Understanding Late Pleistocene Landscapes of Central Italy: a Multidisciplinary Approach

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Abstract

It is now clear in archaeology that a full interpretation of sites cannot be realised if information about the environmental setting and constraints of the surrounding context are not available. The Latium coast (central Italy) has been extensively investigated since the 19th century and is one of the regions with the highest number of prehistoric sites in Italy. In spite of this, multidisciplinary environmental reconstructions of this region are still absent.

This thesis deals with investigations of the travertine quarry Cava Muracci (Latium, central Italy), where excavations were carried out between 2012 and 2016. Seven caves were discovered, coprolites, a large faunal assemblage and a small lithic collection were found at one of them (i.e. Area 3) which was revealed to be a cave hyena den dating between 44–34 ka BP. A holistic palaeoecological study has been undertaken to increase our knowledge of the environment of the coastal Latium, the so-called Pontine Plain.

Pollen analysis of cave hyena coprolites, an extremely undervalued resource, has been carried out for the first time in the region. This study has provided new insights into the vegetation and climate of the Pontine Plain, previously known only through distant pollen records. The faunal assemblage from the den has also been exhaustively studied. The environmental inferences have then been combined with the pollen data and geological information. The results returned a complex reconstruction of the local landscape, with at least three main habitats and a wide biodiversity.

Finally, the role of the Pontine Plain as an ecological *refugium* has been examined. The results of this research suggest the region had milder environmental constraints, providing an optimal place to live to several faunal and vegetational taxa also during the harshest millennia of Late Pleistocene.

“Dissatisfaction is a symptom of ambition. It’s the coal that fuels the fire.”

List of Contents

Chapter V: Human Exploitation of the Landscape……………………………… 102

List of Figures

Chapter I: Research Framework and Aims

Chapter II: Introduction to the Pontine Plain

Chapter III: Previous and Ongoing Prehistoric Research in Latium

Chapter IV: Materials and Methods

Chapter V: Human Exploitation of the Landscape

Chapter VI: Palaeoecological Analysis of the Coprolites

Chapter VII: The Archaeozoological Study of the Fauna Remains

List of Tables

Chapter IV: Materials and Methods

Chapter V: Human Exploitation of the Landscape

Chapter VI: Palaeoecological Analysis of the Coprolites

Chapter VII: The Archaeozoological Study of the Fauna Remains

Preface

Coming from another country with a different tradition and approach to university I had no idea of what to expect from this PhD. Before starting the research thesis, actually before moving to York, I wanted to make sure of what I would soon face. Among several readings I had the pleasure to read a brief guide by Tara Brabazon (2010), there I found many helpful suggestions but one in particular would affect my future work and I have great pleasure to quote it entirely:

“The best Ph.D.s are small. They investigate a circumscribed area, rather than over-egging the originality or expertise. The most satisfying theses emerge when students find small gaps in saturated research areas and offer innovative interpretations or new applications of old ideas.” Tara Brabazon (2010).

The main topic around which this PhD is structured had already been designed (i.e. the environmental reconstruction of Pontine Plain) but this guide led me to restrict the geographical limits originally planned and to focus more on a resource never exploited so far in the region, the coprolites, in order to achieve my target and provide an innovative and at the same time original interpretation.

Six years ago, when for the first time I walked into the travertine quarry which would then become “the site" of Cava Muracci, I had no idea of the archaeological potential that it retained. Only now it is possible to understand the scientific contribution of the site. The research has not only shed light on an aspect of the territory which was previously unexplored, but also shown how individual studies can answer greater questions if combined in a multidisciplinary approach.

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Happiness only real when shared

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Ziva, mo chuisle, love cannot be lost.

Infine, ma al principio di tutto, ringrazio la mia famiglia. Per esser stata disposta a compiere sacrifici e aver rinunciato a tanto a causa mia, per il supporto lungo questo percorso. Per aver reso tutto questo possibile.

Declaration

I declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References.

Some results and aspects of this thesis have already been published through articles or conference proceedings, according to the criteria of scientific diffusion part of the doctorate. All contributions to this work are acknowledged below.

An overview of the research project has been included in:

Gatta M., Rolfo M.F. 2017. Rinvenimenti preistorici nei travertini di Cisterna di Latina, *Proceedings of the conference "De Agro Pomptino"*, Cisterna di Latina 15 March 2014.

Gatta M., Rolfo M.F. 2015. New Pleistocene Evidence from the Western Coast of Italy: A Landscape Approach, *Antiquity Project Gallery* 346.

Gatta M. 2014. Understanding Late Pleistocene landscapes of Central Italy: a multidisciplinary approach, *The Post Hole* 29, 11–16.

Rolfo M.F., **Gatta M**. *in press b*. Prehistoric and palaeontological finds from Cisterna di Latina (loc. Muracci), *Proceedings of the conference Lazio e Sabina 12*, Rome 8-9 June 2015.

Certain chapters are partially published with the following references:

Gatta M., Rolfo M.F. 2017. Cava Muracci: A new Middle-Upper Palaeolithic site in west-central Italy, *Mediterranean Archaeology and Archaeometry* 17 (2), 105–116. Material from this publication is included in Chapter II.

Gatta M., Sinopoli G., Giardini M., Giaccio B., Hajdas I., Pandolfi L., Bailey G., Spikins P., Rolfo M.F., Sadori L. 2016. Pollen from Late Pleistocene hyena (*Crocuta crocuta spelaea*) coprolites: an interdisciplinary approach from two Italian sites, *Review of Paleobotany and Palynology* 233, 56–66. Material from this publication is included in Chapters II, IV and VI.

Gatta M., Kotsakis A., Pandolfi L., Petronio C., Salari L., Achino K.F., Silvestri L., Rolfo M.F. *in press a*. The Late Pleistocene faunal assemblage from Cava Muracci (Latium, Italy): Palaeoenvironmental implications for coastal central Italy during MIS 3, submitted to *Comptes Rendus Palