A., García-Tabernero, A., Estalrrich, A. y Vallverdú, J. (2017b). Changing competition dynamics among predators at the late Early Pleistocene site Barranc de la Boella (Tarragona, Spain). *Palaeogeography, Palaeoclimatology, Palaeoecology* 477: 10-26.

**Artículo 5:** Pineda, A., Saladié, P., Expósito, I., Rodríguez-Hidalgo, A., Cáceres, I., Huguet, R., Rosas, A., López-Polín, L., Estalrrich, A., García-Tabernero, A. y Vallverdú, J. (2017a). Characterizing hyena coprolites from two latrines of the Iberian Peninsula during the Early Pleistocene: Gran Dolina (Sierra de Atapuerca, Burgos) and la Mina (Barranc de la Boella, Tarragona). *Palaeogeography, Palaeoclimatology, Palaeoecology* 480: 1-17.

The results obtained during the analyses of faunal remains from la Mina y el Forn (Barranc de la Boella) are presented in three published papers at *Quaternary International* and *Palaeogeography, Palaeoclimatology, Palaeoecology* (2) journals.

**Paper 3:** Pineda, A., Saladié, P., Huguet, R., Cáceres, I., Rosas, A., García-Tabernero, A., Estalrrich, A., Mosquera, M., Ollé, A. and Vallverdú, J. (2015). Coexistence among large predators during the Lower Paleolithic at the site of La Mina (Barranc de la Boella, Tarragona, Spain). *Quaternary International* 388: 177-187

**Paper 4:** Pineda, A., Saladié, P., Huguet, R., Cáceres, I., Rosas, A., García-Tabernero, A., Estalrrich, A. and Vallverdú, J. (2017b). Changing competition dynamics among predators at the late Early Pleistocene site Barranc de la Boella (Tarragona, Spain). *Palaeogeography, Palaeoclimatology, Palaeoecology* 477: 10-26.

**Paper 5:** Pineda, A., Saladié, P., Expósito, I., Rodríguez-Hidalgo, A., Cáceres, I., Huguet, R., Rosas, A., López-Polín, L., Estalrrich, A., García-Tabernero, A. and Vallverdú, J. (2017a). Characterizing hyena coprolites from two latrines of the Iberian Peninsula during the Early Pleistocene: Gran Dolina (Sierra de Atapuerca, Burgos) and la Mina (Barranc de la Boella, Tarragona). *Palaeogeography, Palaeoclimatology, Palaeoecology* 480: 1-17.

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# Coexistence among large predators during the Lower Paleolithic at the site of La Mina (Barranc de la Boella, Tarragona, Spain)

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## ABSTRACT

Barranc de la Boella is made up of several open-air late Early Pleistocene archaeological sites (Pit 1, La Mina and El Forn) the formation of which is related to a deltaic sedimentary environment. Its age makes it a key site for studying the behavior of the early hominin groups of the Iberian Peninsula and western Europe and the ecological context in which they developed.

At La Mina locality, three archaeostratigraphic levels have been identified, with level 2 being the richest in terms of the archaeological remains recovered. It exhibits high taxonomic diversity, with the most common taxa belonging to open and partially open habitats, although aquatic and riparian taxa have also been identified. Carnivore remains are present, although scarce. Coprolites from a hyaenid have also been found.

Both hominin and carnivore activity has been documented at the site. Evidence of carnivore activity suggests at least one bone-cracking carnivore had access to the assemblage. The anatomical ratios employed suggest that La Mina was formed at a time of high competition (intra and/or inter-specific), with a high number of predators in this ecological context. Anthropic activity in a highly competitive context might suggest that these hominin groups had a high degree of control over the environment and over local resources, as has been shown at other Early Pleistocene sites.

## 1. Introduction

The activity of different biological agents tends to be registered in Pleistocene fossil assemblages, and it is not uncommon to document the presence of both hominin and carnivores in the same space (co-occurrence) (Blumenschine and Selvaggio, 1988; Oliver, 1994; Capaldo, 1997; Egeland et al., 2004; Domínguez-Rodrigo and Barba, 2006). From an archaeological perspective, the co-occurrence of hominins and carnivores (their activity and/or their remains) is well documented. During the European Early Pleistocene, this has mainly been identified at open-air sites (Moullé, 1992; Martínez-Navarro et al., 1997; Oms et al., 2000; Arzarello et al., 2007; Madurell-Malapeira et al., 2010; Martínez et al., 2010; Espigares et al., 2013; Vallverdú et al., 2014), but it is also seen in caves (Saladié et al., 2011, 2014; Huguet et al., 2013). As some researchers suggest, and as Egeland (2014) has examined in detail, in these contexts, the different groups of potential predators involved in the formation of the assemblage can act inter and/or independently (Oliver, 1994; Egeland et al., 2004). Knowing the role

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played by carnivores in contexts in which they co-occur with a hominin population is crucial to understanding the level of competition at the time in which hominin groups undertook activities related to subsistence strategies (Saladié et al., 2014).

Competition is an interaction between individuals, brought about by a shared requirement for a resource, and leading to a reduction in the survivorship, growth and/or reproduction of at least some of the competing individuals concerned (Begon et al., 2006). Competition for resources can take place in two ways: directly, when many consumers target the same resource at the same time; or indirectly, when there is a progression of consumers utilizing the same resource over time (Faith and Behrensmeyer, 2006).

The impact of carnivores on a bone assemblage, including bone choice and transport, modification and/or destruction, is termed "carnivore ravaging" (Binford, 1981; Marean and Spencer, 1991). Many of the differences that account for variation in bone representation and modification lie in the degree of ravaging (Domínguez-Rodrigo and Organista, 2007).

During her studies of the Amboseli ecosystem (southern Kenya), Behrensmeyer (1975) showed that the proportion of complete bones which survive scavenging by carnivores in a taphosystem is closely related to the density of the carnivores and the availability of prey, with a decrease in the number of complete bones when the number of carnivores increases. More recently, Faith and Behrensmeyer (2006) found that the intensity of ravaging results in different skeletal profiles, mainly on limb ends and axial elements, closely linked to different levels of competition among predators. In this respect, Faith et al. (2007) suggest that at times of high competition, carnivores tend to consume nearly all of the skeletal parts that they find, regardless of their mineral density or marrow or fat components. Capaldo (1997) also suggests that the presence of complete bones may be the result of low degrees of competition in the environment.

Early Pleistocene hominins, as large predators with well-developed cynegetic activities (Domínguez-Rodrigo et al., 2002, 2014; Domínguez-Rodrigo and Barba, 2006; Saladié et al., 2011; Huguet et al., 2013), probably shared space and competed for animal resources with a wide range of carnivores. In this respect, several studies have highlighted the need to recognize levels of carnivore ravaging in assemblages in order to perform paleoecological reconstructions that provide data regarding the degree of competition among predators based on the analysis of skeletal profiles (Blumenschine and Marean, 1993; Faith and Behrensmeyer, 2006; Domínguez-Rodrigo and Organista, 2007; Faith et al., 2007; Egeland, 2008, 2014; Saladié et al., 2014). Thus, the taphonomic analysis of competition can be considered an important source of information, as the varying degrees of integrity of the carcasses at a site point to differing levels of competition in the environment (Faith and Behrensmeyer, 2006).

The Barranc de la Boella (BB) is an outdoor archaeological site and a key location for studying hominin behavior during the late Early Pleistocene. Prior studies of the Pit 1 locality suggest that it was the butchering site of a single *Mammuthus meridionalis* (Vallverdú et al., 2014). This type of locality, formed in an alluvial context, is similar to other sites on the Iberian Peninsula such as Vallparadís (Martínez et al., 2010) and the Guadix-Baza Basin (Martínez-Navarro et al., 1997; Toro-Moyano et al., 2013). The main goal of this paper is to examine the degree of competition among predators in the paleoecological context inferred at the site of La Mina (LM).

Egeland et al. (2004) have shown that the presence of modifications on the same remains produced by both hominins and carnivores is a useful tool for making inferences about degrees of inter- or independence between those predators. However, the poor preservation of the surfaces of the bones at LM, which are chemically altered due to the lixiviation of the soluble elements of the sediments, prevented us from identifying cut marks on their surfaces (Pineda et al., 2014). As a consequence, these analyses have been carried out based on skeletal profiles (Marean and Spencer, 1991; Marean et al., 1992; Blumenschine and Marean, 1993; Domínguez-Rodrigo et al., 2002; Faith et al., 2007; Egeland, 2008; Saladié et al., 2014).

## 2. The Barranc de la Boella site

Barranc de la Boella is located in the north-eastern corner of the Iberian Peninsula, in the township of la Canonja, 6 km from the city of Tarragona and the Mediterranean coast (Catalonia, Spain). Six litho-stratigraphic units have been identified in a sequence with a thickness of 9 m, fully described in Vallverdú et al. (2014) (Fig. 1). Litho-stratigraphic unit II is the most archaeologically fertile stratum at the site, containing a 2-m thick homogeneous sequence with poorly stratified sands and gravel, characteristic of subaerial and subaquatic mass flow deposits. A chronology of slightly less than a million years (0.96–0.78 Ma) has been proposed for this unit, based on biochronology, paleomagnetism and cosmogenic nuclides (Lozano-Fernández et al., 2014; Vallverdú et al., 2014).

Fieldwork in BB started in 2007 and has involved three different localities: Pit 1, La Mina and El Forn. Specifically, the current fieldwork being conducted at LM affects 25 $m^2$ and has enabled us to recover over 900 remains, including stone tools, faunal remains and coprolites.

To date, three different types of deer (*Cervus* elaphus, *Megaloceros* savini and *Dama* cf. *vallonetensis*) have been identified at LM, along with other taxa: *Equus* cf. stenonis, *Hippopotamus antiquus*, *Mammuthus meridionalis*, *Ursus* sp., and *Canis* cf. *mosbachensis*, together with coprolites belonging to a hyaenid. In addition, the site has yielded remains belonging to *Mimomys savini* and *Victoriamys chalinei* (Vallverdú et al., 2008, 2014; Lozano-Fernández et al., 2014) and 80 stone tools, mainly made of flint (Vallverdú et al., 2014; Mosquera et al., 2015).

The technological record documented at BB sites has been ascribed to an ancient Acheulean. The identification of large cutting tools (a cleaver-like tool recovered at El Forn and a pick from the Pit 1), the methods of core reduction and the technical features of several small and medium-sized simple and retouched flakes have been used to identify an Early Acheulean technology in Europe in chronologies ~1 million of years (Vallverdú et al., 2014; Mosquera et al., 2015).

## 3. Material and methods

Three archaeopalaeontological levels have been identified in LM Unit II, with level 2 being the richest in fossil remains (Fig. 2). This paper focuses exclusively on level 2, which has been almost entirely excavated.

The faunal remains from LM were analyzed using zooarcheological and taphonomic methods. All remains measuring more than 2 cm were analyzed. Non-identified remains were grouped into body-weight categories (Table 1) and bone-type categories (Saladié et al., 2011). The age of death profiles of the individuals were established based on the degree of ossification (Schmid, 1972; Barone, 1976) as well as dental eruption and wear sequence (Hillson, 1996; Bunn and Pickering, 2010). The integrity of the sample was evaluated by means of the number of identified specimens (NISP), minimal number of elements (MNE), minimal number of individuals (MNI) and the minimal animal unit (MAU) (Brain, 1981; Binford, 1984; Bunn et al., 1988; Marean and Spencer, 1991; Lyman, 1994; Stiner, 1994). Shannon's diversity index (Shannon

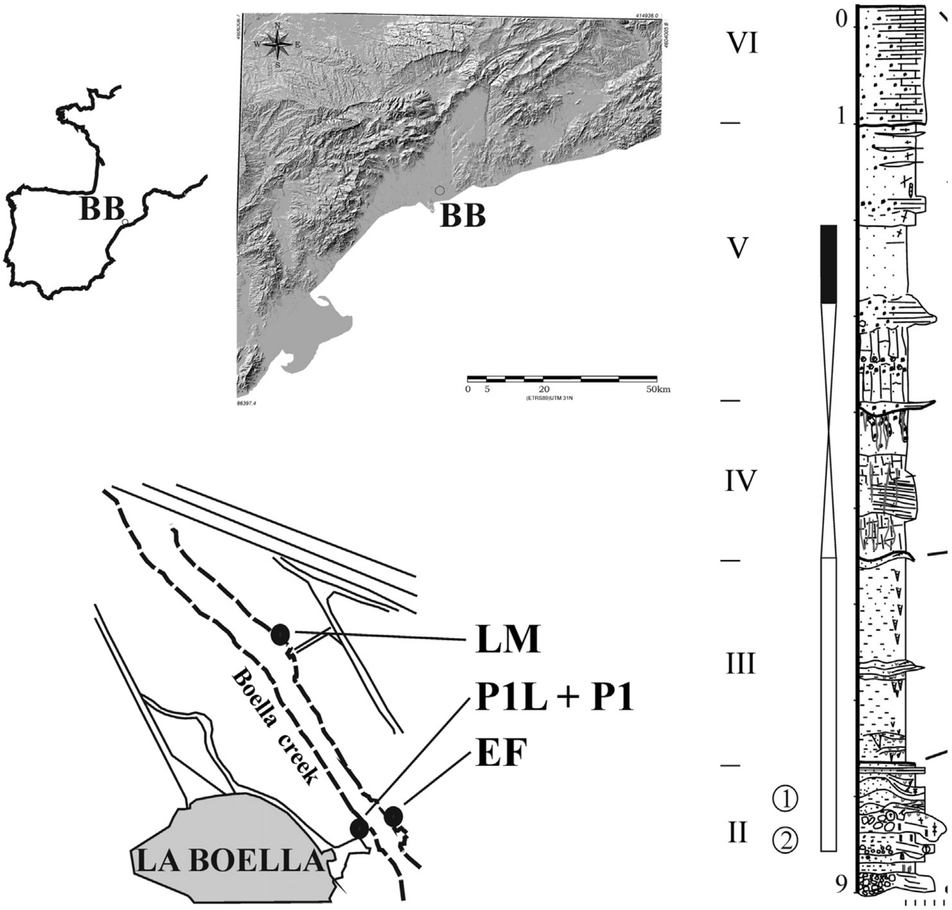

**Fig. 1.** Location of Barranc de la Boella in relation to western Europe and Iberian Peninsula (top, left); distribution of the different sites excavated at Barranc de la Boella (bottom, left) and lithostratigraphic units and archeopaleontological levels identified at La Mina (right). Modified from Vallverdú et al. (2014).

and Weaver, 1949) was used (from MNI) to measure the ecological diversity based on the proportional abundance of species identified, including remains belonging to micromammal species (Lozano-Fernández et al., 2014) recovered until 2013.

The mineral density of the bones was taken into account in assessing the integrity of the sample (Lyman, 1994:234). A Shapiro–Wilk's test was applied to compare the normality of the variables, as was Kendall's tau for statistical significance. The MAU from LM was correlated with %MGUI and the mineral density of the bones, in keeping with that established by Lyman (1994:264). The fragmentation of the long bones, both in length and cross-section, and fracture morphologies were analyzed, in accordance with the methods of Bunn (1983) and Villa and Mahieu (1991).

The surfaces of all the remains were analyzed using a stereomicroscope (OPTECH 120 HZ) and in some cases with a scanning electron microscope used in low vacuum mode (ESEM, FEI QUANTA 600). The carnivore-induced modifications identified consisted of pits, scores, modifications produced by gastric acids, pitting, furrowing, lacking, scooping out, crenulated edges and shaft cylinders (Haynes, 1980, 1983; Maguire et al., 1980; Binford, 1981; Brain, 1981; Blumenschine, 1995). The presence/absence of pits and scores, their location on the anatomical segment and their

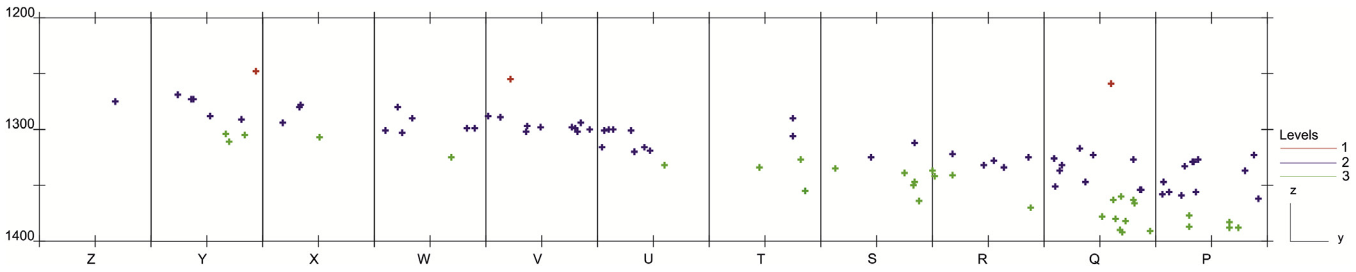

**Fig. 2.** Three archaeopalaeontological levels identified at La Mina, unit II. Only level 2 (blue), the richest in fossil remains, has been included in the current study. Level 1 is poor in archaeological remains and fieldworks in level 3 are currently underway. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

**Table 1**
Different weight-size categories established and different taxa included in each one.

| Weight-size categories | Taxa |
|---|---|
| Very large sized (>1000 kg) | *Mammuthus meridionalis* |
| | *Hippopotamus antiquus* |
| Large sized (300–1000 kg) | *Megaloceros savini* |
| | Bovini |
| | Adult *Equus* cf. *stenonis* |
| Medium sized (100–300 kg) | Adult *Cervus elaphus* |
| | Infant *Equus* cf. *stenonis* |
| | *Ursus* sp. |
| | Felidae (large) |
| | *Panthera* cf. (*onca*) *gombaszoegensis* |
| Small Sized (10–100 kg) | *Macaca sylvanus* (*florentina*) |
| | *Dama* cf. *vallonetensis* |
| | *Canis* cf. *mosbachensis* |
| | *Vulpes* sp. |
| | *Lynx* sp. |
| Very small sized (<10 kg) | *Chelonia* |
| | Leporidae |
| | Aves |

distribution over the surface were also considered. Along with punctures, pits are the type of tooth mark that provides the most information about the predator, because they are related with the size of the teeth of the animal that chew the piece (Selvaggio, 1994; Domínguez-Rodrigo and Piqueras, 2003). The length and width of the pits and width of the scores were measured in keeping with the approaches of Andrés et al. (2012). In accordance with their method, the data obtained were compared with the results of several previously developed experimental approaches: Selvaggio (1994), Delaney-Rivera et al. (2009), Saladié (2009), Andrés et al. (2012), Rodríguez-Hidalgo et al. (2013), Saladié et al. (2013) and Sala et al. (2014). On the other hand, the identification of percussion notches has been interpreted as an evidence of the anthropic processing of the carcasses (Blumenschine and Selvaggio, 1988).

Levels of ravaging and competition among predators were also calculated taking into account the different approaches based on the analysis of the skeletal profiles. Domínguez-Rodrigo and Organista (2007) propose a model to determine of the degree of carnivore ravaging on an assemblage using MNE. Following this approach, a correlation of the axial:appendicular ratio with the (proximal humerus + distal radius):(distal humerus + proximal radius) ratio was completed in order to measure levels of ravaging on the assemblage.

The epiphysis:diaphysis ratio (Domínguez-Rodrigo et al., 2002) was also calculated. The percentage of change was calculated as described in Marean and Spencer (1991) and Domínguez-Rodrigo et al. (2002). The epiphysis:diaphysis fragment ratio, along with tooth mark frequency (Blumenschine and Marean, 1993), was used to determine different degrees of competition over the assemblage. According to Blumenschine and Marean (1993), low levels of competition are reflected in a low ratio and a high frequency of tooth marks, whereas contexts with high levels of competition also present a lower frequency of tooth marks.

We used a theoretical method developed by Egeland (2008) for measuring competition among carnivores based on axial:appendicular bones and epiphysis:diaphysis ratios. According to Egeland (2008), contexts with low levels of competition are reflected in high results in both ratios, whereas high competition contexts result in ratios near to 0.

Other taphonomic modifications, both biostratinomic and fossil-digenetic, were also analyzed: weathering, trampling, hydric abrasion, oxide staining and root-etching (Behrensmeyer, 1978; Brain, 1981; Shipman, 1981; Lyman, 1994; Cáceres, 2002; Fernández-Jalvo and Andrews, 2003). These modifications were analyzed by presence/absence, except hydric abrasion, that was analyzed following the degrees of rounding and polish developed by Cáceres (2002) (Table 2).

## 4. Results

Seventeen different taxa have been identified (Table 3). Ungulates are the most abundant group, although remains from carnivores and a primate, associated with coprolites belonging to a hyaenid have also been recovered. Shannon-Weaver's diversity Index (2.2) suggests intermediate levels of diversity in the BB inferred ecosystem with the taxa recovered.

The assemblage is mainly represented by dental remains and shaft fragments. Axial skeletal elements are scarce and belong mainly to large animals. The study of the mineral density related to %MAU suggest a minor relationship between the preserved sample and its structural density. Kendall's tau for non-parametric variables suggests a positive and statistically significant relationship for medium-sized ($t > 0.05$; $p < 0.05$) and large ($t > 0.05$; $p < 0.05$) animals. The scarcity of remains belonging to small animals prevents their inclusion in this analysis. As a reduced or ravaged assemblage, it can be classified as a class 4 assemblage as established by Lyman (1994:264).

A total of 397 fracture outlines were analyzed, belonging to 138 shaft fragments. Curved, oblique and smooth (34.4%) and longitudinal, oblique and smooth (17.8%) fracture outlines are the most commonly occurring morphologies (Fig. 3a). Villa and Mahieu (1991) determined that these types of fractures occur on fresh bones. Fractures on dry bones (mainly characterized by transverse delineation and right angles) were only documented on 3.1% of the sample.

The most commonly occurring long bones remains in the assemblage (74.6%) are fragments with less than a quarter of the length and less than a third of the cross-section preserved. On the other hand, a very low percentage of long bones (2.7%) were recovered with complete or near-complete diaphyses (Fig. 3b).

### 4.1. Anthropic and carnivore activity

Although no cut marks have been identified at LM (Pineda et al., 2014), the identification of percussion pits on four bones (the humerus of a bovid and the humerus, femur and metatarsus of a cervid), together with the abundant and fresh lithic technology recovered (Vallverdú et al., 2014; Mosquera et al., 2015), confirms the presence of hominins in the ecological context in which the fossil assemblage was formed.

Tooth marks are the most abundant carnivore-induced modification documented in the assemblage. They have been identified on 36 bones (6.2%), mainly belonging to the appendicular skeleton (68.6%). Taxonomically, the deer remains present a high percentage of tooth marks (34.4%), although several taxa have been affected, including two remains belonging to a carnivore. The tooth marks are concentrated on the diaphyses, because of the relative scarcity of epiphyses (epiphysis:diaphysis ratio $= 0.39$).

Seventy pits have been observed in the LM assemblage. Width measurements are limited to 65 pits, because five of them were identified on the fracture outline. Comparison of the length and width of the pits identified at LM with data related to different carnivores (Fig. 4) showed that the values found at LM are included among the range of modifications produced by hyaenids, ursids and medium-sized and large felids, indicating the intervention of at least one large carnivore.

Scores constitute the other type of tooth marks documented at LM. A minor number of scores has been identified ($n = 25$) and the information they provide is most ambiguous (Domínguez-Rodrigo and Piqueras, 2003). Furthermore, the low number of remains

**Table 2**
Different categories established by Cáceres (2002) for identifying levels of rounding and polish on the surfaces of faunal remains.

| Rounding (R) | Grade | Polish (P) |
|---|---|---|
| No modification | 0 | No modification |
| Rounding in anatomical end and edge breakage detectable between 18 and 50 magnifications | 1 | Brightness zones in anatomical end and edge breakage detectable between 18 and 50 magnifications |
| Rounding affects bone surface, detectable macroscopically | 2 | Brightness zone affect bone surface, detectable macroscopically |
| All bone surfaces is round. Loss original morphology | 3 | Bone is completely bright |

**Table 3**
Taxonomic identification of the faunal remains from La Mina. Non-taxonomically identified remains have been included in a weight-size category or entered as indeterminate. Number of identified specimens (NISP), minimal number of elements (MNE) and minimal number of individuals (MNI) are included.

| Taxa | NISP | MNE | MNI |
|---|---|---|---|
| *Macaca sylvanus* | 1 | 1 | 1 |
| *Cervus elaphus* | 23 | 14 | 1 |
| *Dama* cf. *vallonetensis* | 25 | 13 | 4 |
| *Megaloceros savini* | 5 | 3 | 2 |
| Cervidae indet. | 24 | 4 | – |
| *Equus* cf. *stenonis* | 20 | 15 | 2 |
| Bovini | 3 | 3 | 1 |
| *Hippopotamus antiquus* | 5 | 1 | 1 |
| *Mammuthus meridionalis* | 1 | 1 | 1 |
| *Ursus* sp. | 11 | 10 | 1 |
| *Canis mosbachensis* | 3 | 1 | 1 |
| *Panthera* cf. *gombaszoegensis* | 1 | 1 | 1 |
| *Vulpes* sp. | 1 | 1 | 1 |
| *Lynx* sp. | 1 | 1 | 1 |
| Felidae (large) | 1 | 1 | 1 |
| Carnivora indet. | 1 | 1 | – |
| *Chelonia* | 1 | 1 | 1 |
| Leporidae | 14 | 14 | 1 |
| Aves | 3 | 3 | 1 |
| Very large size | 14 | – | – |
| Large size | 53 | – | – |
| Medium size | 145 | – | – |
| Small size | 55 | – | – |
| Indeterminate | 167 | – | – |
| **Total** | **578** | **89** | **22** |

affected by this type of tooth mark (n < 30) prevents us from making comparisons, as statistical representativeness is not guaranteed (Andrés et al., 2012).

Other modifications produced by carnivores have been identified as well (Fig. 5), among which corrosion caused stomach acids is the most abundant (n = 21). This modification has been documented on the antler of a cervid and three dental remains (including an incisor of a canid), although it mainly affects bone remains, three of which are larger than 40 mm (50, 51 and 87 mm). Excreted and regurgitated bones tend not to exceed 40 mm (Horwitz, 1990). Tappen and Wrangham (2000) determined that only large hyaenids are capable of ingesting and regurgitating remains larger than 40 mm. Pitting (n = 5), licking (n = 5), crenulated edges (n = 1) and two diaphyseal cylinders (the femurs of a cervid and a bovid) have also been identified.

### 4.2. *Ravaging and competition among predators*

In keeping with Blumenschine and Marean (1993), the low epiphysis:diaphysis ratio (0.39) together with the low percentage of tooth marks (6.2%) has been interpreted as the result of high levels of competition during the formation process of LM level 2. The percentage of change (Marean and Spencer, 1991; Domínguez-Rodrigo et al., 2002) yielded relatively high values (Table 4), with the total absence of the epiphyses of the femur and tibia. This ratio in conjunction with the low correlation among the skeletal sample recovered and the mineral density index also suggest high levels of competition, which would have led, according to the interpretation of Faith and Behrensmeyer (2006) and Faith et al. (2007), to the exhaustive consumption of the carcasses by carnivores, including the portions with least amount of fat.

The ratio of axial and appendicular elements (0.16) and the epiphyses to shaft ratio (0.39) also support high levels of competition (Egeland, 2008) (Fig. 6), which is reflected in the scarcity of ribs, vertebrae and epiphyses, as these remains are considered low-survival elements according to Marean and Cleghorn (2003).

### 4.3. *Postdepositional modifications*

Hydric abrasion is one of the most abundant taphonomic modifications in the LM level 2 sample. It has been documented on 51.7% of the remains (n = 299) as rounding and/or polish of the surfaces. In accordance with the degree system established by Cáceres (2002), grade 1 is documented on 86% of the abraded remains (n = 257). This suggests a limited modification of these specimens by transport flows or that the flows were on short distances. Breaks, splinters, and exfoliation have been documented on 329 remains (56.9%), on 117 (22.2%) of which these modifications have been associated with weathering. Generally, the weathering documented is classified as grade 1 as established by Behrensmeyer

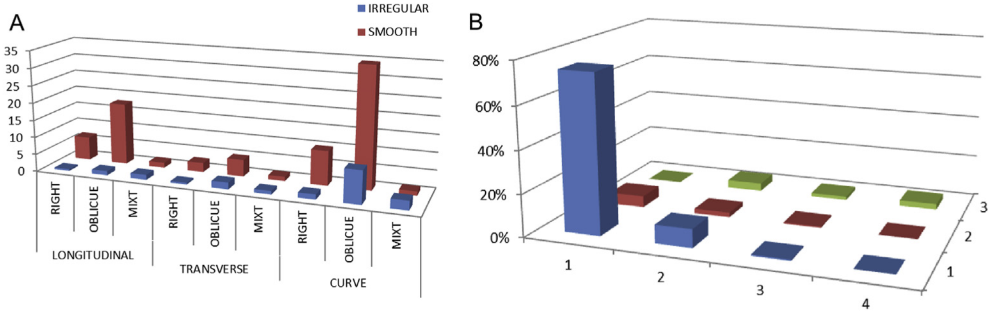

**Fig. 3.** Analyses of the fracturing at La Mina, level 2: (A) analysis of the fracture angle, outline and edge following Villa and Mahieu's (1991) methodology; (B) Analysis of the shaft circumference and length following Bunn's (1983) methodology.

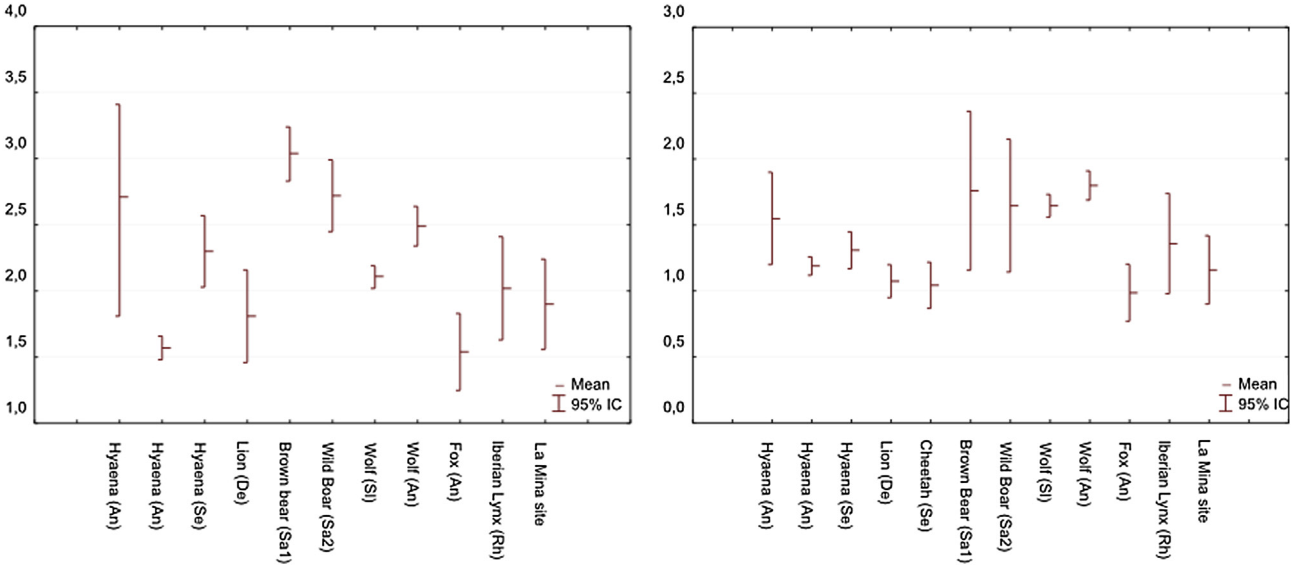

**Fig. 4.** Comparison of the length (left) and width (right) of the pits identified at La Mina with the data presented by Selvaggio (1994) (Se), Delaney-Rivera et al. (2009) (De), Saladié (2009) (Sa2), Andrés et al. (2012) (An), Rodríguez-Hidalgo et al. (2013) (Rh), Saladié et al. (2013) (Sa1) and Sala et al. (2014) (Sl).

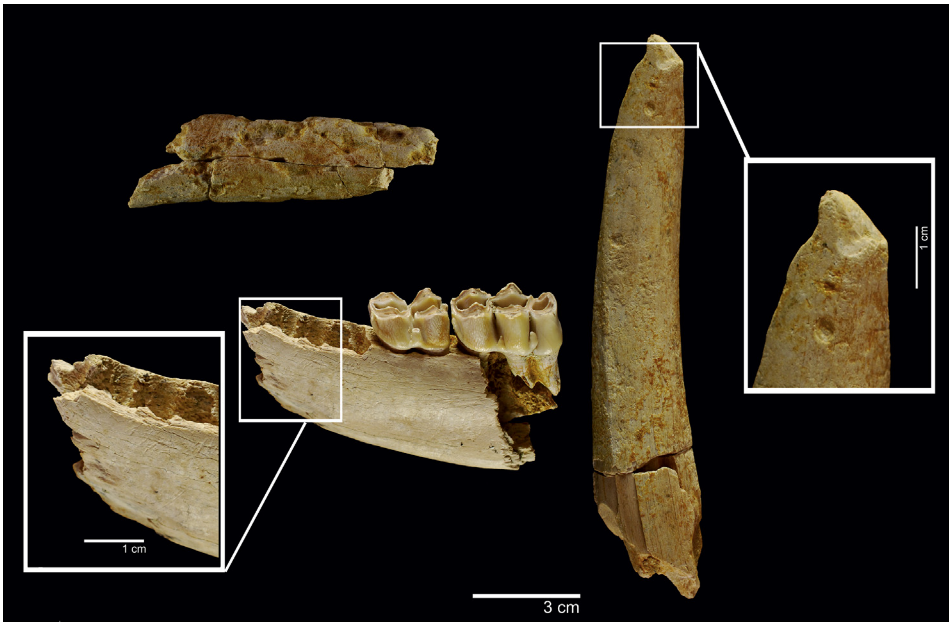

**Fig. 5.** Carnivore activity documented on different bones: Digested bone larger than 8 cm (top, left); Pitting documented on the tibiae of a cervid (right); and Scooping out of the jaw of a cervid (bottom, left); Scale: 3 cm.

(1978) (96.6% of weathered remains). Other degrees of weathering (grades 2, 3 and 4) have been identified on only four remains. Trampling has been documented on 19 remains (3.3%), mostly consisting of striae on the surface, and in only one case a notch.

**Table 4**
Percentage of change of the long bones recovered at La Mina.

| | Sizes 1-2 | Size 3 | Sizes 4-5 |
|---|---|---|---|
| Humerus | – | 75 | 100 |
| Radius-Ulna | – | 50 | 50 |
| Femur | – | 100 | 100 |
| Tibia | – | 100 | 100 |
| Metapodial | 50 | 83.3 | 100 |
| **Total** | **50** | **81.7** | **90** |

Root-etching has been documented on 21.3% of the remains (n = 123) and manganese oxides are documented on 60.9% of the remains (n = 352). The percentage of deformed remains and concretionary or dissolved surfaces is <1%.

## 5. Discussion

The Barranc de la Boella is an open-air archaeopalaeontological site that adds to the body of knowledge of the Iberian Peninsula Lower Paleolithic along with other Early Pleistocene sites such as the lowest levels of Gran Dolina (TD7-TD4) (Parés et al., 2013), especially level TD6.2 because of the abundant anthropic activity recorded there (Carbonell et al., 1999; Saladié et al., 2011), and the

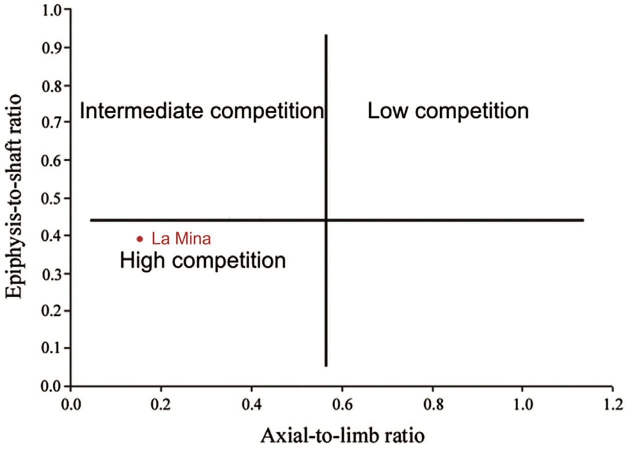

**Fig. 6.** Placement of La Mina on the theoretical model established by Egeland (2008) for measuring levels of competition. High levels of competition have been suggested at the LM site.

lowest levels of Sima del Elefante (TE16-TE7) (Rosas et al., 2001, 2006; Carbonell et al., 2008), both at Sierra de Atapuerca; Barranco León (Toro-Moyano et al., 2013) and Fuente-Nueva 3 (Martínez-Navarro et al., 1997) in the Guadix-Baza Basin; and Vallparadís (Martínez et al., 2010; Duval et al., in press). This increasing number of sites unequivocally confirms the occupation of south-western Europe during the late Early Pleistocene.

Based on the taxonomic variety identified at the BB (Lozano-Fernández et al., 2014; Vallverdú et al., 2014; present paper), the ecological mosaic shaped by the fossil assemblage had to be complex. The presence of hominin groups in the environment should be added to this taxonomic variety, identified through anthropic activity on faunal remains and through the stone tools recovered at the three localities (Vallverdú et al., 2014; Mosquera et al., 2015). The taxa documented at BB mainly inhabited open (horses and bovids) and semi-open (deer) landscapes. However, other taxa belonging to aquatic environments have also been recovered, such as *Hippopotamus antiquus* (Palmqvist et al., 2003; Madurell-Malapeira, 2012), which confirms the presence of large volumes of water in the area. Furthermore, riparian taxa, such as *Macaca sylvanus*, have also been identified. Carnivore remains are scarce, although remains from bone-cracking carnivores (such as *Canis* cf. *mosbachensis*) (Palmqvist et al., 1999) and meat-eating carnivores (such as *Panthera* cf. *gombaszoegensis*) are present. Coprolites belonging to a hyaenid complete the taxonomic variability in this ecological mosaic, which includes animals belonging to every level of the trophic chain. Carnivore activity is the most abundant in the sample. This dataset suggests that BB was set in a landscape in which a great number of taxa lived concurrently, where there were large volumes of water and, probably, high-grade animal resources and raw materials for the production of stone tools by hominin groups.

The skeletal composition, its relationship with the utility index and its mineral density suggest that the assemblage from level 2 of LM must have been lag or ravaged by carnivores, following Lyman's (1994:264) criteria. The presence of different sized remains (including <5 cm), the low number of remains with hydric abrasion and, within this group, the rare identification of marked abrasions, together with the fresh stone tools recovered (Vallverdú et al., 2014) indicate that hydric transport had little importance on the alteration of the assemblage. Therefore, the preserved sample could be the result of carnivore activity (consumption and probably destruction or partial disappearance of bones and/or their portions). As shown in the results of the experiment conducted by Fernández-Jalvo and Andrews (2003), fresh bones are more resistant to the abrasion process than other types of bones and only sand can produce a similar degree of abrasion. The sediment of LM unit II is made up of poorly stratified sands and gravels. Taking into account the low levels of abrasion documented, we suggest that the bones were fresh when abrasion occurred. On the other hand, the low levels of weathering documented at the site suggest a fast burial process.

Although the lithic technology is well preserved, the surfaces of the bones in the sample are heavily altered (Pineda et al., 2014). As a consequence, the modifications caused by carnivores are more well preserved (they are deeper, which facilities their preservation and identification) than the hominin modifications. In this respect, carnivore activity is more frequently documented than hominin activity in the assemblage, although it is impossible to determine which one had a more marked influence on the assemblage through bone surface modifications alone. Therefore, information about the relationships among the different types of predators identified, hominins included, has been obtained through the analysis of the skeletal profiles, considering actualistic and archaeological research (Marean and Spencer, 1991; Marean et al., 1992; Blumenschine and Marean, 1993; Domínguez-Rodrigo et al., 2002; Faith et al., 2007; Egeland, 2008; Saladié et al., 2014). The high rate of disappearance of the epiphyses, the size of the tooth marks, the presence of digested specimens larger than 40 mm and the intensity of some of the modifications produced on the bones point to the intervention of at least one hyaenid (Haynes, 1980, 1983; Tappen and Wrangham, 2000; Delaney-Rivera et al., 2009; Andrés et al., 2012). It is likely that the extensive modifications caused by this agent have masked other modifications produced by smaller carnivores, such as canids, or meat eating carnivores, such as felids, since that the different carnivores accessing the same carcasses is common in open landscapes (Kruuk, 1972; Schaller, 1972; Brain, 1981; Binford, 1983; Blumenschine, 1986; Domínguez-Rodrigo, 1999).

The percentage of remains with evidence of consumption by carnivores is 9.7%. Capaldo (1995) suggests that percentages lower than 15% occur in assemblages with secondary access by carnivores. When secondary access by carnivores is documented, tooth marks on long bones tend to be located on the epiphyses and near epiphyses areas (Blumenschine and Marean, 1993; Blumenschine, 1995; Capaldo, 1997). However, the tooth marks at LM are documented mainly on the diaphyses, indicative of primary access to the carcasses by at least some of the carnivores at the site.

It is common to find evidence of the presence of both hominins and carnivores in the same assemblage in European Early Pleistocene archaeological sites (Martínez-Navarro et al., 1997; Arzarello et al., 2007; Martínez et al., 2010; Saladié et al., 2011, 2014; Espigares et al., 2013; Huguet et al., 2013). Several studies have stressed the importance of understanding levels of competition among predators in archaeological assemblages in order to make palaeoecological inferences related to pressure among predators and habitat selection (Blumenschine and Marean, 1993; Egeland et al., 2004; Faith and Behrensmeyer, 2006; Domínguez-Rodrigo and Organista, 2007; Faith et al., 2007; Egeland, 2008; Saladié et al., 2014). Current research on the Early Pleistocene assemblages from Sierra de Atapuerca defends the high adaptive capacity of these hominin groups within their environment (Saladié et al., 2011, 2014; Huguet et al., 2013). These adaptations, according to these researchers, include the development of cynegetic capacities to obtain prey and meat sharing. In this environment, the Sierra de Atapuerca karstic system may have been used as a refuge where the butchering process and prey consumption could be carried out with lesser risk, reducing the level of competition with other predators (Saladié et al., 2014).

However, open-air assemblages seem to show higher levels of competition. Espigares et al. (2013) defend a high competition context among *Pachycrocuta* and *Homo* for the scavenging and consumption of a *Mammuthus meridionalis* carcass in the Guadix-Baza Basin through the study of the upper archaeological level at Fuente Nueva 3 (FN3). BB was an ecological context more similar to FN3 than to TD6.2 because it is also a fluvial-lacustrine and open-air setting, in which a high variability of taxa would have converged, including both predators and prey.

Egeland et al. (2004) based their work on the presence of modifications on the same remains produced by both hominins and carnivores in order to analyze levels of inter- or independence between the two types of predators. Unfortunately, the poor preservation of the anthropic modifications in level 2 of LM makes this type of research difficult and the study of the relationship between predators is based solely on skeletal profiles.

The survival or disappearance of different skeletal elements and their portions (Blumenschine and Marean, 1993; Faith and Behrensmeyer, 2006; Domínguez-Rodrigo and Organista, 2007; Egeland, 2008) points to a highly competitive environment during the formation process of the deposit. The percentage of change and the low correlation of the mineral density of the remains (Faith and Behrensmeyer, 2006; Faith et al., 2007) suggest a high level of inter- and intra-specific competition among predators. In addition, to the low correlation of the mineral density, a lower %MAU of the axial skeleton compared to the appendicular skeleton, the high presence of diaphyses fragments and the scarcity of the ends of the radius and tibia, as seen at LM, are characteristic of high competition contexts (Faith and Behrensmeyer, 2006).

Data from LM contrast with that from TD6.2, where hominin groups used the karstic system as a refuge and, probably, as protection from the pressure and risk by carnivores (Saladié et al., 2014). We suggest that the use of a space by hominins may be related to the levels of competition observed at different sites, FN3 included. BB and FN3 were probably transit areas during the foraging activities, while TD6.2 was used as a refuge and home base.

Ravaging and competition among predators was measured at Olduvai Gorge for both beds I and II (Domínguez-Rodrigo and Organista, 2007: Egeland, 2008, 2014), both of which are open-air sites like BB. The hominin and carnivore impact on these sites is variable (Leakey, 1971; Bunn, 1982; de la Torre, 2004; Domínguez-Rodrigo et al., 2007; Egeland, 2007; summarized in; Egeland, 2008). For example, at FLK Zinj, although the site was formed in an open-air context, it has been shown that it was in a wooded grassland during the formation of the assemblage and it was used as a central place by hominin groups, and low levels of competition have been inferred (Domínguez-Rodrigo et al., 2010). LM was formed around a fluviodeltaic paleoenvironment, where competition was high and where no occupation was established, which is also supported by the lithic technology sequence (Vallverdú et al., 2014; Mosquera et al., 2015). It is therefore a transit place, where resources, including fresh water, were available.

A correspondence analysis was conducted in order to statistically compare the different levels of ravaging and competition among predators at LM *versus* that at TD6.2 and at several assemblages from Olduvai Gorge (Fig. 7). The different ratios used are presented on Table 5.

The correspondence analysis shows three clear groups. One of them includes TD6.2, BK and FLK 22, three sites interpreted as home bases (Domínguez-Rodrigo et al., 2009, 2010; Saladié et al., 2011) where hominins played a primary role in the accumulation process (Leakey, 1971; Monahan, 1996; Domínguez-Rodrigo et al., 2002, 2007, 2009; 2010; Saladié et al., 2011, 2014). At TD6.2 and FLK 22, studies (Domínguez-Rodrigo and Organista, 2007; Saladié et al., 2014; respectively) suggest a low competition context for carcass processing, while at BK, Egeland (2008) suggests a high competition context during the formation process of the deposit. TK LF and FC West form the second group. Both sites are

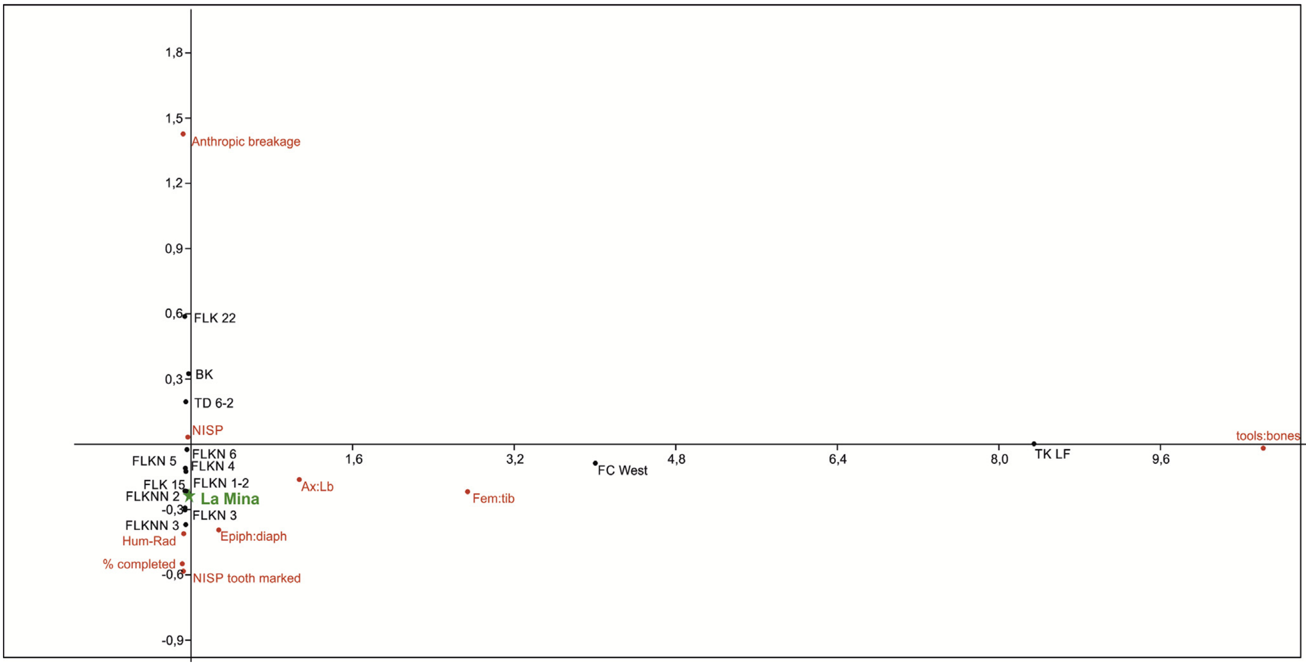

**Fig. 7.** Different ratios and analysis methods to determine the degree of involvement of hominins and carnivores in the assemblage formation (data from Table 5) has been included in the correspondence analysis. DK, HWK E 1-2, HWK E 3-5, MNK and TK UF assemblages have not been included on the plot because of the absence of information about some of the variables included. Hum-Rad = PH + DR:DH + PR ratio; Epiph:Diaph = ephiphysis:diaphysis ratio; Ax:Lb = axial:limb ratio; Fem:Tib = femur:tibia ratio; tools:bones = stone tools:bones ratio. Data origin of both TD6.2 and Olduvai Gorge sites are detailed on Table 5.

**Table 5**
Different ratios and analysis methods to determine the degree of involvement of hominins and carnivores in assemblage formation applied to La Mina, level TD6.2 of Gran Dolina and different sites from beds I and II of Olduvai Gorge. TD6.2 data extracted from Saladié et al. (2014). Olduvai bed I data extracted from the summary by Domínguez-Rodrigo et al. (2007) and Egeland (2008). Olduvai bed II data extracted from Egeland and Domínguez-Rodrigo (2008) and the summary by Egeland (2008). Original data from: Bunn (1982), Blumenschine (1989), Selvaggio (1994), Domínguez-Rodrigo (1996), Monahan (1996), Capaldo (1998), Faith and Behrensmeyer (2006), Dominguez-Rodrigo et al. (2007), Egeland (2007). *DK 2 and 3 data, extracted from Egeland (2007), are presented together, as the lithic industry data (Leakey, 1971) are presented as such. **Manuports are not included.

| | Epiphysis: shaft | % Completed bones | Axial:limb ratio | Femur:i:tibia ratio | HP + RD:HD + RP ratio | NISP | NISP tooth-marked bones | Anthropic breakage (long bones) | Stone tools:bones ratio |
|---|---|---|---|---|---|---|---|---|---|
| La Mina | 0.39 | 2.7 | 0.16 | 1 | 2 | 158 | 36 | 4 | 0.12 |
| TD6.2 | 0.05 | 2.7 | 0.28 | 1.1 | 0.44 | 3373 | 16 | 53 | 0.13 |
| DK 2-3* | – | – | – | – | – | 1732 | 234 | 6 | 0.32 |
| FLKNN 2 | 0.88 | 23.3 | 0.24 | 0.55 | 0.23 | 338 | 53 | 0 | 0 |
| FLKNN 3 | 0.37 | 40 | 1 | 1.25 | 0.54 | 373 | 62 | 0 | 0.03 |
| FLKN 1-2 | 0.46 | 13.8 | 0.35 | 0.58 | 0.31 | 2873 | 510 | 12 | 0.51 |
| FLKN 3 | 0.58 | 14.9 | 0.63 | 0.6 | 0.13 | 902 | 182 | 0 | 0.17 |
| FLKN 4 | 0.89 | 10.1 | 0.36 | 0.9 | 0.22 | 628 | 65 | 0 | 0.09 |
| FLKN 5 | 0.6 | 16.3 | 0.36 | 0.67 | 0.24 | 1193 | 118 | 0 | 0.08 |
| FLKN 6 | 4.8 | 32 | 1.4 | 0.6 | 0.83 | 616 | 8 | 0 | 0.21 |
| FLK 15 | 0.34 | 2.7 | 0.14 | 0.66 | 0.18 | 211 | 33 | 0 | 0.04 |
| FLK 22 | 0.1 | 11.8 | 0.8 | 0.71 | 0.3 | 699 | 61 | 109 | 0.06 |
| HWK E 1-2 | 1.7 | – | 0.71 | – | – | 634 | 3 | 127 | 0.74 |
| HWK E 3-5 | 1.6 | – | 0.73 | – | – | 212 | 28 | 0 | 15.33 |
| MNK | 0.21 | – | 0.33 | – | – | 842 | 15 | 45 | 7.14 |
| FC West | 0.23 | 0 | 0.33 | 2 | 0 | 38 | 3 | 0 | 12.23 |
| TK LF | 0.14 | 0 | 0.4 | 1.7 | 0 | 31 | 0 | 0 | 29.06 |
| TK UF | 0.13 | 0 | 0.36 | 0.5 | – | 59 | 0 | 0 | 38.07 |
| BK | 0.14 | 4.4 | 0.31 | 0.88 | 0.26 | 1444 | 49 | 83 | 2.91 |

characterized by a predominance of stone tools and high levels of competition, although the agent responsible for the accumulation has not been determined (Egeland, 2008). LM and the rest of the sites from Olduvai form the third group. In these assemblages, the influence of the hominins on the deposit accumulation is low or zero, and several studies (Domínguez-Rodrigo and Organista, 2007; Egeland, 2008; present paper) suggest diverse competition contexts. In this regard, the correspondence analysis tends to divide the sites according to the role played by hominins and carnivores in the accumulation process of the deposits, although the inferred levels of competition are diverse. Previously, Egeland (2014) suggested difficulties to compare levels of competition at assemblages with different intensities in the occupations. Some of these assemblages have been defined as vertical dispersion sites (Leakey, 1971) where hominin activity cannot be singled out, such as FLKN 1-2 (Domínguez-Rodrigo and Barba, 2007) and FLKNN 2 (Barba and Domínguez-Rodrigo, 2007). LM should be included in this category, formed through the occurrence of several events that may or may not be related. We have therefore documented several events with or without a relationship.

However, we can infer that the hominins at LM were present in a high competition environment, intra- and/or inter-specific among predators. As Egeland (2008) suggest at BK, hominin access to carcasses at times of high competition can be considered indicative of the high levels of control these groups had over their environment and its resources. These inferences are consistent with previously presented conclusions at other Early Pleistocene sites on the Iberian Peninsula (Saladié et al., 2011, 2012, 2014; Huguet et al., 2013), where a high degree of control over the environment by hominin populations has been suggested.

## 6. Conclusions

This paper presents a zooarchaeological and taphonomic analysis of the macromammal remains recovered from level 2 of the locality of La Mina, dated to ~1 million years. The variability identified in the ecological context inferred at BB suggests that its formation took place in a landscape in which a great number of taxa lived concurrently, where there were large volumes of water and, probably, high-grade animal resources and raw materials for the production of stone tools by hominin groups.

The poor preservation of the bone surfaces at LM has prevented the identification of marks related to butchering processes. However, the stone tools recovered leave no doubt with regard to the hominin presence in the environment. Carnivore activity has also been documented and the intervention of at least one hyaenid identified. The preserved sample could be the result of carnivore ravaging of the original osteological sample. However, this palimpsest is identified as a vertical and horizontal dispersion site, with several events that may or may not be related in a high competition environment.

The anatomical ratios employed suggest high levels of intra or inter-specific competition among predators in a space which hominins shared with other predators. The statistical comparison between levels of competition at different sites is difficult, because the contribution of different agents in the accumulation process of the deposits seems to play a greater role in the distribution of the assemblages. The ability of the hominin groups that inhabited BB to obtain resources in contexts of high competition (probably sharing the space and competing for animal resources with a wide range of carnivores) suggests that these hominins had a high degree of control over the territory and the resources it contained, as Egeland (2008) suggests at BK and extensive previous research has shown at different sites dating to the Early Pleistocene.

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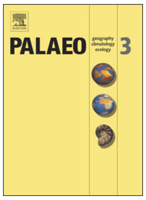

# Changing competition dynamics among predators at the late Early Pleistocene site Barranc de la Boella (Tarragona, Spain)

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## ABSTRACT

The late Early Pleistocene site Barranc de la Boella provides an unparalleled opportunity to assess the context of the activities of the hominin populations that inhabited the Iberian Peninsula at 1 Ma. Recently, strong evidence for access to mammoth meat has been described at the Pit 1 locality. At the la Mina and el Forn excavation areas, little evidence exists for the anthropogenic processing of macromammals. However, the presence of humans is recorded, and the available evidence suggests these populations had access to several interesting resources. By analysing and comparing five separate assemblages at Barranc de la Boella, we assess the fluctuating presence of hominins and carnivores and the levels of competition among predators in each assemblage. Our analysis reveals different levels of competition intensity during the formation of assemblages when hominin groups were present, as evidenced by the abundance and diversity of stone artefacts. The analyses of skeletal component ratios indicate several competitive contexts, and the greatest presence of hominin groups is associated with the most competitive scenarios. The palaeoenvironment at Barranc de la Boella was rich in resources that hominins could exploit. The presence of hominin and carnivore groups appears to have been higher in levels with more inferred competition. This scenario supports prior research that concludes that carnivore abundance and highly competitive contexts were two constants in the lives of these hominin groups. Thus, the criteria determining whether hominins could inhabit a given landscape were most likely related to the presence or absence of resources, such as animal resources, water and raw materials, rather than the dynamics of the carnivore populations, to which the hominins were able to become habituated.

## 1. Introduction

Zooarchaeological studies of Early Pleistocene sites have been conducted to evaluate four primary topics related to early hominin populations: their diet, their mode for obtaining animal resources, their social component in acquiring and maintaining resources, and their adaptation to the environment and relationships with other agents (e.g., Isaac, 1971; Leakey, 1971; Binford, 1981; Brain, 1981; Blumenschine, 1986; Bunn and Kroll, 1986; Stanford and Bunn, 2001; Egeland et al., 2004; Faith and Behrensmeyer, 2006; Domínguez-Rodrigo et al., 2007a; Faith et al., 2007; Egeland, 2008; Rodríguez-Gómez et al., 2016a; Saladié et al., 2014).

Meat was an important resource in the diet of early hominin groups, and this dietary preference affected factors such as brain expansion and social organization (e.g., Aiello and Wheeler, 1995; Stanford and Bunn, 2001; Ungar, 2006; Bunn et al., 2016). Consequently, these populations had to compete with other predators for access to these resources. Competition is the interaction between two or more individuals that results in reducing the fitness of at least one of the individuals. This may occur between members of the same (intraspecific) or different (interspecific) species and may be confrontational when it occurs directly or exploitative when the competitors are competing for the same resource (Wiens, 1989). For large carnivores, interactions between species

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profoundly affect the natural population dynamics and the structure of communities (Périquet et al., 2015).

Some researchers have suggested that the daily life of early hominin groups was heavily conditioned by competition with other large carnivores and that access to mammal carcasses was limited to carrion abandoned by lions and/or hyenas (Binford, 1981; Blumenschine, 1986; Marean, 1989; Turner, 1992; Martínez-Navarro and Palmqvist, 1995; Arribas and Palmqvist, 1999). However, other researchers have suggested that the meat acquisition strategies of these populations were sufficiently developed in these early periods, both in Africa and Europe, to allow these groups to acquire carcasses directly by hunting (Domínguez-Rodrigo, 1997; Domínguez-Rodrigo et al., 2007a, 2010a; Saladié et al., 2011, 2014; Huguet et al., 2013) and/or confrontational scavenging (Huguet et al., 2013).

Several methods have been employed to infer the relationships among hominins and large carnivores in past and present ecosystems (Egeland et al., 2004; Faith and Behrensmeyer, 2006; Domínguez-Rodrigo and Organista, 2007; Faith et al., 2007; Egeland, 2008; Rodríguez-Gómez et al., 2016a). Recently, Rodríguez-Gómez et al. (2016a) developed a mathematical model to quantify the available trophic resources demanded by different species of carnivores and, on that basis, measured competition intensity in the carnivore guild. This method has been applied in Orce Basin and Atapuerca Gran Dolina (TD6-2), two early Pleistocene assemblages on the Iberian Peninsula. Their results show that humans successfully exploited the Atapuerca ecosystems at different levels of competition intensity, inferring a low degree of competition in the TD6-2 assemblage (Rodríguez-Gómez et al., 2013). In contrast, for the open-air site of Orce Basin, they inferred high levels of competition (Rodríguez-Gómez et al., 2016b).

From another perspective, the interactions or relationships among large predators, including hominins, over the same carcasses have been evaluated based on the frequency and distribution of carnivore and anthropogenic modifications or signals. On one hand, some methods are based on the frequency and distribution of certain elements, such as percussion marks and hominin and carnivore tooth marks (Domínguez-Rodrigo, 1997; Capaldo, 1998; Lupo and O'Connell, 2002; Domínguez-Rodrigo and Piqueras, 2003; Saladié et al., 2014). On the other hand, Egeland et al. (2004) proposed quantifying the surface modifications produced by hominins and carnivores on the same bones to analyse grades of independence or interdependence among these predators during their contribution to the formation of archaeological deposits. Interdependence is understood by Egeland et al. (2004: 345) as "*the utilization by hominids and carnivores of the same carcass at any stage of assemblage formation*" with a variety of levels of overlap in assemblage formation from independent (when there is no overlap between agents in the assemblage formation process) to fully interdependent (when both agents overlap across the entire archaeological sequence of an assemblage). In this approach, the co-occurrence of modifications produced by both agents on the same bones in assemblages in which hominins and carnivores acted independently should be >1%. However, in assemblages with a high degree of interdependence, the percentage should be approximately 15% (Egeland et al., 2004).

Marean and colleagues (Marean and Spencer, 1991; Marean et al., 1992) observed that carnivores differentially modify bones and their portions, resulting in a partial skeletal representation that is characterized by the loss of axial bones and epiphyses. Based on these observations, Blumenschine and Marean (1993), for example, proposed alternative methods for understanding the intensity of carnivore activity on assemblages based on the absence of axial bones and epiphyses to evaluate the degree of ravaging in assemblages. Selvaggio (1994b) also noted that the percentage of preserved long-bone epiphyses increases when competition decreases. In the last decade, these observations have been validated, demonstrating that it is possible to infer the level of competition among predators (hominin versus carnivores, as well as the amount of predators in the same environment) in ecosystems. This process is based on the skeletal ratios that result from the intensity of carcass exploitation (Faith and Behrensmeyer, 2006; Domínguez-Rodrigo and Organista, 2007; Faith et al., 2007; Egeland, 2008), with an increasing number of complete bones that survive scavenging by carnivores in taphosystems with lower densities of carnivores and competition in a biotope (Capaldo, 1997).

Recent interpretations of the Early Pleistocene sites of Olduvai Bed I indicate a need to identify the nature of these accumulations to highlight the importance of foraging for these hominin groups and to conduct additional research on such activities (Domínguez-Rodrigo et al., 2007a). In this paper, we present an analysis of five different assemblages at the Early Pleistocene site Barranc de la Boella (BB) (Tarragona, Spain). Our main goals were to determine the levels of competition among predators during the formation of each level and their relationship to the presence of hominin groups.

Bone surfaces at BB are poorly preserved because they have been heavily altered by leaching and surface marks (Pineda et al., 2014), preventing the preservation and identification of most hominin- and carnivore-imparted bone surface modifications and related studies. However, a model to assess the level of competition among predators based on the analysis of skeletal ratios has recently been used at BB, at the site of la Mina, and has been shown to be a useful tool for these types of inferences (Pineda et al., 2015). This work has demonstrated that the hominin populations at BB existed in highly competitive conditions. The application of this model to different archaeological levels within BB should allow us to compare the dynamics of predators in a same ecosystem at different times and to infer whether the carnivore abundance was a critical factor for the presence of these hominin populations in the landscape. Our hypothesis is that carnivore abundance and competition was not a significant limitation for hominin groups.

## 2. Barranc de la Boella

Barranc de la Boella (BB) is an open-air archaeo-palaeontological site that formed in a fluvio-deltaic sedimentary environment. BB is located in an active ravine in the town of la Canonja (Tarragona) in the north-eastern corner of the Iberian Peninsula and is 6 km from the Mediterranean coast.

BB consists of a 9-m-thick sedimentary succession that contains 6 lithostratigraphic units, which have been described in detail by Vallverdú et al. (2014) (Fig. 1A–B). To date, excavation has occurred on three different sites, sharing the same lithostratigraphic units: Pit 1 (P1), with an excavated area of 13 $m^2$; el Forn (EF), with an excavated area of 68 $m^2$ near Pit 1; and la Mina (LM), with an excavated area of 40 $m^2$ and located 180 m from P1. Lithostratigraphic Unit II is the richest in terms of archaeo-palaeontological fossil abundance among the three sites. This unit is 2 m thick and contains poorly stratified sand and gravel in Pit 1 and el Forn and massive sand in la Mina (Vallverdú et al., 2014). Units II and III has recently been dated to slightly less than one million years old (0.96–0.781 Ma) in the 3 pits, based on biostratigraphy, palaeomagnetism and cosmogenic nuclides dates (Lozano-Fernández et al., 2014; Vallverdú et al., 2014).

The three sites excavated at BB are taxonomically diverse and include >20 taxa. The palaeoecological context at BB corresponds to a rich ecosystem with large water bodies, open areas and a nearby riparian forest (Lozano-Fernández et al., 2014; Vallverdú et al., 2014; Pineda et al., 2015). Archaeological materials from P1 have been studied recently by Mosquera et al. (2015). The exploitation of a *Mammuthus meridionalis* carcass has been described for P1 level II.2 and was spatially associated with 125 lithic artefacts, including one pick (Vallverdú et al., 2014; Mosquera et al., 2015), reflecting a single-use butchering site according to the classification of Isaac (1978).

Three archaeostratigraphic levels have been identified at LM Unit II (Fig. 1C–D). Level 2, which ranges between 30 and 65 cm, contains the most remains, including fauna ($n = 578$), lithic artefacts ($n = 64$) and coprolites ($n = 204$), and is the focus of our analyses (for additional

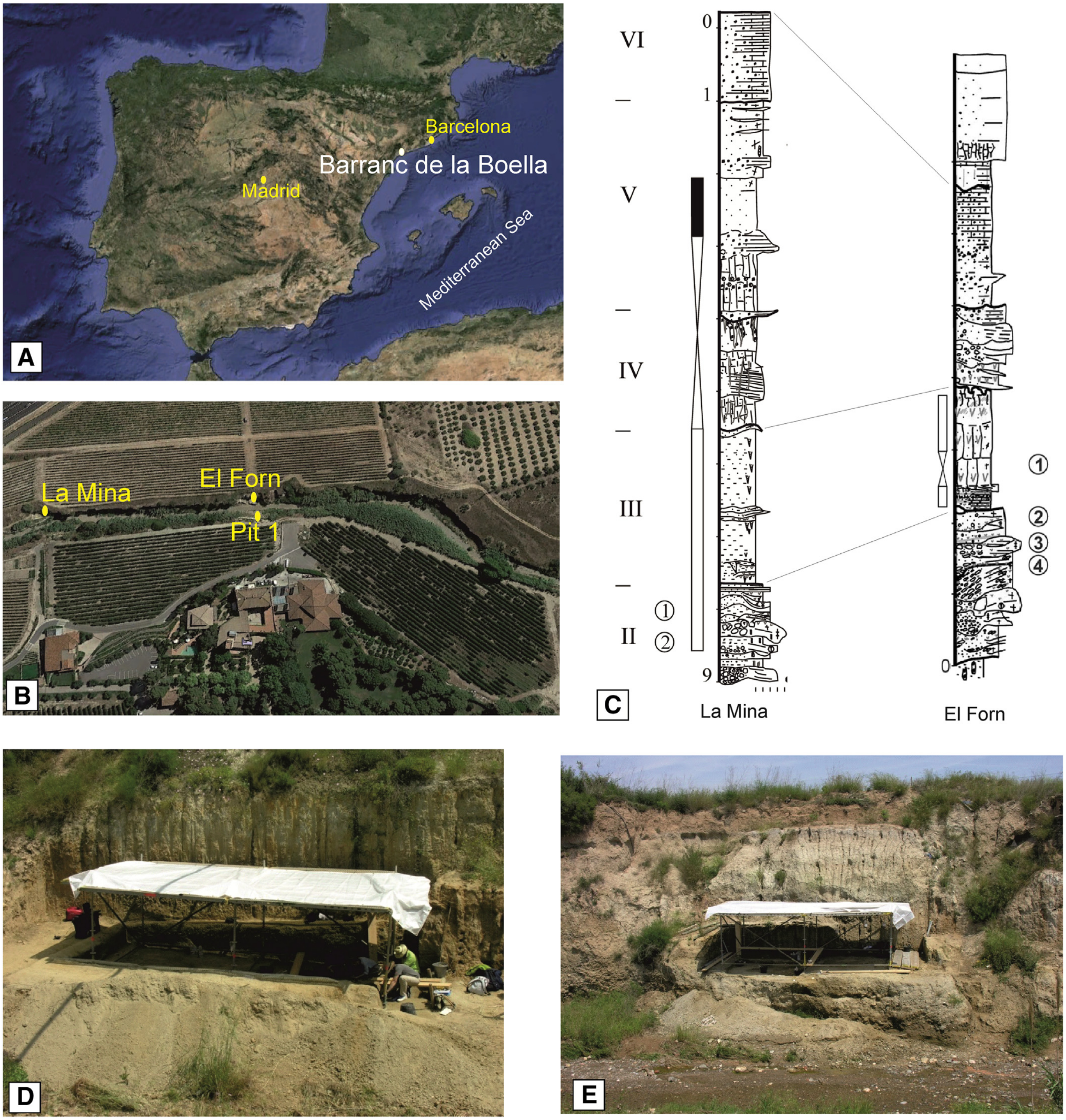


**Fig. 1.** Barranc de la Boella site: A) Location of the Barranc de la Boella site on the Iberian Peninsula; B) Panoramic view of Barranc de la Boella; C) View of the LM and EF sequences; D) Excavated area at the la Mina site; E) Excavated area at the el Forn site.

details, see Pineda et al., 2015, Fig. 2). LM Unit II is composed of poorly stratified massive sand.

In the EF succession, Unit II consists of poorly stratified gravels and sands, and Unit III consists of massive mud (Fig. 1C and E). Therefore, the position and profile of the remains were used to verify the identified archaeo-palaeontological levels (Rosas et al., 2015). In total, seven levels have been recognized at EF (1–7, from top to bottom), of which the upper four (EF1 to EF4) are the most fossiliferous levels included in the present paper (Fig. 2). EF1, which ranges between 20 and 50 cm, belongs to Unit III, whereas EF2 to EF7 belong to Unit II (Vallverdú et al., 2014). EF2 ranges between 25 and 45 cm, EF3 between 10 and 20 cm and EF4 between 20 and 45 cm. For EF, this study analysed a total of 177 archaeo-palaeontological remains from EF1, 171 remains from EF2, 134 remains from EF3 and 237 remains from EF4. Additionally, excavation recovered 66 artefacts from EF2, 22 artefacts from EF3 and 7 artefacts from both EF1 and EF4 (Mosquera et al., 2016).

Broadly, the three sites exhibit a similar lithic technological record in terms of composition, knapping methods and the differential use of different locally sourced raw materials (Mosquera et al., 2016). The primary difference among the sites is the presence of two large cutting tools at P1 and EF, which are absent at LM (Vallverdú et al., 2014; Mosquera et al., 2016).

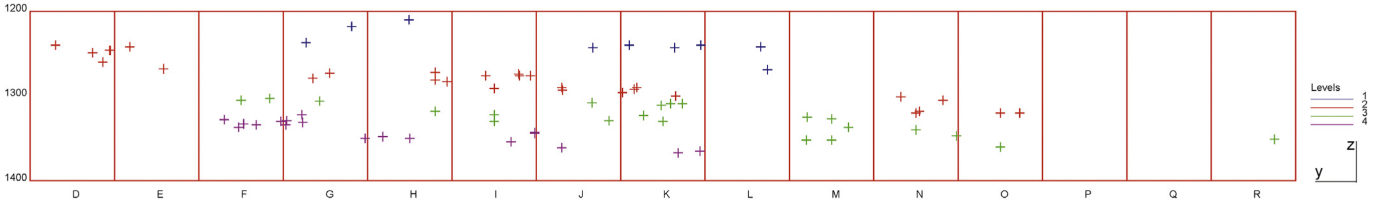


**Fig. 2.** Archaeostratigraphic levels identified at el Forn and included in this analysis (1 to 4). Levels 5–7 contain few remains and are not documented in this section.

## 3. Methods

This study included LM level 2 (LM2) and EF levels 1 to 4 (EF1 to EF4) because they contain the most extensive archaeo-palaeontological assemblages in which a hominin presence has been clearly identified through lithic artefacts (Vallverdú et al., 2014; Mosquera et al., 2016). To measure the relative abundance of material in each level, the number of remains per m$^2$ (nr/m$^2$) was calculated for each level, accounting for differences in the thickness of each deposit.

The analysis of faunal remains includes all remains that were larger than 2 cm. Estimates of the Number of Identified Specimens (NISP), the Minimal Number of Elements (MNE), the Minimal Number of Individuals (MNI) and the Minimal Animal Units (MAU) were calculated (Brain, 1981; Binford, 1984; Gayson, 1984). Non-identified remains were grouped according to bone type and weight-size categories (Table 1).

The mineral density of the bones was used to evaluate the integrity of a sample (Lam et al., 1999). Spearman's rho was used to determine the statistical correlation of the variables. Bone density was tested against differences in the degree of preservation of the anatomical parts for major limb bone ends based on the approach developed by Palmqvist and Arribas (2001) and Palmqvist et al. (2011). Log-log regressions for patterns of survival/destruction of proximal and distal epiphyses of %MAU were estimated for medium-sized carcasses in terms of their marrow content from data from modern caribou (Binford, 1978) and large-sized carcasses in terms of their fat content from data from modern bison (Emerson, 1993).

The fragmentation of long bones both in length (FRL) and in cross section (FRS) was documented based on the method of Bunn (1983) modified by Villa and Mahieu (1991), in which FRL refers to the per cent of the length preserved (1 ≤ 25%; 2 = 25–50%; 3 = 50–75%; 4 ≥ 75%) and FRS refers to the per cent of the circumference preserved (1 ≤ 33%; 2 = 33–66%; 3 ≥ 66%). The analysis of the edge of fractures of the limb bones was conducted according to the methods of Villa and Mahieu (1991). The surfaces of all remains were analysed with a stereoscope (OPTHEC 120 HZ with magnification between 7× to 40×). The main carnivore-produced modifications that were identified are described as pits and scores according to Maguire et al. (1980) and Binford (1981). Other carnivore-produced modifications include alteration by digestion acids, pitting, furrowing, scooping out, crenulated edges and shaft cylinders (Haynes, 1980; Maguire et al., 1980; Binford, 1981; Brain, 1981; Horwitz and Smith, 1988; Blumenschine, 1995). The pit dimensions were compared with the results from actualistic research (Selvaggio, 1994a; Delaney-Rivera et al., 2009; Andrés et al., 2012; Rodríguez-Hidalgo et al., 2013; Saladié et al., 2013). Anthropogenic butchering of the carcasses was identified by the presence of percussion pits, which were recognized based on the criteria of Blumenschine and Selvaggio (1988).

**Table 1**
Weight-size categories established for non-identified specimens and taxa included in each one.

| Weight-size categories | Included taxa |
|---|---|
| Very large sized<br>>1000 kg | *Mammuthus meridionalis* |
| | *Hippopotamus antiquus* (adult) |
| | *Stephanorhinus hundsheimensis* |
| Large sized<br>(300–1000 kg) | *Megaloceros savini* |
| | Bovini |
| | *Hippopotamus antiquus* (immature) |
| | *Equus* sp. (adult) |
| Medium sized<br>(100–300 kg) | *Cervus elaphus* |
| | *Equus* sp. (immature) |
| | *Ursus* sp. |
| | *Panthera* cf. *(onca) gombaszoegensis* |
| | Felidae (large sized) |
| Small sized<br>(10–100 kg) | *Macaca sylvanus (florentina)* |
| | *Dama* cf. *vallonetensis* |
| | *Canis* cf. *mosbachensis* |
| | *Vulpes* sp. |
| | *Lynx* sp. |
| | *Sus* sp. |
| | *Castor* sp. |
| Very small sized<br>(<10 kg) | Chelonia |
| | Leporidae |
| | Aves |

Archaeological deposits should be interpreted as palimpsests, i.e., vertically and horizontally dispersed deposits in which isolated and independent events are sometimes singled out (Bailey, 2008; Domínguez-Rodrigo et al., 2010a). Domínguez-Rodrigo et al. (2010a) identified an isolated and independent event in a palimpsest based on the stratigraphic correlation of the remains, and the results were supported by the homogeneity of the modifications present on different skeletal elements. We used these criteria to identify the remains possibly belonging to an individual: a horse in the EF1 assemblage and a bear in the LM2 assemblage.

These vertically and horizontally dispersed deposits are also useful for studying the level of competition among predators and the degree of ravaging in ancient ecosystems based on the resulting skeletal profiles (Domínguez-Rodrigo et al., 2007a; Egeland, 2008, 2014; Saladié et al., 2014). Epiphysis deletion has been defended as a useful method for calculating carnivore ravaging. Therefore, the epiphysis-to-shaft ratio (Blumenschine and Marean, 1993; Domínguez-Rodrigo et al., 2002) was calculated from the NISP of green-broken bones. The epiphysis-to-diaphysis fragment ratios and tooth-mark frequencies (Blumenschine and Marean, 1993) were used to determine different levels of competition. Based on the methods established by Faith and Behrensmeyer (2006) and Faith et al. (2007), the %MAU of limb ends was correlated with mineral density to infer competition levels in the ecological contexts of the different assemblages analysed in the present study. The MNE of limb bones was calculated for each portion (following Faith et al., 2007: 2032), including diaphyses, which were the most represented limb bone elements. As epiphyses were relatively uncommon, the percentage of change was calculated based on the method of Marean and Spencer (1991) and modified by Domínguez-Rodrigo et al. (2002) to gain insight into the epiphysis destruction process. Finally, the theoretical method of Egeland (2008) was used to measure competition among predators based on the relationships between the axial-to-appendicular ratio and the epiphysis-to-shaft ratio (NISP).

We also documented the presence of other taphonomic modifications. Weathering and water abrasion were analysed based on the stages that were established by Behrensmeyer (1978) and Cáceres (2002). The presence or absence of other modifications (e.g., trampling, manganese oxide stains, surface dissolution, root-etching and deformation) was also documented (Brain, 1981; Shipman, 1981; Fernández-Jalvo, 1992; Lyman, 1994).

Finally, a Correspondence analysis and a Hierarchical Clustering analysis were conducted in order to know how the different assemblages are grouped according to the ratios included in our analyses.

## 4. Results

### 4.1. La Mina, level 2 (LM2)

In total, 578 faunal remains from LM2 have been analysed, and they represent 27 taxa categories including 15 species (Table 2), including remains from carnivores, ungulates and a primate, as well as hyaenid coprolites. A taphonomic study of LM2 was recently published by Pineda et al. (2015). These results have been expanded and updated in the present paper.

The density of the remains is 17.1 nr/m$^2$. The samples are primarily bones, most of which belong to the appendicular skeleton, with rare axial elements. An ulna and several metatarsus and phalanges of *Ursus* sp. were recovered and were most likely from an individual. The correlation of the mineral density of the bones to the %MAU of the preserved sample suggests a low-to-moderate relationship between these variables. The Spearman's rho value suggests a small, positive, statistically significant relationship between the preserved remains and their structural density for medium (rho = 0.44; $p \leq 0.01$) and large (rho = 0.21; $p \leq 0.05$) animals (Table 3). The scarcity of small animal remains at la Mina prevents using this type of analysis for small animals.

A small positive non-statistically significant relationship exists between the major long bone epiphyses recovered at LM2 and their marrow content for medium-sized animals (Fig. 3) ($r = 0.15$; $p \geq 0.05$). For large-sized animals, this relationship for fat content is negative and statistically significant ($r = -0.93$; $p \leq 0.01$). According to Palmqvist and Arribas (2001), this pattern indicates that the skeletal portions that are better represented in the assemblage are those that have lower marrow contents.

**Table 3**
Correlations of mineral density for the various weight categories with %MAU in different levels of La Mina and El Forn. Spearman's rho values and statistical significance are presented.

| Site | Weight category | Spearman's rho | *p* |
|---|---|---|---|
| LM2 | Medium | 044 | <0.001 |
| | Large | 0.21 | <0.005 |
| EF1 | Small | 0.12 | >0.05 |
| | Medium | 0.23 | <0.05 |
| | Large | 0.20 | <0.05 |
| EF2 | Large | 0.15 | >0.05 |
| EF3 | Medium | 0.34 | <0.001 |
| | Large | 0.24 | <0.05 |
| EF4 | Medium | 0.32 | <0.001 |
| | Large | 0.19 | >0.05 |

Fig. 4 illustrates the MNE of the limb bones recovered at BB and shows that there is a total absence of humeri and tibiae epiphyses at LM, with scarce representation for radii and femora and major presence of metapodials.

The taphonomic modifications identified in LM2 are listed in Table 4. Pineda et al. (2015) concluded that LM2 represents a reduced or ravaged assemblage based on the criteria of Lyman (1994: 364). This assemblage contains a low percentage of water abraded remains and an almost complete absence of high grades of water abrasion, which indicates a low degree of remain modifications by low-intensity water flows. In addition, the assemblage contains a remarkably low percentage of weathered bones (22.2%), most of which are classified as stage 1 (Behrensmeyer, 1978), indicating rapid burial of the samples. Among the modifications identified as either present or absent, oxide coating (60.9%) and root etching (21.3%) are the most abundant, whereas trampling (3.3%) and the dissolution and deformations of bone surfaces (<1% in both cases) are rare.

A total of 297 fracture outlines were analysed (Fig. 5A). Among these, 52.2% are characterized by longitudinal or curve fractures with an oblique angle and a smooth texture, which occur when a fresh bone is broken (Villa and Mahieu, 1991). In this sample, fragmentation

**Table 2**
Quantification of the remains that were recovered from LM2 and EF1 to EF4. When possible, identified non-taxonomic remains were included in weight-size categories.

| Taxa | LM2 | EF1 | EF2 | EF3 | EF4 |
|---|---|---|---|---|---|
| *Macaca Sylvanus (florentina)* | 1/1/1 | | | | |
| *Mammuthus meridionalis* | 1/1/1 | | 1/1/1 | 1/1/1 | 6/5/1 |
| *Hippopotamus antiquus* | 5/1/1 | 1/1/1 | 5/2/1 | 6/4/2 | 12/10/2 |
| *Stephanorhinus hundsheimensis* | | 2/2/1 | 3/2/1 | 3/2/1 | 7/4/1 |
| *Cervus elaphus* | 23/14/1 | 4/3/1 | 6/4/1 | 17/13/2 | 7/5/2 |
| *Dama* cf. *vallonetensis* | 25/13/4 | 17/8/2 | 7/5/2 | 1/1/1 | 6/4/2 |
| *Megaloceros savini* | 5/3/2 | 3/2/1 | 1/1/1 | 1/1/1 | 3/3/1 |
| *Cervidae* indet - Medium/small sized | 24/4/– | 16/2/– | 5/–/– | 6/1/– | 13/5/1 |
| *Equus* sp. | 20/15/2 | 31/12/2 | 17/7/2 | 10/8/1 | 15/14/3 |
| Bovini | 3/3/1 | | 1/1/1 | 1/1/1 | 2/2/1 |
| *Sus* sp. | | 1/1/1 | | | |
| *Castor* sp. | | | | | 1/1/1 |
| *Ursus* sp. | 11/10/1 | | | | 1/1/1 |
| *Panthera* cf. (*onca*) *gombaszoegensis* | 1/1/1 | | | | |
| *Canis* cf. *mosbachensis* | 3/1/1 | | | | |
| *Vulpes* sp. | 1/1/1 | | | | 1/1/1 |
| *Lynx* sp. | 1/1/1 | | | | |
| Felidae (large) | 1/1/1 | | | | |
| Carnivora indet | 1/1/– | | | | 1/–/– |
| Chelonia | 1/1/1 | | | | |
| Leporidae | 14/14/1 | | | 1/1/1 | |
| Aves | 3/3/1 | 1/1/1 | 1/1/1 | 1/1/1 | |
| Total (NISP/MNE/MNI) | **144/89/22** | **76/32/10** | **47/24/11** | **48/34/12** | **75/55/17** |
| Very large sized | 14/–/– | 8/–/– | 4/–/– | 4/–/– | 13/–/– |
| Large sized | 53/–/– | 30/–/– | 34/–/– | 11/–/– | 42/–/– |
| Medium sized | 145/–/– | 29/–/– | 27/–/– | 36/–/– | 43/–/– |
| Small sized | 55/–/– | 6/–/– | 7/–/– | 9/–/– | 12/–/– |
| Indeterminate | 167/–/– | 28/–/– | 52/–/– | 26/–/– | 52/–/– |
| Total (NR) | **578** | **177** | **171** | **134** | **236** |

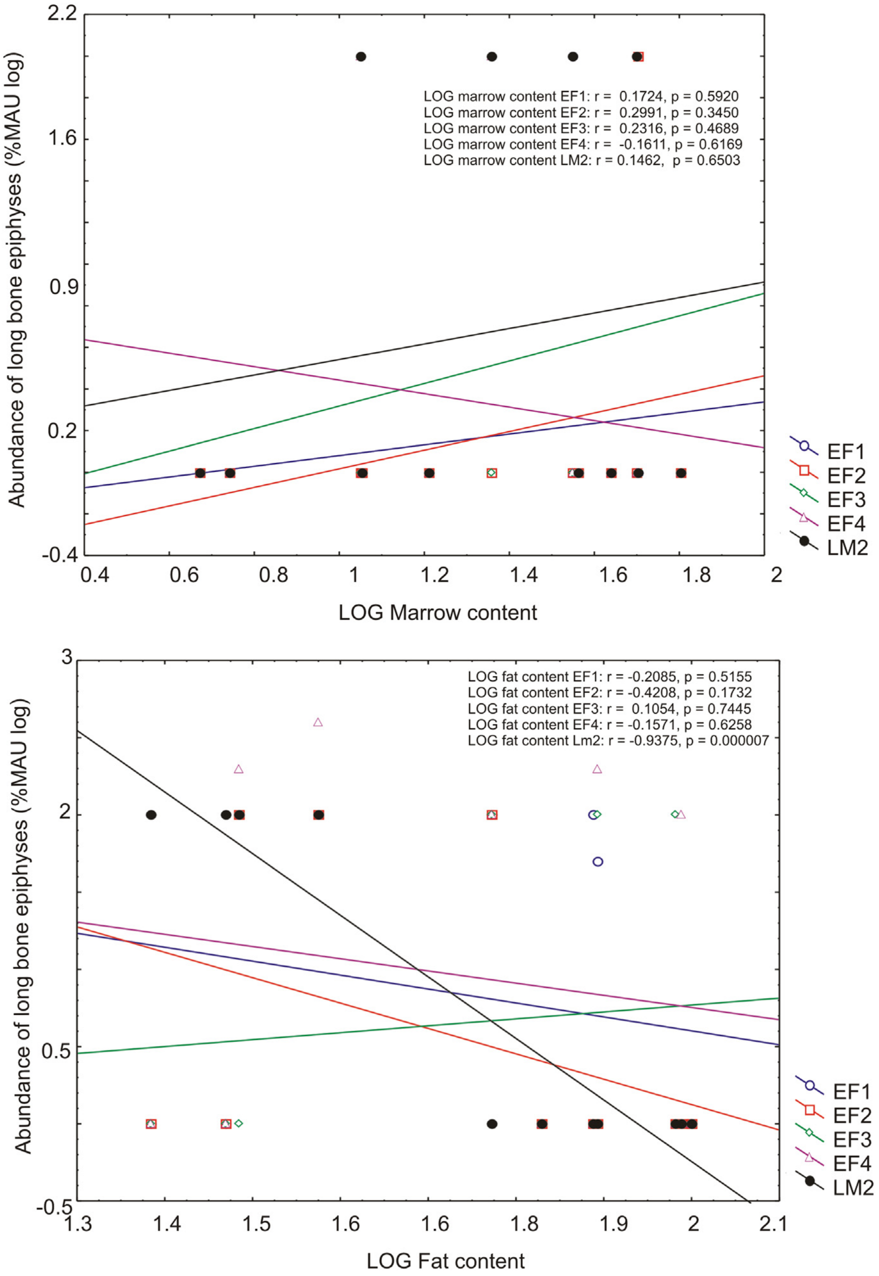


**Fig. 3.** Regression graphs of the abundance of limb bone epiphyses for medium-sized (top) and large-sized animals (bottom) versus mean marrow content based on the %MAU logarithm. Data for the medium-sized animals are from modern caribou (Binford, 1978), and the data for large-sized animals are from modern bison (Emerson, 1993). MNE for medium-sized animals: LM2 = 4; EF1 = 1; EF2 = 1; EF3 = 3; EF4 = 2. MNE for large-sized animals: LM2 = 4; EF1 = 9; EF2 = 3; EF3 = 4; EF4 = 11.

is high (Fig. 5B), with 74.6% of remains having a 1:1 ratio (Bunn, 1983; Villa and Mahieu, 1991), and only 4.3% of the limb bones having a complete or near-complete shaft (ratios of 4:3 and 3:3).

Percussion pits were detected on four remains (one humerus of a bovid and one humerus, one femur and one metatarsus of a cervid), indicating that hominins had access to some of the carcasses. Cut marks were not identified at LM2 due to the poor preservation of the bone surfaces due to chemical alterations (Pineda et al., 2014). The presence of hominins is based on the lithic artefacts recovered at the site (the ratio of stone tools to bone is 0.14) (Vallverdú et al., 2014; Mosquera et al., 2016).

Carnivore tooth marks were identified on 36 remains (6.2%). A comparison of the dimensions of the pits from LM2 with experimental data (Selvaggio, 1994a; Delaney-Rivera et al., 2009; Andrés et al., 2012; Rodríguez-Hidalgo et al., 2013; Saladié et al., 2013) indicates that at least one large carnivore intervened at the site (Fig. 6). Analogous observations suggest the presence of hyaenid activity at LM2 based on the high degree of epiphysis disappearance, the size of the pits, the presence of digested bones larger than 4 cm (Tappen and Wrangham, 2000) and the intensity of several of the identified carnivore-induced modifications, such as a shaft cylinder in one bovid femur. However, we cannot exclude the activity of small- and medium-sized predators.

The percentage of change following Domínguez-Rodrigo et al. (2002) indicates that there was a high degree of epiphysis disappearance (83%) in LM2 (Table 5). A high but non-significant correlation exists between the %MAU of limb ends and the mineral density for large carcasses ($r^2 = 0.61$; $p \leq 0.05$) at LM2 (Table 6). According to Faith et al. (2007), highly positive and significant results are expected in lower competition settings. However, significant correlations can be found when no such correlation exists, related to the small

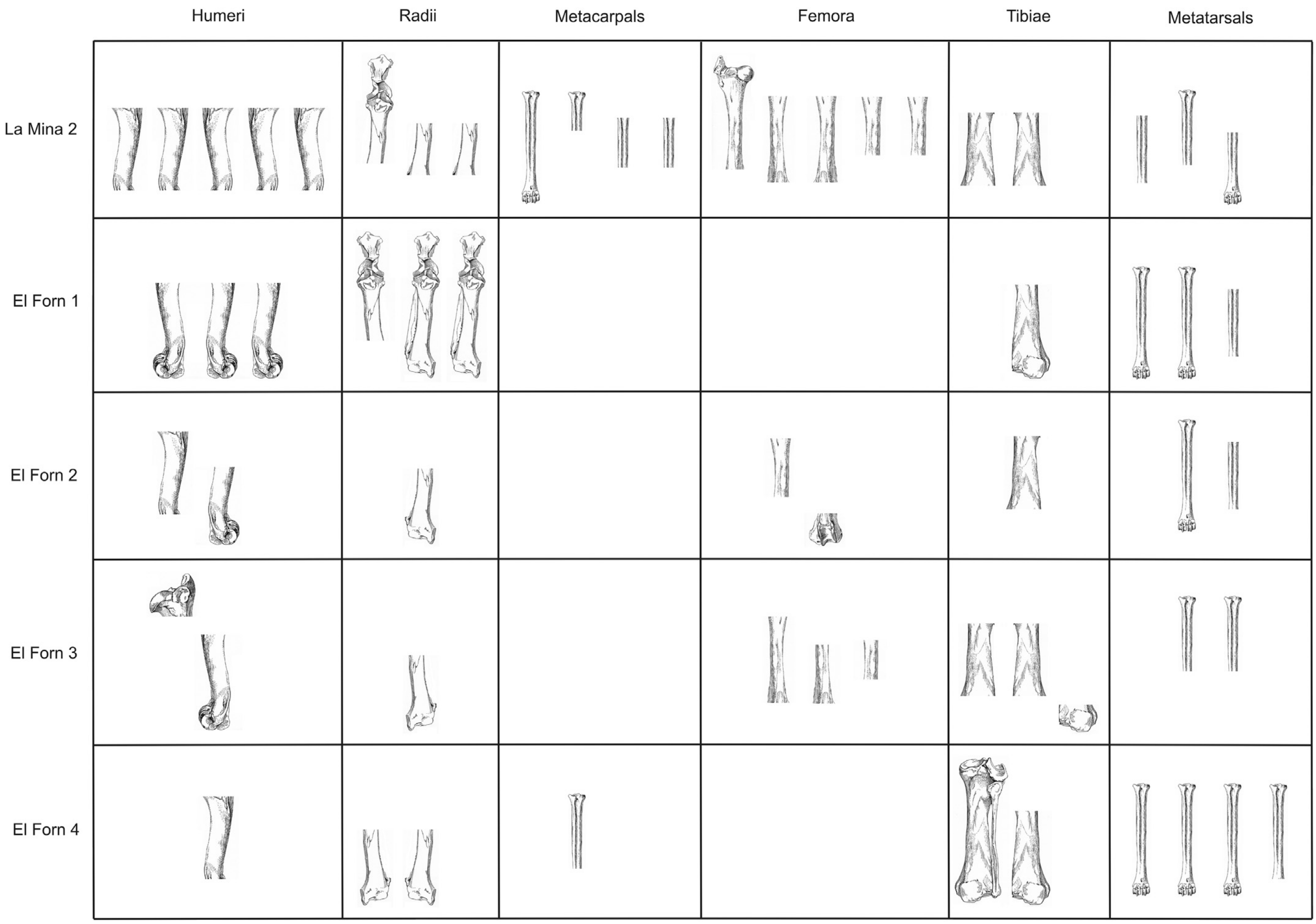


**Fig. 4.** Representations of the MNE of limb bones identified in LM2 and EF1 to EF4. MNE values: LM2 = 22; EF1 = 10; EF2 = 8; EF3 = 11; EF4 = 10.

sample size, i.e., a Type I error (Faith and Gordon, 2007) as in LM2 where NME = 4. The moderate epiphysis-to-diaphysis ratio (0.11) and the low percentage of tooth-marked specimens suggest that high levels of competition were present during the formation of the assemblage (Blumenschine and Marean, 1993). The theoretical model of Egeland (2008) also suggests that low epiphysis-to-shaft and axial-to-limb bone ratios indicate high-competition episodes.

### 4.2. El Forn (EF), levels 1 to 4

A total of 736 faunal remains were identified across the EF sequence, the majority of which (97.6%) were found in the upper levels: EF1 (nr = 177), EF2 (nr = 171), EF3 (nr = 134) and EF4 (nr = 237) (Table 2). The nr/m$^2$ values reveal a low number of recovered remains (EF1 = 2.5; EF2 = 3.5; EF3 = 2.3; and EF4 = 4.3). These levels are characterized by the almost exclusive presence of ungulates and the absence of carnivores (carnivores were only documented at EF4: three isolated remains belonging to *Ursus* sp., *Vulpes* sp. and another unidentified carnivore). Vallverdú et al. (2014) described the presence of a hyaenid dental fragment in EF3. However, a subsequent review of the material led us to reject this identification (Madurell-Malapeira, pers. comm.). In addition, the absence of mammoth and bovid remains (present in the other analysed levels) and the presence of *Sus* sp. remains in EF1 and a *Castor* sp. tooth recovered from EF4 (not identified in the other analysed levels) are remarkable.

In EF3, some anatomically connected left limb bone elements (tarsal bones, included both talus and astragalus, linked to the metapod) of *Cervus elaphus* were recovered. In EF1, different dental and

**Table 4**
Taphonomic modifications documented in level 2 of la Mina and levels 1 to 4 in el Forn. Data are presented as absolutes and as percentages. For the weathered bones, the percentages of remains at the various stages are related to the total number of weathered bones and not recovered bones. NR: LM2 = 578; EF1 = 177; EF2 = 171; EF3 = 134; EF4 = 237.

| | Weathering | | | Abrasion | | | Root-etching | Trampling | Oxides (mn and fe) | Dissolution | Deformations |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Weathered bones | Slightly weathered (Stages 1) | Heavily weathered (Stages 2-5) | Non-abraded (Stage 0) | Slightly abraded (Stage 1) | Heavily abraded (Stages 2-3) | | | | | |
| LM2 | 117 - 22.2% | 113 - 96.6% | 4 - 3.4% | 279 - 48.3% | 257 - 44.5% | 42 - 7.2% | 123 - 21.3% | 19 - 3.3% | 352 - 60.9% | 1 - <1% | 1 - <1% |
| EF1 | 53 - 30.4% | 26 - 55% | 27 - 45% | 123 - 70.7% | 33 - 18.9% | 18 - 10.3% | 27 - 15.5% | 4 - 2.3% | 106 - 60.1% | 7 - 4% | 1 - <1% |
| EF2 | 90 - 52.6% | 72 - 80% | 18 - 20% | 144 - 84.2% | 24 - 14% | 3 - 1.8% | 42 - 26.3% | 2 - 1.2% | 142 - 83% | 1 - <1% | 1 - <1% |
| EF3 | 73 - 54.4% | 70 - 95.9% | 3 - 4.1% | 121 - 90.2% | 12 - 8.8% | 1 - 1% | 45 - 33.6% | 1 - <1% | 106 - 79.1% | 13 - 9.7% | 1 - <1% |
| EF4 | 70 - 29.5% | 63 - 90% | 7 - 10% | 179 - 75.5% | 49 - 20.7% | 9 - 3.7% | 66 - 27.8% | 11 - 4.6% | 164 - 69.2% | 22 - 9.2% | 2 - <1% |

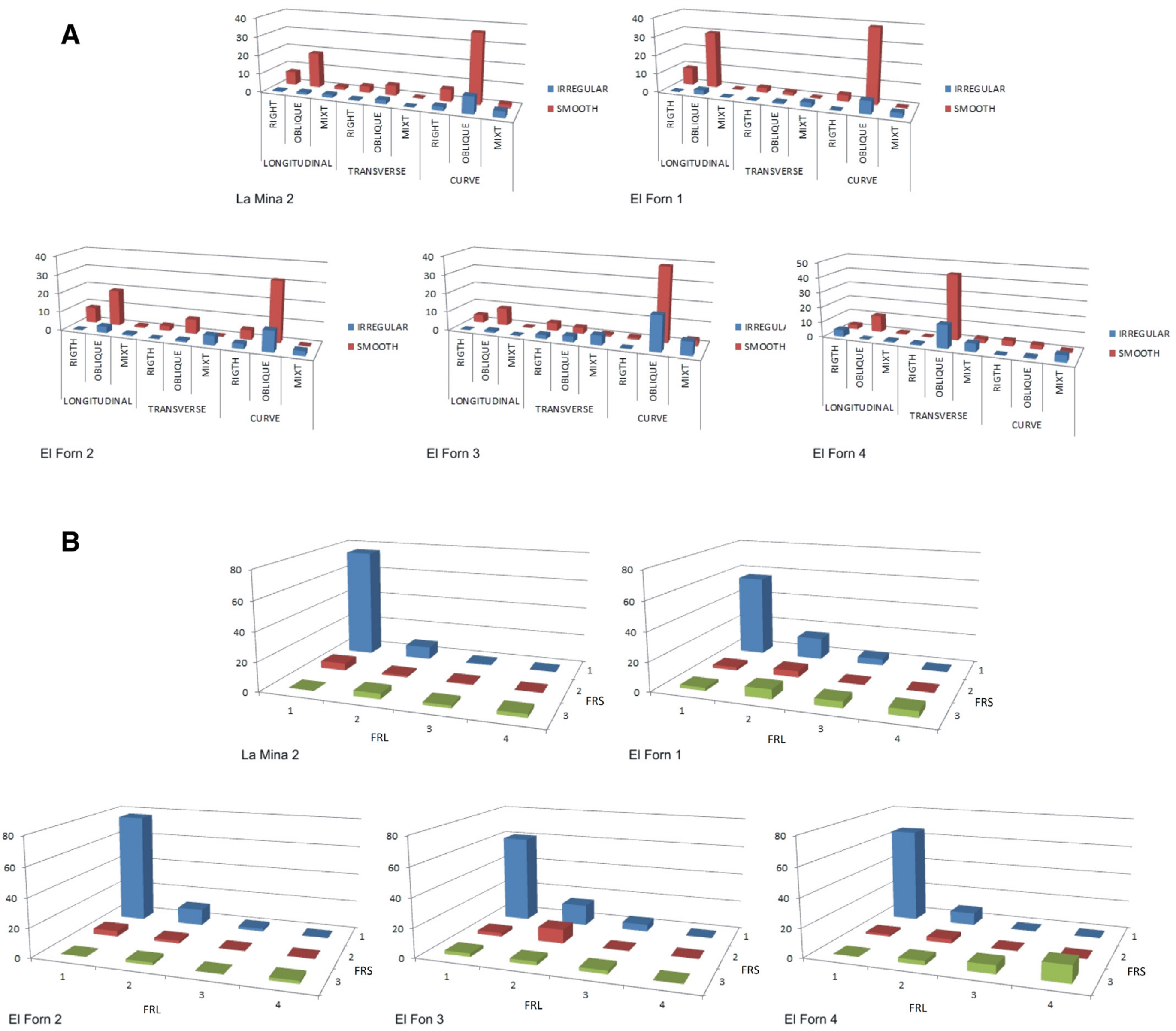


**Fig. 5.** A) Analysis of fracture angle, outline and edge for the la Mina and el Forn levels based on the criteria of Villa and Mahieu (1991). NR: LM2 = 337; EF1 = 121; EF2 = 121; EF3 = 99; EF4 = 111. B) Analysis of the fragmentation of bone shaft circumference (FRS) and length (FRL) at the la Mina and el Forn sites based on Bunn (1983) and Villa and Mahieu (1991). See text for acronyms. NR: LM2 = 148; EF1 = 46; EF2 = 52; EF3 = 41; EF4 = 68.

appendicular elements of an *Equus* sp. were interpreted as possibly belonging to a single individual (Fig. 7A). These elements include the upper dentition. All upper teeth were found together, forming an almost complete upper tooth formula, without repetition of the same teeth and with a wear pattern that suggests the same age of death. The postcranial skeleton includes both humeri, the radius, tibia, astragalus, calcaneus, cuboid, grand cuneiform, and one undetermined metapodial and a first phalanx. These elements are located close to the current section of the gully, which is being eroded by modern flow in this active gully. These remains are archaeostratigraphically correlated with a deposit of approximately 40 cm (Fig. 7B), which could have resulted from a vertical dispersion that could have moved remains up to 1 m from their original position (Domínguez-Rodrigo et al., 2010a).

The relationship between the mineral density of the bones and the %MAU appears to be slight for the preserved sample in all cases with a possible correlation. The Spearman's rho values suggest a small, positive, statistically significant correlation, except in the small carcasses of EF1 and the large animals of EF2 and EF4, in which the Spearman's rho values suggest a small positive non-statistically significant relationship (Table 3). However, this absence of significance could be due to the small sample sizes. For EF, the relationship between the long-bone epiphyses and their marrow or fat content is positive for medium-sized animals in EF1, EF2 and EF3 and for large-sized animals in EF3 and negative in the rest of cases (Fig. 3). Regardless, neither relationship is statistically significant. However, these results do indicate the survival of the densest, less marrow epiphyses in the case of medium-sized animals and the less dense, greatest marrow epiphyses in the case of large-sized animals.

The taphonomic modifications identified in the EF levels are summarized in Table 4. The percentage of abraded remains is low in EF3 (9.8%) but high in EF2 (15.8%), EF4 (24.4%) and EF1 (29.2%). Stage 1 (Cáceres, 2002) is the most common stage in all of the assemblages. This stage is indicative of limited exposure of the remains to low-intensity water flows. However, abrasion can also occur in bones undergoing no movement (Thompson et al., 2011). Only EF1 has a relatively high percentage of abraded elements characterized by abrasion stages higher than stage

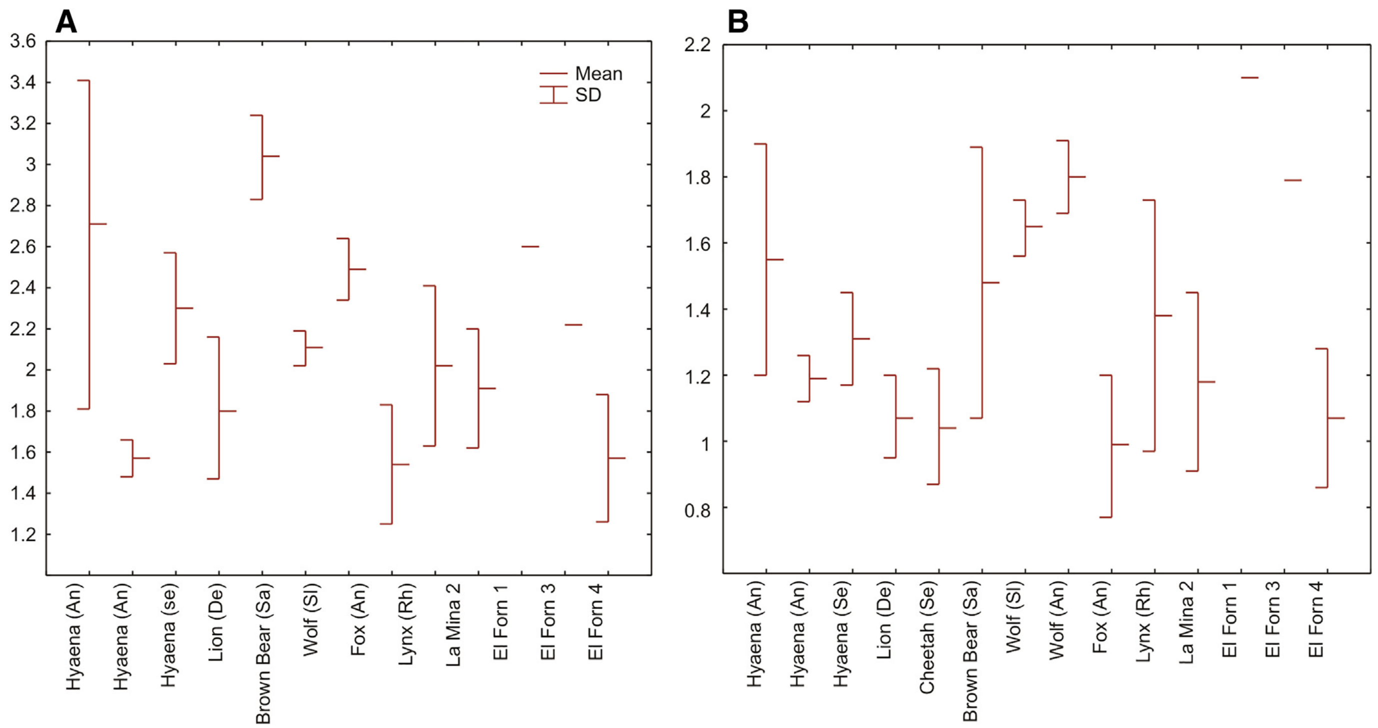


**Fig. 6.** Comparisons of the length (left) and width (right) of the tooth marks identified in el Forn levels 1, 3 and 4 with data from actual research (Selvaggio, 1994a (Se); Delaney-Rivera et al., 2009 (De); Saladié, 2009 (Sa2); Andrés et al., 2012 (An); Rodríguez-Hidalgo et al., 2013 (Rh); Saladié et al., 2013 (Sa1)) and fossil data from Barranc de la Boella (la Mina level 2) (Pineda et al., 2015). All EF levels shows <30 pits (EF1: 3; EF3: 4; EF4: 20), and statistical comparison is not possible. Number pits at LM2 = 65. No measurable pits were identified in EF2.

1 (10.3%). Weathering varies widely among the EF1 assemblages. The percentages were low in EF1 (30.4%) and EF4 (29.5%) but higher in EF2 (52.6%) and especially EF3 (72.4%). In all levels, weathered bones are primarily associated with dry factures: 75.5% in EF1; 87.8% in EF2; 88% in EF3; and 75.3% in EF4. However, in all levels, Behrensmeyer's (1978) stage 1 was predominant, indicating a relatively short exposure of the bone surface and a low degree of destruction. These data allow us to describe the site as a well-preserved assemblage in which post-depositional processes, although present, were not significant enough to have altered the resulting anatomical profiles. Generally, the assemblages are also characterized by high levels of oxide coating or staining (between 60 and 83%) and, to a lesser degree, by root etching (15.5% in EF1 and approximately 30% in the other levels), with low values for the remaining modifications.

The number of analysed fracture outlines was similar for all levels: EF1 and EF2, nr = 121; EF3, nr = 111; and EF4, nr = 99. The upper levels (EF1-3) have a high percentage of fractures described as longitudinal or curved, oblique and smooth. In total, the percentages of green fractures based on the classification of Villa and Mahieu (1991) are as follows: EF1: 68.6%, EF2: 50.4% and EF3: 47.5%. In contrast, in EF4, only 13.5% of the bones have signs of fracturing when fresh. The most represented fractures at EF4 (58.5%) are transverse and smooth (Fig. 5A).

**Table 5**
Percentage of change in the limb bones that were identified at the la Mina and el Forn sites. MNE: LM2 = 17; EF1 = 16; EF2 = 12; EF3 = 14; EF4 = 19.

| % of change | LM2 | EF1 | EF2 | EF3 | EF4 |
|---|---|---|---|---|---|
| Humeri | 87.5 | 50 | 83.3 | 50 | 67 |
| Radii-Ulna | 50 | 56.3 | 75 | 50 | 58 |
| Femora | 100 | 100 | 50 | 88 | 50 |
| Tibiae | 100 | 100 | 100 | 88 | 67 |
| Metapodials | 77.7 | 61.1 | 50 | 50 | 58 |
| Total | 83 | 73.5 | 71.6 | 56.2 | 60 |

These fractures are associated with dry or subfossil bones based on the method of Villa and Mahieu (1991) and are not related to the breaking of bones by hominins and carnivores for nutritive proposes. In all assemblages, the fragmentation is high (Fig. 5B). The number of limb bones that have a ratio of 1:1 (Bunn, 1983; Villa and Mahieu, 1991) ranges between 56.6% (EF1) and 76.9% (EF2). In EF3 and EF4, the ratios are slightly <60%. However, the percentages of limb bones with complete or near-complete shafts in EF1 (8.6%) and especially EF4 (17.7%) are remarkable. In the other two assemblages, the percentages are close to 3%. Fig. 4 shows that complete limb bones are common in EF1 (radii and metatarsals) and EF4 (tibiae and metatarsals). Distal epiphyses of humeri and tibiae are preserved in almost all cases in these assemblages, while the proximal epiphyses of these bones are virtually absent. In EF2 and EF3, complete bones are absent (except for the metatarsals), and the number of epiphyses that are preserved in these levels is relatively minor in relation to the other EF levels.

As in the LM assemblage, no cut marks were preserved at EF. Hominin access to carcasses was determined by identifying percussion pits in two limb bones belonging to a medium-sized animal in EF1. However, the lithic artefacts recovered from the four assemblages

**Table 6**
Correlation of %MAU of limb ends with mineral density for the size categories (when possible) for each level. MNE: LM2 = 4; EF1 = 10: EF2 = 3 (in each size category); EF3 = 4; EF4 = 10.

| Site | Weight-size category | Pearson's $r^2$ | Probability | +95% conf. | −95% conf. |
|---|---|---|---|---|---|
| La Mina 2 | Large size | 0.61 | <0.05 | 1.26 | −0.04 |
| El Forn 1 | Large size | 0.08 | >0.05 | 0.62 | −0.46 |
| El Forn 2 | Small size | 0.014 | >0.05 | 0.67 | −0.64 |
|  | Large size | 0.40 | >0.05 | 1.05 | −0.25 |
| El Forn 3 | Large size | 0.05 | >0.05 | 0.7 | −0.6 |
| El Forn 4 | Large size | 0.1 | >0.05 | 0.75 | −0.55 |

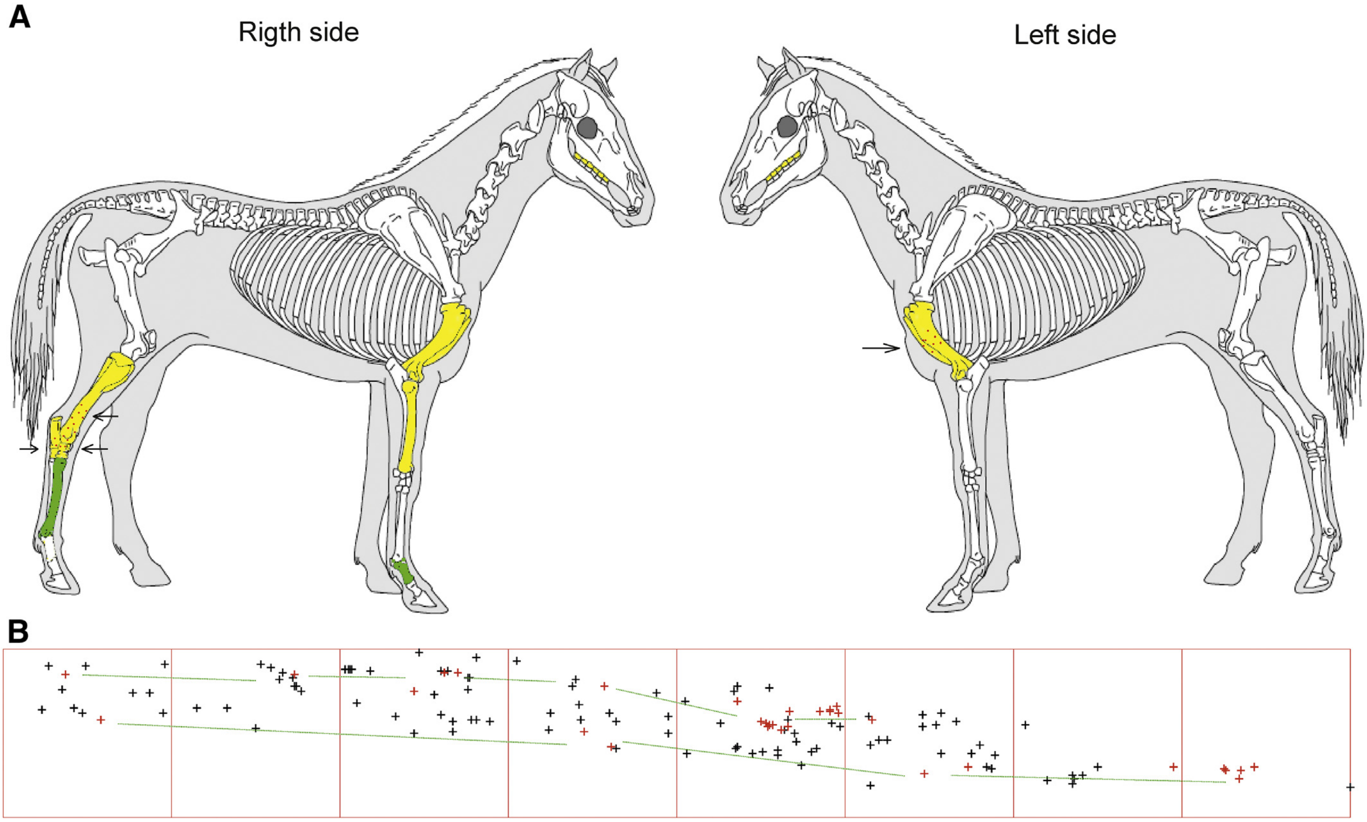


**Fig. 7.** Elements recovered from EF1 that possibly belonged to a single horse. A) Several recovered elements possibly belonging to a single horse. Pits and scores are represented as red points and are indicated with arrows; side-determined elements are represented in yellow on the respective side; side-undetermined elements are represented in green on the right side. B) The stratigraphic distribution of the horse elements in EF1. Horse remains are represented in red, and the stratigraphic connection among these elements is indicated in green. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

confirm the presence of hominins at these sites (Vallverdú et al., 2014; Mosquera et al., 2016). The stone tools to bone ratio differs among the levels: the lowest ratios occur in EF1 (0.04) and EF4 (0.03), and larger values occur in EF3 (0.16) and EF2 (0.37).

Carnivore activity on the carcasses is evidenced in all EF levels. Tooth marks are present on 4.5% of the remains in EF1, 2.3% of the remains in EF2, 9% of the remains in EF3 and 11% of the remains in EF4. A comparison of the length and width dimensions of the pits in EF1, EF3 and EF4 (Fig. 6) suggests that at least one large carnivore was involved in the formation of the assemblages. However, in all levels, the total number of tooth marks is <30, which prevents statistically significant comparisons (Andrés et al., 2012). Therefore, limited inferences could be made about the carnivore responsible for these marks. Unfortunately, the pits on remains in EF2 could not be measured or compared because they were heavily altered.

Other carnivore-induced modifications and evidence can be used to identify modifying agents in these levels. In EF1, two digested bones were recovered, and one was larger than 8 cm, which may be related to hyaenid activity (Tappen and Wrangham, 2000). In this level, limb elements possibly belonging to a horse contain evidence of carnivore consumption. This evidence includes pits and scores on one humerus, tibia and astragalus, furrowing on one calcaneus, and the scooping out of the other humerus (Fig. 8). Remarkably, several limb elements, such as the metatarsus and phalanges, were completely or almost completely recovered in this study.

Levels EF2 and EF3 contain little evidence of carnivore activity. EF2 features tooth marks on two cervid limb bones, one small central limb bone and one large flat bone, but it was not possible to determine the agents that produced the tooth marks. In EF3, tooth marks were primarily identified on the bones of medium and large animals, although pits were documented on one rib of a very large animal. Additionally, a digested bone larger than 4 cm was identified and is inferred to be related to hyena activity (Tappen and Wrangham, 2000). However, these observations should be treated with caution due to the very small sample sizes.

In EF4, carnivore-induced modifications were identified in cranial (mandibles), axial post-cranial (ribs and vertebrae) and appendicular (humeri, tibiae and metapodials) elements belonging to all size categories. Three digested bones (36, 45 and 50 mm) and heavy modifications were documented on megaherbivore bones (scooping out and heavy furrowing on the ends of the mammoth tibia and shaft cylinders on a mammoth metapodial and a rhinoceros humerus) (Fig. 9). Some researchers have suggested that only hyenas are able to make these types of alterations on megaherbivore remains (Arribas and Palmqvist, 1998; Faith and Behrensmeyer, 2006; Haynes and Klimowicz, 2015), which may indicate that these carnivores acted on the above elements.

The epiphysis-to-diaphysis ratio is low in the EF levels: EF1 (0.21), EF2 (0.2) and EF3 (0.24), and EF4 (0.25). These ratios and the low percentage of tooth-marked specimens suggest that there were considerable levels of competition in these assemblages (Blumenschine and Marean, 1993) but that these levels of competition were less than those in LM2. The correlation between %MAU of the end limb bones and the mineral density of the bones was no-significant in all EF levels (Table 6). The absence of significant positive correlations is expected in open-air sites where carnivores consume any and all parts they encounter, regardless of their density and/or nutritional yield, and indicates high levels of competition among predators (Faith et al., 2007). However, the Pearson determination coefficients for the EF levels show that the correlation levels are low, $r^2 \leq 0.2$ in all cases except large-sized carcasses in EF2, suggesting no relationship exists among the deleted epiphyses and their mineral density. However, this lack of statistical significance could be the result of a Type II statistical error

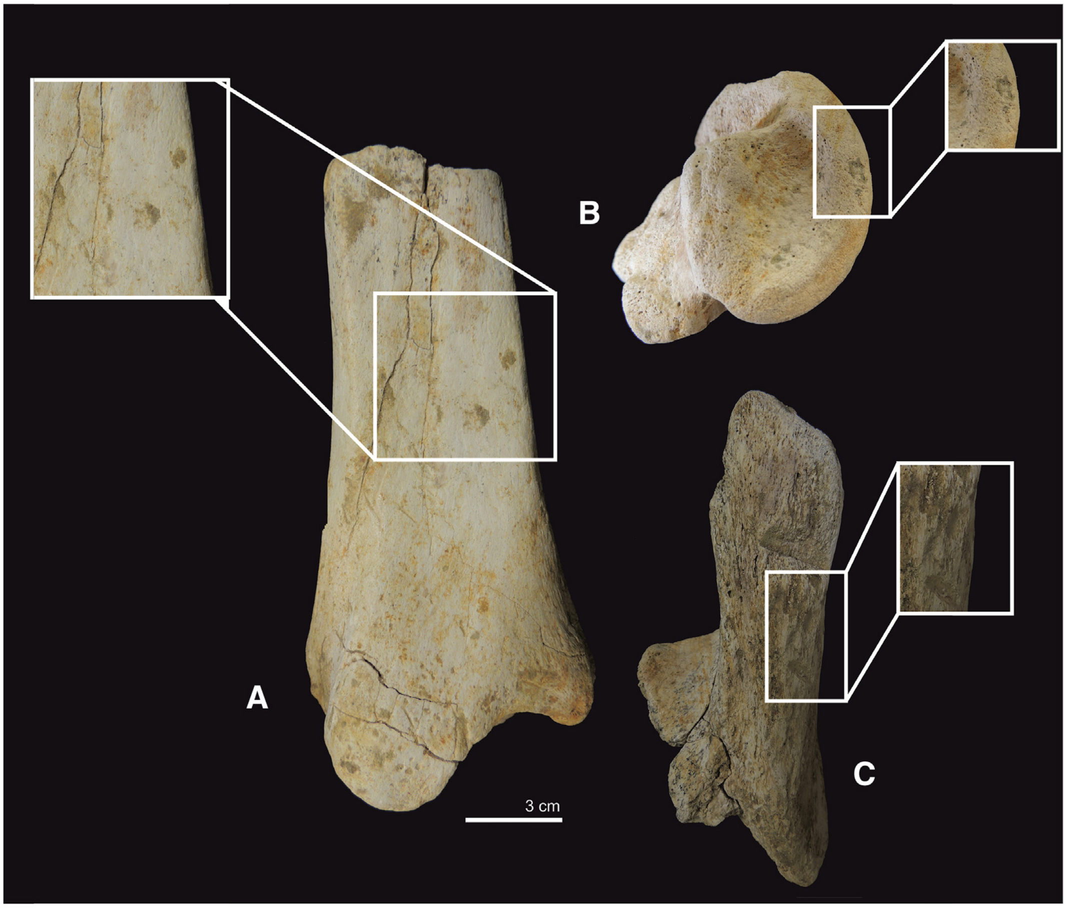


**Fig. 8.** Several tooth-marked specimens from a right posterior limb of the horse referred to in Fig. 7: distal tibia (A), talus (B) and calcaneus (C).

caused by the small sample size (as described in Faith and Gordon, 2007). Importantly, an archaeological assemblage is the result of a dynamic model where different contexts and different consumption sequences are mixed together across decades, centuries or millennia and may not fully capture the competition among predators in an ecosystem (Domínguez-Rodrigo and Organista, 2007). This concept is also important for interpreting possible discordances during the application of the Faith et al. (2007) model. According to the MNE of shafts and limb bone ends (following Faith et al., 2007), the percentage of change indicates that the disappearance of epiphyses is high in EF1 (73.5%) and EF2 (71.6%) and moderate-to-high in EF3 (56.2%) and EF4 (60%) (Table 5). Thus, taking into account both methods, we infer high and moderate to high removals of epiphyses in the different EF levels. The theoretical model of Egeland (2008) suggests moderate levels of competition were present in all EF levels, as indicated by the low axial-to-limb and epiphysis-to-shaft ratios in all the assemblages.

## 5. Discussion

BB is an open-air archaeo-palaeontological site that formed in a fluvio-deltaic sedimentary environment. The excavated sites are located within fluvial and debris flow deposits, similar to sites located within or near flowing streams of different intensities (Vallverdú et al., 2014). To date, three sites have been excavated at BB. Level II.2 of P1 represents a flood-plain environment that contains a single-event *Mammuthus meridionalis* butchering site with specialized anthropic activity and a short temporal resolution (Vallverdú et al., 2014; Mosquera et al., 2015). Unlike P1, the other two sites, LM and EF, have poorly stratified sediments. However, taphonomic studies indicate that the dispersion of the materials is low because the recovered remains were only slightly abraded (Pineda et al., 2015). Additionally, documenting cervid elements in anatomical connection (EF3) supports this interpretation.

Evidence of hominin forager activity (primarily in the form of recovered stone tools) and the presence of megaherbivores were identified at the three excavated sites. However, EF and LM are characterized by their taxonomic diversity and documented carnivore activity and are dissimilar to P1, which features a monospecific assemblage (i.e., mammoth remains represent 99% of the identified specimens) and little evidence of carnivore activity (Mosquera et al., 2015). At BB, a complex ecological mosaic has been inferred based on the taxonomic variety, which includes open, riparian and aquatic taxa (Lozano-Fernández et al., 2014; Vallverdú et al., 2014; Pineda et al., 2015; present paper). This environment was probably rich in resources.

The analysis of the five assemblages (i.e., LM2 and EF1 to EF4) allowed us to make comparisons based on skeletal compositions and taphonomic modifications. All of the assemblages shared a common element: a high degree of limb bone fragmentation. Limb bones preserving < 1/4 of the shaft were predominant in all assemblages. Additionally, LM2, EF1, EF2 and EF3 were associated with green fractures. The fragmentation rates were too high to be attributed to felids (Gidna et al., 2013, 2015) or canids (Haynes, 1983). In contrast, at EF4, high rates of fragmentation were associated with post-depositional fractures. However, EF1 and EF4 also had high percentages of complete limb bones, reflecting the presence of resources that have non-exploited nutrients (primarily marrow and fat in epiphyses), low consumer-carcass ratios or the absence of visibility of the carcasses (Egeland, 2008).

Carnivore activity is documented in all of the assemblages at different intensities. Hyena activity has been described at LM2 based on comparisons of the size of tooth marks, the presence of coprolites and large digested bones, the high degree of limb end disappearance, and the

**Fig. 9.** Megaherbivore remains with evidence of carnivore damage: A) mammoth tibia; B) a detailed view of the proximal shaft of the mammoth tibia; and C) rhinoceros humerus. Red arrows indicate evidence of carnivore damage. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

intensity of specific modifications to the original osteological sample, such as shaft cylinders. At EF, there was also clear evidence of carnivore activity. In EF1, limb elements belonging to an equid exhibited evidence of carnivore consumption, including epiphysis removal. *Canis mosbachensis*, the wolf identified at BB, was defined as a canid with a better capacity for meat defleshing than bone cracking (Flower and Schreve, 2014). The data suggest that hyenas were the most likely agent that consumed the equid carcass. Additionally, several mammoth elements recovered from EF4 exhibited evidence of carnivore consumption. As Haynes and Klimowicz (2015) recently demonstrated, proboscidean bones with grease potentially usable by carnivores can remain on the surface for several decades, and hyenas and lions are known to be able to modify elephant remains (Schaller, 1972; Diedrich, 2014; Haynes and Klimowicz, 2015). Although carnivore-induced modifications occur in EF2 and EF3, their scarcity prevents us from precisely determining the causative agent. The various carnivores that coexisted in this biotope could have modified the original samples. However, the most visible influence of bone-consumer carnivores on the archaeological assemblage may masks other modifications that were induced by small or defleshing carnivores (Saladié et al., 2014; Pineda et al., 2015).

The presence of hominins in all of the assemblages, albeit to different degrees, has been confirmed. The recovered lithic artefacts (Vallverdú et al., 2014; Mosquera et al., 2016) are the primary element that allows us to identify this presence, and artefacts are abundant in LM2, EF2 and EF3. In contrast, EF1 and EF4 are characterized by limited evidence of the presence of hominin groups.

Despite the hominin presence, evidence of anthropic processing of carcasses is scarce and limited to the percussion pits identified in LM2 and EF1. Percussion pits are indicative of the processing of at least some carcasses by hominin groups during the nutritive phase (sensu Capaldo, 1997). Domínguez-Rodrigo and Barba (2007a) suggest that anthropogenic bone breakage without defleshing may indicate secondary access by hominin groups in closed environments. However, these inferences should be strictly limited to assemblages with well-preserved bone surfaces (Domínguez-Rodrigo et al., 2010b; Pineda et al., 2014). In the present study, the absence of cut marks limits our ability to assess the hominin access to carcasses. The scarce anthropic evidence only indicates that these populations had little or no role in forming the deposits. In fact, the spatial association among the stone tools and the documented knapping activity coupled with the mammoth carcass in P1 confirms that these hominins could access meat.

In summary, LM2 is characterized by abundant evidence of hominin and carnivore activity, with high levels of bone breakage characterized by green fractures. The features of EF2 and EF3 are similar to those of LM2, although there are differences that include the limited evidence of carnivore. In contrast, EF1 and EF4 differ from the other studied sites. In these assemblages, complete or near-complete limb bones are abundant, and evidence of the presence of hominins is scare. Additionally, evidence of carnivore activity is abundant.

**Table 7**
Different ratios and analysis methods used in the correspondence analysis (Fig. 10) and in the Hierarchical Clustering analysis (Fig. 11) for determining the distributions in LM2 and EF1 to EF4 based on the skeletal composition, breakage patterns and the intensity of the anthropic and carnivore activity.

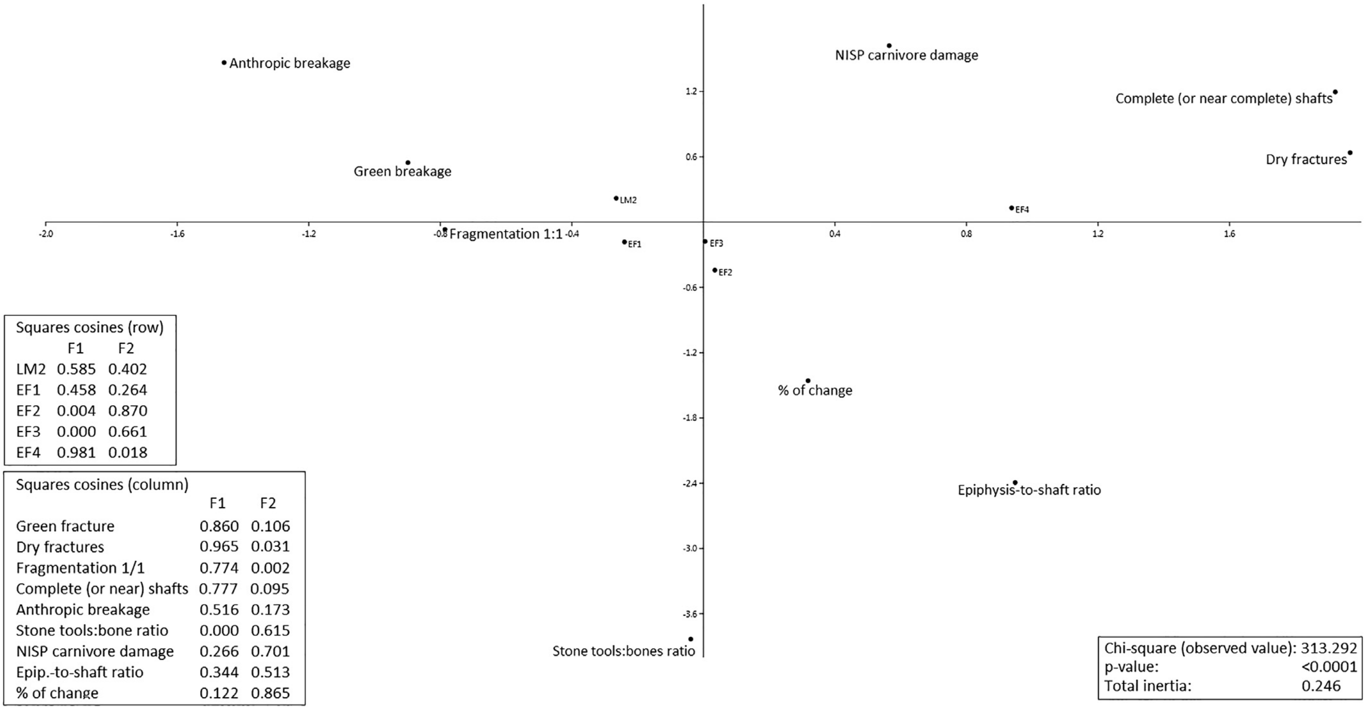
| Features | Green fractures | Dry fractures | Fragmentation 1:1 | Complete (or near complete) shafts | Anthropic fractures | Stone tools:bones ratio | NISP carnivore damage | Ep-to-shaft ratio | % change |
|---|---|---|---|---|---|---|---|---|---|
| LM2 | 218 | 44 | 122 | 7 | 4 | 0.14 | 53 | 0.11 | 83 |
| EF1 | 83 | 9 | 36 | 4 | 2 | 0.04 | 8 | 0.21 | 73,5 |
| EF2 | 31 | 19 | 40 | 1 | 0 | 0.37 | 4 | 0.2 | 71,6 |
| EF3 | 47 | 18 | 25 | 1 | 0 | 0.16 | 12 | 0.24 | 56,2 |
| EF4 | 15 | 75 | 8 | 12 | 0 | 0.03 | 28 | 0.25 | 60 |

A correspondence analysis was conducted to analyse the different assemblages based on skeletal composition, activity of biological agents and breakage (see Table 7) (Fig. 10). The first axe explains the 71.655% of the inertia and the second one, the 23.290%; thus, both axes explain the 94.945% of the inertia. This analysis shows that anthropic and green breakage are the elements that differentiate LM2 from the other sites, as anthropic breakage was only documented on four bones and was therefore not significant. In contrast, dry breakage and the presence of complete or near-complete shafts differentiate EF4, while the levels EF1 to EF3 are grouped together based on the percentage of change and the epiphysis-to-shaft ratio as the strongest elements for describing these levels.

The application of the Hierarchical Clustering analysis based on the ratios presented on Table 7 supports the grouping identified through the Correspondence analysis (Fig. 11). EF2 and EF3 are grouped together, suggesting that are the most similar assemblages. These assemblages are grouped in a second level with EF1 and in the next levels with EF4. On the other hand, LM2 is shown as the most different assemblage at the site.

Based on these data, different patterns of competition were inferred in the assemblages. First, high levels of competition were inferred at LM2 based on the high rate of epiphysis disappearance in the skeletal ratios and the almost total absence of complete limb bones. Second, a decrease in these values is associated with a decrease in the level of competition among predators, as observed in EF2 and EF3. The presence of limb ends or axial skeleton elements suggests that these assemblages experienced little carnivore damage (Domínguez-Rodrigo and Organista, 2007) because ravagers tend to delete the axial elements faster than the limb bones (Capaldo, 1997). Based on Domínguez-Rodrigo and Organista (2007), the lowest levels of ravaging are sometimes correlated with low levels of environmental competition for resources. Under high-competition conditions, bone-cracking carnivores tend to produce assemblages characterized by high rates of bone destruction (Faith and Behrensmeyer, 2006). The presence of complete limb bones is related to non-exhaustive carcass processing (Egeland, 2008), which occurs in low- or moderate-competition contexts (Capaldo, 1997; Faith and Behrensmeyer, 2006). EF1 and especially EF4 exhibit osteological samples that are typical of these scenarios. Distal epiphyses of humeri and tibiae are preserved in almost all of the cases in EF1 and EF4, while the proximal epiphyses of these bones are almost absent. These observations are consistent with the pattern of hyena consumption under low-competition conditions (Palmqvist and Arribas, 2001), in which hyenas consume the less dense epiphyses, which contain more marrow.

Additionally, at EF1, evidence of the consumption of horse allows for inferences about the competition context. Several researchers (Pobiner and Blumenschine, 2003; Faith and Behrensmeyer, 2006) suggest that the substantial evidence of carnivore modification in large-sized carcasses (including limb-bone breakages) should be exclusively attributed to hyena activity. Faith and Behrensmeyer (2006) suggest that access to the marrow of horse limb bones includes more effort and less reward than bovid limb bones because they are denser and contain



Squares cosines (row)

| | F1 | F2 |
|---|---|---|
| LM2 | 0.585 | 0.402 |
| EF1 | 0.458 | 0.264 |
| EF2 | 0.004 | 0.870 |
| EF3 | 0.000 | 0.661 |
| EF4 | 0.981 | 0.018 |

Squares cosines (column)

| | F1 | F2 |
|---|---|---|
| Green fracture | 0.860 | 0.106 |
| Dry fractures | 0.965 | 0.031 |
| Fragmentation 1/1 | 0.774 | 0.002 |
| Complete (or near) shafts | 0.777 | 0.095 |
| Anthropic breakage | 0.516 | 0.173 |
| Stone tools:bone ratio | 0.000 | 0.615 |
| NISP carnivore damage | 0.266 | 0.701 |
| Epip.-to-shaft ratio | 0.344 | 0.513 |
| % of change | 0.122 | 0.865 |

| | |
|---|---|
| Chi-square (observed value): | 313.292 |
| p-value: | <0.0001 |
| Total inertia: | 0.246 |

**Fig. 10.** Correspondence analyses of the distribution of LM2 and EF1 to EF4 based on the different methods for measuring skeletal composition, breakage and anthropic and carnivore intensity in the assemblages presented in Table 7. The chi-square (observed value), the *p*-value, the total inertia and the square cosines of both row and columns are presented.

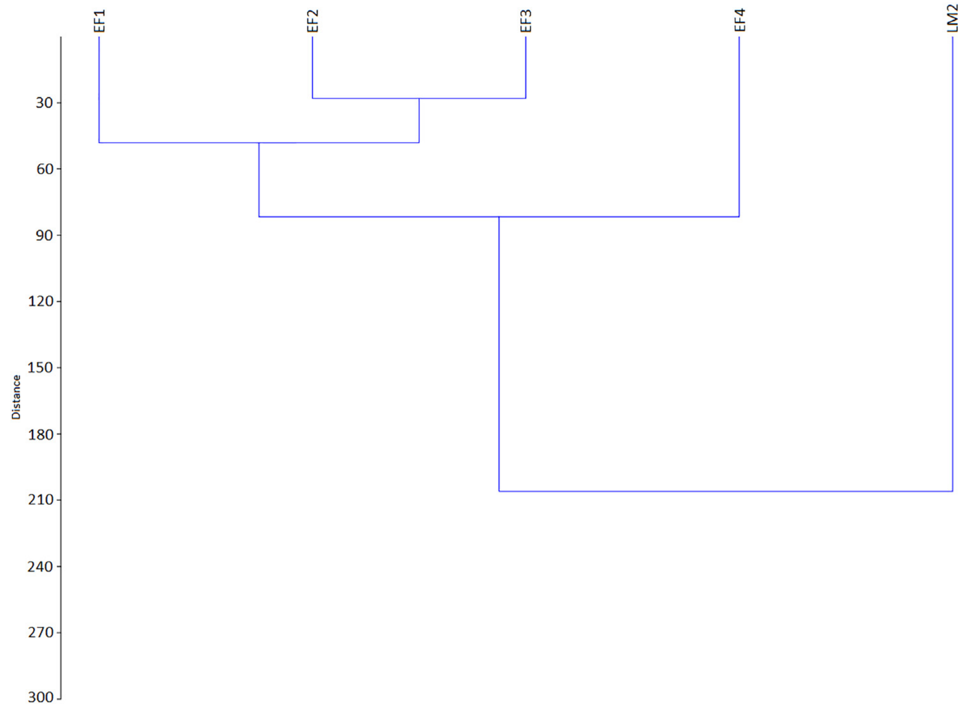


**Fig. 11.** Hierarchical Clustering analysis of the distribution of LM2 and EF1 to EF4 based on the different ratios presented in Table 7.

smaller amounts of marrow. Supporting this point, similar differences were quantified by Palmqvist and Arribas (2001). Therefore, Faith and Behrensmeyer (2006) conclude that hyenas only fracture bones when intra- or interspecific competition increases (i.e., when competition for resources is higher). However, these researchers affirm that high-competition contexts can be reflected by the disappearance of the distal end of the tibia. In EF1, the tibia displays evidence of consumption, and the proximal end has disappeared, while the distal end is preserved. In addition, several complete limb elements from this individual were recovered. Therefore, the non-exhaustive consumption of these horse bones indicates that the competition was not high during the formation of EF1.

Despite the inferred levels of competition across the different assemblages, the foraging patterns of hominin groups spatially overlapped with those of carnivores. From an archaeological perspective, Binford (1980) proposed that this type of foraging activity resulted in a palimpsest accumulation that resembled sites that contained aggregates of artefacts, lacked internal structure, and were characterized by accretional formation histories. The majority of open-air archaeological sites, such as BB, can be defined as spatial palimpsests. These types of deposits are characterized by a mixture of episodes that are spatially segregated but have temporal relationships that are difficult to determine (Bailey, 2008). In these types of accumulations, some events may be more visible than others due to better preservation of the archaeological remains. Bunn (1986) described faunal accumulations that had non-stone tools or very few artefacts as natural background scatters, which may have been a consequence of carnivore activity or another non-anthropic accumulation process.

Domínguez-Rodrigo et al. (2007a) highlighted the importance of identifying these vertically dispersed deposits in which the anthropogenic artefacts have accumulated independently from the carcasses. Thus, assemblages such as FLK N3-4 and FLK NN1 from Olduvai Gorge Bed I, which Leakey (1971) traditionally interpreted as living floors, have been recently described as palimpsests that have no relationships with the fauna or stone tools and that formed with only a marginal hominin contribution (Barba and Domínguez-Rodrigo, 2007; Domínguez-Rodrigo et al., 2007b, 2010a). The reinterpretation of FLK N1-2 (Domínguez-Rodrigo and Barba, 2007b; Bunn et al., 2010), which was previously described as a central foraging site (Bunn, 1986), is in line with this research. However, the literature on FLK NN3 is more complex. This site was described by Leakey (1971), Binford (1981) and Potts (1988) as an anthropogenic deposit with differing interpretations of the mode and timing of carcass procurement. However, re-examinations (Domínguez-Rodrigo and Barba, 2007c; Domínguez-Rodrigo et al., 2010a) suggest that this assemblage resulted from carnivore activity with little anthropic activity. As result of these reinterpretations, Domínguez-Rodrigo et al. (2010a) highlighted the importance of foraging among these populations and emphasized that the production of the artefacts found in these sites may not have involved the exploitation of wildlife resources. Obviously, meat resources were an important component in the diet of these populations, which demonstrated the ability to hunt in even the early records (Domínguez-Rodrigo, 1997; Domínguez-Rodrigo et al., 2002). In the Iberian Peninsula, zooarchaeological analyses support these interpretations for the Early Pleistocene, which has been described at Sierra de Atapuerca (Saladié et al., 2011, 2014; Huguet et al., 2013). However, at Orce Basin, Espigares et al. (2013) and Rodríguez-Gómez et al. (2016b) defended the hypothesis that the hominins acted as scavengers rather than as active predators.

The descriptions of the LM and EF sites provided in this paper reflect patterns that resemble the interpretations for several Olduvai Gorge Bed I sites, i.e., vertically dispersed deposits in which the relationship among fauna and stone tools is scarce or non-existent. The different levels at LM and EF are the result of complex taphonomic histories in which the presence of hominins and carnivores generally reflects the accumulation of independent events. Although no cut marks were observed at BB, the identification of anthropogenic breakage in a few bones shows that hominins had a small role in the formation of the deposits. These modifications, together with stone tools, suggest that BB was a foraging location for these populations, perhaps due to the availability of resources. At BB, the clearest evidence for using animal resources was found in the neighbouring site P1 (Mosquera et al., 2015), where a spatial relationship between stone artefacts and a mammoth carcass has been demonstrated. However, BB has been described as an open ecosystem with large quantities of water and close riparian cover (Lozano-Fernández et al., 2014; Vallverdú et al., 2014; Pineda et al., 2015). Several types of resources (biotic and abiotic) would have been present and available to the hominin populations who inhabited this region. In fact, BB seems to be an environment with abundant raw material. Evidence from BB supports the hypothesis of Egeland (2014) that resources other than meat resources, such as water and raw materials for stone tool production, also played an important role in the hominin decisions to concentrate their foraging activities.

Our data indicate that BB reflects a varied biotope in which different agents converged on a rich environment. Among these agents were hominins, which were present in all of the studied levels. Their contribution to the formation of the faunal deposits was small in certain levels and absent in others, with rare evidence of carcass processing in a context in which the presence of hominins would have been linked to foraging. However, the greatest anthropic record documented at BB is present in the assemblages with abundant evidence of high levels of carnivore activity and competition. The observed relationship indicates that the presence of carnivores did not limit the hominin presence at the sites. Competition would have been high but was not sufficient to force competitive exclusion, as has been suggested in prior research (Brantingham, 1998). This coexistence may have been related to the abundance of resources available to early hominins and carnivores, specifically because both agents overlapped in the use of at least two key aspects: large mammal carcasses and space (Egeland, 2014). As Egeland suggests, the presence of carnivores was most likely a part of the daily life of these early hominins. For example, at TD6.2 in the Gran Dolina site, the acquisition, processing and consumption of several animals has been identified (Saladié et al., 2011), and the use of the cavity as a refuge to reduce competition with other predators has been documented (Saladié et al., 2014). Using the cavity as a refuge indicates the ability of these early populations to develop systems to transport, process and consume their prey while decreasing the risk of encounters with other predators in the environment.

Intra and interspecific competition was most likely as intense as it is in modern African ecosystems (Egeland, 2014) if we assume that past carnivore densities were higher (Van Valkenburgh, 2001). In addition, competition was high in open-air landscapes, such as BB, due to the greater visibility and the ease of locating carcasses (Blumenschine, 1986; Domínguez-Rodrigo, 2001; Faith and Behrensmeyer, 2006; Faith et al., 2007; Egeland, 2008, 2014; Saladié et al., 2014). Resource portioning may represent a logical way for dividing wildlife resources (Brantingham, 1998). BB demonstrates the ability of the hominin populations to inhabit these fluvio-deltaic environments under highly competitive conditions via the successful development of subsistence strategies early in their evolution.

## 6. Conclusions

BB is a late Early Pleistocene open-air site that provides data on the presence of early human groups in an open landscape. Hominin access to large animals was documented in P1, which was identified as a *Mammuthus meridionalis* butchering site. However, the presence of hominin groups is not as intense at the other sites. The anthropic evidence in LM2 and EF1 to EF4, which date to slightly later than 1 Ma, is scarce and limited to stone artefacts that are not directly related to the recovered faunal remains. Evidence of carnivore activity is more plentiful and appears to be unrelated to the activity of human groups. The studied assemblages are deposits of vertically dispersed remains. Thus, there is an accumulation of several events in this location, with little to no human contribution. The human activities were related to foraging activity. The presence of human and carnivore groups is documented in all of the studied levels, but the intensity of the presence varies for both groups.

BB has been described as an environment that has a wide variety of resources. The BB palaeoenvironment would have been highly attractive for many predator populations, which would have resulted in periods of high competition for resources among predators. When competition was higher in the various levels, there is more taxonomic diversity, including abundant carnivore taxa in LM2. High competition is also associated with exhaustive exploitation of carcasses, which is reflected by a high percentage of green fractures and especially by high fragmentation rates for limb bones, which are rarely present as complete bones with epiphyses. The presence of hominin and carnivore groups may have been higher in levels in which the inferred competition was also greater, possibly as a consequence of periods in which the abundance of resources was highly attractive for both predator types. This evidence indicates that hominin presence/absence in the landscape was probably related to the abundance of several resources (e.g., animal resources, raw materials, water and tree cover) rather than carnivore dynamics. In fact, from a regional perspective, the two groups shared an interest in several of the available resources.

BB demonstrates the ability of these early populations to successfully inhabit fluvio-deltaic environments during periods of high competition among predators. This ability resulted from the successful development of subsistence strategies, including during periods of high resource competition.

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# Characterizing hyena coprolites from two latrines of the Iberian Peninsula during the Early Pleistocene: Gran Dolina (Sierra de Atapuerca, Burgos) and la Mina (Barranc de la Boella, Tarragona)

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## ABSTRACT

Coprolites are commonly identified in the Pleistocene archaeo-palaeontological record. They have often been described as indirect evidence for the presence of carnivores (usually hyenids) during the formation of a depositional sequence. However, coprolites are a much larger source of information that can provide data relating to factors affecting an archaeological assemblage, including its taphonomic history and palaeoecology. In this paper, two fossil coprolite accumulations dating to the late Early Pleistocene are described: Level TD6.1 of Gran Dolina (Sierra de Atapuerca, Burgos) and Unit II of la Mina (Barranc de la Boella, Tarragona). The results highlight the morphological homogeneity of these hyena coprolites, despite a considerable variation in size. The presence of microspherulites is clearly identified in all of the analysed hyena coprolites. Their composition is rich in elements characteristic of bone-origin, such as calcium (Ca) and phosphorus (P). A major difference, however, differentiating the remains from these sites was a higher frequency of bone fragments in the la Mina coprolites, regarding to TD6.1. Pollen, spores, and palynomorphs are scarce in the samples from both sites, which in fact share similar ecological characteristics such as the presence of pine, wild grasses, and coprophilous fungi. Hyena coprolites are relatively easy to differentiate from those of other taxa; however, they show intra-specific similarities in their micro- and macro-morphology and composition, despite their wide size range. The species of hyenids responsible for the coprolites is not possible to identify based exclusively on the size range, and the importance of a multidisciplinary study of the latrines and the coprolites is discussed as a source of palaeoecological and taphonomic information. In this study, coprolites are analysed, compared, and attributed to a hyenid, identified as *Crocuta crocuta* in the case of TD6.1, but without specific attribution in the case of la Mina.

## 1. Introduction

Coprolites (fossilized faeces) are irregular and highly variable masses of soft tissue that have been desiccated and/or mineralized (Chin, 2002). The broad spectrum of coprolites documented up to now includes: herbivorous, aquatic, and terrestrial carnivorous, and even human (Hunt et al., 2012). Hyena coprolites are the most common type reported in Pleistocene fossil assemblages. They consist of an outer layer, which was originally sticky and then quickly hardened (usually as a result of drying after

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elemental or subaerial exposure), thus preserving its original morphology and also sealing its matrix, enriched in calcite and phosphate of bone origin (Kruuk, 1972; Horwitz and Goldberg, 1989; Larkin et al., 2000; Pesquero et al., 2011; Gil-Romera et al., 2014). As a consequence of the high levels of bony tissue present in the diets of spotted hyena, their faeces are highly characteristic in comparison to those produced by other carnivores (Kruuk, 1972). They are also are stronger and more resistant than herbivore faeces (Linseele et al., 2013), thus favouring their preservation.

Previous studies have described the characteristics of hyena coprolites and have shown that is it possible to identify hyenas as the agent defecators (Horwitz and Goldberg, 1989; Larkin et al., 2000; Pesquero et al., 2011; Linseele et al., 2013; Sanz et al., 2016). However, Linseele et al. (2013) suggested that correct identification of the defecator requires a holistic view, with a complete study of the morphological features of the coprolites, their contents, and the archaeological context in which they were found. In general, fresh faeces and the coprolites they form are irregular and highly variable in both morphology and dimensions (Chame, 2003). However, Stuart and Stuart (1998) defended that the morphological variability of faeces is less pronounced in the case of the spotted hyena (*Crocuta* crocuta) and other bone-cracker carnivores, because they tend to have less variability in their diets, in comparison with other mammal groups.

Generally, a complete spotted hyena drop specimen is characterized by different aggregates (also named pellets or segments) with a globular or rounded morphology and with several shapes described (Diedrich, 2012, his Fig. 4). This researcher has highlighted the wide variability of the hyena faeces and pellets and has also established a classification system, which includes different shapes and morphologies that could be documented in a complete hyena drop: conical, disk, oval, long-oval, round, irregular and drop. Conical (anterior pellets) were described as conical in lateral view but round in cross-section, which only have one disk-shaped side with an attachment surface for the next pellet. Disk pellets are flattened or triangular shaped in lateral view, with attachment surfaces for other pellets at both sites. Oval shapes are attributed to middle pellets which often display two attachment surfaces (although these may be absent), variable in size but generally similar in length and height. Long-oval shapes belong to the second part of the aggregate, following the oval ones. Round pellets, usually situated at the end of long-oval pellets, are rounded or polygonal in form and usually without attachment surfaces. The irregular pellets show a variable morphology and usually are found at the end of elongated aggregations forming complexes of two to four pellets. Finally, drop shapes generally correspond with the posterior pellets of an aggregate, being drop or double drop shaped and relatively small (Diedrich, 2012). The proximal end of a single coprolite is slightly pointed, as a consequence of the presence of an apex, and the distal end has convex and flat surfaces, related to the peristaltic movement of the hyenas' digestive tract (Dietrich, 1951).

A broad variety of inclusions can be identified and studied in hyena coprolites such as bone fragments (Horwitz and Goldberg, 1989; Berger et al., 2009; Pesquero et al., 2011), hair (Backwell et al., 2009) and elements of a vegetal origin, like phytoliths or pollen (Carrión et al., 2001; Gil-Romera et al., 2014). Incorporation of pollen into hyena coprolites could be related to their settlement from the air or into water and their subsequent ingestion by the animal, among other circumstances. The most plausible way to explain pollen ingestion is, however, through its adherence to a dietary item, such as the stomach contents of prey (Carrión et al., 2001). The palynological spectrum recovered in hyena coprolites is generally highly variable, ranging between absence and abundance. The presence of faecal palaeoparasites (Pesquero et al., 2014) and the nature of a coprolite as a source of extraction of the DNA of the defecator and its diet (Poinar et al., 1998; Bon et al., 2012) can provide additional information that is not always present in the fossil skeleton (Chin, 2002).

Coprolite accumulations dating to the Miocene (Pesquero et al., 2011), Middle Pleistocene (Larkin et al., 2000; Berger et al., 2009) and Late Pleistocene (Horwitz and Goldberg, 1989; Mangano, 2011; Sanz et al., 2016) have rarely been identified. In this paper, two accumulations of coprolites of the Iberian Peninsula dated in the late Early Pleistocene are characterized: Level TD6.1 of Gran Dolina (Sierra de Atapuerca, Burgos) and Unit II of la Mina (Barranc de la Boella, Tarragona) (Fig. 1A). Latrines and the coprolites identified within them are discussed, through morphological (both macro- and micro-morphologic) and taphonomic descriptions, as well as palynological, compositional, and content analyses. The goal is to characterize these assemblages using a variety of approaches, to identify valid criteria for distinguishing hyena latrines and to show that fossil latrines are a potential source of palaeoecological information when a broad study is carried out.

## 2. Latrine-use in extant *Crocuta crocuta*

'Social defecation' (Kruuk, 1972; Brain, 1981) is an habitual part of the behaviour of many modern gregarious mammals, in which many individuals deposit their drops in specific areas, named latrines, occasionally forming large accumulations. In the archaeo-palaeontological record, the identification of these accumulations is unusual (Pesquero et al., 2011), although, when described, they provide ecological information concerning palaeoecosystems, the individual that generated it, and its diet (Poinar et al., 1998; Chin, 2002; Berger et al., 2009; Pesquero et al., 2011; Bon et al., 2012; Linseele et al., 2013).

The use of latrines is a behaviour described in all of the extant hyena species: *Crocuta crocuta* (Kruuk, 1972; Bearder and Randall, 1978; Mills and Gorman, 1987), *Hyaena hyaena* (Macdonald, 1980), *Hyaena brunnea* (Gorman and Mills, 1984), and *Proteles cristatus* (Nel et al., 2002). A latrine is identified by the presence of a high number of faeces (generally white) dropped by several individuals in the same place (Kruuk, 1972; Bearder and Randall, 1978). Several studies have documented and described the use of latrines among spotted hyenas (Kruuk, 1972; Bearder and Randall, 1978; Mills and Gorman, 1987), including the sharing of a single latrine by members of two surrounding clans (Kruuk, 1972). Together with *drawing* and *pasting*, the use of latrines is considered as scent-marking by a determined clan (Kruuk, 1972; Gorman and Mills, 1984; Mills and Gorman, 1987). Latrines tend to be distributed throughout a territory, but not in a unified way (Mills and Gorman, 1987), having a greater tendency to be located in fringe areas, near rivers, roads, paths (Kruuk, 1972; Mills and Gorman, 1987) and caves (Brain, 1981).

The dimensions of a latrine may vary, extending up to 100 $m^2$ (Skinner and Van Aarde, 1981) and visible up to 2 km away (Mills and Gorman, 1987). Bearder and Randall (1978) distinguished between temporary (near to a kill site) and permanent (used for long periods) latrines, although not all researchers use this differentiation (Kruuk, 1972; Mills and Gorman, 1987). Spotted hyenas visit their latrines regularly, usually once every week, as can be determined by the presence of new trails, bruises faeces, and/or urination (Krell et al., 2003). Skinner and Van Aarde (1981) identified an average of 12.4 faeces by latrine (they studied five latrines), although Tilson et al. (1980) recovered 460. Although they may have high-morphological variety, the faeces are usually elongated, formed by several pellets and contain abundant organic remains, such as hair, skin, feathers, scales, or vegetal remains (Kruuk, 1972; Chame, 2003; Krell et al., 2003).

## 3. The sites

### *3.1. Gran Dolina: sub-unit TD6.1*

Gran Dolina is an archaeo-palaeontological site located in the Trinchera del Ferrocarril, at la Sierra de Atapuerca (Burgos). Is composed of 11 litho-stratigraphic units, eight of them yielding significant archaeo-palaeontological remains (from TD3-4 to TD10) (Rodríguez et al., 2011) (Fig. 1E). Excavation in Unit TD6 was developed in two phases: the first one (1994–1996), a bio-stratigraphic test pit (6 $m^2$), was carried out in the southern section of the site; and the second one (2003 − 2011)

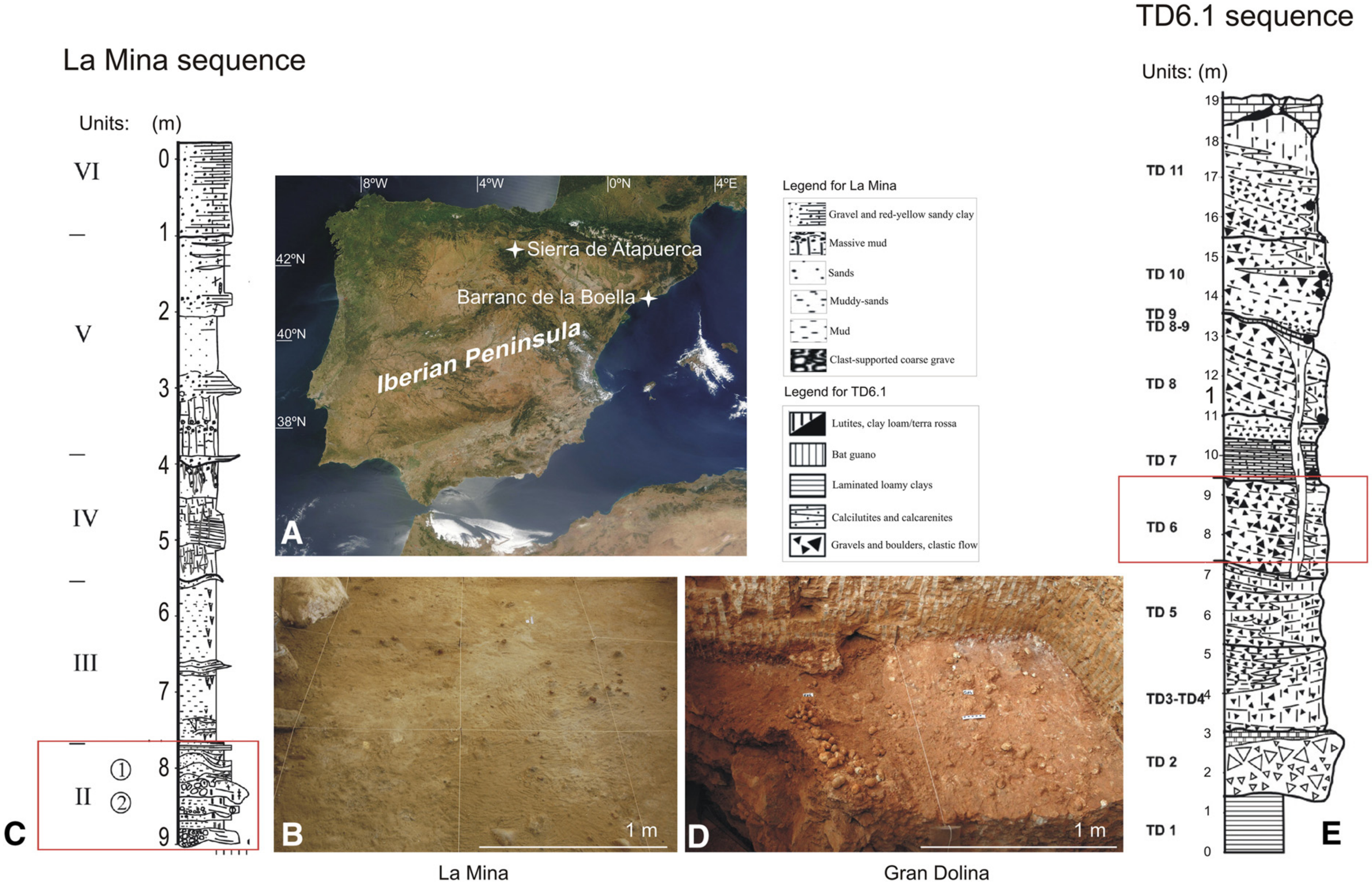

**Fig. 1.** A) Location of the Sierra de Atapuerca and the Barranc de la Boella in the context of the Iberian Peninsula; B) Accumulation of coprolites identified during excavation process of Level II.3 of la Mina; C) Stratigraphy of la Mina (modified from Vallverdú et al. (2014: p. 9)); D) Accumulation of coprolites identified during excavation works of the TD6.1 subunit of Gran Dolina; E) Stratigraphy of Gran Dolina (modified from Ollé et al. (2013: p. 141)). Red boxes show the stratigraphical position of levels included in this paper.

was the result of the removal of overhangs and profiling. Three sub-units have been identified: TD6.1–TD6.3 from top to bottom, with TD6.2 corresponding to where most of the remains belonging to *Homo antecessor* were found (Bermúdez de Castro et al., 1997). New palaeomagnetic data, together with a revision of the data obtained by thermoluminescence (TL) and Uranium series-electron spin resonance (US-ESR), provide a date of 0.8–0.9 Ma for TD6 Unit (Parés et al., 2013; Moreno et al., 2015).

Nearly 1000 items have been recovered from TD6.1, most of which ($n = 581$) are faunal remains. The identified taxa include two carnivores (*Panthera gombaszoegensis* and *Baranogale* sp.) and three ungulates (*Equus* sp., *Stephanorhinus etruscus* and *Bison* sp. v*oigdtedtensis*). Carnivore activity has been identified on over 7.5% of the remains, including tooth marks, removal of epiphyses, pitting, carnivore breakage, and evidence of digestion, suggesting the activity of both large and small carnivores (Saladié, 2009). In the southern section of the TD6.1 excavated area, a significant volume of coprolites was identified (Fig. 1D). However, the presence of coprolites decreases sharply to the north, where there is abundant osteological material, probably as a consequence of re-elaboration and re-sedimentation and not related with the accumulation of coprolites.

### 3.2. Barranc de la Boella: La Mina Unit II

Barranc de la Boella (BB) (La Canonja, Tarragona) is an open-air site with a 9 m sequence composed of six lithostratigraphic units (Fig. 1C) described in detail by Vallverdú et al. (2014). Unit II, presents an age slightly lower than 1 Ma (Lozano-Fernández et al., 2014; Vallverdú et al., 2014). It is a rich archaeological sequence that has been formed by a homogeneous deposition of 2 m of poorly stratified sand and gravel (Vallverdú et al., 2014). Excavation at la Mina (LM) has recovered over 1500 archaeological remains, mainly fauna ($n = 1055$), coprolites ($n = 204$), and stone tools ($n = 181$). The taxonomical spectrum includes several carnivores (*Ursus* sp., *Panthera* cf. *gombaszoegensis*, *Canis mosbachensis*, *Lynx* sp. and *Vulpes* sp.), a primate (*Macaca sylvana*), and a variety of ungulates (*Mammuthus meridionalis*, *Hippopotamus antiquus*, and *Equus* cf. *stenonis*), together with bovid remains and several species of deer. Numerous coprolites have been also recovered (Vallverdú et al., 2014; Pineda et al., 2015) from throughout Unit II, but the majority of the accumulation comes from the top of Level II.3 (Fig. 1B).

In a previous study (Vallverdú et al., 2014), the identification of a possible dental fragment of *Pachycrocuta* cf. *brevirostris* at Barranc de la Boella, at the site of el Forn, was discussed. However, a later analysis of the material called for the revision of this identification (Madurell-Malapeira, pers. comm.). During the 2015 excavation, an upper incisor (I3) was recovered at la Mina (Level II.3) that could belong to the family Hyenidae. In any case, remains of these animals are scarce, not just at la Mina Unit II, but in all of the excavated areas at Barranc de la Boella (Vallverdú et al., 2014). However, their activity and, consequently, their presence, seems to be common, as indicated by the taphonomic signs identified from the osteological samples (Vallverdú et al., 2014; Pineda et al., 2015, 2017). For example, tooth marks are present on 6.2% of the skeletal remains from LM and the dimensions of the pits suggest the activity of at least one large carnivore. Moreover, the furrowing of limb bones and digested bones recovered point to hyenid activity (Pineda et al., 2015, 2017).

## 4. Material and methods

Coprolites analysed in this study belong to Level TD6.1 of Gran Dolina and Unit II of la Mina. The number of coprolite fragments recovered at la Mina is 204, while 369 are from TD6.1. Not all of the coprolites from TD6.1 were coordinated during the excavation process. However, non-coordinated coprolites (squares F14, G14 and G15) have also been included in this work. The coprolites from TD6.1 are well preserved, consistent, and did not require special treatment prior to extraction. On the other hand, most coprolites from la Mina needed to undergo a full conservation treatment.

The la Mina coprolites were highly inconsistent and tended to disintegrate during excavation. As the goal was preserving their morphology, consolidants were applied prior to lifting. Once extracted, they were wrapped with cotton gauze and placed in plastic boxes. The coprolites were then treated to deeper cleaning and consolidation in the laboratory. Two different consolidating products were used, either alone or combined in a single specimen: acrylic resin, Paraloid-B72, dissolved in acetone and vinyl aqueous dispersion, Mowitlith DMC2. Both products strengthened the coprolites, but aqueous dispersion is applicable to wet materials, whereas Paraloid B72 is only fully efficient in dry conditions, although it may be effective for restoring slightly damp samples. The sediments from the site, and consequently the coprolites, are usually somewhat humid. The moisture content may increase during the field season due to rain. In this situation, aqueous products work more efficiently. Applying them, however, inevitably increases the water content of the samples and, therefore, their drying time. This may slow down the excavation process and expose samples to the poorly controlled conditions of the field for a longer period of time. Therefore, when the coprolites are sufficiently dry, Paraloid may be a good option. Once consolidated, the samples were cleaned in the laboratory using small tools, such as scalpels and soft brushes, and alcohol or acetone was used to remove the remains of sediment and consolidating products. These conservation treatments are still preliminary, and tests are still ongoing to assess the most suitable products and methods.

**Table 1**
Modern and fossil drops analysed in the present study.

| Sample nr. | Taxa | Provenance | Chronology | Microspherulites? |
|---|---|---|---|---|
| 1 | Hyaenidae | LM II.1 | 0.96–0.78 Ma[1,2] | Yes |
| 2 | Hyaenidae | LM II.2 | | Yes |
| 3 | Hyaenidae | TD6.1 | 0.8–0.9 Ma[3,4] | Yes |
| 4 | Hyaenidae | | | Yes |
| 5 | *Crocuta crocuta* | Cova Foradada | Post-34 Ka BP[5] | Yes |
| 6 | *Lynx* sp. | | | No |
| 7 | *Lynx pardinus* | Sala de las Chimeneas (Cueva de Maltravieso) | 17.840 ± 90 Ka[6,7] | No |
| 8 | *Crocuta crocuta* | IPHES reference collection | Modern | Yes |
| 9 | *Ursus arctos* | | Modern | No |
| 10 | *Felis silvestris* | | Modern | No |
| 11 | *Canis lupus (signatus)* | | Modern | No |
| 12 | *Martes foina* | | Modern | Yes |
| 13 | *Meles meles* | | Modern | No |
| 14 | *Capra pyrenaica* | | Modern | No |

Modern and fossil drops analysed, belonging to different carnivores and herbivores. Chronology obtained from: [1]Vallverdú et al. (2014); [2]Lozano-Fernández et al. (2014); [3]Parés et al. (2013); [4] Moreno et al. (2015); [5]Morales et al., 2016; [6]Rodríguez-Hidalgo et al. (2013); [7]Canals et al. (2014).

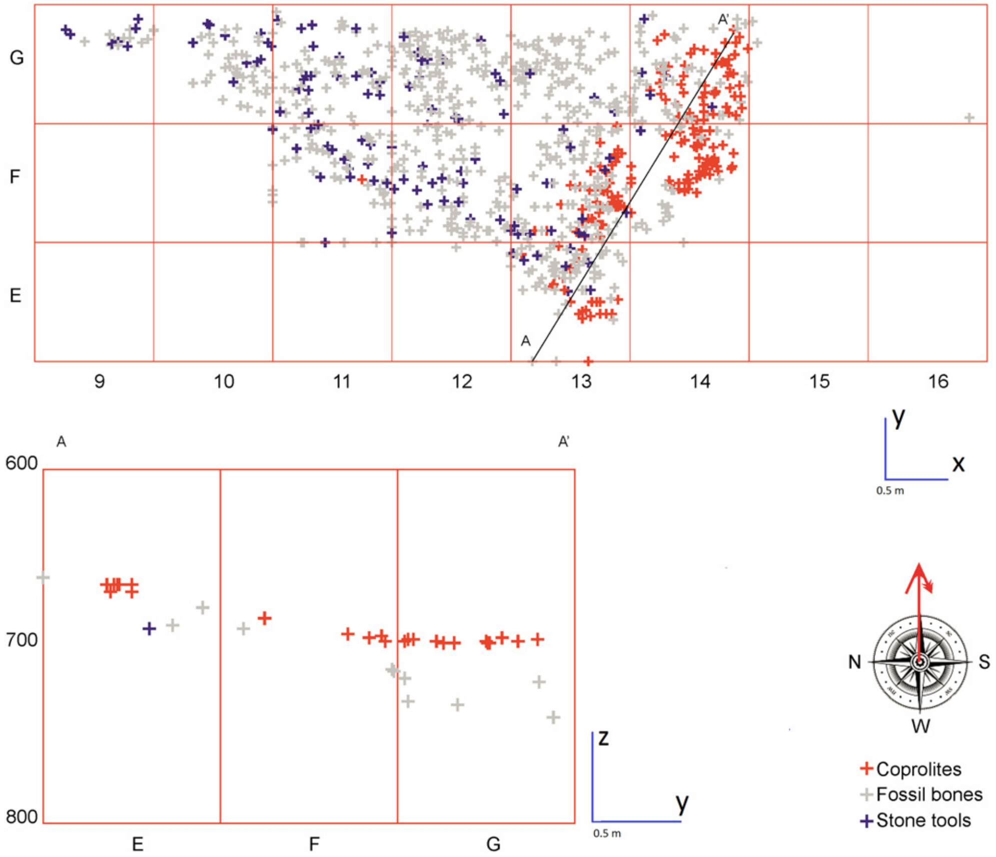

**Fig. 2.** Spatial distribution of coprolites, bones, and stone remains recovered at TD6.1. In the view of the excavated surface (top), the accumulation of coprolites in the east part of the excavated area; in the transversal section (bottom) is appreciable the accumulation located in the top of the sub-unit TD6.1. Non-coordinated coprolites recovered during the excavation process (recovered at F14, G14 and G15 squares) have not been represented. Red arrow indicates theoretical north.

The surfaces and matrices of the remains were analysed following the methods developed by Jouy-Avantin et al. (2003), Diedrich (2012) and Sanz et al. (2016), considering other previous researches (Horwitz and Goldberg, 1989; Chin, 2002). In the assemblages analysed, the remains have been classified as pellets, distinguishing between fused or single pellets, or indeterminable fragments, following the descriptions made by Diedrich (2012). A stereo microscope (OPTECH 120 HZ) was used to observe the surfaces of all of the coprolites. Among the taphonomic modifications, mineralization, weathering, oxidation, leaching, cracking, fissures, and modern plant roots have all been identified. The colour of each coprolite was determined using the Munsell Colour System (Munsell Color, 1994) for soil terminology. Taphonomic alterations and the presence of inclusions (in the outer layer and the matrix) were analysed in all coprolites. However, the size and morphology were recorded only for the complete pellets. Destructive techniques were not used during taphonomic analyses with the stereo microscope. The size of the coprolites was compared to the values presented by Larkin et al. (2000), for faeces belonging to modern *Crocuta crocuta* and coprolites recovered at West Runton Freshwater Bed (WRFB) (Middle Pleistocene), by Pesquero et al. (2011) for coprolites of *Lycyaena chaeretis* recovered at La Roma 2 (LR2) (Late Miocene), and by Sanz et al. (2016) for hyena coprolites from Cova del Coll Verdaguer (CCV) (Late Pleistocene).

The surfaces and the chemical composition of coprolites belonging to both LM and TD6.1 were analysed using a Scanning Electronic Microscope used in low-vacuum mode (ESEM, FEI QUANTA 600). Micro-morphological analysis of modern faeces from diverse mammals available in the IPHES reference collection was also conducted. Faeces belonging to

**Table 2**
Classification of the coprolites according to the state of preservation.

| State of preservation | Descriptive features | TD6.1 | LM |
|---|---|---|---|
| Fused pellets | Two or more fused pellets. Constriction lines are visible.<br>Size and shape of each pellet are measurable and classifiable. | 54 | 7 |
| Isolated pellet | Single, isolated entire pellet.<br>Size and shape are measurable and classifiable. | 172 | 27 |
| Fragmented pellet | Single, isolated fragmented pellet. Classifiable according to its morphology, although size is not measurable. | 31 | 45 |
| Disaggregated/heavily fragmented | Loss of the original morphology of the specimen.<br>Impossible to classify or measure. | 112 | 125 |
| Total | | 369 | 204 |

Classification of the coprolites of TD6.1 and LM according to the state of preservation. Each state of preservation is described.

**Table 3**
Metric analysis of pellets.

| | Fused pellets | | | | Conical (or anterior) | | | | Disk | | Oval | | Long-oval | | | | Rounded | | Irregular | | | | Drop (or posterior) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Length TD6.1 | Length LM II | Width TD6.1 | Width LM II | Length TD6.1 | Length LM II | Width TD6.1 | Width LM II | Length LM II | Width LM II | Length TD6.1 | Width TD6.1 | Length TD6.1 | Length LM II | Width TD6.1 | Width LM II | Length TD6.1 | Width TD6.1 | Length TD6.1 | Length LM II | Width TD6.1 | Width LM II | Length TD6.1 | Length LM II | Width TD6.1 | Width LM II |
| Number | 48 | 7 | 48 | 7 | 88 | 7 | 88 | 7 | 3 | 3 | 3 | 3 | 1 | 3 | 1 | 3 | 6 | 6 | 30 | 4 | 30 | 4 | 129 | 15 | 129 | 15 |
| Max | 76 | 61 | 52 | 57 | 62 | 29 | 56 | 35 | 33 | 44 | 43 | 31 | 55 | 33 | 39 | 49 | 76 | 47 | 49 | 26 | 51 | 46.2 | 55 | 41 | 59 | 53 |
| Min | 27 | 25 | 20 | 21 | 11 | 16 | 14 | 20 | 17 | 40 | 27 | 26 | – | 19 | – | 31 | 38 | 29 | 14 | 33 | 25 | 60 | 7 | 14 | 17 | 20 |
| Mean | 44.4 | 43.4 | 32.2 | 37.7 | 32.4 | 22.7 | 31.8 | 28.4 | 23.7 | 41.7 | 36.7 | 29 | – | 23.7 | – | 38.3 | 36.9 | 37.5 | 24.5 | 22 | 35.6 | 32 | 25.5 | 24.3 | 33.7 | 35.5 |
| +95% conf | 47.5 | 51.9 | 34 | 40.6 | 34.7 | 26 | 33.8 | 30.6 | 30.5 | 43.4 | 44.6 | 31.4 | – | 31.2 | – | 47 | 47.6 | 44.4 | 27.4 | 26.9 | 38 | 43.3 | 27.6 | 27.4 | 35.6 | 39.2 |
| −95% conf | 41.3 | 34.9 | 30.4 | 34.8 | 30.1 | 19.4 | 29.8 | 26.2 | 16.9 | 40 | 28.8 | 26.6 | – | 16.2 | – | 29.6 | 26.2 | 30.3 | 21.6 | 17.1 | 33.2 | 20.7 | 23.4 | 21.2 | 31.8 | 31.8 |
| S.D. | 11.2 | 11.5 | 6.3 | 11.2 | 10.1 | 4.5 | 8.1 | 5.8 | 7.7 | 1.9 | 6.9 | 2.2 | – | 6.6 | – | 7.7 | 13.3 | 9 | 8.1 | 5 | 6.8 | 11.6 | 7.7 | 6.1 | 7.8 | 7.2 |

Dimensions (in mm) of the coprolites and pellets recovered in the studies assemblages. Data of different segments includes both isolated segments and fused pellets, when measure was possible.

large (*Crocuta crocuta*, *Canis lupus* and *Ursus arctos*) and small carnivores (*Lynx pardinus*, *Felis silvestris*, *Martes foina* and *Meles meles*), as well as one herbivore (*Capra pyrenaica*), were analysed to identify the similarities and differences in the micromorphology of the drops (Table 1), taking into account the differences in the diet of these species (see Supplementary Table 1). The availability of coprolites of spotted hyena and lynx from other Pleistocene assemblages of the Iberian Peninsula allowed to compare the micromorphology and the components. The samples were compared with coprolites attributed to lynx from Cueva de Maltravieso-Sala de las Chimeneas (Late Pleistocene) and to spotted hyena and lynx recovered from Cova Foradada (Late Pleistocene). The attribution of the coprolites from these sites to lynx is certainly tentative. We have based this determination on direct evidence, such as coprolite morphology and size-range compared with actual Iberian lynx (*Lynx pardinus*) faeces and the high presence of leporid skeletal remains contained in the coprolites. As indirect evidence, the important role of the lynx in the formation of Cueva de Maltravieso-Sala de las Chimeneas and Cova Foradada deposits (Rodríguez-Hidalgo et al., 2013; Morales et al., 2016) supports this determination. Because no specific research about the characterization of lynx coprolites is available, we cannot discard a small carnivore as the defecator agent (Sanz et al., 2016). In any case, substantial differences pertaining to the morphology or the digestions grades of the bone remains in these coprolites allows us to discard their attribution to a hyena.

ESEM images were taken at 100×, 250×, 500×, 1500× and 3000× magnification. Microspherulites (Canti, 1999; Pesquero et al., 2014) documented in the different samples, were measured and compared to identify possible variations, applying $\chi 2$ analysis for statistical significance. Back-scattering was applied at 3000× in order to identify the composition of the coprolites through the spectrum obtained. Raman spectra of two thin sections from two coprolites of la Mina were obtained and compared with reference Raman spectra in order to determine what minerals are present in the coprolites.

For palynological analysis, a set of 16 disaggregated samples from la Mina Unit II.2 and Unit II.3 and a set of disaggregated eight samples from TD6.1 were analysed. The treatment of the samples has meant the total destruction of the coprolites. It is for this reason that all of them were measured, weighed, described and photographed before being processed. Samples were treated with HCl, KOH, concentrated with heavy liquid (Thoulet Liquor), and finally HF (Goeury and de Beaulieu, 1979; Burjachs et al., 2003). Counting was performed at 400× magnification. Fossil pollen and Non-Pollen Palynomorphs (NPP) were identified using published keys (Moore et al., 1991; Reille, 1992, 1995; van Geel, 1986; Jarzen and Elsik, 1986) and a reference collection. Pollen, NPP, and micro-charcoal values were expressed in concentrations (grains or particles present in a gram of dry sediment) (Loublier, 1978; Burjachs et al., 2003).

## 5. Results

### 5.1. Gran Dolina TD6.1

A total of 369 remains were recovered from TD6.1 of Gran Dolina, scattered in segment 10–25 cm thick, where artefacts and faunal remains are scarce (Fig. 2). The highest concentration was identified in the southern end of the excavated area, following the slope that characterizes the assemblage (although the largest part of the area is yet to be excavated).

The remains are well preserved (Table 2) and present low fragmentation ratios. This has allowed for the identification of the specific pellet in 257 cases and for metric analyses to be performed on isolated and fused pellets (Table 3). High values of standard deviation and confidence intervals show the high variability in the size of the coprolites throughout the assemblage.

The external layer of most of the coprolites is reddish-yellow (87%) or dark brown (10%) (Fig. 3A). Manganese colouring is documented in

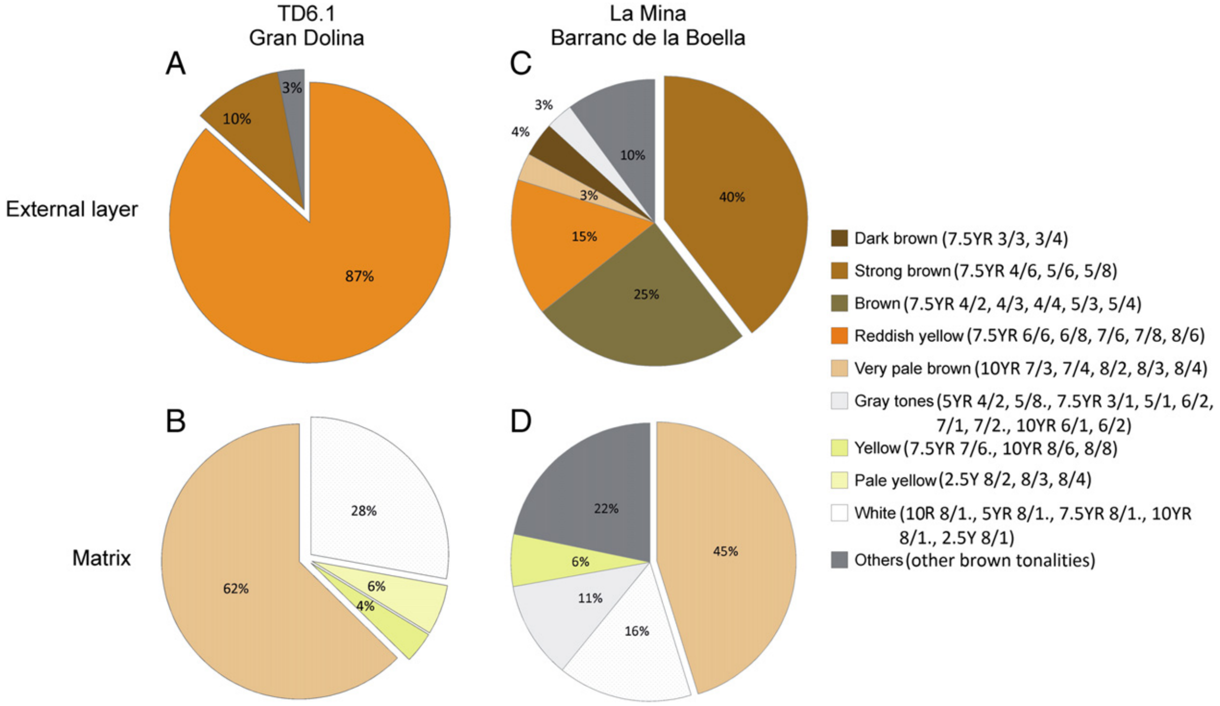

**Fig. 3.** Colour of the external layer and the matrix of the coprolites recovered at TD6.1 (A, B) and la Mina (C, D), following Munsell Soil-Colour Chart.

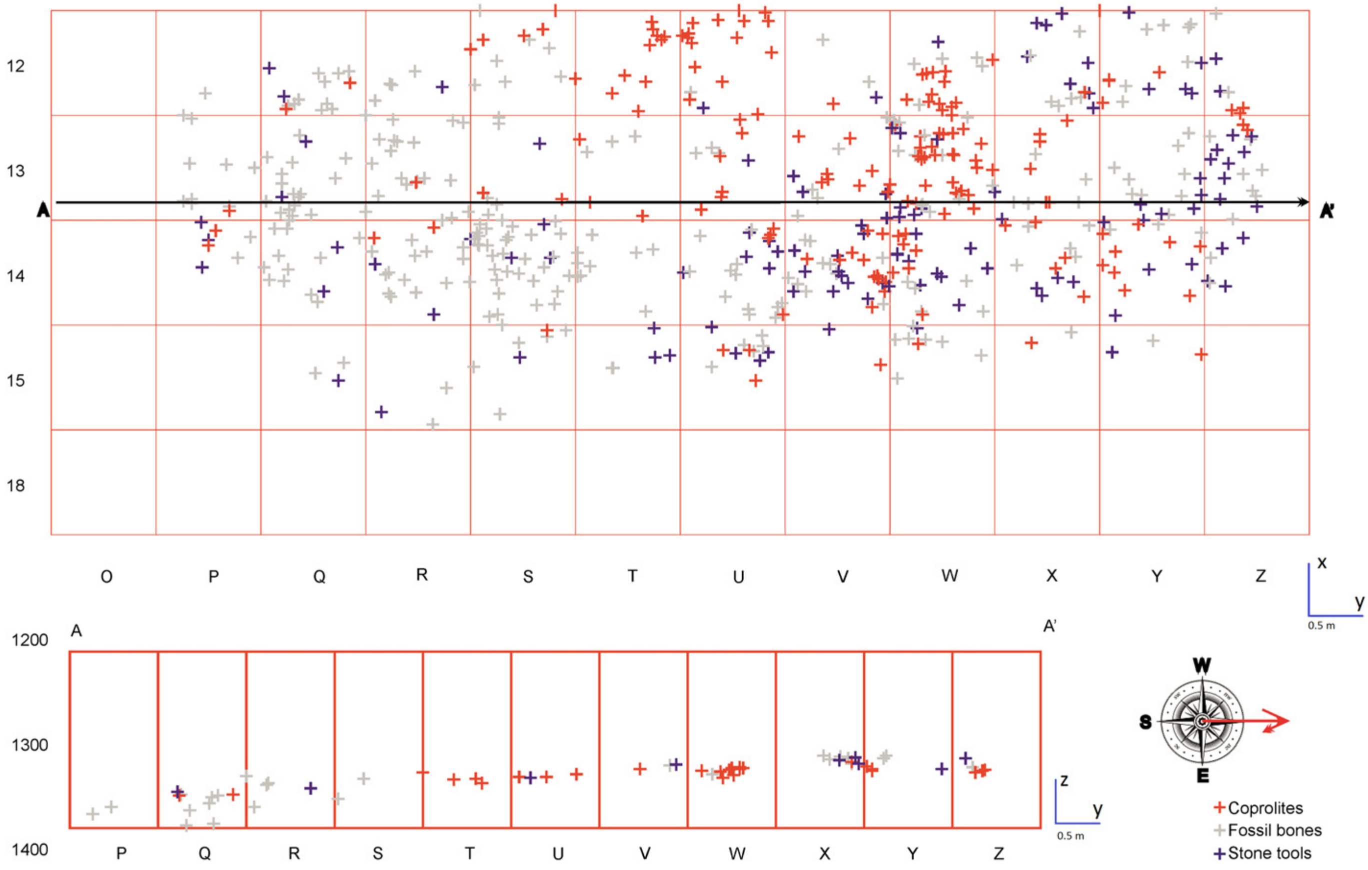

**Fig. 4.** Spatial distribution of coprolites and bone and stone remains recovered at la Mina Unit II. In the view of the excavated surface (top), the distribution of the coprolites in the entire surface is appreciable. In the longitudinal section (bottom), the accumulation of coprolites in the top of the Level II.3 is appreciable. Red arrow indicates theoretical north.

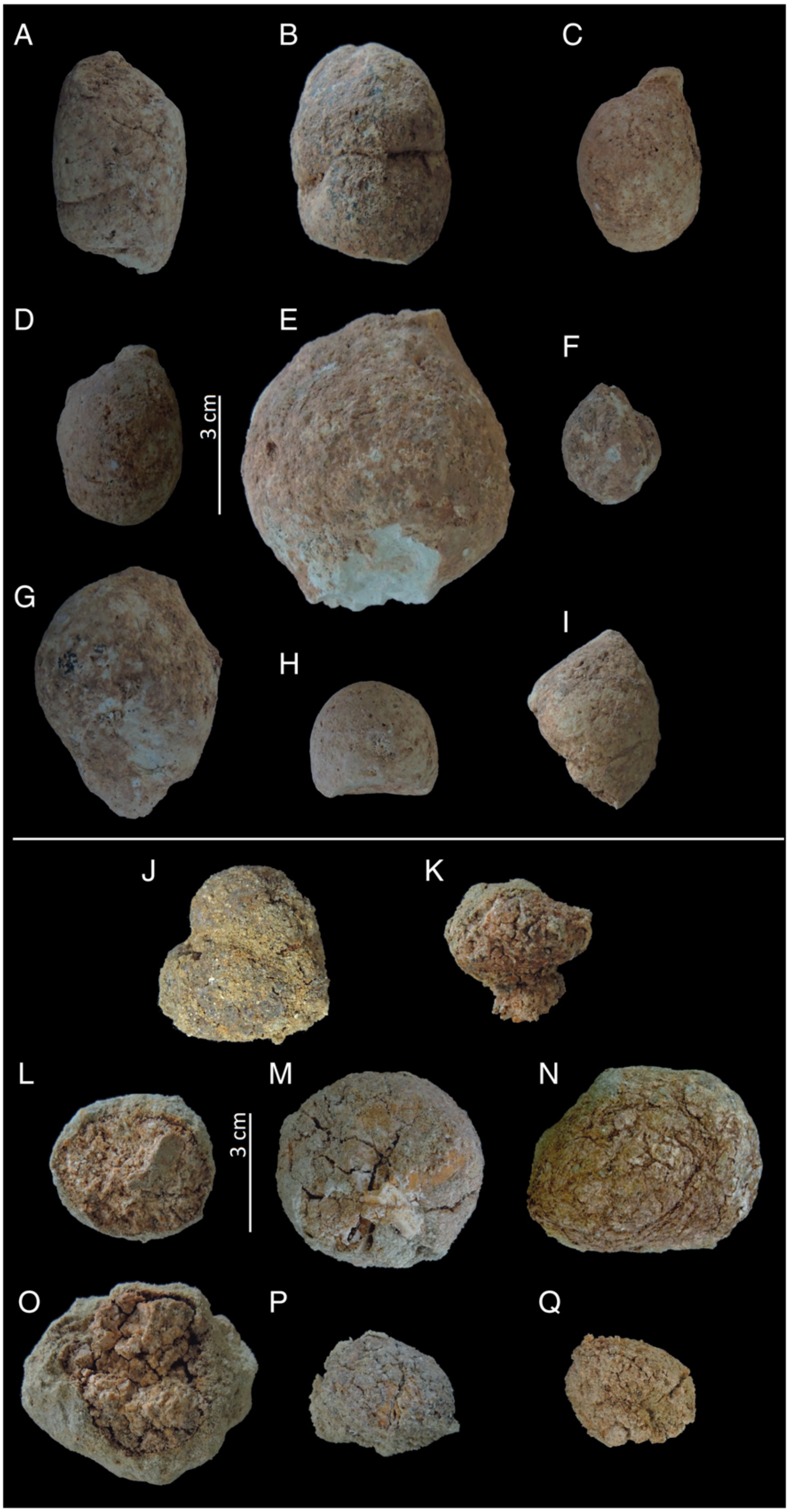

**Fig. 5.** Different coprolites recovered at both LM.II and TD6.1 sites. Top: coprolites recovered at TD6.1: A–D) complete coprolites formed by two fused pellets; E–F) conical pellets; G) isolated pellet; H) drop pellet; I) irregular pellet. Bottom: coprolites recovered at LM II: J–K) complete coprolites formed by two fused pellets (the second one (K) is heavily desegregated); L–M) drop, within visible bone fragments; N) drop; O–Q) irregular, undetermined and desegregated pellet.

99.2% of the samples. The percentage of coprolites showing cracking or fissures is 15.2%. Most of the matrices are very pale brown (62%) and, in a few cases, white (28%) (Fig. 3B). Five coprolites have indeterminate macro-mammal bone fragments in their matrix, measuring between 5 and 20 mm in length. However, it is noteworthy that coprolites were not destroyed for this analysis and the good preservation of the major

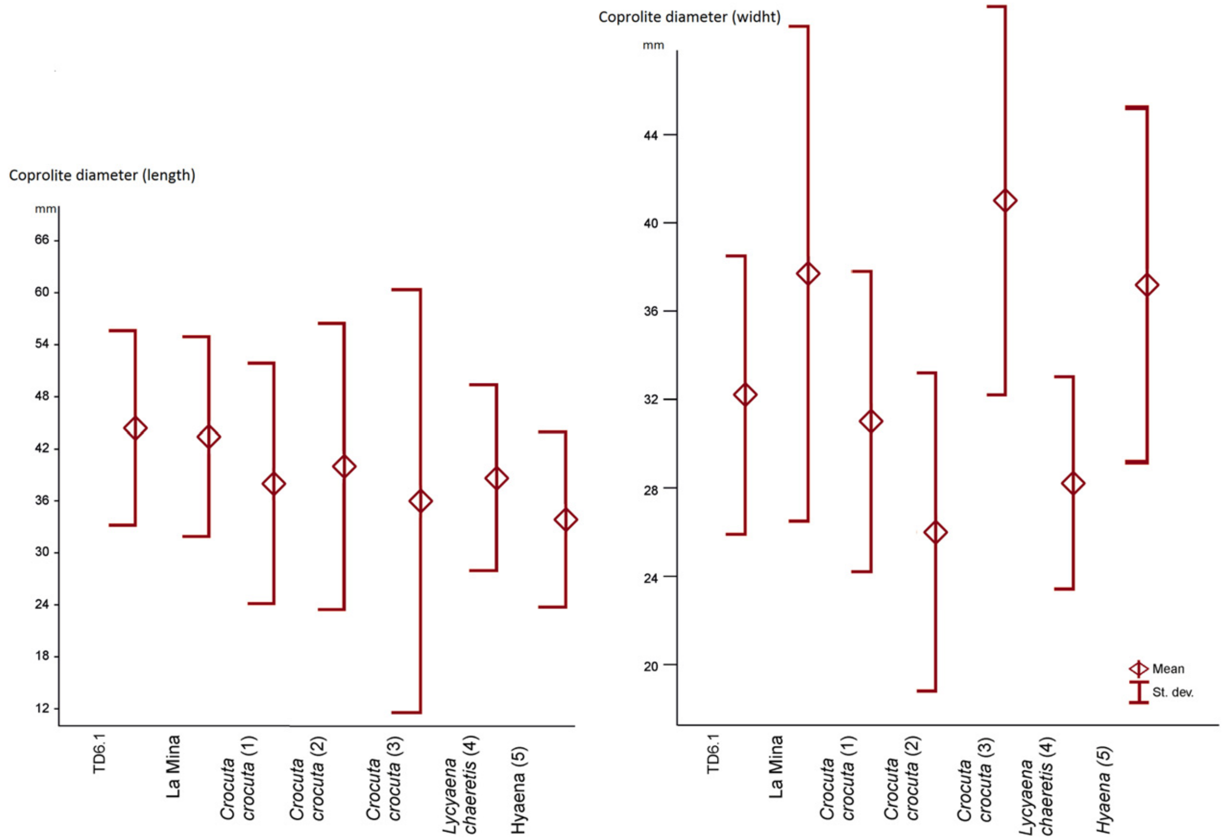

**Fig. 6.** Comparison of the length (left) and width (right) of the coprolites recovered at TD6.1 and la Mina with the data presented in previous research. (1) Modern drops of *Crocuta crocuta* (with pellets., Larkin et al. (2000)); (2) modern drops of *Crocuta crocuta* (without pellets., Larkin et al. (2000)); (3) Coprolites of *Crocuta crocuta* from WRF (Larkin et al., 2000); (4) Coprolites of *Lycyaena chaeretis* from LR2 (Pesquero et al., 2011); (5) Coprolites attributed to Hyaena from CCV (morphotype 1) (Sanz et al., 2016).

part of the recovered coprolites prevented the analysis of their matrix and the identification of bone fragments in most cases that may have been present.

### 5.2. La Mina, Unit II

Coprolites have been documented throughout the entire formation of Unit II at la Mina, although their highest concentration was observed at the top of Level II.3, in a layer between 10 and 20 cm thick that contains faunal remains and stone tools (Fig. 4). However, including all of the coprolites recovered from Unit II provides a more significant sample assemblage for this study.

Among the total number of remains ($n = 204$), the identification of the specific pellet was possible in 34 cases. One complete coprolite was recovered in the form of three separate pellets that were preserved together. Fragmentation, lixiviation, or problems of preservation affected 170 of the coprolites recovered (83.3%) (Table 2). The metric data relating to the size of the measurable coprolites and pellets is presented in Table 3. At la Mina and at TD6.1, high metric variability of the coprolites has been evidenced by their standard deviation and confidence intervals.

Taphonomic analysis was conducted for only 176 of the remains, since the other samples are completely altered. The colour of the external layer of the la Mina samples shows wider variability than for those from of TD6.1, with a predominance of brown (25%) and strong brown (40%). The percentage of reddish-yellow coprolites is notably lower (15%) (Fig. 3C). Cracked or fissured surfaces are present in 18.2% of the remains recovered at la Mina and 27.8% of the them are lixiviated. Manganese painting and root-etching were documented for 6.9% and 4.5% of the coprolites, respectively. The matrices also present a larger variety of colours than at TD6.1. Very pale brown (45%) and white (16%) are the predominant colours, although is remarkable that 11% of the remains have different grey tonalities (Fig. 3D). Macro-mammal bone remains were identified in 30 coprolites (14.7%), measuring between 3 and 15 mm in length, without anatomic or taxonomic identification.

### 5.3. Morphological features

In this and subsequent sections, the analysis and results from both assemblages are discussed together, providing an overview of the differences and similarities obtained in the comparison of the morphology and the contents of the coprolites.

As has been documented in the faeces of modern spotted hyenas (Horwitz and Goldberg, 1989; Larkin et al., 2000; Chame, 2003), the archaeological coprolites (Fig. 5) show the characteristic conical shape at the anterior end, due to the presence of the apex, and a drop shaped posterior end, as described by Diedrich (2012).

In general, pellets recovered from TD6.1 are larger than the la Mina coprolites (see Table 3). Data relative to their size in comparison with the values of both modern and fossil faeces belonging to *Crocuta crocuta* (Larkin et al., 2000), *Lycyaena chaeretis* (Pesquero et al., 2011), and hyenid provided by Sanz et al. (2016) (Fig. 6), show the overlapping of the values in all cases, being especially similar in length.

ESEM analysis indicated the presence of microspherulites in both fossilized and modern hyena faeces (Fig. 7A–D). Microspherulites were previously documented and described by Canti (1999). This researcher reported that microspherulites produced by ruminants, omnivorous and carnivorous mammals seem to have a similar composition, with the main difference being that ruminants produce them in larger numbers. Canti (1999) also suggested that deposition in the gut is the most likely explanation for the origin of microspherulites; specifically, formed in the more alkaline, lower part of the small intestine, thus discarding the possibility that they originated from grazing or from the deposited

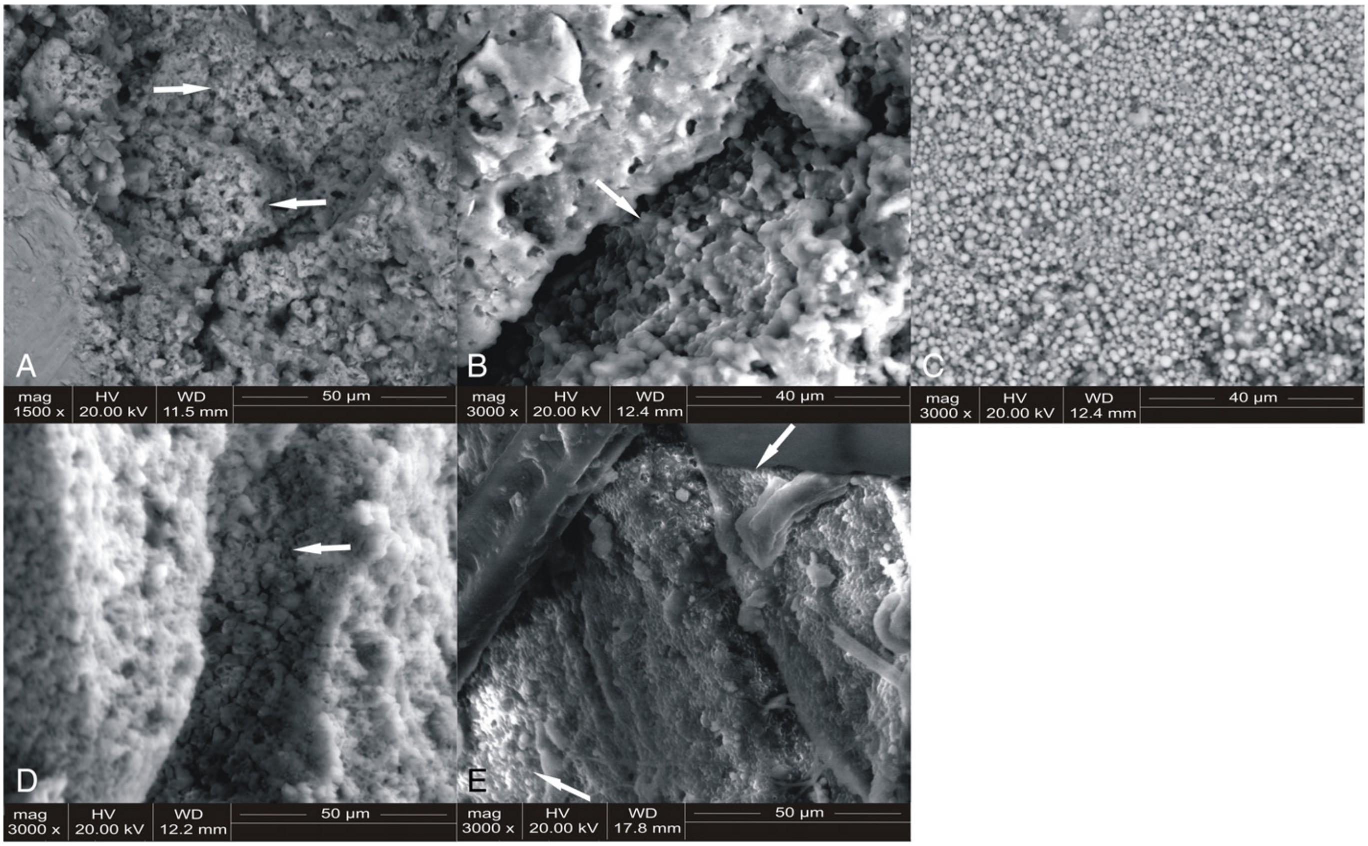

**Fig. 7.** Detailed view of the surfaces of different coprolites and modern drops, with the presence of microspherulites: A) hyena coprolite from TD6.1; B) hyena coprolite recovered at LM; C) modern drop of *Crocuta crocuta*; D) hyena coprolite recovered from Cova Foradada; E) modern drop of *Martes foina*. Photos were taken with an ESEM with 1500× (A) and 3000× (B–E). Arrow indicates concentrations of microspherulites.

faeces. Pesquero et al. (2014) previously documented the presence of microspherulties in fossil hyena drops described as '*are mostly embedded in a fine grained calcium phosphate precipitate*, *with brighter areas indicative of enrichment in Na and Cl*' (Pesquero et al., 2014; p. 999). In the hyena coprolites (LM, TD6.1 and Cova Foradada), microspherulites are observable from 1500×, being clearly visible from 3000×. In the case of la Mina, where coprolites were most poorly preserved, microspherulites were documented in the fissures, and, therefore, in the inner content of the coprolite. These inclusions are clearly visible in the modern sample from 1500×.

Microspherulites were also observed in the drops of *Martes foina* (Fig. 7E), but were not documented in the rest of the modern samples nor in the lynx coprolites (see Supplementary Fig. 1). However, in the *Martes foina* sample, the microspherulites are remarkably smaller in comparison with those present in hyena coprolites and modern drops and they required 3000× magnification for observation and 6000× for measurement (Fig. 8).

Metrical analysis of the microspherulites (see Supplementary Table 2) provides similar results for the different hyena drops. The diameter of the microspherulites tends to be between 1 and 3 µm. However, in all cases, the maximum value exceeds 3 µm, reaching up to 5.5 µm for the biggest microspherulite documented. The mean is near to or exceeds 2 µm in all cases, and the confidence values range between 0.5 and 1 µm.

### 5.4. Compositional analysis

The chemical composition of the modern and fossil hyena drops confirms a common pattern for all of the spectrums (Fig. 9A–D): high peaks of Ca (calcium), P (phosphorus), C (carbon) and, in minor values, elements such as Si (siliceous) and oxygen (O) (Fig. 9E). Although the presence of phosphates and carbonates in small quantities is common in faeces, the documentation of high quantities of calcium and phosphorus is expected in the case of hyena drops, because bone ingestion is common during carcass consumption (Kruuk, 1972; Brain, 1981; Larkin et al., 2000). The identification of siliceous elements could be attributed to the sedimentary context (clays) (Larkin et al., 2000).

The overall similarity of the spectra obtained and the Raman bands identified from the two samples of la Mina (Fig. 10A) indicate a similar composition in both cases. These were compared with fluorapatite and hydroxyapatite spectra (Fig. 10B), two minerals present in teeth and bones, respectively. The identification of peak 965 of the Raman band in all obtained spectra shows that fluoro-hydroxyapatite is present in the coprolites recovered from la Mina.

### 5.5. Palynological analysis

The concentrations of pollen, spores, and other palynomorphs are scarce in TD6.1 samples. The identified tree cover only includes pine (*Pinus* sp.), cf. *Juniperus*, hazel (*Corylus*), *Olea-Phillyrea*, and birch (*Betula*). Herbaceous vegetation is represented by wild grasses (Poaceae), Asteraceae, and *Asphodelus* (Fig. 11).

The most abundant Non-Pollen Palynomorphs (NPP) are ubiquitous fungal forms. Spores of sordariaceous fungi, which are often coprophilous, are present in all the samples analysed (van Geel, 1978; van Geel et al., 1989) (see Supplementary Fig. 2A). The micro-charcoal concentrations are low and only reach more significant values in the G14-6 specimen.

Pollen, spores, and other palynomorphs are also rare in the la Mina samples, probably because of the erosion processes that have affected the deposits. The identified tree cover only includes pine (*Pinus* sp.), Cupressaceae, evergreen oak (*Quercus ilex-coccifera* type), and *Olea-Phillyrea*, while herbaceous vegetation is represented by wild grasses

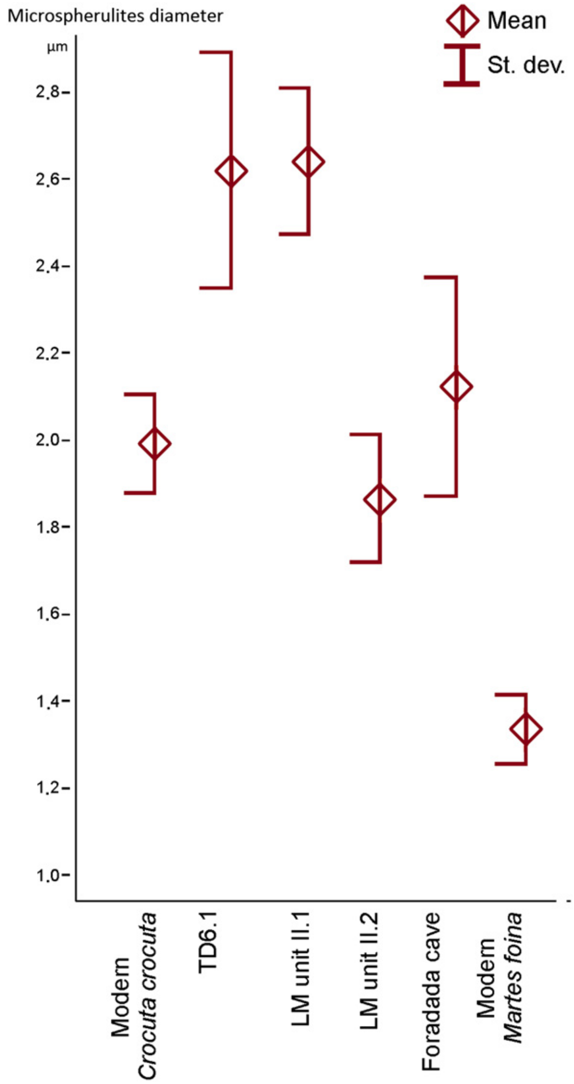

**Fig. 8.** Comparison of the dimensions of the microspherulites identified in the modern drops of *Crocuta crocuta* and *Martes foina* and different coprolites of hyena from TD6.1, LM and Cova Foradada.

(Poaceae), Asteraceae, Liliaceae, and the hygrophilous Cyperaceae (Fig. 12).

The Non-Pollen Palynomorphs results also show a significant representation of fungal remains in some of the coprolites analysed, although the coprophilous fungi are much less abundant than the lignicolous fungi. These fungal forms feed on wood and are associated with the erosive activity of tree roots (van Geel et al., 1989; van Hofwegen, 1983). The other fungal palynomorphs identified are found in a great variety of sedimentary contexts and are linked to the presence of decaying organic matter (Jarzen and Elsik, 1986; Carrión and van Geel, 1999) (see Supplementary Fig. 2B). The micro-charcoal concentrations are not particularly significant, except in the case of U13-3. These particles are present in the sediments and are possibly related to natural forest fires.

## 6. Discussion

The metrical, macro- and micro-morphological taphonomic analyses, compositional analysis, and content analysis of the coprolites recovered from Level TD6.1 of Gran Dolina (Sierra de Atapuerca) and Unit II of la Mina (Barranc de la Boella) suggest that they could be two hyena latrines of the Iberian Peninsula dating in the late Early Pleistocene. Data obtained in the present study, in concordance with that of in previous works (Table 4), provides useful comparisons contributing to correctly characterizing latrines and coprolites, as well as providing an approach to identifying the generating agent of these accumulations.

### 6.1. Location context of the latrines

Level TD6.1 of Gran Dolina and the top of Level II.3 of la Mina are described as two latrines with a high number of spatially related coprolites. However, both represent very different contexts: while TD6.1 is in a cavity, the latrine identified at la Mina corresponds to an open-air context. Both contexts represent spaces where modern *C. crocuta* tended to locate their latrines (Kruuk, 1972; Brain, 1981; Mills and Gorman, 1987). The use of the cavities for the establishment of latrines is a common behaviour documented among modern spotted hyenas (Brain, 1981) as previously identified in the fossil record (Berger et al., 2009; Mangano, 2011). Also, modern-day spotted hyena latrines have also been documented in open-air contexts (Kruuk, 1972; Brain, 1981; Mills and Gorman, 1987), as well as in the fossil record (Pesquero et al., 2011). Elsewhere, studies of Kalahari hyenas (*Crocuta crocuta* and *Hyaena brunnea*), Gorman and Mills (1984, Mills and Gorman, 1987) have revealed numerous latrines in open-air sites, noting that they tend to be situated near landmarks such as; a riverbeds (where they were most highly concentrated), dry pools, or close to trees or tall, thick vegetation. This is in agreement with the description from the Barranc de la Boella (Vallverdú et al., 2014), a formerly flooded habitat near the confluence of a tributary and axial river, where channels and pools of water were located nearby.

### 6.2. Assemblage formation

The TD6.1 coprolite layer was formed on a red decantation facies, indicating a slow sedimentation rate (Campaña et al., 2017). The presence of contiguous coprolite pellets and the absence of water abrasion leads us to discard the hypothesis of re-deposition of the materials that, are not related to the osteological samples identified to the north of the excavated area (Saladié, 2009). The identification in several cases of contiguous pellets is also indicative of burial in situ with little distribution of the materials (Saunders and Dawson, 1998). Sedimentation in Unit II of LM was formed by poorly stratified sands and gravels, indicative of subaerial and subaquatic flow in mass deposits (Vallverdú et al., 2014). This context could have modified the original disposition of the coprolites composing the latrine. Larkin et al. (2000) have shown that drops of modern *Crocuta crocuta* are very dense and require relatively high currents to be displaced. The identification of three separated pellets of the same coprolite spatially associated within a few centimetres is indicative of rapid burial and little disturbance of the materials (Saunders and Dawson, 1998). This is in accordance with previous taphonomic studies, which suggested low water abrasion in the modification of archaeological remains (Vallverdú et al., 2014; Pineda et al., 2015).

### 6.3. Taphonomy

Contextual differences (cave vs. open-air site) could better explain the preservation of coprolites from TD6.1 (mineralized and restored preserving the original morphology in many cases) compared with those from la Mina (dried at source and retrieved, in many cases, partial or completely disaggregated). Lam (1992) has shown that bone remains deposited in caves or shelters tend to be less affected by weathering because changes in temperature and humidity render them soft and unstable, especially when they were deposited nearby to cave entrances. Certainly, bones recovered from both sites reflect differential preservation, as reflected also in the faunal remains which are well preserved from TD6 levels and altered from la Mina (humid and needing conservation treatment in most cases).

It is to be expected that this pattern explain, at least in part, problems regarding coprolites preservation at la Mina in relation to TD6.1. Site humidity, together with trampling by hyenas, caused the coprolites to be fragmented according to Mangano (2011). The study conducted by this

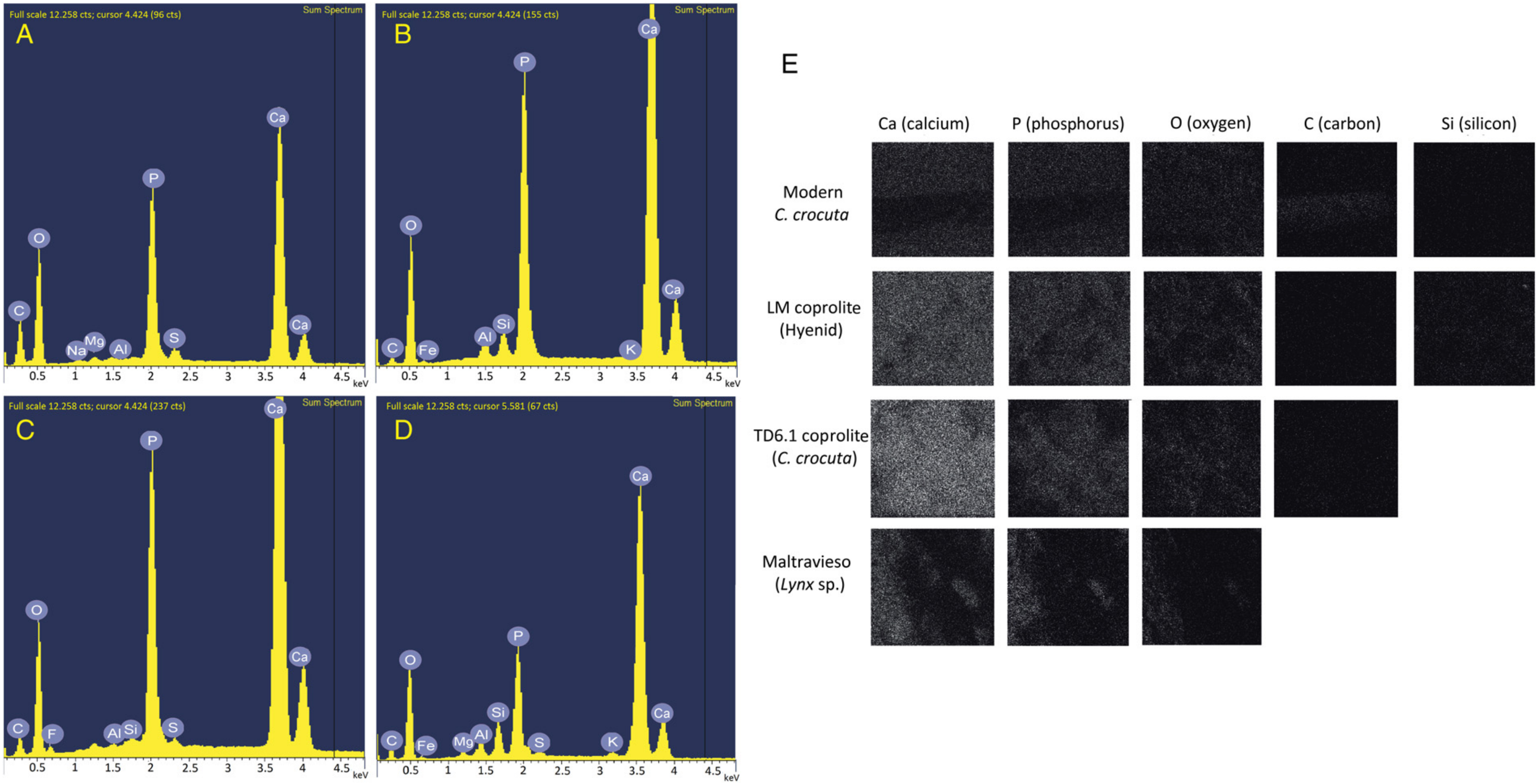

**Fig. 9.** Chemical composition of the different analysed samples: A) modern drop of *Crocuta crocuta*; B) hyena coprolite from la Mina; C) coprolite of *Crocuta crocuta* from TD6.1; D) coprolite of *Lynx* sp. from Cueva de Maltravieso; E) presence and distribution of the different components in the same samples. Maps and spectra obtained with ESEM.

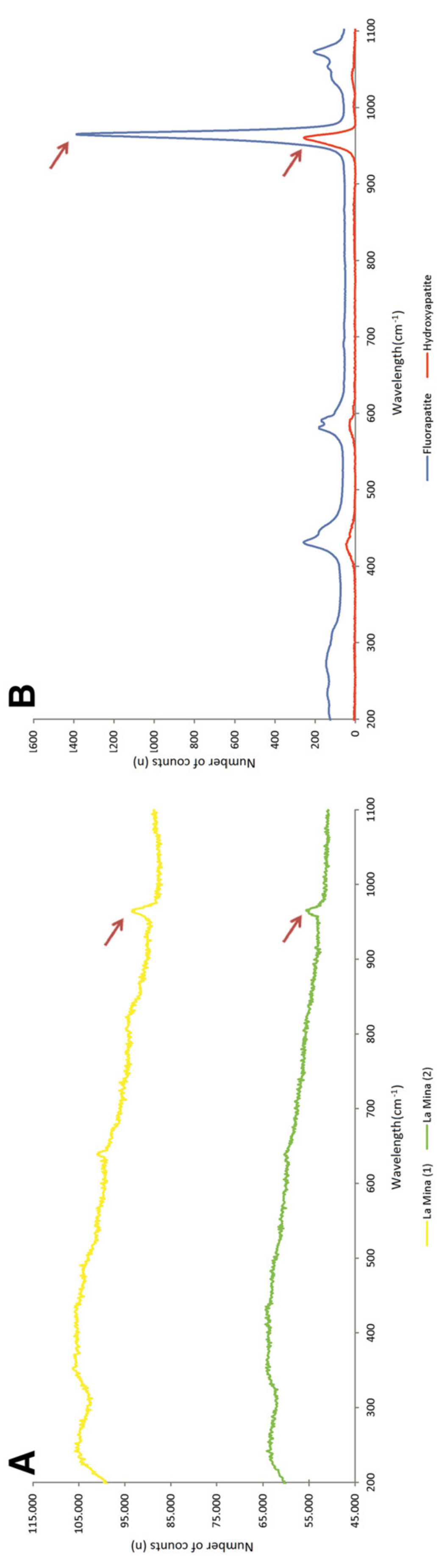

**Fig. 10.** Raman spectra of two samples of la Mina (A) and two minerals (fluorapatite and hydroxyapatite) present in the composition of the skeleton and expected to be identified in hyena coprolites (B). Raman spectra are shown in separate graphs due to differences in waveform emission intensity in both cases (less than 1500 in the first graph and higher than 100,000 in the second one). Red arrows mark the presence of a Raman band in all spectra at point 965.

researcher of two levels (BI and B-II) rich in coprolites (8249 and 1670 coprolites, respectively) in the Late Pleistocene site of San Teodoro Cave (Italy) provides very interesting data since coprolites recovered from B-II were much more fragmentary. The study shows that a frequency of complete remains leads to the exclusion of trampling as the cause of breakage, while in very humid conditions, such as those existing during the formation of B-II, coprolites would be poorly preserved (Mangano, 2011).

The predominance of white colours in the matrix is due to the composition of the coprolite, formed by a layer of powder consisting of $Ca_3(PO_4)_2 1.5Ca(OH)_2$, which corresponds to the inorganic content of ingested bones (Kruuk, 1972; Larkin et al., 2000). Brown tonalities, although less common, are also documented (Sillero-Zubiri and Gottelli, 1992). The external colour of coprolites is generally related to the colour of the sediment. However, the greater chromatic variability of the coprolites recovered at la Mina, in comparison with TD6.1, is probably related to taphonomic processes. In any case, these differences were related to the composition of the coprolites, which is similar in both assemblages.

Bone fragments were identified in less than 3% of the coprolites from TD6.1, while they have been identified in almost 15% of the remains from la Mina, thus representing the major difference in the coprolites from both sites. However, we should remark that in this study, coprolites were not intentionally disaggregated for identification purposes of the internal content. For this reason, the high disaggregation of the coprolites from la Mina, due to problems of preservation, allowed for macroscopic observation of the internal content of many coprolites, thus enabling us to identify a larger number of bone fragments in their matrix. The fact that the TD6.1 coprolites were mineralized and better preserved, with a sealed matrix, explains why less bones were identifiable without resorting to destructive techniques.

### *6.4. Palynological analysis*

Pollen provided by both sets of samples are extremely rare because of diagenetic processes that have affected their preservation. Only the presence of some arboreal, shrubby, and herbaceous taxa have been noted. This hinders reliable palaeoenvironmental reconstructions, although several inferences can be made. For example, the identification of Cyperaceae, related to wet environments, agrees with the sedimentation description of the site and the faunal studies of Barranc de la Boella, where the presence of mammals in this biome (i.e. *Hippopotamus antiquus*, *Castor* sp. or *Mimomys savini*) has been described (Lozano-Fernández et al., 2014; Vallverdú et al., 2014; Pineda et al., 2015). Previous sedimentological and faunal studies also suggest that there were grassland areas (i.e. the presence of horse and bovid), where wild grasses, Asteraceae, and other herbaceous plants identified by the palynological analysis, could have proliferated. On the other hand, the NPP identified in our samples are fundamentally fungal types related to the presence of faeces or decaying organic matter. However, we must emphasize that, in the samples from la Mina, the most important fungal forms are those related to the activity of the plant roots, especially the mycorrhizal fungi *Glomus* sp.

### *6.5. Morphological and size comparisons*

Analysed coprolites were characterized by homogeneity in their morphology, according to the different categories of pellets established by Diedrich (2012). However, our results show a high variability in size within each assemblage. The variability of these elements is to be expected (Chin, 2002; Diedrich, 2012) and may be due to multiple factors, such as: the age of the individual who produced it, the food ingested, or the absorption capacity of defecators (Chame, 2003). Comparison of the size of the coprolites recovered at TD6.1 and la Mina with the data presented by Larkin et al. (2000) of modern *Crocuta crocuta* drops and fossil drops from WRFB, Pesquero et al. (2011) from LR2 and Sanz et al. (2016) from CCV also provides very interesting data. Coprolites from WRFB

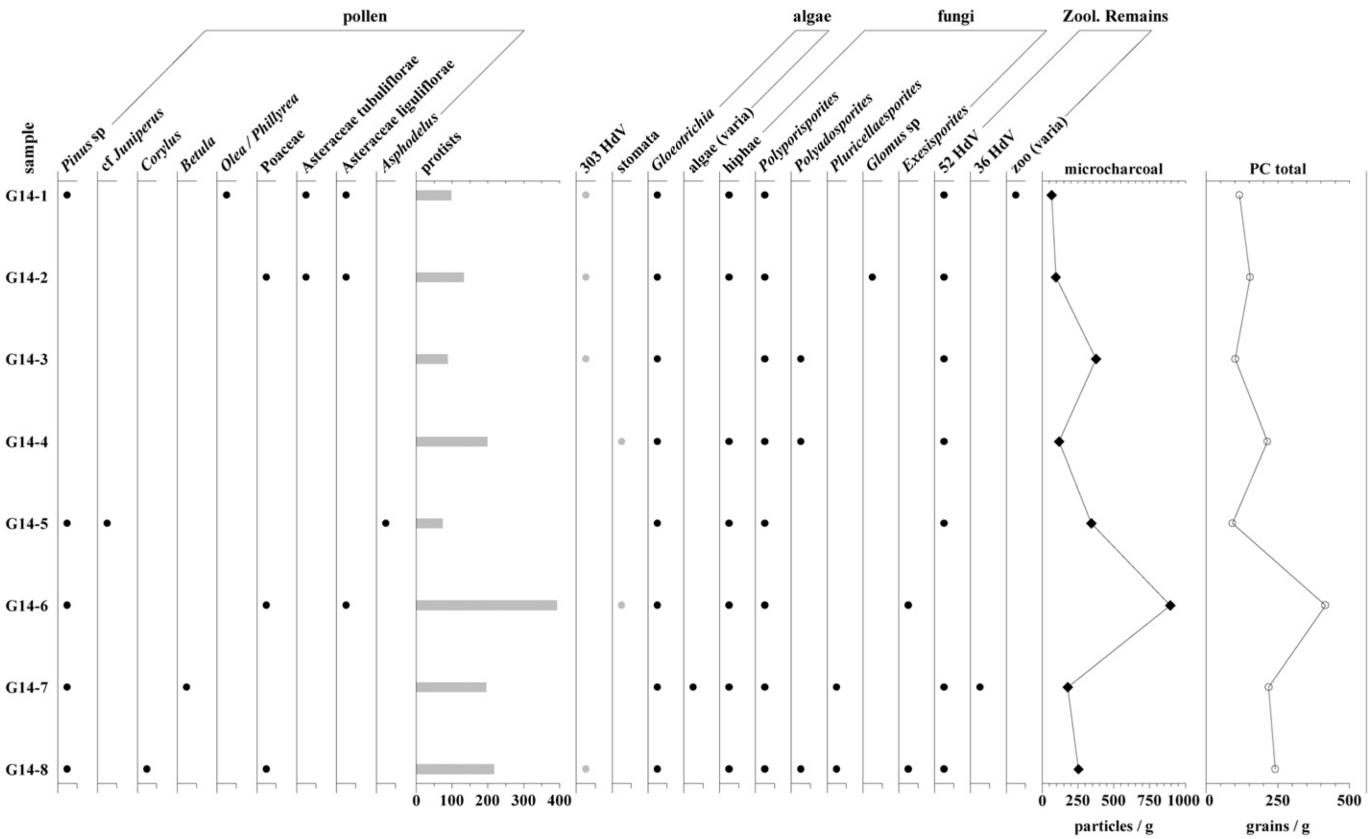

**Fig. 11.** Palynological diagram of TD6.1 showing concentrations values of microcharcoal, pollen, and Non-Pollen Palynomorphs. Points indicate presence of taxa.

were attributed to *Crocuta crocuta* (Larkin et al., 2000). These researchers based their attribution on morphology, the analysis of the chemical composition, and the identification of the remains of *Crocuta crocuta* from elsewhere. In LR2, to the contrary, Pesquero et al. (2011) remarked that two different hyenids were identified in the set: *Hyaenicitherium* sp. and *Lycyaena chaeretis*. These researchers have suggested that *Lycaena chairetis* could be the hyenid that would have generated the accumulation of LR2, based on the larger size of the species regarding to *Hyaenicitherium* sp. and a possible stronger presence of bones in their diet. On the other hand, Sanz et al. (2016) described three distinct morphotypes of coprolites at CCV and determined that coprolites from one of these groups (morphotype 1) were produced by hyenas.

In any case, comparison of our values with those reported in these works shows the similarity in size thereof, even though they are produced by different species (at least the coprolites of the Miocene site of LR2 without doubt). We cannot assign the coprolites to a particular species based only on their size in contexts such as the late Early Pleistocene, where two hyenids (*Crocuta crocuta* and *Pachycrocuta brevirostris*) have been identified on the Iberian Peninsula (Turner, 1992; García and Arsuaga, 2001; Rodríguez et al., 2011). Based on this premise, coprolites that were recovered at la Mina have been assigned to a hyenid, identified as member of the family Hyenidae, without inferences to genus or species, because the absence of hyenas in the Barranc de la Boella for the moment. However, we highlighted that a complete study including morphology, surface analysis, matrix content, and the context in which the coprolites have been found may provide, in some cases, sufficient data to identify the defecator species (Jouy-Avantin et al., 2003; Linseele et al., 2013); this is the case of TD6.1, where we conclude that *Crocuta crocuta*, identified a Gran Dolina during the Early Pleistocene (Rodríguez et al., 2011), could have been the agent that caused the accumulation.

Microspherulites were documented in all examined hyena drops (both fossil and modern samples) and in the modern drops of *Martes foina*. Previously described by Pesquero et al. (2014) in the coprolites of *Lycyaena chaeretis* of LR2, they suggested an abiotic origin due to the presence of two thin walls made of needle-shaped crystals. There do not seem to be differences between the microspherulites described by Canti (1999) for ruminants and those identified here in hyena faeces. We discard the hypothesis that microspherulites in hyena drops could appear through the consumption of their prey's guts because, as Canti (1999) described, microspherulites do not survive in the more acidic upper parts of the small intestine. This researcher also identified microspherulites in small carnivore faeces (cat, dog and fox) although considering that these taxa produce them in lesser quantity. Our analyses reveals that hyena also produce high quantities of microspherulites, indicating that this could be a useful criteria for identifying hyena drops in the fossil record. These microspherulites are visible from 1500×. They were not documented in the modern drops of carnivores or herbivores, nor in coprolites attributed to lynx.

### 6.6. Compositional analysis

The most descriptive characteristic of the carnivore coprolites is the presence of phosphates in their composition, especially in the case of hyena coprolites (Kruuk, 1972; Horwitz and Goldberg, 1989; Larkin et al., 2000; Pesquero et al., 2011; Sanz et al., 2016). Calcium and phosphorus are the most abundant elements in the coprolites analysed, as in the coprolites from LR2 (Pesquero et al., 2011, 2014), WRFB, Boxgrove, and in the modern drops of *Crocuta crocuta* (Larkin et al., 2000). Larkin et al. (2000) determined that the content of Ca in the coprolites ranged from 25 to 35%, while the P supposed 10–15%. The organic content ranged between 5 and 31%. This data confirms, according to the researchers, the substantial ingestion of bones by hyenids. The Raman spectra obtained for two samples from la Mina shows the presence of calcium phosphate (fluorohydroxyapatite). This component, present in bones and teeth, is to be expected in hyenids coprolites due to the ingestion of skeletal elements or other fragments of their prey (Kruuk, 1972; Larkin et al., 2000).

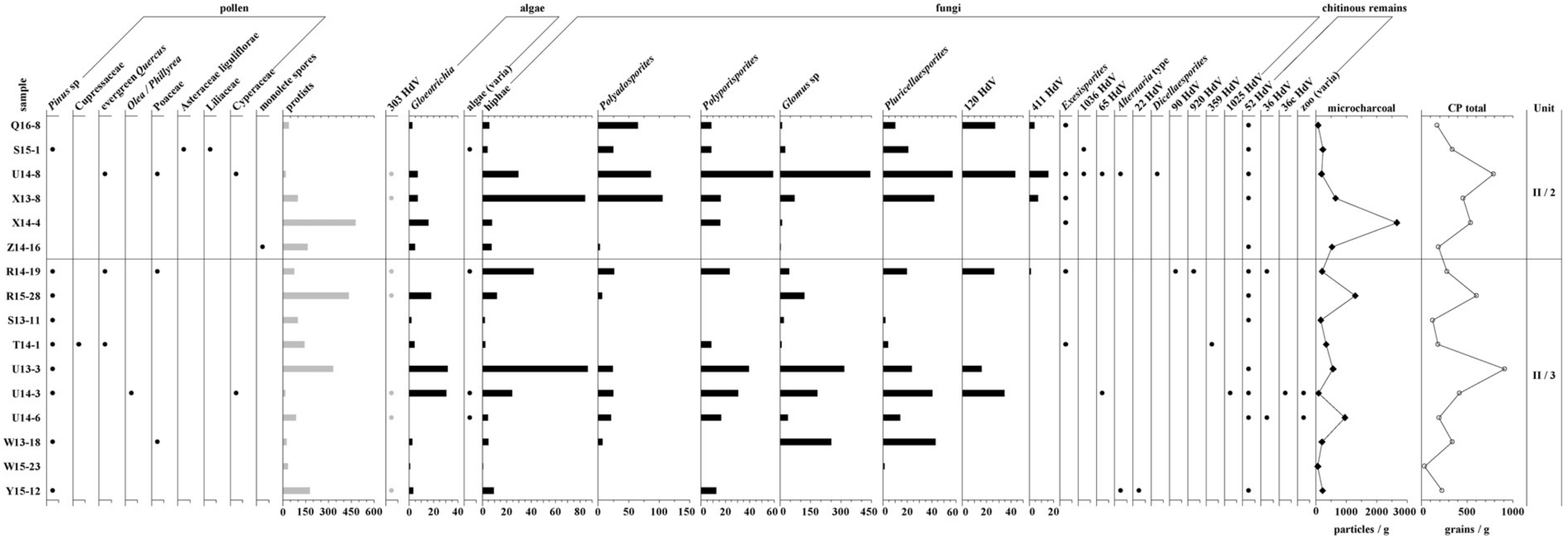

**Fig. 12.** Palynological diagram of la Mina showing concentrations values of microcharcoal, pollen and NNP. Points indicate presence of taxa.

**Table 4**
A holistic view of the criteria for study coprolites in this and previous researches.

| | Present study | | | Previous studies | | | |
|---|---|---|---|---|---|---|---|
| | TD6.1 coprolites | LM. unit II coprolites | Modern *Crocuta crocuta* drops | Modern *Crocuta crocuta* drops* | *Crocuta crocuta* coprolites (WRFB)* | *Lycyaena chaeretis* coprolites (LR2)** | Hyena coprolites (CCV)*** |
| Latrine description | ■ | ■ | | | | ■ | |
| Characteristic morphology**** | ■ | ■ | | ■ | ■ | ■ | ■ |
| Size variability | ■ | ■ | | | ■ | ■ | ■ |
| Taphonomic modifications | ■ | ■ | | | ■ | | ■ |
| Size comparison | ■ | ■ | | ■ | ■ | ■ | ■ |
| Specie identification | ■ | | | | ■ | ■ | ■ |
| Presence of microspherulites | ■ | ■ | ■ | | | ■ | |
| Presence of fluor-hydroxyapatite | | ■ | | | | ■ | |
| Chemical composition | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Palynological analyses | ■ | ■ | | | | ■ | |

Comparison of the criteria included in our analysis of the coprolites and in previous research. *Data from Larkin et al. (2000); **Data from Pesquero et al. (2011); ***Data from Sanz et al. (2016); ****Characteristic morphology, as have been described by Larkin et al. (2000) and Diedrich (2012). Black cells represent the criteria for study coprolites applied in each research.

## 7. Conclusions

In this study, two latrines dated in the late Early Pleistocene excavated in Level TD6.1 of Gran Dolina (Sierra de Atapuerca) and Unit II of la Mina (Barranc de la Boella) have been analysed, as well as the coprolites included therein. Our results show that these accumulations could represent two hyena latrines, thus allowing to characterize both the space and the coprolites recovered and to try to identify their generating agent. The analyses conducted illustrate the morphological homogeneity of the coprolites, despite their wide-metric range and that of other coprolites described in previous research. This allows us to discard size as a criteria for identifying the defecator species. The presence of abundant microspherulites appears to be a common element in hyena faeces and could be used as a criteria for identifying hyena drops in the fossil record. Their composition is characterized by an abundance of elements of bone-origin, such as calcium (Ca) and phosphorus (P). A major difference between both sites was the relative abundance of bone fragments in the la Mina coprolites, compared to TD6.1 although this could be related to problems of preservation of the coprolites from la Mina. Pollen, spores, and palynomorphs are scarce in the samples from both sites, which share several ecological characteristics, such as the presence of pine, wild grasses, and coprophilous fungi. The analytical complexity of the study of coprolites reflects that these elements are, in essence, packages that represent changes in diets and digestive processes of animals that generated the coprolites and various processes of diagenetic alteration. This complexity underscores the importance of conducting the study of these materials from an integrative perspective, which allows to obtain the maximum information possible relating to defecators and their ethology, the taphonomic history of the assemblages, and the landscape in which they were deposited. Our work highlights the high metric variability of these elements and the importance of a wide study of coprolites and their contexts in order to make inferences about the agent that generated the accumulation. This is the case of TD6.1, where our study allows us to identify *C. crocuta* as the defecator agent, while at la Mina, we conclude that the defecator was a hyenid, without specific inferences.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.palaeo.2017.04.021.

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# Capítulo 7. Torralba

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Los resultados obtenidos durante el análisis de los restos faunísticos de Torralba se presentan en un artículo enviado a la revista *Archaeological and Anthropological Sciences*.

**Artículo 6:** Pineda, A. y Saladié, P. (enviado). The Middle Pleistocene site of Torralba (Soria, Spain): A taphonomic view of the Marquis de Cerralbo and Howell faunal collections. *Archaeological and Anthropological Sciences.*

The results obtained during the analysis of faunal remains from Torralba are presented in a submitted paper at *Archaeological and Anthropological Sciences* journal.

**Paper 6:** Pineda, A. and Saladié, P. (submitted). The Middle Pleistocene site of Torralba (Soria, Spain): A taphonomic view of the Marquis de Cerralbo and Howell faunal collections. *Archaeological and Anthropological Sciences*

# The Middle Pleistocene site of Torralba (Soria, Spain): A taphonomic view of the Marquis de Cerralbo and Howell faunal collections

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## Abstract

Since the beginning of the first excavation work carried out by Cerralbo (1909-1913) at the Torralba site, it has become a reference point for the study of the earliest settlers of the Iberian Peninsula, as well as for the evaluation of the hunting and cognitive abilities of Middle Pleistocene hominins. The most abundant remains at Torralba are elephant remains, which has directed the debate towards the link between these carcasses and human groups. However, the faunal record of Torralba is broader and includes greater species diversity. This work describes a taphonomic review of the macro-faunal materials of the classic excavations of Torralba (Cerralbo, 1909-1913; Howell, 1961-1963) housed in the Museo Numantino de Soria, Museo Nacional de Ciencias Naturales of Madrid and the Museo Arqueológico Nacional of Madrid. Our results show that other taxa, such as the horse and the bovid, are also represented. Evidence of anthropic activity is scarce. Carnivore activity has been documented mainly in the form of tooth marks. There is no evidence of the co-occurrence of both agents on the same carcasses. The possible formation of these deposits as identified as spatial palimpsest in which various independent events of different natures and characteristics in terms of ecological composition are recorded in the same place, one on top of the other. Middle Pleistocene hominins were clearly adapted to environments with an abundance of resources throughout the Lower Paleolithic on the Iberian Peninsula.

**Keywords:** Competition dynamics, Iberian Peninsula, Lower Paleolithic, paleoecology, zooarchaeology

## 1. Introduction

The Torralba and Ambrona deposits, discovered in 1888 by Enrique de Aguilera y Gamboa, XVII Marquis of Cerralbo, placed the Lower Paleolithic on the Iberian Peninsula at the center of research during the 20th century (e.g. Aguilera y Gamboa, 1913; Howell et al., 1963; Howell, 1966; Binford, 1981; 1987; Freeman and Howell, 1982; Shipman and Rose, 1983b; Klein, 1987; Villa, 1990). The large accumulations of faunal remains (mainly from elephants) and lithic tools attracted the attention of a great number of researchers, including Francis Clark Howell, Leslie Gordon Freeman, Emiliano Aguirre, Karl W. Butzer, Richard G Klein and Lewis R. Binford during the 1970s and 80s (Howell et al., 1963; 1995; Biberson, 1964; Butzer, 1965: Freman and Butzer, 1966; Howell, 1966; Freeman, 1975; 1978; Binford, 1981; 1897; Howell and Freeman, 1982; Klein, 1987). In recent years, these materials have become the object of study once again, this time with a focus on the stone tools (Sánchez-Cervera et al., 2015) and the wood recovered at the site (Postigo-Mijarra et al., 2017).

Neither of the two sites, which are considered sibling sites, is free of controversy, as they were both part of the great debate that centered around the zooarchaeological and taphonomic studies of the 1980s (and continues today) regarding the hunting abilities of Pleistocene hominins (e.g. Binford et al., 1988). Cerralbo, as well as Howell and Freeman (Aguilera y Gamboa, 1913; Howell et al., 1963; 1995; Howell, 1966; Freeman, 1975; 1978), concluded that these early hominins were hunters of elephants and other taxa in settings characterized by the presence of ponds or lagoons. In addition to these pioneering interpretations, there was also some interest in how this practice was carried out. Aguilera y Gamboa (1913) proposed that these hunting events made use of ambushing or trap-setting in places near the water sources that the animals frequented. Howell (1966) and Butzer (1971) proposed hunting by driving herds. However, Klein (1987) dismissed this proposal after studying mortality profiles, and concluding that the mortality profile was attritional and not catastrophic as would be expected in mass hunts. Binford (1981; 1987), in keeping with his position defending hominins as the most marginal of scavengers at least until well into the Upper Pleistocene, supported a minor anthropic role in the formation of the two deposits. According to his criteria, anthropic activity at the sites would have been limited to the scavenging of the few remains abandoned by the carnivores, which would have been primarily responsible for the formation and modification of the assemblages.

Shipman and Rose (1983b) used SEM (scanning electron microscopy) and applied what were at the time the most novel methods of microscopic observation to the butchery and tooth marks previously identified in the Torralba fossil assemblage. Their work verified the presence of cut marks and carnivore scratches, although both in values lower than 1%. According to their proposals, these low percentages may be due to erosion, since signs of abrasion were the most common in the assemblages. Thus, Shipman and Rose (1983b) clearly demonstrated that hominins and carnivores had modified the bones of these deposits, but could not confirm or rule out the interpretation of these sites as possible butchering sites or the product of carnivore activity. Haynes (1988; 1991), by analogy with the large accumulations of elephant remains in the African savannas, concluded that Torralba (and Ambrona) are accumulations of remains of natural origin, and related the fracturing in the deposit to trampling by the proboscideans themselves. Meanwhile, Díez (1993) suggested that, together with natural death, it was possible that lion hunting might explain the concentration of elephant and large bovine remains in Torralba; the role of hominins was limited to the scavenging of the smaller animals abandoned by canids. However, Domínguez-Rodrigo (1998) noted that the percentage of tooth marks is lower than that produced by felids in circumstances of early and primary access and the death profiles of equids and large bovids did not correspond to those produced by canids. Domínguez-Rodrigo (1998) and Yravedra Sainz de los Terreros (2000) agreed that the sites correspond to a complex taphonomic history, formed by multiple accumulation processes and events in which hominins and carnivores would have been involved in some cases.

The present work presents the complete study of the macro-mammal faunal remains from the classic collections of Torralba deposited in the Museo Numantino de Soria (MNS), the Museo Nacional de Ciencias Naturales (MNCN-CSIC) of Madrid and the Museo Arqueológico Nacional (MAN) of Madrid, with the aim of taphonomically characterizing these materials considering the role of hominins and carnivores in these accumulations.

### *1.1. The classic excavations in Torralba: the Marquis de Cerralbo phase (1909-1913) and the Howell phase (1961-1963)*

The first archaeological interventions in the archaeological-paleontological site of Torralba (Torralba del Moral, Medinaceli, Soria) were carried out between 1909 and 1913 by the Marquis of Cerralbo, after work on the old railway station of Torralba exposed the remains of Pleistocene proboscideans (Santonja et al., 2005a; 2014). In his notes, Cerralbo states that his work covered an area of 200 m$^2$ at Torralba (Aguilera y Gamboa, 1911) over the course of six excavation campaigns between 1909 and 1913, although subsequent research by Howell et al. (1962) suggested that Cerralbo's work may have affected an area of approximately 2000 m$^2$, though perhaps not completely excavated (Santonja et al., 2014). The excavation work led to the recovery of more than 600 faunal remains, mostly elephant (n = 525), along with 552 lithic tools (Aguirre, 2005). Cerralbo proposed that it was the oldest human occupation in Europe, and that the site reflected the hunting of elephant herds by a hominin group that had presumably settled on the shore of an ancient lake (Santonja et al., 2014).

Starting in 1914, Cerralbo moved his work to the neighboring site of Ambrona, and the archaeological intervention at Torralba was put on hold for more than four decades. Howell started works in Torralba in 1960, and carried out three excavation campaigns between 1961 and 1963 (Aguirre, 2005; Santonja et al., 2005b; 2014). During this period, the boundaries of the excavation, which covered an area of up to 5000 m2, were investigated by means of pits (Aguirre, 2005), and the geology of the Torralba deposit and the surrounding environment was described (Butzer, 1965; Freeman and Butzer, 1966). More than 2000 faunal remains were recovered during this period, again, with the elephant the most abundant taxon (Biberson, 1968; Aguirre, 2005). In line with the interpretations proposed by Cerralbo, Howell and his team interpreted Torralba as resulting from organized hunting by Middle Pleistocene hominin groups, who would have led the herds of animals to mudflats where they would have been killed, butchered and prepared for consumption (Howell et al., 1962; Howell, 1966; Biberson, 1968; Freeman and Howel,l 1982).

Two studies of lithic technology were also derived from these excavation campaigns (Biberson, 1964; Freeman, 1975), in which the technology was attributed to the Middle and Late Acheulean, respectively. Subsequent works (e.g. Carbonell et al., 1987; Santonja and Villa, 1990) have discussed the stone tools of Torralba and their place in the Iberian Middle Pleistocene. Recently, Sánchez-Cervera et al. (2015) reviewed the lithic collections of the Cerralbo and Howell excavations. In total, 552 pieces from the Cerralbo collection and 977 from the excavations undertaken in 1960 were studied. The researchers placed the lithic industry within the Acheulean techno-complex, which in light of the new dates (Santonja et al., 2014), makes it the latest Acheulean identified in southern Europe. They also highlight the presence of progressive technological elements, which give rise to the need to investigate whether there might be technological traditions within the Middle Paleolithic in the Torralba levels (Sánchez-Cervera et al., 2015), as they have been identified in the neighboring site of Ambrona (Santonja and Pérez-González, 2010).

Since then, work on the Torralba (and Ambrona) deposits has continued intermittently. Alfredo Pérez-González and Manuel Santonja undertook new project at Torralba and Ambrona, with Rafa Mora leading field works in Torralba between 1994 and 1999, including the excavation of more than 20 preliminary pits, mainly focused on controlling the degree of conservation of the deposit and evaluating the potential for future excavations (Santonja et al., 2005b). Between 1998 and 1999 an area located in the NE part of the site was excavated; it is an area near the ruins of the old railway station and, therefore, adjacent to the area originally excavated by the Marquis of Cerralbo (Santonja et al., 2005b). The excavation works at Ambrona were resumed recently, but no excavation campaigns were conducted at Torralba to date.

### *1.2. Geology and dating*

The first geological studies were conducted by Butzer in the 1960s (Butzer 1965; Freeman and Butzer 1966), who carried out studies of the surrounding area called the 'Meseta Caliza'. The detailed stratigraphic data available to us correspond to the works of Butzer (1965), from the N-S section of the assemblage. It is described as a composite profile that begins with red colluvial facies deposited on red clays and plaster from Keuper, up to 3-4 meters thick, which disappear to the north. Above that, they found "a deposit of gray sands in which angular and subangular gravel facies of carbonated composition are interspersed, with sizes of 1-3 cm of major axis and a thickness of 1 m" (Santonja et al., 2014: 527). At the top, they found a very continuous unit of grayish-green marl, somewhat sandier at the base, reaching a depth of up to 2 m. Finally, superimposed on these shallow lacustrine facies there is a red alluvial-colluvium deposit with a thickness ranging between 0 and 1.5 m (Butzer 1965; Santonja et al. 2014).

It was from these fluvial facies of sands and gravels that the Marquis de Cerralbo and Howell recovered archaeological remains during those early excavation campaigns (Santonja et al., 2014). At that time, the archaeo-paleontological site of Torralba was considered contemporary to the aforementioned site of Ambrona, described as part of the same stratigraphic sequence (Butzer, 1965). The context was described as the shore of the same lake (Butzer, 1965). However, we are now certain that these inferences are mistaken. Recent data place Torralba around 200 ky (MIS 7) (N. Mercier, in Santonja et al., 2014), being more recent than the Ambrona deposit, dated by ESR/U series at around 350 ka (Falguères et al., 2006).

The fossils of these collections have stratigraphic/spatial relationships in some cases. Fossils with identification codes B1, B2, B3, B4, B5 and B7 have been documented at the site, while others do not have any identifying code. Although we have not found any description of these possible stratigraphic units, our results will be described in relation to each of these groups (see Butzer, 1965: Table 1 and Fig. 2).

## 2. Materials and methods

The materials included in the present work are 3345 macro-mammal remains from the excavation work of the Marquis de Cerralbo (1909-1913) and Howell (1961-1963) at Torralba, housed in the Museo Numantino de Soria (MNS) (n=2286), the Museo Nacional de Ciencias Naturales (MNCN-CSIC) of Madrid (n=878) and the Museo Arqueológico Nacional (MAN) of Madrid (n=181). The assemblages additionally include three bird remains (annatids and rallids) (Sánchez-Marco 2005), a leporid remain and various remains of malacofauna and microfauna that are not considered in this study.

Due to factors such as the antiquity of the excavations, the lack of effective methods for recording the materials, and the dispersion in the current location of the materials, it has not been possible to ascertain the precise stratigraphic or spatial origin of all the materials analyzed. The remains whose exact origin is known have been grouped according to attributed archaeological levels (B1-B5, B7). The remainder of the materials have been classified, when possible, according to the excavation phase from which they came: the Marquis de Cerralbo phase (hereinafter, the Cerralbo collection) and the Howell excavation phase (the Howell collection). The remains for which the provenance and excavation phase are unknown have been considered remains of undetermined origin (hereinafter, indeterminate group) (Table 1). This group of materials has been excluded from some of the analyses, because it is comprised of remains of unknown origin that cannot be treated as a homogeneous whole.

The faunal remains have been analyzed in keeping with zooarchaeological and taphonomic methods. Bone surfaces have been classified according to their state of conservation in three categories: good (> 2/3 well preserved cortical surface, i.e., with no flaking and/or abrasions), moderate (between 1/3 and 2/3 parts of well-preserved surface) and poor (<1/3 of well-preserved surface).

The poor preservation of bone surfaces has generally been associated with the presence of taphonomic modifications such as weathering (characterized by the presence of cortical tissue exfoliations and cracks), chemical corrosion, etc. Problems derived from the poor preservation of the remains or irreversible restoration practices that prevented the analysis of bone surfaces have made the taphonomic analysis of some bone surfaces impossible.

The remains have been identified anatomically and taxonomically whenever possible. Unidentified remains were grouped according to bone type and weight size (Table 2).

**Table 1.** Distribution of the remains analyzed in the different groups of provenance (levels, collections or indeterminate).

| Level-collection | Nº |
|---|---|
| B1 | 656 |
| B2 | 626 |
| B3 | 2 |
| B4 | 415 |
| B5 | 143 |
| B7 | 5 |
| Cerralbo col. | 158 |
| Howell col. | 87 |
| Indeterminate | 1253 |
| **Total** | **3345** |

The death age profiles of individuals have been established based on the eruption and the degree of tooth wear (Hillson, 1996; Bunn and Pickering, 2010; Marín et al., 2017). The sample size was counted by means of the Number of Identified Specimens (NISP), the Minimum Number of Elements (MNE), the Minimum Number of Individuals (MNI) and the Minimal Animal Unit (%MAU) (Binford 1981; Brain 1981; Lyman 1994).

The correlation between the %MAU and bone mineral density was used to evaluate the presence/absence of the different anatomical elements and their portions and the possible relationship with taphonomic processes that affect bones according to their mineral density (Lyman, 1994). The Shapiro-Wilk test was used to assess the normality of the variables and Spearman's rho was used for statistical significance. The fragmentation index of the length and cross-section of the limb bones was calculated and the fracture edges of limb bones were analyzed in keeping with Bunn (1983) and Villa and Mahieu (1991).

The main identified modifications produced by carnivores are furrows and pits (Maguire et al., 1980; Binford, 1981), whose dimensions have been compared with current data (Selvaggio, 1994; Delaney-Rivera et al., 2009; Andrés et al., 2012; Saladié et al., 2013) to determine possible modifying agents using the methodological proposals of Andrés et al. (2012). Evidence of digestion, pitting and furrowing has also been identified (Bonnichsen, 1973; Haynes, 1980; 1983; Maguire et al., 1980; Binford, 1981; Brain, 1981; Horwitz and Smith, 1988; Blumenschine, 1995). Furrowing has been established in three different degrees: a) low, when the epiphyses maintain their anatomical structure and tissue loss is difficult to see macroscopically; b) moderate, when part of the cancellous tissue has disappeared and; c) intense, when damage to the epiphysis is high, although a part is still preserved (Saladié et al., 2013).

**Table 2.** Different weight-size categories and taxa included in each of them.

| Weight-size categories | Included taxa |
|---|---|
| **Very large sized**<br>>1000 kg | *Palaeoloxodon antiquus*<br>*Hippopotamus* cf. *antiquus*<br>*Stephanorhinus hemitoechus* |
| **Large sized**<br>(300 - 1000 kg) | *Equus caballus (torralbae)* (adult)<br>*Bos antiquus*<br>*Cf. Eucladoceros* |
| **Medium sized**<br>(100 - 300 kg) | *Cervus elaphus*<br>*Equus caballus* (torralbae) (immature) |
| **Small sized**<br>(10 - 100 kg) | *Dama* cf. *clactoniana*<br>Caprinae<br>Carnivora (small) |

Anthropic activity was documented by identifying cut marks on the bone surfaces, based on the criteria described by Binford (1981), Potts and Shipman (1981), Shipman (1981), Shipman and Rose (1983a) and Domínguez-Rodrigo et al. (2009). The works of Binford (1981) and Nilssen (2000) were used to correlate the cut marks with concrete butchery activities.

The percentage of change was calculated using the proposals of Marean and Spencer (1991) and modified by Domínguez-Rodrigo et al. (2002) for archaeological assemblages. A theoretical model was applied in which the axial:appendicular bone ratio was related to the (proximal humerus+distal radius):(distal humerus+proximal radius) ratio, to assess the degree of ravaging in the assemblages (Domínguez-Rodrigo and Organista, 2007). The correlation of the %MAU of the epiphyses of the large animal limb bones and mineral density was used to infer levels of competition in the ecological environment in the different assemblages in keeping with the method established by Faith and Behrensmeyer (2006) and Faith et al. (2007). The theoretical model established by Egeland (2008) was applied to measure the competition among predators based on the relationship between the axial: appendicular bone ratio and the epiphysis: diaphysis ratio.

The presence of other taphonomic modifications, both biostratinomic and diagenetic, has also been documented. Weathering and water abrasion were analyzed according to the grades established by Behrensmeyer (1978) and Cáceres (2002), respectively. The presence of other modifications (trampling, oxidation, corrosion or dissolution of surfaces, concretions, gnawing and alterations produced by roots or by the pressure of sediments) were recorded as well (Brain, 1981; Shipman, 1981; Haynes, 1991; Fernández-Jalvo, 1992; Lyman, 1994; Blasco et al., 2008).

The *PAleontological STatistics* (PAST) free software (Hammer et al., 2001) was used for statistical analyses.

## 3. Results

More than half of the remains were assigned to a specific stratigraphic level (55.2%), with levels B1 and B2 containing the greatest number of remains. Levels B3 and B7 yielded few remains (two and five, respectively) and were excluded from the rest of the analysis. 7.3% of the remains could be assigned to an excavation phase (Cerralbo collection or Howell collection) and the remaining 37.5% have been grouped as remains of indeterminate provenance (Table 3).

Taxonomic identification was possible in 69.1% of cases, with the elephant, identified as *Palaeoloxodon antiquus* (Howell et al., 1963; Aguirre, 2005), as the most represented taxon. The high identification of this species is, in part, a consequence of the ease with which elephant remains can be taxonomically attributed due to their size, although fragmentation or conservation problems prevent their anatomical identification in some cases. Other abundant taxa are the horse, identified by Prat (1977) as *Equus caballus torralbae* (Santonja et al., 2005a), and the bovine, considered *Bos antiquus* (Aguirre, 2005; Fuentes, 2005), as well as deer including *Cervus elaphus*, *Dama* cf. *clactoniana* (Howell et al., 1995) and a large deer (cf. *Eucladoceros*). The rhinoceros (*Stephanorhinus hemitoechus* (Sesé and Soto, 2005), hippopotamus, goat and a small unidentified carnivore are represented by isolated remains.

### *3.1.1. Preservation of bone surfaces*

The analysis of the conservation of bone surfaces reveals surface conservation problems, with a high presence of poor (47.5%) and moderately (42.1%) preserved surfaces and only 10.4% well-preserved surfaces (Figure 1a). If the elephant remains are taken separately from the other materials, a differential pattern emerges between the two groups. Elephants are characterized by a greater presence of poorly preserved surfaces (61.9 %%), and only 4.1% of surfaces with good conservation (Figure 1b). The rest of the materials, on the other hand, are characterized by a greater presence of moderately conserved surfaces (49%), with a higher percentage of well-preserved surfaces than in the case of elephants (15.7%) and 35.3% of poorly conserved surfaces (35.3%) (Figure 1c). The application of the F-test suggests that these differences are statistically significant (ANOVA, F = 280.8, p = 1.715E-70). These results seem to suggest different taphonomic histories between the two groups.

Table 4 summarizes the taphonomic modifications identified in the different assemblages. Weathering, identified by the presence of fissures and exfoliations, was documented in approximately 70-80% of the remains, and has mostly been attributed to Stage 1 (Behresnmeyer, 1978). Evidence of abrasion (rounding and polishing) affects from 40-60% of the samples in each level, except in the Howell collection, where evidence of abrasion is found on approximately 70% of the remains. Trampling affects from 10-20% of the samples in the assemblages, mostly in the form of striae on the bone surfaces, although notches have been

**Table 3.** NISP/MNE/MNI of the different taxa identified at Torralba. Unidentified remains were grouped in weight-size categories or classified as indeterminate.

| *Taxa* | **B1** | **B2** | **B3** | **B4** | **B5** | **B7** | **Cerralbo col.** | **Howell col.** | **Indeterminate** |
|---|---|---|---|---|---|---|---|---|---|
| *Palaeoloxodon antiquus* | 271/46/2 | 150/22/1 | | 124/12/1 | 16/3/1 | 2/2/1 | 53/11/1 | 48/11/1 | 765/205/16 |
| *Stephanorhinus hemitoechus* | 5/5/1 | 4/4/1 | | | | | 2/2/1 | 1/1/1 | 4/4/2 |
| *Hippopotamus* cf. *antiquus* | | 1/1/1 | | | | | | | |
| *Equus caballus torralbae* | 81/35/3 | 106/42/3 | 1/1/1 | 60/30/3 | 34/19/1 | | 66/10/6 | 8/6/1 | 174/69/8 |
| *Bos antiquus* | 21/14/3 | 26/14/2 | | 12/5/2 | 4/3/1 | | 4/4/1 | 8/6/1 | 53/34/3 |
| *Cervus elaphus* | 2/1/1 | 2/2/1 | | | | | 4/3/1 | 2/2/1 | 6/2/1 |
| *Dama* cf. *clactoniana* | 1/1/1 | 3/3/1 | | | | | | | 9/9/2 |
| cf. *Eucladoceros* | 4/4/1 | 3/3/1 | | 2/2/1 | | | | | 3/1/1 |
| Cervidae medium-sized | 26/14/1 | 39/28/1 | | 16/6/1 | 11/6/1 | | 7/5/- | | 50/15/3 |
| Caprinae | | | | | | | 1/1/1 | 1/1/1 | |
| Artirodactyla | | 2/-/- | | | 1/-/- | | | | 2/1/- |
| Ungulata | | 4/-/- | | 3/1/- | 1/-/- | | | | |
| Carnivora (Small) | | 1/1/1 | | | | | | | 1/1/1 |
| ***Total identified*** | **411/120/13** | **341/120/13** | **1/1/1** | **217/56/8** | **67/31/4** | **2/2/1** | **137/36/11** | **68/27/6** | **1067/341/37** |
| Very large-sized | 39/-/- | 21/-/- | | 30/-/- | 2/-/- | | 12/-/- | 1/-/- | 53/-/- |
| Large-sized | 76/-/- | 102/-/- | | 63/-/- | 16/-/- | 1/1/1 | 6/-/- | 12/-/- | 43/-/- |
| Medium-sized | 30/-/- | 38/-/- | 1/1/1 | 25/-/- | 27/-/- | | | 5/-/- | 20/-/- |
| Small-sized | | 1/-/- | | 2/-/- | 2/-/- | | | | 2/-/- |
| ***Total weight-sized*** | **145/-/-** | **162/-/-** | **1/1/1** | **120/-/-** | **47/-/-** | **1/1/1** | **18/-/-** | **18/-/-** | **117/-/-** |
| ***Indet. remains*** | **100/-/-** | **123/-/-** | | **78/-/-** | **29/-/-** | **2/-/-** | **3/-/-** | **1/-/-** | **69/-/-** |
| ***Total*** | **656/120/13** | **626/120/13** | **2/2/2** | **415/56/8** | **143/31/4** | **5/3/2** | **158/36/11** | **87/27/6** | **1253/341/ 37** |

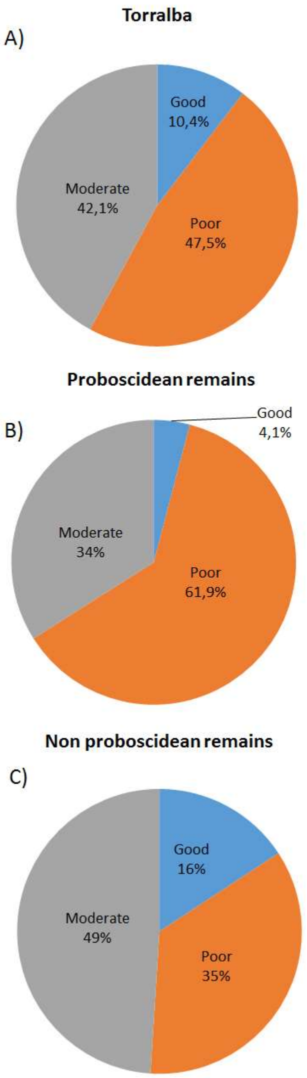


**Figure 1.** Preservation of bone surfaces at Torralba. A) The whole assemblage of Torralba; B) Elephant remains; C) Non-elephant remains.

documented at the fracture edges of 10 remains, mainly belonging to elephant. The Howell collection again presents higher percentages, with trampling identified in 42.7% of the sample.

Evidence of differential modification was revealed when the taphonomic changes on elephant remains alone were compared to those on the remains of other medium-sized and large animals (the most abundant groups) (Table 5). The elephant remains include a high proportion of Stage 2 weathered remains (29.2%), while weathered remains in the second group account for 3.7% of the sample. A higher percentage of Grade 2 rounded remains among the elephant remains was also documented, although the differences are not as pronounced. Polishing, contrarily, presents similar values in both groups. These differences are proved in the case of weathering (ANOVA, F = 3.758, p = 1.584E-78) and rounding (ANOVA, F = 57.08, p = 5.68E-14), but not in the case of polishing (ANOVA, F = 0.8805, p = 0.341).

### *3.2. Levels B1, B2, B4 and B5*

Elephant and horse are, in that order, the most abundant taxa at all levels in terms of NISP, NME and NMI, with the exception of level B5, in which equids are more abundant than elephants. The number of cervids and bovids is lower than that of elephants and horses, while few remains of the other taxa have been recovered at any level (Table 3). The scarce representation of small animals has led to their partial exclusion from our analyses.

The application of %MAU shows a greater representation of cranial elements for all sizes and levels, due to the abundance of dental elements and, to a lesser extent, appendicular

**Table 4.** Different taphonomic modifications identified within the different assemblages of Torralba. Data as percentage.

| | *B1* | *B2* | *B4* | *B5* | *Cerralbo col.* | *Howell col.* | *Indeterminate* |
|---|---|---|---|---|---|---|---|
| *Non weathered* | 20,7 | 24,1 | 21,4 | 31,3 | 20,3 | 33,7 | 13,5 |
| *Slightly weathered* | 79 | 75,9 | 78,6 | 68,7 | 79,3 | 66,3 | 86,5 |
| *Heavy weathered* | 0,3 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Non polished* | 62,2 | 60,9 | 58,4 | 68,8 | 65,2 | 25,8 | 58,8 |
| *Slightly polished* | 15,4 | 20,1 | 20 | 19,4 | 24,7 | 59,6 | 23,1 |
| *Heavy polished* | 22,4 | 19 | 21,6 | 11,8 | 10,1 | 14,6 | 18,1 |
| *Non rounded* | 51,7 | 59,6 | 49,3 | 63,9 | 62 | 29,2 | 56,1 |
| *Slightly rounded* | 17,4 | 20,1 | 20,7 | 18,1 | 15,2 | 37,1 | 19,5 |
| *Heavy rounded* | 30,9 | 20,3 | 30 | 18 | 22,8 | 33,7 | 24,4 |
| *Trampling* | 9,8 | 11,7 | 9,1 | 11,8 | 13,3 | 42,7 | 19,8 |
| *Root-etching* | 32 | 20,8 | 24,8 | 27,1 | 28,5 | 43,8 | 43,5 |
| *Corrosions* | 0 | 0 | 0,2 | 0 | 0 | 0 | 0,6 |
| *Dissolutions* | 18,1 | 10,4 | 13,9 | 7,6 | 12,7 | 6,7 | 24,3 |
| *Concretions* | 11,4 | 9,3 | 6 | 10,4 | 0,6 | 1,1 | 1,7 |
| *Gnawing* | 0 | 0,2 | 0 | 0 | 0 | 0 | 0,6 |
| *Deformations* | 0,2 | 0,5 | 0,2 | 0 | 0,6 | 1,1 | 0 |
| *Mn painting* | 78 | 81,5 | 78,4 | 67,4 | 95,6 | 91 | 91,9 |
| *Fe painting* | 61,6 | 65 | 64,4 | 67,4 | 57,6 | 50,6 | 82,7 |

elements (Figure 2). Low-survival elements (see Marean and Clerghorn, 2003) tend to be less abundant in the assemblages, although a high proportion of these elements has been documented in some cases (e.g. level B1 yielded a high proportion of axes and scapulae of large-sized and very large-sized animals).

The low correlation of the mineral density of the bones with the %MAU of the preserved sample suggests a weak relationship between the two variables (<0.1 in all cases) for the medium-sized and large-sized animals (Table 6). Spearman's rho indicates a positive correlation, although close to nullity and statistically significant for the medium-sized animals of levels B2 and B4 and the large animals of levels B1, B2 and B4. The correlation is negative in the case of the large animals of level B5, but also close to 0 and lacking statistical significance (>0.05).

The complete bones are mostly elephant metapodials. A complete metapodial of deer has been documented in level B2, and metapodials belonging to deer and equid in level B1. The dimensions of the length and cross-section of the limb bones (B1=123; B2=103; B4=75; B5=25) (Figure 3) reveals a greater abundance of highly fragmented bones (1:1 and 2:1 in keeping with Bunn (1983) and Villa and Mahieu (1991)) (>70% in all sets) and a low presence of remains presenting complete or almost-complete shafts (3:3 or 4:3, based on the work of the same researchers), less than 4% in all cases.

The most abundant fractures in the limb bones are of the curved, oblique and smooth types in the B1 levels (66%; n=53), B4 (54.3%; n=46) and in B5 (58.6%; n=29), associated with fresh breakage (Villa and Mahieu, 1991) (Figure 3). In level B2, the most abundant fractures are contrary, curved, oblique and irregular (69.2%; n=91).

Regarding the anthropic modifications, a set of two parallel incisions was documented on the posterior face of the middle shaft of a radius of a large animal from level B2 (Figure 4), which can be associated with cutting the brachial muscle.

Carnivore activity has been documented in all the assemblages. Table 7 shows the metric data relating to the pits and scores documented in the cortical tissue of the bone surfaces. In all cases, the number of tooth marks is low (<30), and the analyses therefore lack statistical significance (Andrés et al., 2012), although their descriptive value should not be ignored. In addition, scores were found on the proximal epiphysis of a horse femur and furrows on the soft tissue of an elephant rib, both from level B2.

Tooth marks are documented mainly on elephant bones (ribs) and indeterminate bones; however, they have also been documented in other taxa: on a bovid humerus from level B1; a horse metapodial, femur and scapula from level B2; a cervid metapodial from level B4 and a limb bone from a medium-sized animal from level B5. The size of the pits was compared with the updated data (Figure 5) based on the average due to the small sample, except in level B2. The dimensions correspond to the data on large carnivores, such as hyena, lion, wolf or bear. Other documented evidence of carnivore activity includes intense furrowing on the distal epiphysis of a bovid humerus in level B1 and pitting on an equid metatarsus in B2.

The percentage of change (Table 8) evidences the moderate-to-high disappearance of epiphyses in level B1 and, especially, level B2. In both assemblages, the metapodials preserve a greater number of epiphyses, while the humeri, radii-ulnae (in level B1) and tibiae (in B2) show the greatest disappearance of limb bones ends. Levels B4 and B5 present the greatest disappearance of epiphyses (>70%). Level B4 shows a total absence of epiphyses in humeri, radii-ulnae and tibiae, while the metapodials retain the highest percentage of epiphyses. The metapodials also have the highest percentage of epiphyses in level B5, in which the humeri and femora lack epiphyses completely.

The correlation of the axial:limb ratio with the (HP+RD):(HD+RP) ratio (Figure 6) points to a context of moderate ravaging (Stage 2) for levels B1 and B2, associated, according to Domínguez-Rodrigo and Organista (2007), with moderate levels of competition in the environment. Levels B4 and B5 would be

**Table 5.** Different weathering and water abrasion stages at Torralba, differentiating between remains belonging to elephant and middle-sized and large-sized animal, the most abundant groups. Data as percentage.

| ***Weathering*** | | | | |
|---|---|---|---|---|
| *Stage* | **0** | **1** | **2** | **3** |
| *Palaeol. antiquus* | 11.3 | 59.5 | 29.2 | 0 |
| *Middle + Large sized* | 28.3 | 68 | 3.7 | 0 |
| ***Rounding*** | | | | |
| *Grade* | **0** | **1** | **2** | **3** |
| *Palaeol .antiquus* | 49.3 | 19.2 | 31.3 | 0.2 |
| *Middle + Large sized* | 61.1 | 20.4 | 18 | 0.5 |
| ***Polish*** | | | | |
| *Grade* | **0** | **1** | **2** | **3** |
| *Palaeol. antiquus* | 58.8 | 22.8 | 18.3 | 0.1 |
| *Middle + Large sized* | 58.2 | 21.3 | 20.5 | 0 |

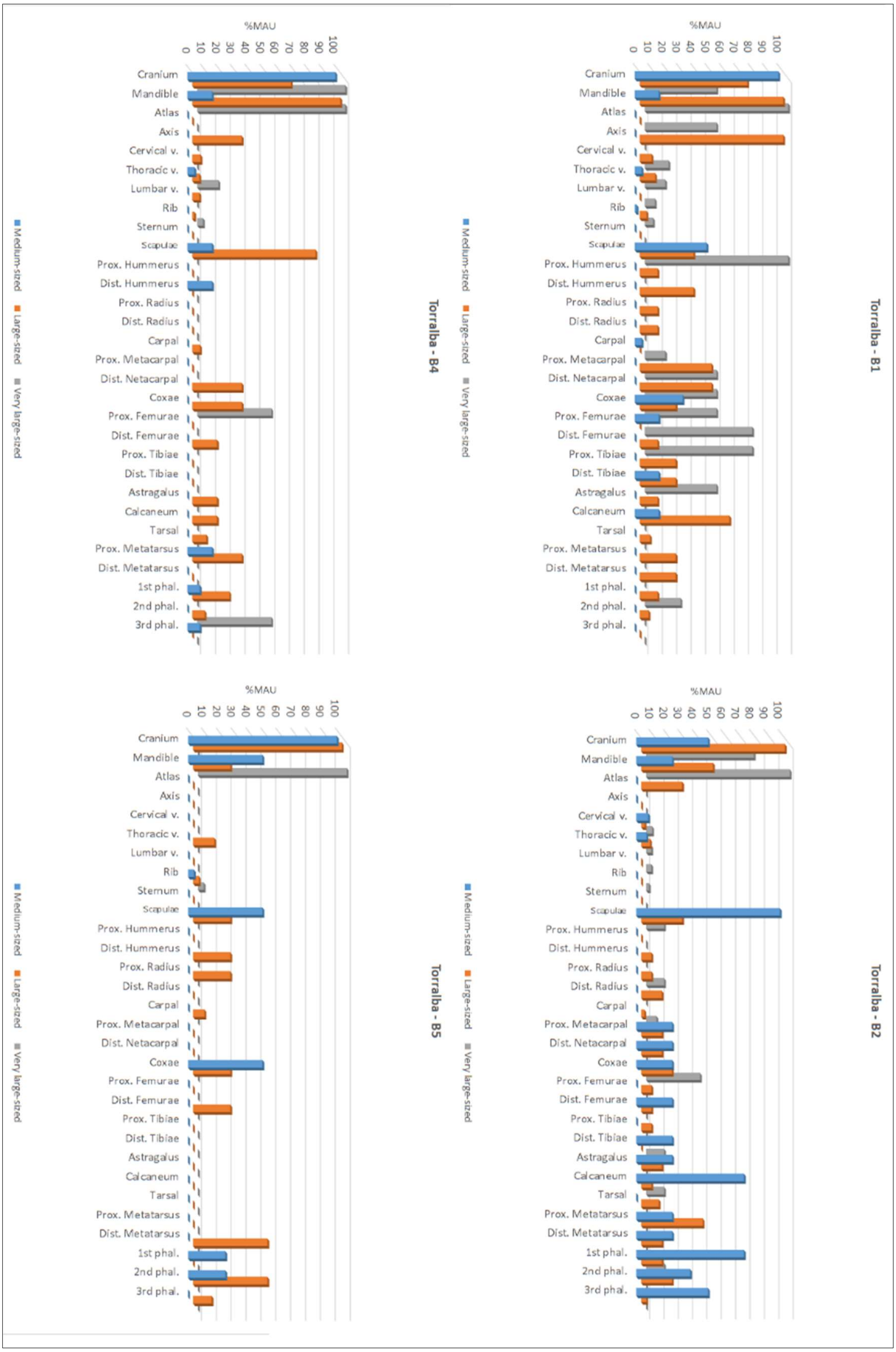


**Figure 2.** %MAU for medium-sized, large-sized and very large-sized carcasses of levels B1, B2, B4 and B5.

included in Stage 3, which implies a high degree of ravaging associated with high levels of inferred competition. The correlation of the %MAU of the ends of the limb bones of large

**Table 6.** Correlation of the mineral density of the bones and the %MAU of the preserved sample.

| *Assemblage* | *Size-category* | *Correlation ($r^2$)* | *Spearman's rho* | *(p)* |
|---|---|---|---|---|
| *B1* | Large | 0.04 | 0.19 | >0.05 |
| | Large | 0.06 | 0.33 | <0.01 |
| *B2* | Medium | 0.07 | 0.36 | <0.01 |
| | Large | 0.10 | 0.4 | <0.01 |
| *B4* | Medium | 0.01 | 0.08 | <0.01 |
| | Large | 0.07 | 0.3 | <0.01 |
| *B5* | Medium | 0.03 | 0.03 | >0.05 |
| | Large | 0.002 | -0.14 | >0.05 |
| *Cerralbo col.* | Medium | 0.002 | 0.03 | <0.01 |
| | Large | 0.01 | 0.17 | <0.01 |
| *Howell col.* | Medium | 0.02 | 0.16 | >0.05 |
| | Large | 0.03 | 0.16 | >0.05 |
| *Indeterminate* | Medium | -0.08 | 0.18 | >0.05 |
| | Large | 0.04 | 0.41 | <0.01 |

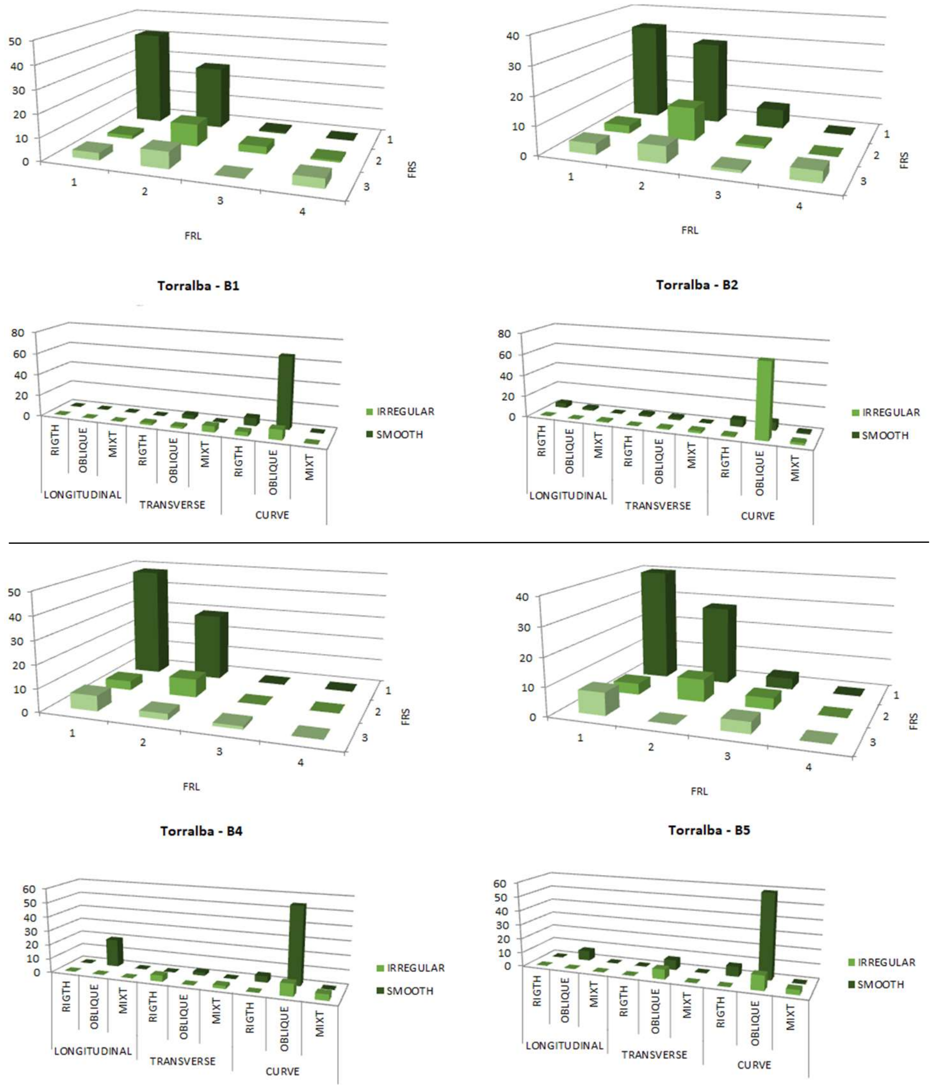


**Figure 3.** Fragmentation (top) and analysis of fracture edges (bottom) of limb bones from B1, B2, B4 and B5 levels.

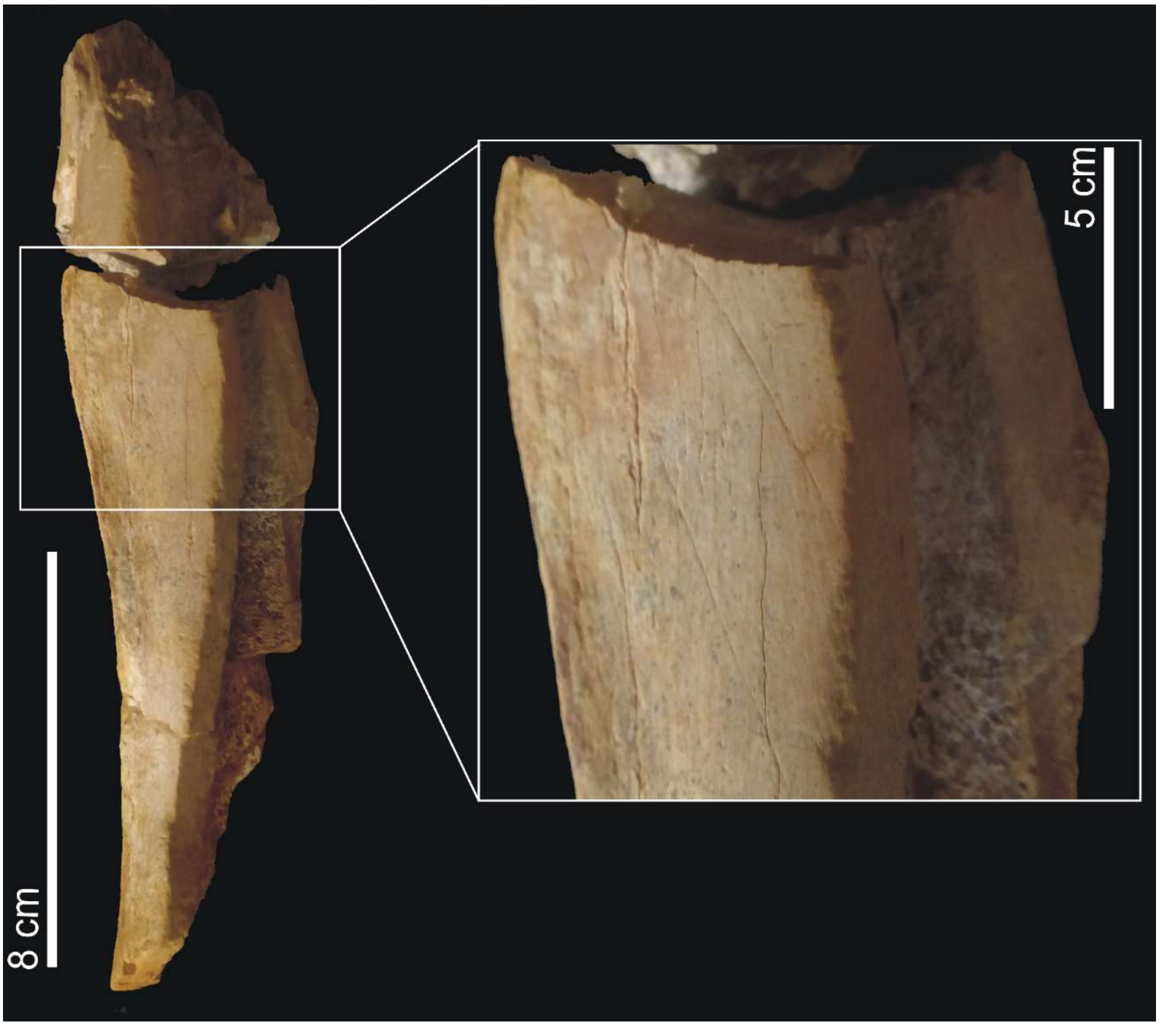


**Figure 4.** Cut marks identified on a middle shaft of a large-animal radius. Housed on MNS. Reference: Torr-J18-B2-Fe29-det-Q837.

**Table 7. Metrical** analysis of tooth marks measured in the different assemblages of Torralba.

| *Assemblage* | *Tooth-mark* | *Number* | *Mean* | *Confidence* | *Min.* | *Max.* | *Standard deviation* |
|---|---|---|---|---|---|---|---|
| *B1* | Pits (length) | 5 | 2,81 | 0,58 | 2,01 | 3,49 | 0,66 |
| | Pits (width) | 5 | 1,51 | 0,50 | 0,83 | 2,11 | 0,57 |
| | Scores (width) | 14 | 0,47 | 0,09 | 0,20 | 0,80 | 0,17 |
| *B2* | Pits (length) | 10 | 3,00 | 0,70 | 1,20 | 4,47 | 1,12 |
| | Pits (width) | 10 | 1,74 | 0,51 | 0,80 | 2,86 | 0,82 |
| | Scores (width) | 11 | 0,70 | 0,13 | 0,31 | 1,08 | 0,23 |
| *B4* | Pits (length) | 2 | 4,28 | 3,16 | 2,67 | 5,89 | 2,28 |
| | Pits (width) | 2 | 1,91 | 2,07 | 0,85 | 2,96 | 1,49 |
| | Scores (width) | 16 | 0,60 | 0,08 | 0,39 | 0,95 | 0,17 |
| *B5* | Pits (length) | 1 | 2,99 | - | 2,99 | 2,99 | - |
| | Pits (width) | 1 | 2,79 | - | 2,79 | 2,79 | - |
| | Scores (width) | - | - | - | - | - | - |
| *Cerralbo col.* | Pits (length) | - | - | - | - | - | - |
| | Pits (width) | - | - | - | - | - | - |
| | Scores (width) | - | - | - | - | - | - |
| *Howell col.* | Pits (length) | - | - | - | - | - | - |
| | Pits (width) | - | - | - | - | - | - |
| | Scores (width) | 3 | 0,67 | 0,52 | 0,33 | 1,19 | 0,46 |
| *Indeterminate* | Pits (length) | 6 | 4,29 | 1,10 | 2,64 | 6,19 | 1,37 |
| | Pits (width) | 6 | 2,90 | 0,67 | 1,61 | 4,09 | 0,84 |
| | Scores (width) | 3 | 0,54 | 0,43 | 0,26 | 0,98 | 0,38 |

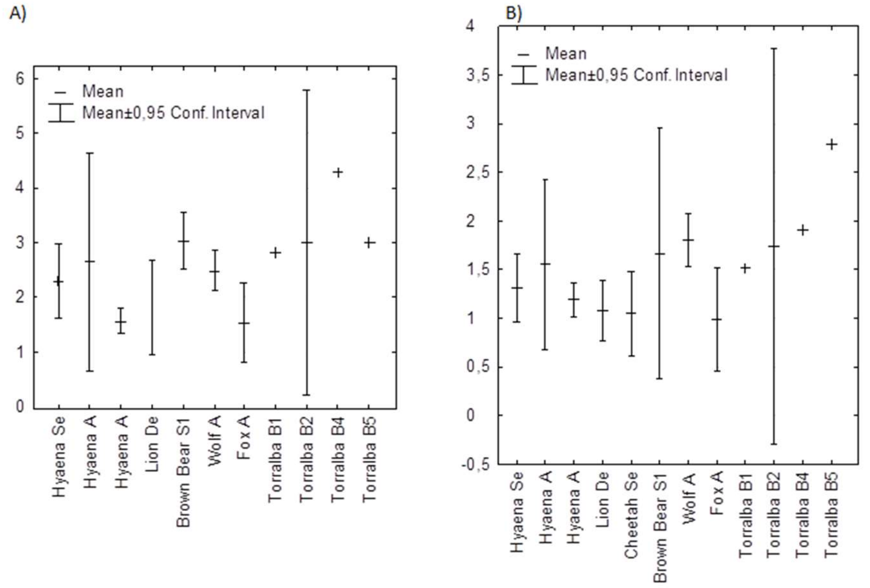


**Figure 5.** Comparisons of the length (left) and width (right) of the pits identified in Torralba levels B1, B2, B4 and B5 with data from current research (Selvaggio 1994a (Se); Delaney-Rivera et al. 2009 (De); Andrés et al. 2012 (An); Saladié et al. 2013 (Sa1)). All levels show <30 pits, and statistical comparison is not possible. Not possible to compare with the Cerralbo or Howell collection due to low number of pits documented.

**Table 8.** Percentage of change of limb bones of the different assemblages. The Cerralbo collection was excluded due to the low number of limb bones. Data as percentage.

| | ***B1*** | | | | ***B2*** | | | |
|---|---|---|---|---|---|---|---|---|
| | *Medium-sized* | *Large-sized* | *Very large-sized* | **Total** | *Medium-sized* | *Large-sized* | *Very large-sized* | **Total** |
| *Hummerus* | 100 | 50 | - | **75** | 100 | 50 | - | **75** |
| *Radius-ulnae* | - | 50 | 100 | **75** | - | 75 | 50 | **62,5** |
| *Femorae* | 50 | 75 | - | **62,5** | 50 | 0 | - | **25** |
| *Tibiae* | 100 | 33,3 | 50 | **61,1** | 90 | 75 | 50 | **71,7** |
| *Metapodials* | 50 | 60 | 12,5 | **40,8** | 0 | 38,9 | 0 | **13** |
| *Total* | **80** | **53,1** | **34,4** | **62,8** | **66,7** | **50,0** | **88,2** | **49,3** |
| | **B4** | | | | **B5** | | | |
| *Hummerus* | 100 | - | - | **100** | 100 | 100 | - | **100** |
| *Radius-ulnae* | - | 100 | - | **100** | - | 50 | - | **50** |
| *Femorae* | - | 50 | - | **50** | - | 100 | - | **100** |
| *Tibiae* | - | 100 | - | **100** | - | - | - | **-** |
| *Metapodials* | 50 | 33,3 | 50 | **38,9** | 50 | 25 | - | **37,5** |
| *Total* | **75** | **50,0** | **88,9** | **77,8** | **75** | **50,0** | **-** | **71,8** |
| | **Howell col.** | | | | | | | |
| *Hummerus* | 100 | 100 | - | **100** | | | | |
| *Radius-ulnae* | 100 | 87,5 | 50 | **79,7** | | | | |
| *Femorae* | 100 | 100 | 50 | **83,3** | | | | |
| *Tibiae* | - | 100 | - | **100** | | | | |
| *Metapodials* | - | 83,3 | - | **83,3** | | | | |
| *Total* | **100** | **90,9** | **86,4** | **89,1** | | | | |

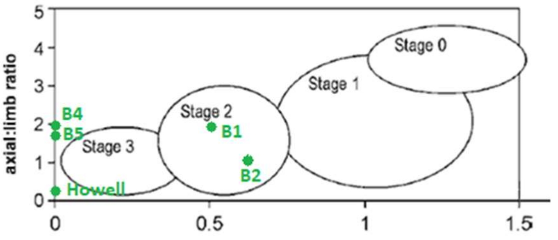


**Figure 6.** Correlation of the axial:limb ratio with the (HP+RD):(HD+RP) ratio for measuring ravaging in the assemblages, in accordance with Domínguez-Rodrigo and Organista (2007).

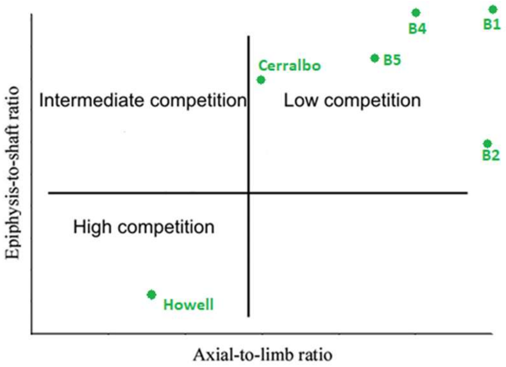


**Figure 7.** Correlation of the epiphysis:shaft ratio with the axial:limb ratio for measuring competition in the assemblages, in accordance with the method established by Egeland (2008).

animals with the mineral density (Table 9) yields a weak positive correlation for levels B1 and B4, moderate for level B2 and negative for level B5, though lacking statistical significance in all cases. The absence of statistical significance is expected in open-air contexts, in which carnivores can consume all skeletal bone parts (regardless of density or nutritional value) at times of high competition (Faith et al., 2007). In level B2, the positive and non-significant correlation could suggest moderate to high levels of competition in the inferred environment. In the remaining levels, however, values close to 0 suggest an absence of a relationship between the two variables, although it is true that this could be the result of a type II statistical error (Faith and Gordon, 2007) due to the low volume of the archaeological sample. The correlation of the axial:limb bone ratio with the epiphysis:shaft bone ratio, in keeping with the theoretical model of Egeland (2008), places the four assemblages in contexts of low inferred competition (Figure 7).

### *3.3. The Cerralbo and Howell collections and remains of indeterminate provenance*

Horse and elephant are the most represented taxa (NISP) among the remains of the Cerralbo collection. Among the Howell collection, elephant remains represent the largest volume of material, and horse remains are relatively scarce. Finally, among the remains of indeterminate provenance, the most represented animals are *Palaeoloxodon antiquus*, *Equus caballus torralbae*, *Bos antiquus* and, to a lesser extent, remains attributed to the Cervidae family (Table 3).

The %MAU (Figure 8) suggests a high representation of cranial remains among the indeterminate group and in the Cerralbo collection, where post-cranial remains are scarce. The remains of indeterminate provenance include abundant post-cranial elements from large carcasses (appendicular skeleton), and few post-cranial elements from medium-sized and very large animals. Cranial elements in the Howell collection, on the other hand, are only documented among the remains of very large animals, but are not the most abundant element. Proximal radii and coxae are the most represented elements in this assemblage.

The correlation of the mineral density of the bones with the %MAU of the preserved sample is weak in all groups (<0.1 in all cases), and is negative in the medium-sized remains of indeterminate origin (Table 6). The Spearman's rho suggests a weak positive and statistically significant correlation for the remains of the Cerralbo collection and the large animals of the indeterminate group.

The analysis of the fragmentation of the length and cross-section of the limb bones (Figure 9) points to high fragmentation in both the Cerralbo (100%, n=15) and Howell (91.6%, n=60) collections. In the indeterminate group (n=143), high levels of fragmentation also predominate (53.9%), although complete or almost complete diaphyses represent 19.6% of the total. The complete limb bones are again

**Table 9.** Correlation of the %MAU of the end of limb bones of large-sized animals and mineral density.

| | *B1* | *B2* | *B4* | *B5* | *Cerralbo col.* | *Howell col.* |
|---|---|---|---|---|---|---|
| *Pearson 'r* | 0,008 | 0,43 | 0,12 | -0,02 | 0,15 | 0,51 |
| *(p)* | >0,05 | >0,05 | >0,05 | >0,05 | >0,05 | >0,05 |

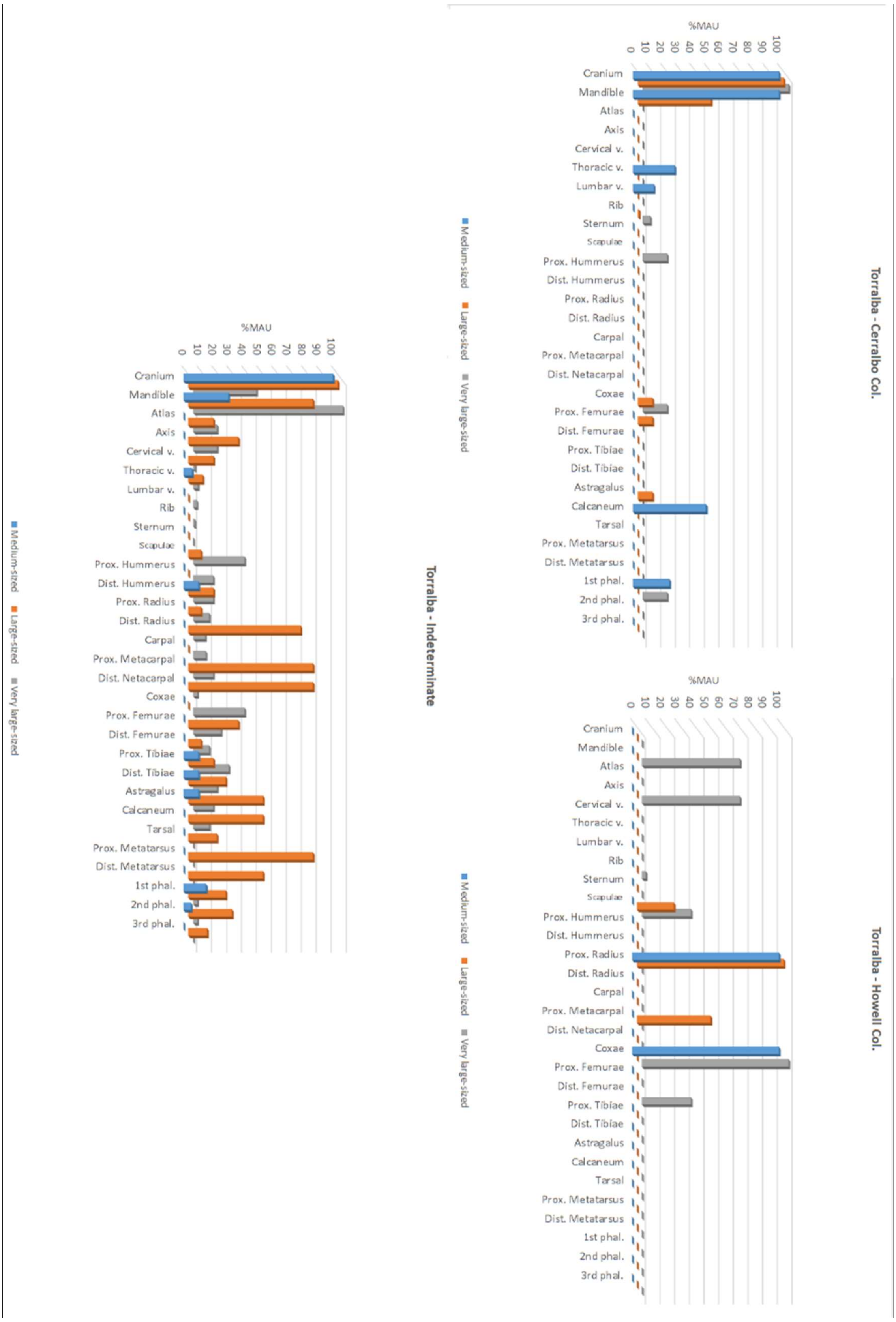


**Figure 8.** %MAU for medium-sized, large-sized and very large-sized carcasses of Cerralbo and Howell collections and indeterminate group.

mostly elephant metapodials. Equid and bovid metapodials and a complete bovid tibia of have only been recovered in the indeterminate provenance group Curved, oblique and smooth fractures are the most abundant in the limb bones of the Howell collection (58.8%; n=119) and indeterminate group (32.5%; n=160) and are associated with fresh breakage (Villa and Mahieu 1991) (Figure 9). It was not possible to analyze the remains of the Cerralbo collection due to the total absence of analyzable fractures.

Three bone fragments with cut marks have been documented among the remains of the indeterminate group: two incisions near the condyle of an equid mandible, on the medial side; two groups of incisions (n=5) on a bovid tibia, located on the anterior and lateral faces of the crest; and an incision on an unidentified elephant remain. The incisions on the mandible are associated with its disarticulation from the skull, while those on the tibia correspond to defleshing.

Scores and pits on cortical tissue have been documented in both the Howell collection and the indeterminate group (Table 7). In all cases, the number of remains is low and the metric analysis lacks statistical significance. Furrowing has also been documented in the soft tissue of an unidentified elephant bone. It has not been possible to compare the size of the depressions in the Cerralbo and Howell collections with the updated data, due to the low number of depressions documented in both cases.

In addition, other evidence of carnivore activity has been documented in the form of intense furrowing on an elephant phalanx belonging to the Cerralbo collection. Among the remains of indeterminate origin, furrowing has been documented on eleven remains (10 elephant and one indeterminate) in all grades (low, moderate and intense) (Binford, 1981; Saladié et al., 2013).

The percentage of change shows that the Howell collection presents a high disappearance of epiphyses (89.1%), with the total absence of epiphyses among the humeri and femora (Table 8). The calculation could not be applied to the

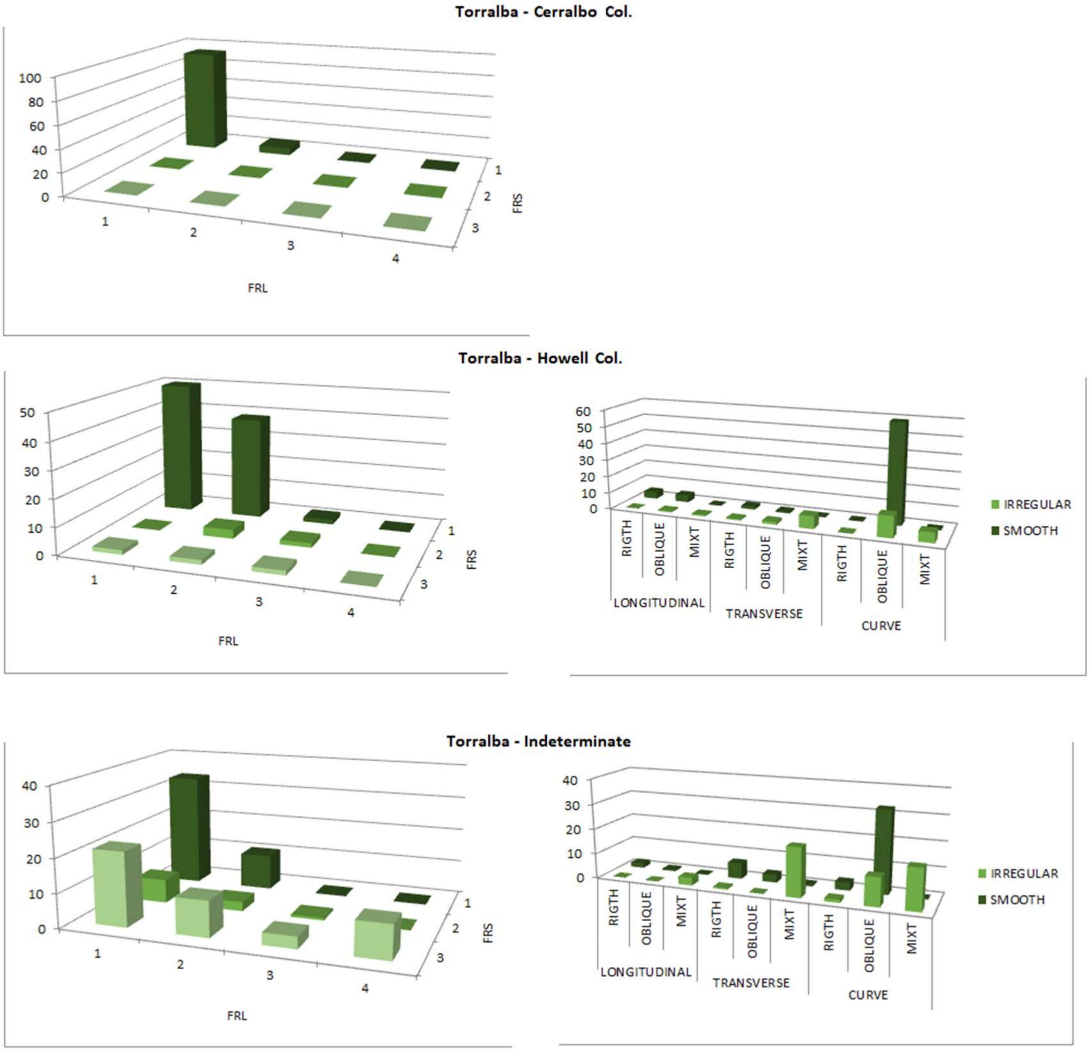


**Figure 9.** Fragmentation (left) and analysis of fracture edges (right) of limb bones from Cerralbo and Howell collections and indeterminate group. Analysis of fracture edges was not possible in Cerralbo collection due to the scarcity of limb bones with analyzable edges.

Cerralbo collection. The correlation of the axial:limb ratio to the (HP+RD):(HD+RP) ratio (Figure 6) seems to indicate that the Howell collection, associated with Stage 3, underwent intense ravaging, related to high levels of competition in the environment (Domínguez-Rodrigo and Organista 2007). This estimation could not be applied to the Cerralbo collection due to the almost total absence of limb bones.

The correlation of the %MAU of the ends of the large-animal limb bones with the mineral density (Table 9) provides a moderate (0.51) and not significant correlation for the Howell collection, which would mean moderate to high levels of competition in the inferred environment of Torralba (Faith et al. 2007). The correlation of the Cerralbo collection is lower and could correspond to a real absence of correlation or it may be the result of a type II statistical error (Faith and Gordon 2007). The application of the theoretical model of Egeland (2008) (Figure 7) suggests low levels of competition inferred in the Cerralbo collection and high levels of competition in the Howell collection.

## 4. Discussion

More than a century has passed since the Marquis of Cerralbo carried out the first excavation work at the Torralba site. The site was considered among the oldest evidence of the human occupation of Europe (Aguilera y Gamboa, 1913). In addition, it was one of the most important sites in defense of the hunting capabilities of Middle Pleistocene hominin groups, reflected in the apparent specialization in elephant hunting (Aguilera y Gamboa, 1913; Howell et al., 1963; Howell, 1966; Biberson, 1968; Freeman and Howell, 1982). These interpretations were discussed in studies that have highlighted the paleontological nature of the site (Binford, 1981; 1987; Shipman and Rose, 1983b; Klein, 1987; Villa, 1990) and the scarce presence of evidence of anthropic processing of elephant carcasses (Shipman and Rose, 1983b), suggesting that human groups played a secondary role in these assemblages (Binford, 1981) through the secondary and marginal access to elephant carcasses (Binford, 1987).

Since that time, the focus of the taphonomic studies at Torralba has been on the elephant carcasses and their relationship to hominin groups (Aguilera y Gamboa, 1913; Howell et al., 1963; Howell, 1966; Binford, 1981; 1987; Freeman and Howell, 1982; Shipman and Rose, 1983b; Klein, 1987; Villa, 1990). However, the fauna record of Torralba is more diverse, with several species of macro-mammals identified among the faunal remains that have been little studied to date (Howell et al., 1963; Prat, 1977; Villa et al., 2005; Sesé and Soto, 2005).

Any discussion of the fossil record of Torralba must first make reference to one of the problems that affect all assemblages deriving from classical excavations: the bias in the recovered record. Villa (1990) refers to this in her review of the materials from the site, where she refers to a loss of the smallest remains (bone and stone), as a consequence of the absence of a systematic triad during the excavation work.

The elephant (*Palaeoloxodon antiquus*) is the most abundant taxon in the classic collections of Torralba, representing 61% of the material studied. The presence of accumulations formed by the remains of one or several proboscides associated with lithic industry has been described in several Pleistocene assemblages of the Iberian Peninsula. Evidence from the Lower Pleistocene can be found in Pit 1 (Barranc de la Boella) (Vallverdú et al., 2014; Mosquera et al., 2015) and in Fuente Nueva 3 (Guadix-Baza Basin) (Espigares et al., 2013). These types of accumulations are, however, more abundant at Middle Pleistocene sites, with deposits such as Torralba and Ambrona (Aguilera y Gamboa, 1913; Howell et al., 1963; Howell, 1966; Biberson, 1968; Freeman and Howell, 1982; Villa, 1990), Áridos 1 and Áridos 2 (Santonja et al., 1980; Villa, 1990; Yravedra et al., 2010) and PRERESA (Yravedra et al., 2012).

The relationship between human groups and the proboscidean carcasses seems to be confirmed in some of these assemblages. Some of them, such as Pit 1 (Vallverdú et al., 2014; Mosquera et al., 2015) and Áridos 2 (Yravedra et al., 2010), have been described as butchering sites reflecting a single carcass processing event. Anthropogenic processing has also been proposed in palimpsests in which the presence of elephants is associated with other taxa, such as at Fuente Nueva 3 (Espigares et al., 2013), Ambrona (Shipman and Rose, 1983b, Villa et al., 2005) and PRERESA (Yravedra et al., 2012). At other sites, such as Áridos 1, the processing of elephants has been inferred from indirect evidence such as use-wear traces on stone tools (Ollé, 2005).

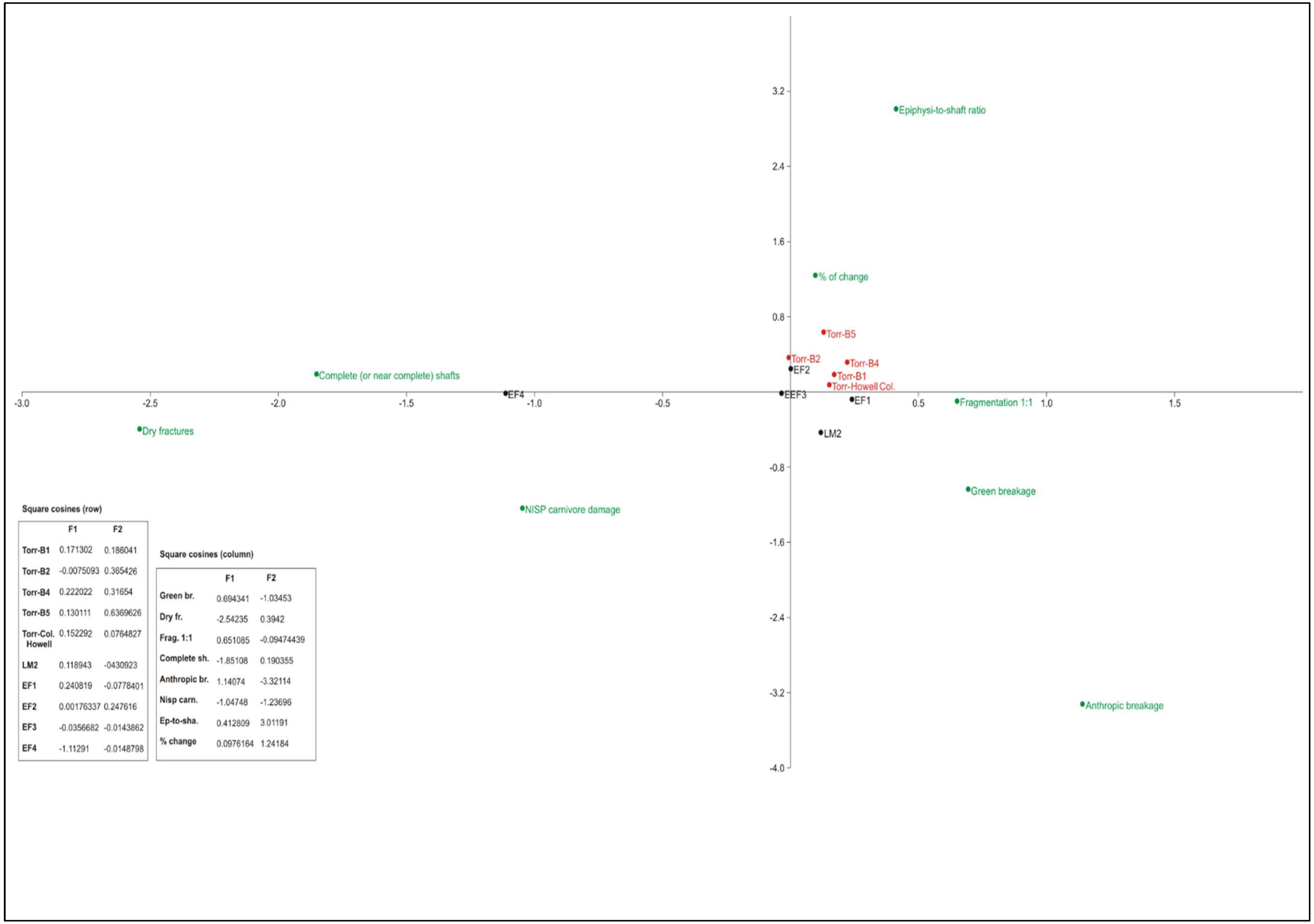
At Torralba, however, this evidence is not clear. Villa's (1990) review of the materials led her to affirm that there was no evidence to define Torralba as a butchering site. Our results revealed an elephant remain with cut marks. These butchery marks have allowed us to confirm human access to the meat content of at least one of the carcasses. However, this means that only 0.1% of the elephant remains bear evidence of anthropogenic alteration, ruling out the anthropic origin of the accumulations as described by Villa (1990), and precluding inferences about the type of access to them. However, this low frequency may be related to two other factors. First of all, the poor conservation of the bone surfaces could have obliterated any striae there may have been. Secondly, cut marks do not frequently occur during the processing of megaherbivore carcasses, and it is difficult to identify them (Crader, 1983; Haynes, 1991; Villa et al., 2005; Haynes and Klimowicz, 2015). The presence of lithic industry, recently re-examined by Sánchez-Cervera and colleagues (2015), is indisputable in both collections. Its existence testifies to the presence of hominin groups in the Pleistocene environment of Torralba, although it is true that the scarce evidence of processing of the carcasses seems to rule out human groups as the main accumulating or modifying agents. Our results support the position defended by Shipman and Rose (1983b): we cannot accept the leading role of hominins at least in the use of these animals, although it is not possible to dismiss their intervention.

The Torralba deposit was formed in an open, fluvial environment (Howell et al., 1962; Butzer, 1965; Howell, 1966; Biberson, 1968; Freeman and Howell, 1982) in which numerous herbivores have been documented. Due to the scarcity of carnivore remains recovered, the variety of carnivores is unknown, but competition and ravaging indices point to the possible existence of pressure from carnivores. The different methods of analysis applied (Marean and Spencer, 1991; Blumenschine and Marean, 1993; Domínguez-Rodrigo et al., 2002; Domínguez-Rodrigo and Organista, 2007) suggest high degrees of ravaging in the Howell collection (Stage 3 according to Domínguez-Rodrigo and Organista, (2007)). Levels B4 and B5 have also undergone intense ravaging, although less than in the case of the Howell collection. Ravaging has been inferred as less intense (Stage 2) in assemblages B1 and B2. All levels have yielded complete, non-exploited limb bones. They are mostly metapodials, non-meaty limb bones that tend to survive fracturing due to their density and low nutritive value (Domínguez-Rodrigo and Barba, 2007). However, meaty limb bones (e.g. femora, tibiae, etc.) have also been documented, which implies the presence of elements that were not fully exploited (Capaldo, 1997). This suggests that there were guilds of different taxa of carnivores in the area in which these assemblages were formed, coexisting in the environment with hominins; however, neither of these two actors seems to be responsible for the accumulation, nor the main modifier of the assemblage.

The high percentage of mainly elephant remains with trampling notches could be the result of trampling by the proboscideans themselves. These agents tend to displace skeletal elements of other elephants, trampling the remains and producing striae on the surfaces and notches at the edges of the fracture (Haynes, 1988; 1991; 2005). In the case of Torralba, the fractured edges of the materials were generally poorly preserved. The presence of surficial striae together with some notches would thus indicate that this was an area intensely visited by these animals. Haynes's studies (e.g. 1988; 1991; 2005) on the behavior of African elephants described a repeated pattern of elephants dying in environments with available water, forming accumulations of carcasses in the same place. These data support the formation of the deposit due to the overlapping of independent events, in which natural causes intervened to a greater extent, as suggested by Haynes himself (2005).

The bones of Torralba display different stages of weathering, which suggests they were deposited at different times. The absence of weathering, or Stage 1, is the most abundant in the case of the medium-sized and large-sized animal remains, which could be indicative of their rapid burial, in accordance with the descriptions of Behrensmeyer (1978). Among the elephants, weathered bones predominate in Stages 1 and 2. This is indicative of the greater subaerial exposure of these remains. The taphonomic differences between taxa may be related to the dimensions of the bones. It is logical to think that the large bones of the elephants would take longer to be buried and would therefore be more exposed to the weather. According to Haynes and Klimowicz (2015) the dimensions of elephant remains means they can remain exposed for decades before being buried. This suggests a formation due to different cumulative events at Torralba, possibly produced over decades. The formation due to the accumulation of different events was proposed by Domínguez-Rodrigo (1998) and Yravedra Sainz de los Terreros (2000), in contrast to Díez's (1993) interpretation of the assemblage as one uniform collection.

A correspondence analysis was conducted to analyze the different assemblages based on skeletal composition, anthropic and carnivore activity and fragmentation (Figure 10). The Cerralbo collection was excluded from this analysis because the low number of remains made it impossible to obtain some of the data applied. With the aim of establishing comparisons with open-air assemblages on the Iberian Peninsula in which this type of analysis



Square cosines (row)

| | F1 | F2 |
|---|---|---|
| Torr-B1 | 0.171302 | 0.186041 |
| Torr-B2 | -0.0075093 | 0.365426 |
| Torr-B4 | 0.222022 | 0.31654 |
| Torr-B5 | 0.130111 | 0.6369626 |
| Torr-Col. Howell | 0.152292 | 0.0764827 |
| LM2 | 0.118943 | -0430923 |
| EF1 | 0.240819 | -0.0778401 |
| EF2 | 0.00176337 | 0.247616 |
| EF3 | -0.0356682 | -0.0143862 |
| EF4 | -1.11291 | -0.0148798 |

Square cosines (column)

| | F1 | F2 |
|---|---|---|
| Green br. | 0.694341 | -1.03453 |
| Dry fr. | -2.54235 | 0.3942 |
| Frag. 1:1 | 0.651085 | -0.09474439 |
| Complete sh. | -1.85108 | 0.190355 |
| Anthropic br. | 1.14074 | -3.32114 |
| Nisp carn. | -1.04748 | -1.23696 |
| Ep-to-sha. | 0.412809 | 3.01191 |
| % change | 0.0976164 | 1.24184 |

**Figure 10.** Correspondence analyses of the distribution of Torralba B1, B2, B4, B5 and the Howell collection based on the different methods for measuring skeletal composition, breakage and anthropic and carnivore intensity in the assemblages presented in Table 10. The Cerralbo collection was not included because of the absence of data due to the scarcity of remains included. The square cosines of both rows and columns are presented

**Table 10.** Different ratios included in the correspondence analysis. Data from LM2 and EF1-EF4 from Pineda et al. (2017).

| *Features* | *Green fractures* | *Dry fractures* | *Fragmentation 1:1* | *Complete (or near complete) shafts* | *Anthropic breakage* | *NISP carnivore damage* | *Ep-to-shaft ratio* | *% change* |
|---|---|---|---|---|---|---|---|---|
| *Torr-B1* | 35 | 7 | 51 | 6 | 0 | 6 | 1.22 | 62.8 |
| *Torr-B2* | 9 | 7 | 35 | 5 | 0 | 8 | 1.74 | 49.3 |
| *Torr-B4* | 34 | 4 | 36 | 1 | 0 | 7 | 1 | 77.8 |
| *Torr-B5* | 19 | 4 | 10 | 1 | 0 | 1 | 0.89 | 71.8 |
| *Torr- Howell col.* | 75 | 15 | 30 | 1 | 0 | 7 | 0.29 | 89.1 |
| *LM2* | 218 | 44 | 122 | 7 | 4 | 53 | 0.11 | 83 |
| *EF1* | 83 | 9 | 36 | 4 | 2 | 8 | 0.21 | 73.5 |
| *EF2* | 31 | 19 | 40 | 1 | 0 | 4 | 0.2 | 71.6 |
| *EF3* | 47 | 18 | 25 | 1 | 0 | 12 | 0.24 | 56.2 |
| *EF4* | 15 | 75 | 8 | 12 | 0 | 28 | 0.25 | 60 |

has been applied previously, the data belonging to the late Early Pleistocene sites of la Mina (level LM2) and el Forn (levels EF1 to EF4) (Barranc de la Boella) were also included (Pineda et al., 2015; 2017). In these assemblages, different competition scenarios have been described based on the data included in Table 10; LM2 would represent a highly competitive context, the EF1-EF3 levels represent environments with moderate competition, while lower levels of inferred competition have been documented in level EF4 (Pineda et al., 2017).

The correspondence analysis groups 85.2% of the variance, with axis 1 contributing 50.9% and axis 2 34.3%. The different assemblages of Torralba included are grouped with EF1, EF2 and EF3, the assemblages of the Barranc de la Boella in which anthropic presence and moderate levels of competition between predators in the environment have been inferred (Pineda et al., 2017). These results point to little participation of hominins and carnivores in the exploitation of the carcasses and the formation of the deposits.

The lithic industry recovered from Torralba proves that the presence of human groups in the inferred environment of Torralba would have been common. However, our studies have not allowed us to determine the role of humans in the formation of the accumulations.

Different studies have shown the ability of human groups to survive in highly competitive environments (Pineda et al., 2017), and even to reduce the levels of competition in their habitat area, or home bases (Domínguez-Rodrigo and Organista, 2007; Saladié et al., 2014). This occurred even during the Lower Pleistocene, when some researchers have suggested that the density of carnivores and, consequently, the levels of competition for carcasses would have been higher than at present (Van Valkenburgh et al., 2001). In Torralba, the presence of human groups is associated with times of little competition between predators according to the anatomic proxis. This situation should not be considered as a strategy based on the need to acquire resources in non-competitive environments (Egeland, 2008; 2014). The identification of low-competition environments may be a consequence of the possible formation of these deposits as spatial palimpsests (Bailey, 2007; 2008) in which various independent events of different natures and characteristics in terms of ecological composition are recorded in the same place, one on top of the other. These consequent independent events form the same assemblage (Domínguez-Rodrigo and Organista, 2007; Egeland, 2008; 2014; Egeland and Domínguez-Rodrigo, 2008), but reflect different degrees of pressure among predators at different times. Torralba is undoubtedly the product of the accumulation of single events that are difficult to distinguish from one another. The possible formation of these deposits as identified as spatial palimpsest in which various independent events of different natures and characteristics in terms of ecological composition are recorded in the same place, one on top of the other.

## 5. Conclusions

*Palaeoloxodon antiquus* is the most abundant species at Torralba, and has focused the taphonomic studies of the ancient collections from that archaeological site. However, the faunal record is broader and includes other taxa

such *as Equus caballus torralbae, Bos antiquus* and various cervids. The taphonomic history of the proboscidean and other taxa seems to be different, probably due to greater subaerial exposure of the elephant bones, which led to the relatively poor conservation of their surfaces. The presence of human groups in the environment is evidenced by the recovered lithic industry. However, evidence of human activity on the carcasses is limited to four bone remains with cut marks. Carnivore activity has been documented on a greater number of remains. Our analyses suggest moderate levels of competition among inferred predators at all of the levels of Torralba we analyzed. Our interpretations suggest that the presence of contexts of moderate inferred competition could be a consequence of the accumulation of successive independent events, in diverse competition contexts that, from an integrated perspective, cannot be differentiated.

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# Capítulo 8. Discusión

Una de las principales limitaciones asociadas a la realización de una Tesis Doctoral por compendio de artículos es la existencia de una discusión en cada uno de los artículos publicados, en las que se tratan de manera específica las distintas problemáticas. Por ello, en el presente capítulo pretendemos realizar una recapitulación de los resultados obtenidos en las publicaciones que integran la tesis, centrándonos en las cuestiones fundamentales que comparten los conjuntos analizados, con el objetivo de acometer una visión de conjunto de los diferentes aspectos trabajados en nuestras investigaciones.

Cualquier tipo de acumulación registrada en un yacimiento arqueo-paleontológico pleistoceno (Isaac, 1971; Leakey, 1971; Isaac y Crader, 1981) forma parte de un sistema a escala macro-regional más amplio. Estos complejos ocupacionales (Binford, 1983) abarcan la totalidad del territorio conocido y controlado por los grupos de homininos forrajeadores. Esta concepción del espacio paleoecológico fue instaurada por Binford a raíz de sus observaciones de los grupos Nunamiut de las tundras árticas (Binford, 1978b; 1980; 1982). Binford otorgó importancia al amplio entorno que estos esquimales explotan durante el desarrollo de las actividades que forman parte de sus estrategias de movilidad, subsistencia y explotación de los recursos e instó a los arqueólogos a comprender el registro arqueológico como parte del amplio espacio en el que los homininos plio-pleistocenos desarrollarían sus actividades de subsistencia (Binford, 1983). En relación al tipo de entorno en el que instauraron sus hábitats y a la oferta de recursos existentes en cada uno de ellos, los grupos forrajeadores del pasado habrían establecido sus principales relaciones económicas en el entorno paleoecológico y entre los individuos de un mismo grupo, al igual que lo hacen los cazadores recolectores en la actualidad (véase por ejemplo la síntesis presentada por Hayden, 1981).

El uso de diferentes puntos de un territorio como lugares especializados se ve reflejado en el registro arqueológico en forma de conjuntos de diversa índole, que son caracterizados, por ejemplo, como campamentos referenciales, lugares de abrigo o *kill/butchering sites*. Los diferentes tipos de ocupaciones se pueden caracterizar por la existencia de diferencias en la presencia/ausencia de artefactos y/o restos óseos (Binford, 1980) y por la relación espacial existente entre los diferentes tipos de objetos (Isaac y Crader, 1981). En el registro arqueológico, se han identificado *home bases* en cronologías tempranas, como los conjuntos de FLK Zinj (Domínguez-Rodrigo y Barba, 2007c; Domínguez-Rodrigo et al., 2010c) y BK (Domínguez-Rodrigo et al., 2009b) en la Garganta de Olduvai y el nivel TD6.2 de Gran Dolina (Saladié et al., 2011; 2014) en la Sierra de Atapuerca. Durante el Pleistoceno medio, el número de campamentos descritos se amplía. Podemos citar algunos conjuntos como el yacimiento alemán de Bilzingsleben (Schwarcz et al., 1988; Mania y Mania, 2005), el yacimiento israelí de Qesem Cave (Stiner et al., 2009; Blasco et al., 2016) y los conjuntos franceses de Orgnac 3 (Moncel et al., 2005; 2012), Payre (Moncel et al., 2007) o Cueva del Aragó (Moigne, 1983; Moigne y Barsky, 1999). En la Península Ibérica, encontramos TD10.1 de Gran Dolina (Rodríguez-Hidalgo et al., *in press*), la Cueva del Ángel (Botella et al., 2006; Barroso Ruíz et al., 2011) y la Cueva de Bolomor (Blasco, 2008; Blasco y Fernández-Peris, 2009) entre algunos ejemplos. En estos conjuntos, se infieren diversas estrategias de subsistencia, aunque la caza se erige como la estrategia predominante desde los yacimientos de más antigüedad. Rodríguez-

Hidalgo (2015) describe para ellos una serie de características en común, que aparecen en épocas tempranas y destacan en todos los yacimientos del Pleistoceno medio: diversidad taxonómica, predominio de ungulados (entre los que una especie abunda sobre las demás), elevadas proporciones de adultos primos, perfiles esqueléticos en los que predominan elementos craneales y apendiculares, abundantes marcas de corte y bajas evidencias de actividad de carnívoros.

Otros tipos de acumulaciones no son reflejo de actividades residenciales si no de las actividades relacionadas directamente con la adquisición de recursos, generalmente, de origen animal; son los llamado *kill/butchering sites*. Por un lado, encontramos yacimientos como Schöningen (Thieme, 1997.; 1999; 2005; Voormolen, 2008), Cuesta de la Bajada (Domínguez-Rodrigo et al., 2015b) o el nivel TD10.2 de la Gran Dolina (Rodríguez-Hidalgo et al., 2017). En estos lugares, se ha documentado la obtención de grandes ungulados mediante la caza. Según describen Rodríguez-Hidalgo y colegas (2017), han servido para avalar la complejidad de las estrategias cinegéticas que estos grupos practicaban, al menos, desde el Pleistoceno medio. Por otro lado, encontramos lugares que reflejan el aprovechamiento de una carcasa de proboscídeo, como la Pit 1 del Barranc de la Boella (Vallverdú et al., 2014b; Mosquera et al., 2015), Fuente Nueva 3 (Espigares et al., 2013) o Áridos 2 (Yravedra et al., 2010), aunque se desconoce el modo de obtención de las mismas. En Fuente Nueva 3, Espigares y colegas (2013) han podido secuenciar el acceso primario de homininos y secundario de los carnívoros a la carcasa de mamut.

Todos estos yacimientos, junto a otros que registran actividades similares, han resultado clave en el incremento de nuestro conocimiento de los estilos de vida de los homininos ancestrales de Pleistoceno inferior y medio. Sin embargo, igual que los cazadores recolectores actuales, los forrajeadores pretéritos explotaron territorios amplios, en los que se desenvolvieron y desarrollaron diferentes actividades para la obtención de diferentes recursos. El testimonio directo de estas actividades relacionadas con la captación de recursos es menor que el relacionado con las ocupaciones descritas en los párrafos anteriores. Estos testimonios, cuando existen, nos permiten ampliar la información de las actividades forrajeadoras de estas poblaciones, aunque no jugaran un rol destacado en la acumulación o modificación de los restos. Las revisiones tafonómicas de los conjuntos de los beds I y II de Olduvai han evidenciado que muchos de ellos, que originalmente habían sido interpretados como acumulaciones antrópicas en forma de suelos de ocupación (Leakey, 1971; Binford, 1981; Potts, 1984; Bunn, 1986), eran en realidad palimpsestos en los que los homininos habrían realizado ocupaciones discretas y en los que las relaciones fauna-industria y homininos-carnívoros no estaban necesariamente probadas (Egeland et al., 2004; Domínguez-Rodrigo et al., 2007). Es el caso de conjuntos como FLK N3-4 y FLK NN1 (Barba y Domínguez-Rodrigo, 2007; Domínguez-Rodrigo et al., 2010b); FLK N1-2 (Domínguez-Rodrigo y Barba, 2007a; Bunn et al., 2010); o FLK NN3 (Domínguez-Rodrigo y Barba, 2007d; Domínguez-Rodrigo et al., 2010b). Estos conjuntos se definen como depósitos de dispersión vertical y se caracterizan por presentar restos de fauna e industria lítica, aunque las evidencias de procesado antrópico de las carcasas son muy escasas, representando historias tafonómicas independientes para ambos elementos. También se documenta la actividad de carnívoros sobre los restos óseos; generalmente, su presencia se asocia a eventos independientes a la actuación de los homininos (Domínguez-Rodrigo et al., 2007; 2010b).

En Isernia-La Pineta se ha propuesto un origen antrópico para sus acumulaciones (Peretto et al., 1996; Thun-Hohenstein et al., 2009), caracterizadas por: predominancia del bisonte (*Bison schoetensacki*); predominancia de elementos craneal y apendicular, que atribuyen a un transporte diferencial de las carcasas; predominio de individuos adultos y sub-adultos; y abundante fracturación antrópica. Para Thun-Hohenstein y colegas (2009), la caza se erige como estrategia predominante en estos conjuntos. No obstante, el origen antrópico de estas acumulaciones ha sido puesto en duda desde un primer momento (Díez, 1993; Brugal, 1999). Brugal (1999) planteó que estas acumulaciones podrían haber sido producidas por leones, mientras que los humanos habrían llevado a cabo un acceso secundario a las mismas. Sin embargo, la escasez de trabajos tafonómicos publicados hasta la fecha dificulta clarificar la naturaleza de estos depósitos.

Ya hemos mencionado que en Fuente Nueva 3 Espigares y colegas (2013) se han referido a la explotación de una carcasa de mamut por parte de homininos y hiénidos, aunque no se han encontrado evidencias de actividad que los relacionen directamente con la carcasa. Un conjunto del Pleistoceno medio peninsular con características similares es Ambrona. Las primeras hipótesis dadas por el equipo de excavación, que lo describieron, junto al vecino yacimiento de Torralba, como un cazadero de elefantes (Howell et al., 1962; Howell, 1966; Biberson, 1968; Freeman y Howell, 1982), han sido refutadas tras revisiones tafonómicas posteriores (Binford, 1981; Shipman y Rose, 1983b; Villa et al., 2005).

Los resultados obtenidos tras el análisis tafonómico de los restos faunísticos de la Mina, el Forn y las colecciones clásicas de Torralba, nos han permitido relacionar estos depósitos con lugares de tránsito en el que los homininos y otros carnívoros estaban presentes. Sin embargo, según los datos obtenidos nos encontramos ante ocupaciones discretas en los tres sitios, entre los que destaca una mayor presencia antrópica en el nivel II.2 de la Mina.

El Barranc de la Boella y Torralba son dos conjuntos formados al aire libre, ubicados en zonas fluvio-deltaicas (Butzer, 1965; Santonja et al., 2014; Vallverdú et al., 2014b), en contextos que se caracterizan por la disponibilidad de recursos atractivos para las comunidades de animales y los homininos. La diversidad taxonómica documentada en nuestros trabajos, en consonancia con los estudios sedimentológicos previamente citados, nos han permitido dibujar un mosaico ecológico en el que las especies de espacios abiertos y semi-abiertos, como los proboscídeos, rinocerontes, équidos o bóvidos, son predominantes y en el que también encontramos especies que sugieren la presencia de grandes masas de agua en estos ecosistemas (hipopótamo, castor, tortuga…). La industria lítica recuperada es abundante tanto en la Mina y el Forn (Vallverdú et al., 2014b; Mosquera et al., 2015; 2016) como en Torralba (Sánchez-Cervera et al., 2015), pero las evidencias de actuación sobre las carcasas son escasas en ambos conjuntos. Esta situación refleja una problemática que comúnmente se repite en conjuntos abiertos, especialmente en cronologías tempranas: la identificación de conjuntos en los que se recuperan restos de fauna e industria lítica, sin evidencias de procesado antrópico (Shipman y Rose, 1983b; Díez et al., 1997; Villa et al., 2005; Egeland, 2007; 2008; Egeland y Domínguez-Rodrigo, 2008; Espigares et al., 2013). En estos conjuntos, además, suelen documentarse problemas de conservación de las superficies óseas (Díez et al., 1997; Egeland, 2007; 2008; Egeland y Domínguez-Rodrigo, 2008; Mosquera et al., 2015; Yravedra et al., 2016), al igual que ocurre en Torralba (Shipman y Rose, 1983b; Villa, 1990; Villa et al., 2005) y en el Barranc de la Boella (Vallverdú et al., 2014b; Mosquera et al., 2015). Las evidencias de actividad de carnívoros son más abundantes que sus restos. En este mosaico paleoecológico, la presencia de homininos y de carnívoros es indicativa de la disponibilidad de recursos de interés para ambos agentes: presencia de presas, agua y, en el caso de los grupos humanos, vegetales y disponibilidad de materias primas para la fabricación de herramientas (Domínguez-Rodrigo et al., 2007; Egeland, 2008; 2014).

La investigación desarrollada en la presente Tesis Doctoral ha versado en torno a dos problemáticas principales, a través del estudio de los restos óseos de los yacimientos del Barranc de la Boella (la Mina y el Forn) y Torralba: por un lado, la identificación de la actividad antrópica sobre restos de yacimiento al aire libre con diferentes tipos de preservación de las superficies óseas; y por otro lado, el reconocimiento de los tipos de entorno en los que los homininos del Pleistoceno inferior y medio desarrollaron algunas de sus actividades forrajeadoras.

## 8.1. La problemática del estudio de superficies óseas mal conservadas

Una de las características clave para el estudio de los conjuntos incluidos en esta investigación es su condición de formar parte de depósitos sedimentarios formados al aire libre. La exposición de los restos a la intemperie puede producir importantes modificaciones en nuestros conjuntos, ya que elementos como la irradiación solar, los ciclos de hielo y deshielo y las fluctuaciones y cambios de temperatura y humedad acaban afectando negativamente a la preservación de las superficies óseas (Behrensmeyer, 1978; Junod y Pokines, 2014; Fernández-Jalvo y Andrews, 2016). La deposición en cuevas, abrigos o en zonas con cubierta vegetal hace que estos procesos no ocurran tan drásticamente, reduciendo el ritmo en el que la meteorización afecta a los huesos (Fernández-Jalvo, 1992; Lam, 1992; Fernández-Jalvo y Andrews, 2016).La exposición subaérea puede implicar desde un cambio de coloración de las superficies óseas hasta la destrucción total de los restos y el subsecuente reciclaje de los nutrientes en la matriz sedimentaria (Behrensmeyer, 1978; Junod y Pokines, 2014).

Por otro lado, la presencia de agua puede derivar en procesos como la lixiviación de los elementos solubles de los sedimentos, que pueden alterar las superficies de los elementos en este tipo de ambientes. Así mismo, la abrasión por los flujos hídricos se ha demostrado como otro agente modificador en este tipo de contextos, produciendo modificaciones en las superficies óseas en forma de redondeo y pulido (Shipman y Rose, 1983a; Behrensmeyer et al., 1989; Gifford-González, 1989; Cáceres, 2002; Fernández-Jalvo y Andrews, 2003; 2016; Gaudzinski-Windheuser et al., 2010; Rabinovich et al., 2012) y cambios en su morfología original (Cáceres, 2002; Fernández-Jalvo y Andrews, 2003; 2016; Gaudzinski-Windheuser et al., 2010; Rabinovich et al., 2012).

Estos procesos pueden acabar obliterando modificaciones tafonómicas pre-existentes (Behrensmeyer, 1978; Shipman y Rose, 1983a; Behrensmeyer et al., 1989; Gifford-González, 1989; Cáceres, 2002; Fernández-Jalvo y Andrews, 2003; 2016; Gaudzinski-Windheuser et al., 2010; Rabinovich et al., 2012). Después de unas cuatro décadas de investigaciones tafonómicas, actualmente disponemos de información para describir las características de las marcas de corte y diferenciarlas de las estrías producidas por otros procesos, como el trampling (Binford, 1981; Potts y Shipman, 1981; Shipman, 1981b; Shipman y Rose, 1983a; Bromage, 1984; Andrews y Cook, 1985; Behrensmeyer et al., 1986; Olsen y Shipman, 1988; Fiorillo, 1991; Domínguez-Rodrigo et al., 2009a; 2010a; 2017) en condiciones óptimas de preservación de las superficies óseas. No obstante, carecemos de un método objetivo y basado en un método científico y cuantitativo que nos permita su correcta identificación (Domínguez-Rodrigo et al., 2017). Esta problemática se agrava en aquellos conjuntos en los que las historias tafonómicas han dado lugar a superficies óseas mal conservadas, como ocurre en los dos conjuntos estudiados. El Barranc de la Boella y Torralba presentan superficies alteradas en diferentes modos e intensidades. La ausencia de marcas de corte es casi total en ambos conjuntos. La exposición subaérea ha comportado problemas de preservación de las superficies óseas en Torralba y en el Forn. En la Mina, contrariamente, los datos tafonómicos parecen sugerir un enterramiento más rápido de los restos. Aunque es sabido que no podemos establecer una calendarización de los procesos de enterramientos de cada uno de los conjuntos (Lyman y Fox, 1989), los huesos mejor preservados en la Mina pueden ser indicativos de enterramientos rápidos. Por el contrario, las modificaciones del Forn y Torralba implican una exposición más prolongada previa al enterramiento. Las superficies en los restos de la Mina, sin embargo, también se encuentran mal preservadas; en este caso, se ha determinado que la lixiviación de los elementos solubles presentes en los sedimentos podría ser la responsable de la alteración química de los restos.

Todos estos procesos tafonómicos nos han enfrentado ante problemas en la identificación y diferenciación entre marcas de corte y las estrías producidas por la abrasión de sedimentos, principalmente en los diferentes conjuntos del Barranc de la Boella. Para solventar estos problemas de equifinalidad que derivan de la alteración de estas señales hemos desarrollado dos experimentaciones. El objetivo, tal y como hemos planteado en sendos artículos, ha sido establecer criterios diagnósticos que permitan su correcta diferenciación tras la alteración producida por procesos químicos y mecánicos. Los resultados obtenidos sugieren que la alteración química experimentalmente producida conlleva la pérdida rápida de criterios diagnósticos en ambos tipos de estrías, impidiendo su diferenciación. La alteración mecánica, contrariamente, nos ha permitido establecer criterios diagnósticos que nos permitan diferenciar, experimentalmente, marcas de corte de estrías de trampling sometidas al proceso de abrasión. La aplicación de este trabajo a las estrías documentadas en el Barranc de la Boella ha permitido determinar que las estrías documentadas en las superficies óseas de la Mina tendrían un origen natural (trampling), mientras que las posibles marcas de corte que se documentaron sobre tres costillas de mamut de la Pit 1 (Mosquera et al., 2015) han sido ratificadas en su determinación. La identificación de este tipo de estrías en superficies mal preservadas, no obstante, debe ser cautelosa (Domínguez-Rodrigo et al., 2010a) y se requieren de nuevos trabajos experimentales que amplíen la información de la que disponemos.

La mala preservación de las superficies no implica necesariamente la existencia de marcas de corte previas que hayan sido obliteradas. Todos nuestros datos indican que los agregados que componen los conjuntos aquí estudiados son el resultado de eventos independientes que han acabado dando lugar a palimpsestos espaciales (Bailey, 2007; 2008) Estos palimpsestos son el reflejo de las actividades de forrajeo, que no incluyen necesariamente el procesado de carcasas animales.

La problemática respecto a la ausencia de marcas de corte en carcasas de proboscídeos, como encontramos en Torralba, implica tener en cuenta otras consideraciones, además de las previamente expuestas. Las marcas de corte producidas durante el procesado de megaherbívoros suele aparecer en frecuencias bajas y, en ocasiones, son de difícil identificación (Crader, 1983; Haynes, 1991; Haynes y Klimowicz, 2015). A pesar de ello, son diversos los yacimientos en los que se han identificado marcas de corte sobre carcasas de proboscídeo, que demuestran el procesado y consumo de estos animales desde el Paleolítico inferior: Bilzinsgleben (Mania, 1990), Ambrona (Shipman y Rose, 1983b; Villa et al., 2005), la Pit 1 en el Barranc de la Boella (Mosquera et al., 2015), Áridos 2 (Yravedra et al., 2010), Castel di Guido (Mussi, 2005) o PRERESA (Yravedra et al., 2012). En otros conjuntos, como Áridos 1 (Ollé, 2005) y Fuente Nueva 3 (Espigares et al., 2013), no se han encontrado marcas de corte, pero el aprovechamiento de estos animales se ha inferido a partir de los estudios traceológicos y de la relación espacial entre la industria lítica y los restos de mamut, respectivamente.

En Torralba, en el caso de que los homininos hubiesen ejercido un aprovechamiento de la biomasa de estos grandes animales, la mala preservación de las superficies óseas ha podido contribuir a reducir las evidencias de antropización de los restos de elefante, entre los que sólo hemos podido identificar un único resto con marcas de corte. Precisamente por este motivo, no podemos descartar que estas poblaciones no actuasen como agentes modificadores de las carcasas, como ya había sido previamente sugerido para éste y para el vecino yacimiento de Ambrona (Shipman y Rose, 1983b; Domínguez-Rodrigo, 1998; Yravedra, 2000; Villa et al., 2005). Por otro lado, diversos trabajos han demostrado que los elefantes tienden a desplazar los restos esqueléticos de otros elefantes, produciendo estrías y muescas de trampling sobre los restos de los proboscídeos que han ido a morir a zonas cercanas a grandes masas de agua (Haynes, 1988; 1991; 2005). En Torralba, el trampling es una de las modificaciones tafonómicas más abundantes en los diferentes conjuntos y su presencia la hemos relacionado con la actividad de otros elefantes, a los que sí podemos atribuir un rol activo en la modificación de las carcasas.

La Mina, el Forn y las colecciones clásicas de Torralba muestran historias tafonómicas diferentes; sin embargo, comparten unos rasgos en común (p.e. abundante industria lítica, pocas evidencias de antropización de los restos faunísticos, evidencias de actividad de carnívoros, aunque sus restos son escasos) que reflejan el grado de similitud que existe en relación al modo de deposición de los restos y al uso de estos espacios abiertos por parte de homininos y carnívoros. La presencia de los homininos en entornos ricos en recursos bióticos y abióticos apunta que su actividad estuvo ligada a su aprovechamiento, sin que ninguno de estos recursos tuviera necesariamente ningún protagonismo sobre el resto. Tampoco tuvieron porque explotarlos todos. De hecho, no disponemos de evidencias que nos permitan decantarnos por ninguna propuesta. Domínguez-Rodrigo y colegas (2010b), sugieren que la ausencia de relación directa entre los agregados líticos y faunísticos de un conjunto pueda ser indicativa de la elaboración de herramientas para la obtención de recursos que no sean de origen animal. En la Mina y el Forn no disponemos de marcas de corte; sin embargo, sí existen evidencias de fracturación antrópica, aunque son escasas. Además, la localidad pene-contemporánea de la Pit 1 refleja un aprovechamiento intensivo de recursos animales. En Torralba, las evidencias de aprovechamiento cárnico también son escasas, si bien, han sido documentadas. De este modo, podemos apuntar que al menos parte de la actividad de los grupos homininos en estos ambientes fluviolacustres estuvo vinculada con el aprovechamiento de recursos cárnicos.

## 8.2. El entorno hominino

Los parámetros que han sido descritos como condicionantes de la presencia de estos grupos en un determinado entorno incluyen el acceso a agua fresca y recursos alimenticios, la presencia de materias primas para fabricación de herramientas, la existencia de cubierta arbórea u otro de tipo de abrigo y, finalmente, la competencia y el riesgo que comporta la presencia de otros depredadores en su hábitat (Peters y Blumenschine, 1995; Blumenschine y Petters, 1998; Saladié et al., 2011; 2014; Egeland, 2014). La presencia de carnívoros en un entorno prehistórico determinado se identifica a través de sus restos, las mordeduras en los huesos y la presencia de coprolitos (Pickering, 2002).

En base a este tipo de evidencias, los carnívoros tuvieron una mayor presencia y actividad en el Barranc de la Boella. Sin embargo, tampoco se han identificado en la mayor parte de niveles los marcadores típicos de los conjuntos osteológicos generados por la acumulación de los carnívoros (p.e. Hugues, 1954; Kruuk y Turner, 1967; Mech, 1970; Sutcliffe, 1970; Kruuk, 1972; Schaller, 1972; Hill, 1980; 1983; 1984; 1989; Maguire et al., 1980; Skinner et al., 1980; 1986; 1998; Binford, 1981; 1988; Brain, 1981; Klein y Cruz-Uribe, 1984; Binford et al., 1986; Kerbis-Peterhans, 1990; Cruz-Uribe, 1991; Skinner y van Aarde, 1991; Stiner, 1991; Lam, 1992; Domínguez-Rodrigo, 1994; 1995; Fosse, 1995; Martín y Borrero, 1997; Mills y Gorman, 1997; de Ruiter y Berger, 2000; Pickering, 2002; Brugal y Fosse, 2004; Lacruz y Maude, 2005; Fernandez et al., 2006; Montalvo et al., 2007; Pokines y Kerbis Peterhans, 2007; Fernandez y Guadelli, 2008; Lansing et al., 2009; Yravedra et al., 2011; 2012; Stiner et al., 2012; Rodríguez-Hidalgo et al., 2013; 2015; Arriaza y Domínguez-Rodrigo, 2016; Borrero et al., 2018; Saladié et al., *in press*). Por lo que su actividad, junto a la de los hominినos, pudo ser merodeadora. Una excepción es la acumulación de coprolitos en forma de letrina del nivel II.3 de la Mina. Los hiénidos tienden a formar letrinas en zonas cercanas a sus lugares de hábitat (Kruuk, 1972; Mills y Gorman, 1997). Su presencia en la Mina es indicativa de que estos hiénidos tendrían instalados sus cubiles en lugares relativamente cercanos. Aunque el reconocimiento de la actividad de otros carnívoros es más discreto, los restos de félidos (león, jaguar y lince), cánidos (lobo y zorro) y úrsidos evidencian que éstos también estaban presentes en el entorno inferido en el Barranc de la Boella. Contrariamente, entre las colecciones clásicas de Torralba los restos de carnívoros recuperados son muy escasos, aunque esto en parte puede deberse a los sesgos que afectan a dichas colecciones (Villa, 1990). A la luz de cómo se conforman los conjuntos estudiados, en el Barranc de la Boella parece que los grupos de homininos tuvieron una mayor presión y coexistieron con una mayor abundancia de depredadores, al menos en estas áreas específicas.

Ante problemas de preservación de las superficies óseas y la carencia de modificaciones antrópicas es difícil valorar el grado de interdependencia o independencia entre ambos grupos de actores (carnívoros *versus* homininos). Existen abundantes proxis que valoran la frecuencia, la distribución y la coactuación sobre un mismo resto de marcas de cortes y percusiones (ambas señales antrópicas) respecto a las mordeduras de carnívoros (Binford, 1981; Shipman y Rose, 1983a; Blumenschine y Selvaggio, 1988; Domínguez-Rodrigo et al., 2009b), que nosotros no hemos podido valorar en los conjuntos estudiados. Una alternativa a estas limitaciones ha sido el uso de los perfiles anatómicos, que nos ha permitido valorar el grado de competencia existente en estos entornos. El uso de los perfiles anatómicos se ha presentado como una herramienta útil para reconstruir los entornos paleoecológicos habitados por los homininos pleistocenos a través de la analogía con entornos naturalistas actuales (Marean y Spencer, 1991; Marean et al., 1992; Blumenschine y Marean, 1993; Capaldo, 1997; Faith y Behrensmeyer, 2006; Domínguez-Rodrigo y Organista, 2007; Faith et al., 2007; Egeland, 2008; 2014; Saladié et al., 2014).

Estos han resultado eficaces para conocer, por ejemplo, los niveles de saqueo producidos por carnívoros machacadores de huesos (Domínguez-Rodrigo y Organista, 2007; Faith et al., 2007; Egeland, 2008). Por saqueo nos referimos al impacto que ejercen los carnívoros sobre un conjunto osteológico, incluyendo la selección, el transporte, la modificación y/o la destrucción de los elementos (Binford, 1981; Marean y Spencer, 1991). El grado de saqueo acaba dependiendo de la presión del entorno. En momentos de baja presión por los recursos, los carnívoros tienden a destruir solo aquellos elementos o porciones esqueléticas menos densos y con mayor aporte nutricional (Domínguez-Rodrigo y Organista, 2007; Faith et al., 2007; Egeland, 2008). En esos contextos, es frecuente encontrar elementos enteros, como huesos largos, que implican la existencia de recursos nutritivos no explotados en su totalidad (Capaldo, 1997). Sólo en momentos de mayor presión, los carnívoros tienden a machacar estos restos independientemente de su densidad o valor nutritivo (Faith et al., 2007), produciendo una explotación exhaustiva de los mismos.

Esta competencia puede ser inter- o intra-específica, según si afecta a individuos de una misma o de diferentes especies, y se produce de manera directa o indirecta, según si se produce de manera confrontacional o si los diferentes actores intentan acceder a un mismo recurso secuencialmente (Faith y Behrensmeyer, 2006). Como ya se ha planteado, los trabajos de Behrensmeyer (1975) y Faith y Behrensmeyer (2006) en el Parque nacional de Amboseli en Kenia demostraron que la mayor abundancia de carnívoros compitiendo por un mismo recurso se traduce en un mayor saqueo de las carcasas. En general, un mayor nivel de saqueo se puede correlacionar con una mayor competencia en el entorno (Domínguez-Rodrigo y Organista, 2007). No obstante, otros factores o condicionantes, como por ejemplo el estrés nutricional, pueden llevar a los carnívoros a producir un saqueo elevado aun encontrándose en momento de baja competencia (Domínguez-Rodrigo y Organista, 2007). Es por ello que estos investigadores consideran que la relación entre saqueo y dinámicas tróficas paleoecológicas requiere de futuros estudios en profundidad y las extrapolaciones deben realizarse con cautela. No podemos obviar que en estos contextos encontramos un actor añadido, ausente en los contextos actualistas: las poblaciones de homininos. A pesar de ello, a lo largo de nuestra investigación estas herramientas se han demostrado eficaces para, al menos, aproximarnos a este tipo de reconstrucciones paleoecológicas, más si cabe ante la ausencia, tal y como hemos visto, de otras posibles aproximaciones.

El análisis de los perfiles anatómicos de la Mina y el Forn, en consonancia con las evidencias de presencia de homininos y carnívoros, muestra coincidencia de ambos agentes. A la mera coincidencia de actores debemos añadir de modo destacado que se ha observado que, en los momentos de mayor intensidad de actividad de carnívoros, la presencia antrópica es también la más elevada. El nivel II.2 de la Mina es el ejemplo más claro de esta tendencia. Este conjunto se caracteriza por la presencia de abundante industria lítica realizada sobre diferentes materias primas y diferentes tipologías de herramientas. Además, se han localizado restos con estigmas relacionados con la fracturación antrópica, así como abundantes señales producidas por carnívoros. Según los análisis de los perfiles anatómicos el saqueo y, por lo tanto, la competencia entre depredadores (intra o interespecifica) pudo alcanzar niveles elevados. Una de las hipótesis que debemos barajar es que esto se deba a la baja disponibilidad de alimentos cárnicos. Sin embargo, es precisamente este conjunto el que presenta una mayor abundancia de restos (líticos y faunísticos), señales tafonómicas y diversidad taxonómica. Dentro de esta diversidad se han identificado taxones pertenecientes a distintos tipos de ambientes (abierto, semi-abierto, acuático y de boque de ribera). Esta característica no estaría en concordancia con un paisaje pobre en recursos. Por otro lado, la co-ocurrencia de ambos actores en un mismo espacio es indicativa de la existencia de recursos de interés para ambos grupos (Egeland, 2014). La abundancia de carnívoros y el consecuente incremento de los niveles de competencia en los entornos pleistocenos formaron parte de la rutina diaria de estos grupos; factores como la disponibilidad de recursos tendrían un mayor peso en la elección del espacio entre estos grupos que no la existencia de otros depredadores (Egeland, 2014).

Por otro lado, entre las muestras estudiadas en la presente Tesis Doctoral, también hemos documentado contextos de baja y moderada competencia inferida, tanto en el Forn, como en Torralba. Actualmente, disponemos de un conjunto de datos que apoyan que los homininos pudieron habitar y sobrevivir exitosamente en contextos altamente competitivos ya desde el *Early Stone Age* africano (Egeland, 2008; 2014); incluso en TD6.2 se ha propuesto la capacidad de reducir el riesgo de predación en entornos altamente competitivos (Saladié et al., 2014). Estas evidencias no nos permiten considerar que la presencia de grupos forrajeadores en entornos de baja competitividad pueda deberse a una estrategia de supervivencia basada en la reducción del riesgo ante las poblaciones de carnívoros.

De hecho, la identificación de homininos en entornos de baja y moderada competencia inferida puede responder a diversos escenarios, como son las fluctuaciones en las dinámicas ecológicas y de las comunidades de mamíferos o la naturaleza del origen de las acumulaciones. Nuestros conjuntos responden a la definición de *palimpsesto espacial* descrita por Bailey (2007; 2008), que se caracteriza por mostrar una mezcla de episodios segregados espacialmente, en el que las relaciones temporales son borrosas y difíciles de individualizar. En estos contextos deposicionales, los perfiles esqueléticos resultantes responden a la combinación de eventos de diferente naturaleza y composición ecológica. Durante los momentos de menor competencia se pueden introducir en el registro arqueológico elementos no explotados (o no en su totalidad) que, al mezclarse y formar parte de los depósitos, pueden acabar reflejando patrones de baja o moderada competencia. Sin embargo, no debemos desestimar a la ligera que estos resultados sean también un reflejo más o menos fiel del contexto ecológico del pasado. Esto estaría de acuerdo con una interpretación de los grupos homininos capaces de adaptarse a diferentes contextos ecológicos, y que su mayor o menor presencia, tal y como ya hemos apuntado, puede estar principalmente relacionada con la disponibilidad de recursos. Saladié y colegas (2014) apuntan que posibles establecimientos más o menos largos en un mismo entorno están principalmente vinculados a la disponibilidad de recursos en las áreas de abastecimiento. El Barranc de la Boella y Torralba representarían dos de estas áreas, con ocupaciones temporales distintas y modos técnicos diferentes, aunque con similitudes en los patrones de uso y explotación del territorio.

## 8. Discussion

One of the main limitations associated with a doctoral thesis based on a compendium of papers is that each published paper includes a discussion which specifically addresses the different problems associated with that study. For this reason, in this chapter we intend to recapitulate the results obtained in the publications that make up this thesis, focusing on the fundamental issues shared by the assemblages analyzed, with the aim of providing an overall vision that may not be apparent when examining each work individually.

Any type of accumulation recorded at Pleistocene archaeo-paleontological sites (Isaac, 1971; Leakey, 1971; Isaac and Crader, 1978) is part of a wider macro-regional system. These occupational complexes (Binford, 1983) cover the entire territory known and controlled by groups of foragers. This concept of the paleoecological space was established by Binford following his observations of the Nunamiut groups of the Arctic tundra (Binford, 1978b; 1980; 1982). Binford attached importance to the wider environment that these Eskimos exploited as they conducted the activities that constitute their strategies for mobility, subsistence and the exploitation of resources and urged archaeologists to understand the archaeological record as part of an expanse of space in which Plio-Pleistocene hominins would have carried out their subsistence activities (Binford, 1983). The type of environment in which foraging groups of the past established their habitats and the supply of existing resources in those habitats would have conditioned the primary economic relationships in the paleoecological environment and among the individuals of the same group, just as with hunter-gatherers today (see for example the synthesis presented by Hayden, 1981).

The use of different points within a territory for specialized purposes is reflected in the archaeological record in the form of assemblages of diverse natures, which are characterized, for example, as home bases, and kill/butchering sites. The different types of occupations can be characterized by the existence of differences in the presence/absence of artifacts and/or skeletal remains (Binford, 1980) and by the spatial relationship between the different types of objects (Isaac and Crader, 1981). In the archaeological record, home bases have been identified in early chronologies, such as the FLK Zinj deposit (Domínguez-Rodrigo and Barba, 2007c; Domínguez-Rodrigo et al., 2010c) and BK (Domínguez-Rodrigo et al. al., 2009b) in the Olduvai Gorge and in level TD6.2 of Gran Dolina (Saladié et al., 2011; 2014) in the Sierra de Atapuerca. And the number of home bases dating to the Middle Pleistocene is even higher, and include assemblages such as the German site of Bilzingsleben (Schwarcz et al., 1988; Mania and Mania, 2005), the Israeli site of Qesem Cave (Stiner et al., 2009; Blasco et al., 2016) and the French sites of Orgnac 3 (Moncel et al., 2005; 2012), Payre (Moncel et al., 2007) and Cueva del Aragó (Moigne, 1983; Moigne and Barksy, 1999). On the Iberian Peninsula, we find TD10.1 of Gran Dolina (Rodríguez-Hidalgo et al., in press), Cueva del Ángel (Botella et al., 2006; Barroso Ruiz et al., 2011) and the Cave of Bolomor (Blasco, 2008; Blasco and Fernández-Peris, 2009), among other examples. Various subsistence strategies have been inferred at these sites, although hunting is the predominant strategy identified. Rodríguez-Hidalgo (2015) describes a series of common characteristics among these sites, which appear quite early and are prominent at all Middle Pleistocene sites: taxonomic diversity, a predominance of ungulates (among which one species predominates over the others), high proportions of prime adult skeletal profiles in which cranial and appendicular elements predominate, abundant cut marks and little evidence of carnivore activity.

Other types of accumulations are not a manifestation of residential activities, but reflect activities directly related to the acquisition of resources, generally of animal origin; they are called kill/butchering sites. The processing of large ungulates acquired by hunting has been documented at sites like Schöningen (Thieme, 1997; 1999; 2005; Voormolen, 2008), Cuesta de la Bajada (Domínguez-Rodrigo et al., 2015b) and level TD10.2 of Gran Dolina (Rodríguez-Hidalgo et al., 2017). As described by Rodríguez-Hidalgo and colleagues (2017), they have served to underscore the complexity of the hunting strategies that these groups practiced, at least from the Middle Pleistocene. Other places reflect the processing of proboscidean, like the Pit 1 site at Barranc de la Boella (Vallverdú et al., 2014b; Mosquera et al., 2015), Fuente Nueva 3 (Espigares et al, 2013) and Áridos 2 (Yravedra et al., 2010), although how these animals were obtained is unknown. In Fuente Nueva 3, Espigares and colleagues (2013) were able to sequence the primary access of hominins and secondary access of carnivores to a mammoth carcass.

All these sites, together with others at which similar activities have been documented, have added to our knowledge of the ancestral hominins of the Lower and Middle Pleistocene. However, just like current hunter-gatherers, past foragers exploited extensive territories in which they conducted different activities to obtain different resources. The direct testimony of these activities related to the acquisition of resources is not as pronounced as that resulting from activities related to the occupations described in the previous paragraphs. This evidence, when available, allows us to expand upon existing information related to the foraging activities of these populations, even though it does not play a prominent role in the accumulation or modification of remains.

The taphonomic revisions of Olduvai beds I and II have shown that many of them which had originally been interpreted as anthropic accumulations in the form of occupation floors (Leakey, 1971; Binford, 1981; Potts, 1984; Bunn, 1986) were actually interpreted as palimpsests made up of discrete hominin occupations and in which the fauna-industry and hominin-carnivore relationships were not necessarily proven (Egeland et al., 2004; Domínguez-Rodrigo et al., 2007). This is the case of assemblages such as FLK N3-4 and FLK NN1 (Barba and Domínguez-Rodrigo, 2007; Domínguez-Rodrigo et al., 2010b), FLK N1-2 (Domínguez-Rodrigo and Barba, 2007a; Bunn et al., 2010), and FLK NN3 (Domínguez-Rodrigo and Barba, 2007d; 2010b). These assemblages are defined as vertically dispersed deposits and are characterized by the presence of faunal and lithic remains, although evidence of anthropic processing of carcasses is very scarce, representing independent taphonomic histories for the two elements. The activity of carnivores on bone remains has also been documented and its presence is generally associated with events unconnected to the activities of hominins (Domínguez-Rodrigo et al., 2007; 2010b).

An anthropic origin has been proposed for the accumulations in Isernia-La Pineta (Peretto et al., 1996; Thun-Hohenstein et al., 2009) characterized by: a predominance of bison (*Bison schoetensacki*); the predominance of cranial and appendicular elements, attributed to the differential transport of carcasses; the predominance of adult and sub-adult individuals; and abundant anthropic breakage. For Thun-Hohenstein and colleagues (2009), hunting is the predominant strategy used in these assemblages. However, the anthropic origin of these accumulations has been questioned from the beginning (Díez, 1993; Brugal, 1999). Brugal (1999) suggested that they could have been produced by lions, while humans would have had secondary access to them. However, the scarcity of taphonomic works published to date makes it difficult to clarify the nature of these deposits.

As mentioned earlier, in Fuente Nueva 3, Espigares and colleagues (2013) referred to the exploitation of a mammoth carcass by hominins and hyenids, although no evidence of activity on the carcass has been found. Ambrona is an assemblage of the Iberian Middle Pleistocene with similar characteristics. The first hypotheses posed by the excavation team described the site, along with the neighboring site of Torralba, as an elephant hunting site (Howell et al., 1962; Howell, 1966; Biberson, 1968; Freeman and Howell, 1982). However, this hypothesis was refuted after subsequent taphonomic reviews (Binford, 1981; Shipman and Rose, 1983b; Villa et al., 2005)

The results obtained from the taphonomic analyses of the faunal remains from la Mina, el Forn and the classic faunal collections of Torralba have allowed us to relate these deposits to transit sites in which hominins and other carnivores were present. However, the data obtained suggests discrete occupations at all three sites, with a notably greater anthropic presence in level II.2 of la Mina.

The Barranc de la Boella and Torralba are two open-air sites located in fluvial-deltaic areas (Butzer, 1965; Santonja et al., 2014; Vallverdú et al., 2014b) in contexts that are characterized by the availability of attractive resources for animal and hominin communities. The taxonomic diversity documented in our work, in accordance with the descriptions given in previous sedimentological studies, paints an ecological mosaic in which species that inhabit open and semi-open spaces such as proboscideans, rhinoceroses, equids and bovines predominate, and where other species suggest the presence of copious amounts of water in these ecosystems (hippopotamus, beaver, turtle, etc.). The recovered lithic industry is abundant in all three localities, in both la Mina and el Forn in the Barranc de la Boella (Vallverdú et al., 2014b; Mosquera et al., 2015, 2016) and in Torralba (Sánchez-Cervera et al., 2015), but evidence of carcass processing is scarce in all the assemblages. This situation reflects a problem that is commonly repeated in open-air sites, especially in early chronologies: the identification of assemblages in which the remains of both fauna and lithic industry are recovered but without any evidence of anthropic processing (Shipman and Rose, 1983b; Díez et al., 1997; Villa et al., 2005; Egeland, 2007; 2008; Egeland and Domínguez-Rodrigo, 2008; Espigares et al., 2013). Furthermore, problems related to the conservation of bone surfaces are often documented in these sites (Díez et al., 1997; Egeland, 2007, 2008; Egeland and Domínguez-Rodrigo, 2008; Mosquera et al., 2015; Yravedra et al., 2016), as is the case in both Torralba (Shipman and Rose, 1983b; Villa, 1990; Villa et al., 2005) and the Barranc de la Boella (Vallverdú et al., 2014b; Mosquera et al., 2015). Evidence of carnivore activity is more abundant than their remains. In this paleoecological mosaic, the presence of hominins and carnivores is indicative of the availability of resources of interest to both agents: the presence of prey, water and, in the case of human groups, vegetation and the availability of raw materials for the production of stone tools (Domínguez-Rodrigo et al., 2007; Egeland, 2008; 2014).

The research undertaken in this doctoral thesis focuses on two main problems through the study of the bone remains of the deposits of the Barranc de la Boella (la Mina and el Forn) and Torralba: firstly, the identification of anthropic activity on remains from open-air sites with different degrees of preservation of the bone surfaces; and secondly, the recognition of the types of environment in which the hominins of the Lower and Middle Pleistocene conducted some of their foraging activities.

## 8.1. Problems with the study of poorly preserved bone surfaces

One of the common characteristics shared by the different assemblages included in this research is that they are from sedimentary deposits formed in open-air contexts. The exposure of the remains to the weather can give rise to considerable changes in assemblages, as elements such as solar irradiation, ice and thaw cycles, and fluctuations and changes in temperature and humidity end up negatively affecting the preservation of bone surfaces (Behrensmeyer, 1978; Junod and Pokines, 2014; Fernández-Jalvo and Andrews, 2016). Deposition in caves, shelters or in areas with vegetation cover mitigates the occurrence of these processes, reducing the rate at which weathering affects the bones (Fernández-Jalvo, 199; Lam, 1992; Fernández-Jalvo and Andrews, 2016). Subaerial exposure can cause a range of modifications, from a change in the coloration of the bone surfaces to the total destruction of the remains and the subsequent recycling of the nutrients in the sedimentary matrix (Behresnmeyer, 1978; Junod and Pokines, 2014).

In addition, the presence of water can lead to processes such as the leaching of the soluble elements of the sediments, which can alter the surfaces of remains in this type of environment. Likewise, abrasion by water flows has been shown as another modifying agent in this type of context, producing modifications on bone surfaces in the form of rounding and polishing (Shipman and Rose, 1983a; Behresnmeyer et al., 1989; Gifford-González, 1989; Cáceres, 2002: Fernández-Jalvo and Andrews, 2003; 2016; Gaudzinski-Windheuser et al., 2010; Rabinovich et al., 2012) and changes in their original morphology (Cáceres, 2002: Fernández-Jalvo and Andrews, 2003; 2016; Gaudzinski-Windheuser et al., 2010; Rabinovich et al., 2012).

These processes can eliminate pre-existent taphonomic modifications (Behresnmeyer, 1978; Shipman and Rose, 1983a; Behresnmeyer et al., 1989; Gifford-González, 1989; Cáceres, 2002: Fernández-Jalvo and Andrews, 2003; 2016; Gaudzinski-Windheuser et al., 2010; Rabinovich et al., 2012). After four decades of taphonomic research, information is now available that allows us to describe features characteristic of cut marks and to differentiate them from the striae produced by other processes, such as trampling (Binford, 1981; Potts and Shipman, 1981; Shipman, 1981b; Shipman and Rose, 1983a; Bromage, 1984; Andrews and Cook, 1985; Behrensmeyer et al., 1986; Olsen and Shipman, 1988; Fiorillo, 1991; Domínguez-Rodrigo et al., 2009a; 2010a; 2017) in optimal conditions of bone surface preservation. However, we lack an objective method based on a scientific and quantitative methodology that would allow us to correctly identify them (Domínguez-Rodrigo et al., 2017). This problem is aggravated in assemblages in which taphonomic histories have given rise to poorly conserved bone surfaces like in the two sites studied. The surfaces of the materials from the Barranc de la Boella and Torralba are altered in different ways and intensities. The absence of cut marks is almost complete at both sites. Subaerial exposure has led to preservation problems with the bone surfaces in Torralba and in el Forn. In la Mina, on the other hand, the taphonomic data seem to suggest a faster burial of the remains. Although it is known that we cannot establish a schedule of the burial processes of each of the assemblages (Fox and Lyman, 1989), the better preserved bones at la Mina may be indicative of rapid burials. Meanwhile, the modifications on the materials from el Forn and Torralba imply a longer period of exposure prior to burial. The surfaces of the remains from la Mina, however, are also poorly preserved; in this case, it has been determined that the leaching of the soluble elements present in the sediments could be responsible for the chemical alteration of the remains.

All these taphonomic processes give rise to problems in identifying and differentiating between cut marks and striae produced by the abrasion of sediments, mainly in the Barranc de la Boella assemblages. To solve these equifinality problems that derive from the alteration of these marks, we conducted two experiments. The objective, as we have stated in two articles, was to establish diagnostic criteria that allow the correct differentiation of these two modifications after alterations produced by chemical and mechanical processes. The results obtained suggest that experimentally reproduced chemical alteration results in the rapid loss of diagnostic criteria in both types of striae, preventing their differentiation. Mechanical alteration, conversely, made it possible to establish diagnostic criteria that allow us to experimentally differentiate cut marks from trampling striae subjected to the abrasion process. The application of this work to the striae documented at the Barranc de la Boella site has allowed to determine that the striae documented on the bone surfaces from la Mina are of a natural origin (trampling), while verifying the anthropic provenance of the possible cut marks that were documented on the three mammoth ribs from Pit 1 (Mosquera et al., 2015). The identification of these types of striae on poorly preserved surfaces, however, must be taken with a certain amount of caution (Domínguez-Rodrigo et al., 2010a) and new experimental works are required to expand upon the information currently available to us.

The poor preservation of bone surfaces does not necessarily imply the existence of previous cut marks that have been obliterated. All our data indicate that the aggregates that form the assemblages studied here are the result of independent events that have ended up forming spatial palimpsests (Bailey, 2007; 2008). These palimpsests are a reflection of foraging activities, which do not necessarily include the processing of animal carcasses.

The problem with regard to the absence of cut marks on proboscidean carcasses like those in Torralba requires other considerations in addition to those previously discussed. Cut marks produced during the processing of megaherbivores tend to appear at low frequencies and can be difficult to identify (Crader, 1983; Haynes, 1991; Haynes and Klimowicz, 2015). Nevertheless, there are several deposits in which cut marks have been identified on proboscidean carcasses, which demonstrate that these animals were processed and consumed from the Lower Paleolithic on: Bilzinsgleben (Mania, 1990), Ambrona (Shipman and Rose, 1983b; Villa et al., 2005), Pit 1 site at Barranc de la Boella (Mosquera et al., 2015), Áridos 2 (Yravedra et al., 2010), Castel di Guido (Mussi, 2005) or PRERESA (Yravedra et al., 2012). In other assemblages, such as Áridos 1 (Ollé, 2005) and Fuente Nueva 3 (Espigares et al., 2013), no cut marks have been found, but the use of these animals has been inferred from traceological studies and from the spatial relationship between the lithic industry and the mammoth remains.

In Torralba, if hominins processed the biomass of these large animals, the poor preservation of the bone surfaces could be contributing to the limited evidence of anthropogenic activity on the elephant remains, among which only a single remain with cut marks has been identified. Precisely for this reason, we cannot rule out that these populations did not act as modifying agents on the carcasses, as had already been suggested for this and the neighboring site of Ambrona (Shipman and Rose 1983b; Domínguez-Rodrigo, 1998; Yravedra, 2000; Villa et al., 2005). On the other hand, several works have shown that elephants tend to displace the skeletal remains of other elephants, producing trampling striae and notches on the remains of proboscideans that have gone to die in areas close to large bodies of water (Haynes 1988; 1991; 2005). In Torralba, trampling is one of the most abundant taphonomic modifications in the different assemblages and its presence has been related to the activity of other elephants, to which we can attribute an active role in the modification of the carcasses.

La Mina, el Forn and the classic faunal collections of Torralba show different taphonomic histories; however, they share some features in common (e.g. abundant lithic industry, little evidence of anthropic intervention on faunal remains and evidence of carnivore activity, although carnivore remains are scarce) that reflect the degree of similarity that exists in relation to the mode of deposition of the remains and the use of these open spaces by hominins and carnivores. The presence of hominins in environments rich in biotic and abiotic resources indicates that their activity was linked to their use, without any of these resources necessarily taking precedence over the rest. And neither hominins nor carnivores necessarily exploited all of these resources. In fact, there is no evidence that would point to any one proposal. Domínguez-Rodrigo and colleagues (2010b) suggest that the absence of a direct relationship between the stone tools and faunal collections of an assemblage may be indicative of the production of stone tools for obtaining resources that are not of animal origin. No cut marks have been identified at la Mina or el Forn; however, there is evidence of anthropic breakage, although it is scarce. In addition, the penecontemporary locality of Pit 1 suggests an intensive use of animal resources. In Torralba the evidence of meat acquisition is also scarce, although it does exist. Thus, we can suggest that at least part of the activity of hominin groups in these fluviolacustre environments was linked to the use of meat resources.

## 8.2. The hominin environment

The parameters that have been described as determining the presence of these groups in a certain environment include access to fresh water and food resources, the presence of raw materials for tool production, the existence of tree cover or another type of shelter and, finally, competition and the risk that the presence of other predators entails in their habitat (Peters and Blumenschine, 1995; Blumenschine and Peters, 1998; Saladié et al., 2011; 2014; Egeland, 2014). The presence of carnivores in a prehistoric environment is identified through their remains, through tooth-marks on bone remains and the presence of coprolites (Pickering, 2002).

Based on these types of evidence, carnivores were present and active at the Barranc de la Boella. However, the markers typical of osteological assemblages accumulated by carnivores have not been identified in the levels analyzed to date (e.g. Hugues, 1954; Kruuk and Turner, 1967; Mech, 1970; Sutcliffe, 1970; Kruuk, 1972; Schaller, 1972; Hill, 1980; 1983; 1984; 1989; Maguire et al., 1980; Skinner et al., 1980; 1986; 1998; Binford, 1981; 1988; Brain, 1981; Klein y Cruz-Uribe, 1984; Binford et al., 1986; Kerbis-Peterhans, 1990; Cruz-Uribe, 1991; Skinner and van Aarde, 1991; Stiner, 1991;

Lam, 1992; Domínguez-Rodrigo, 1994; 1995; Fosse, 1995; Martín and Borrero, 1997; Mills and Gorman, 1997; de Ruiter and Berger, 2000; Pickering, 2002; Brugal and Fosse, 2004; Lacruz and Maude, 2005; Fernandez et al., 2006; Montalvo et al., 2007; Pokines and Kerbis Peterhans, 2007; Fernandez and Guadelli, 2008; Lansing et al., 2009; Yravedra et al., 2011; 2012; Stiner et al., 2012; Rodríguez-Hidalgo et al., 2013; 2015; Arriaza and Domínguez-Rodrigo, 2016; Borrero et al., 2018; Saladié et al., *in press*); therefore, we suggest that the evidence of their activity, as in the case of the hominins, may have been the result of marauding. One exception is the accumulation of coprolites in the form of a latrine excavated in level II.3 of la Mina. Hyaenids tend to form latrines in areas near their habitat sites (Kruuk, 1972; Mills and Gorman, 1987). The presence of a latrine at la Mina indicates that these hyena denned relatively nearby. Although evidence of the activity of other carnivores is more discreet, the remains of felids (lion, jaguar and lynx), canids (wolf and fox) and ursids show that these were also present in the inferred environment of the Barranc de la Boella. Conversely, among the classic Torralba collections, the carnivore remains recovered are very scarce, although this may be partly due to the biases that affect these collections (Villa, 1990). Considering the make-up of the assemblages studied, it seems that the groups of hominins lived under greater pressure at the Barranc de la Boella and coexisted with more numerous predators, at least in these specific areas.

Given the problems with the preservation of the bone surfaces and the lack of discernable anthropic modifications, it is difficult to assess the degree of independence/dependence between the two groups of actors (carnivores and hominins). There are abundant proxies that evaluate the frequency, distribution and coexistence of cut and percussion marks on the same remain (both anthropic signs) as compared to carnivore tooth-marks (Binford, 1981; Shipman and Rose, 1983a; Blumenschine and Selvaggio, 1988; Domínguez-Rodrigo et al., 2009b), which we have not been able to assess. An alternative to these limitations has been the use of anatomical profiles, which has allowed us to assess the degree of competition in these environments. The use of anatomical profiles has been presented as a useful tool to reconstruct the paleoecological environments inhabited by Pleistocene hominins by means of analogy with current naturalistic environments (Marean and Spencer, 1991; Marean et al., 1992; Blumenschine and Marean, 1993; Capaldo, 1997; Faith and Behrensmeyer, 2006; Domínguez-Rodrigo and Organista, 2007; Faith et al., 2007; Egeland, 2008; 2014; Saladié et al., 2014).

These analyses have been effective in determining, for example, the levels of ravaging produced by bone-cracking carnivores (Faith et al., 2007; Domínguez-Rodrigo and Organista, 2007; Egeland, 2008). 'Ravaging' refers to the impact of carnivores on an osteological assemblage, including the selection, transport, modification and/or destruction of its components (Binford, 1981; Marean and Spencer, 1991). The extent of the impact resulting from ravaging depends on the pressure of the environment. In times of low pressure for resources, carnivores tend to destroy only the less dense elements or skeletal portions and those with the greatest nutritional content (Faith et al., 2007; Dominguez-Rodrigo and Organista, 2007; Egeland, 2008). In these contexts, it is common to find whole remains, such as limb bones, which imply the existence of nutrient resources that were not fully exploited (Capaldo, 1997). Only at times of higher pressure do carnivores tend to crush these remains, regardless of their density or nutritional value (Faith et al., 2007), resulting in their exhaustive exploitation.

This competition can be inter- or intraspecific, depending on whether it affects individuals of the same or different species, and can occur either directly or indirectly, depending on whether it involves confrontation or if the different actors attempt to access to the same resource sequentially (Faith and Behrensmeyer, 2006). The work conducted by Behrensmeyer (1973) and Faith and Behrensmeyer (2006) in the Amboseli National Park in Kenya showed that the abundance of carnivores competing for the same resource translates into greater ravaging of the carcasses. In general, a higher level of ravaging can be correlated with greater competition in the environment (Domínguez-Rodrigo and Organista, 2007). However, other factors or constraints, such as nutritional stress, can lead carnivores to high levels of ravaging even at a time of low competition (Domínguez-Rodrigo and Organista, 2007). For this reason, these researchers consider that the relationship between ravaging and paleoecological trophic dynamics requires future in-depth studies, and extrapolations should be made with caution. We cannot ignore that these contexts include an additional actor, absent in the current contexts: hominin populations. However, throughout our research, these analyses have been used as effective tools to at least approach this type of paleoecological reconstruction, especially, as we have seen, in the absence of other possible approaches.

The analysis of the anatomical profiles of la Mina and el Forn, in accordance with the evidence of the presence of hominins and carnivores, show the coincidence of the two agents in the space. Interestingly, in addition to the spatial coincidence of these actors, we found that when the intensity of carnivore activity was the highest, the anthropic presence was also higher. Level II.2 of la Mina is the clearest example of this pattern. This assemblage is characterized by the presence of abundant lithic tools made from different raw materials and in a variety of types. In addition, remains with modifications related to anthropic breakage have been located, as well as abundant evidence of carnivore intervention. According to these analyses of the anatomical profiles, the incidence of ravaging and, therefore, the competition between predators (intra or interspecific) may have reached high levels. One of the hypotheses that we must consider is that this is due to the scarce availability of meat. However, it is precisely this level that has left behind a greater abundance of remains (lithic and faunal), taphonomic signals and taxonomic diversity. Within this diversity, taxa belonging to different types of environments have been identified (open, semi-open, aquatic and riparian forest), which is inconsistent with a resource-poor landscape. On the other hand, the co-occurrence of both actors in the same space is indicative of the existence of resources of interest for both groups (Egeland, 2014). The abundance of carnivores and the consequential increase in the levels of competition in Pleistocene environments were part of the dailylife lives of the hominins at that time; factors such as the availability of resources would have a greater weight in the choice of space between these groups than the existence of other predators (Egeland, 2014).

On the other hand, we have also documented contexts of low and moderate inferred competition among the assemblages studied in this doctoral thesis in both el Forn and Torralba. Currently, we have a dataset that suggests that hominins could successfully inhabit and survive in highly competitive contexts as early as the African Early Stone Age (Egeland, 2008; 2014), and the ability to reduce the risk of predation in highly competitive environments has even been proposed in TD6.2 (Saladié et al., 2014). However, this evidence does not allow us to consider that the presence of forager groups in low-competition environments could be due to a survival strategy based on the reduction of risk predation.

In fact, the identification of hominins in environments of low and moderate inferred competition can respond to different scenarios, such as fluctuations in ecological dynamics and mammalian communities or the nature of the origin of the accumulations. Our deposits respond to the definition of a spatial palimpsest described by Bailey (2007; 2008), which is characterized by a mixture of spatially segregated episodes, in which temporal relationships are blurred and difficult to individualize. In these depositional contexts, the resulting skeletal profiles reflect the combination of events of different natures and ecological compositions. During times of decreased competition, unexploited (or not entirely exploited) elements can be introduced into the archaeological record, which, when mixed and form part of the deposits, may end up reflecting patterns of low or moderate competition. However, we should not lightly dismiss these results as another a more or less faithful reflection of the ecological context of the past. This would be in accordance with an interpretation of hominin groups capable of adapting to different ecological contexts, and that their greater or lesser presence, as we have already pointed out, may be mainly related to the availability of resources. Saladié et al. (2014) point out that settlements of possibly varying lengths in the same environment are mainly linked to the availability of resources in the capture areas. The Barranc de la Boella and Torralba would represent two of these areas, with different temporary occupations and different technical modes, although with similarities in the patterns of use and exploitation of the territory.

# Capítulo 9. Conclusiones

En la presente Tesis Doctoral se ha realizado un análisis zooarqueológico y tafonómico de los restos faunísticos procedentes de los conjuntos arqueo-paleontológicos de la Mina y el Forn (Barranc de la Boella, Tarragona) y de las colecciones clásicas del yacimiento de Torralba (Soria). Nuestros objetivos consistieron en caracterizar la naturaleza de estas acumulaciones al aire libre y en establecer el rol que homininos y carnívoros desempeñaron en la formación de los depósitos. Así mismo, se planteó la necesidad de enmarcar estas acumulaciones dentro de un sistema más amplio, que englobe el espacio (a escala regional y macro-regional) en el que las poblaciones de homininos del Paleolítico inferior desempeñaban el conjunto de actividades de movilidad, subsistencia y explotación de recursos. Nuestra hipótesis de partida era que homininos y carnívoros tuvieron un escaso rol en la acumulación de los citados depósitos. Estas acumulaciones, por lo tanto, representarían lugares de tránsito, y sin reiteración de actividades, en un entorno paleoecológico conocido y controlado por estas poblaciones.

Los resultados obtenidos han permitido confirmar nuestras hipótesis iniciales, habiéndose ratificado un escaso papel de homininos y carnívoros en la formación de los conjuntos estudiados. La industria lítica recuperada avala la presencia de los grupos de homininos en estos entornos; sin embargo, las evidencias tafonómicas de procesado de las carcasas son escasas, con perfiles muy diferentes de aquellos descritos en las acumulaciones de origen antrópico. Los conjuntos tampoco responden a los patrones descritos para las acumulaciones producidas por carnívoros, que en el Barranc de la Boella y Torralba se documentan principalmente a través de sus modificaciones. La única excepción es la letrina de hienas documentada en el nivel II.3 de la Mina.

En estos conjuntos, la alteración de las superficies óseas ha generado problemas de equifinalidad y ha dificultado la correcta identificación de modificaciones tafonómicas pre-existentes. Para solventar estos problemas se han desarrollado dos trabajos con el objetivo de diferenciar marcas de corte y estrías de trampling en superficies alteradas. Estos trabajos han sido aplicados a los conjuntos del Barranc de la Boella. Los resultados obtenidos han evidenciado la dificultad de identificar correctamente estrías de origen antrópico en superficies mal preservadas y nos han permitido recalcar la necesidad de ser cautos en la identificación de modificaciones tafonómicas en este tipo de conjuntos, pues identificaciones incorrectas pueden llevar, por ejemplo, a inferencias erróneas sobre la conducta de los homininos pleistocenos.

Las observaciones obtenidas de las poblaciones de cazadores-recolectores actuales han mostrado un amplio espacio de movilidad en torno a sus los lugares de hábitat. En este marco contextual es donde se enmarcan nuestros conjuntos, que se corresponden con lugares de tránsito en los que los grupos de homininos pleistocenos podrían transitar regularmente, aunque sin llegar a desempeñar un rol principal como agentes acumuladores. Estos depósitos, por tanto, son el resultado de la multiplicidad de eventos independientes que se suceden en un mismo espacio en prolongados periodos de tiempo; por ello, deben ser entendidos como palimpsestos espaciales en los que las relaciones espacio-temporales de los agregados que los componen son borrosas y difíciles de establecer.

El uso de perfiles anatómicos se ha mostrado como una herramienta útil para acercarnos a los modelos de comportamiento de estos grupos. En nuestros conjuntos hemos podido inferir diversos niveles de competencia entre depredadores en estos entornos. Homininos y carnívoros son más activos en momentos de mayor competencia inferida, lo que nos ha permitido atestiguar que la presencia de otros depredadores no habría limitado la presencia de los grupos de homininos en un determinado espacio, que posiblemente estaría ligada a otros elementos como la disponibilidad de recursos de interés. La presencia de homininos en entornos que se han documentado como de baja o moderada competencia atestigua la capacidad de adaptación de estos grupos humanos a diferentes tipos de ecosistemas.

## 9. Conclusions

In this doctoral thesis, we have conducted a zooarchaeological and taphonomic analysis of the faunal remains from the archaeo-paleontological assemblages of la Mina and el Forn (Barranc de la Boella, Tarragona) and the classical faunal collections of the Torralba site (Soria). Our objectives were to characterize the nature of these open-air accumulations and to establish the role that hominins and carnivores played in the formation of the deposits. Likewise, we raised the need to frame these accumulations within a broader system, which encompasses the space (at a regional and macro-regional level) in which the populations of hominins of the Lower Paleolithic conducted all of the activities related to mobility, subsistence and the exploitation of resources. Our initial hypothesis was that hominins and carnivores played a small role in the accumulation of the aforementioned assemblages. These accumulations, therefore, would represent places of transit without repeated activities, in a paleoecological environment known and controlled by these populations.

The results obtained have allowed us to confirm our initial hypotheses, having established a limited role of hominins and carnivores in the formation of the sites studied. The recovered lithic industry supports the presence of groups of hominins in these environments; however, the taphonomic evidence of carcass processing is scarce, with profiles very different from those described in accumulations of anthropic origin. The assemblages do not respond to the patterns described for accumulations produced by carnivores, which in the Barranc de la Boella and Torralba are documented mainly through modifications on bone surfaces. The only exception is the hyena latrine documented in level II.3 of la Mina.

In these assemblages, the alteration of the bone surfaces has generated equifinality problems and has hindered the correct identification of pre-existing taphonomic modifications. To solve these problems, two works have been developed with the aim of differentiating trampling and cut marks on altered surfaces. These works have been applied to the sites of the Barranc de la Boella. The results obtained have shown the difficulty of correctly identifying anthropogenic striae on poorly preserved surfaces and have allowed us to emphasize the need for caution in the identification of taphonomic modifications in these types of assemblages, since incorrect identifications can lead, for example, to erroneous inferences about the conduct of Pleistocene hominins.

Observations of current hunter-gatherer populations have identified a large mobility space around their habitat locations. This is the contextual framework in which our sites are framed, which correspond to places of transit in which these Pleistocene hominin groups would have travelled regularly, although without playing a major role as accumulating agents. These deposits, therefore, are the result of the multiplicity of independent events that occur in the same space over prolonged periods of time; therefore, they must be understood as spatial palimpsests in which the spatiotemporal relationships of the aggregates that compose them are blurred and difficult to establish.

Anatomical profiles have proven a useful tool in approaching the behavioral models of these groups. In our assemblages we have been able to infer different levels of competition among predators in these environments. Hominins and carnivores are more active at times of greater inferred competition, which has allowed us to demonstrate that the presence of other predators would not have limited the presence of groups of hominins in a given space, which could possibly be linked to other factors such as the availability of resources of interest. The presence of hominins in low or moderate competition environments testifies to the ability of these human groups to adapt to different types of ecosystems.

# Capítulo 10. Perspectivas de futuro

La investigación que se deriva de la realización de la presente Tesis Doctoral se ha enmarcado, tal y como hemos ido viendo, en torno a dos problemáticas principales: por un lado, la necesidad de ahondar en los problemas de equifinalidad que se derivan de cómo los procesos fosildiagenéticos afectan a los conjuntos osteológicos depositados al aire libre y, sobretodo, en el reconocimiento de ciertas modificaciones antrópicas; por otro lado, ampliar el conocimiento sobre el uso del espacio regional de movilidad que tendrían los homininos del Pleistoceno inferior y medio y entender cómo éste se plasma e identifica en el registro arqueológico, así como interpretar si la presión ejercida por otros depredadores fue determinante para su presencia en determinados contextos ecológicos.

Sobre las conclusiones extraídas, se nos abren nuevas preguntas para encarar futuras investigaciones y, especialmente, la necesidad de una mayor investigación y un registro que avale nuestras interpretaciones. El registro arqueológico pleistoceno de Eurasia nos ha aportado un innumerable número de yacimientos al aire libre, con condiciones, en cierta medida, similares a las del Barranc de la Boella y Torralba. Nos encontramos ante la necesidad de implementar este tipo de estudios a otros conjuntos, ampliando la horquilla cronológica y geográfica que aquí se ha tratado. Ampliar la muestra deviene necesario a estas alturas.

Todas estas aproximaciones, además, deben desarrollarse dentro del nuevo marco científico en el que nos encontramos. Algunos métodos que empleamos en el análisis tafonómico fueron propuestos hace más de tres décadas. Actualmente, nos encontramos ante una hornada de trabajos que están revisando estas metodologías, a la luz de los conocimientos y recursos técnicos de los que disponemos. Esta Tesis Doctoral ha evidenciado que queda pendiente un largo recorrido en esta dirección. El análisis de los materiales del Barranc de la Boella nos ha evidenciado que necesitamos implementar nuestro conocimiento sobre como la fosildiagénesis afecta a los huesos y a las modificaciones superficiales. Por poner un ejemplo, ¿cuál es el origen de la corrosión química que afecta a los fósiles de la Mina? Experimentaciones que nos permitan ahondar en que agentes o procesos han provocado la alteración de estas superficies deviene necesario y se plantea como un objetivo a desarrollar en un futuro cercano. El camino que abre la contrastación mediante la realización de experimentaciones es todavía largo y en gran parte está por recorrer.

## 10. Implications for the future

The research derived from this doctoral thesis has been framed, as mentioned, around two main problems: first of all, the need to examine the equifinality problems that arise from the manner in which fossil diagenetic processes affect osteological assemblages in open-air contexts, and especially in the recognition of certain anthropic modifications in these contexts; and secondly, the need to expand upon our knowledge regarding the use of the regional space of mobility of Lower and Middle Pleistocene hominins, and understand how it is identified in the archaeological record, as well as to interpret if pressure exerted by other predators was a decisive factor in its presence in certain ecological contexts.

Our conclusions raise new questions to be answered in future research, and especially point to the need for further research with a larger the fossil record in order to support our interpretations. The Pleistocene archaeological record of Eurasia includes innumerable open-air sites, with conditions, to a certain extent, similar to those of the Barranc de la Boella and Torralba. This type of study should be conducted at other sites, expanding the chronological and geographic range discussed here. Increasing the sample size is also necessary at this point.

All these approaches, in addition, must be undertaken within the new scientific framework in which we find ourselves. Some methods that we used in the taphonomic analysis were proposed more than three decades ago. Several works are currently reviewing these methods in light of the knowledge and technical resources now available. This doctoral thesis has shown that there is still a long way to go in this respect. The analysis of the materials of the Barranc de la Boella has shown us the importance of applying our knowledge of how fossil diagenesis affects bones and surface modifications. For example, what is the origin of the chemical corrosion that affects the fossils of la Mina? An experiment that allows us to delve into what agents or processes have caused the alteration of the surfaces is necessary and is proposed as an objective to be explored in the near future. The path embarked upon by means of these experiments is long and much remains to be done.

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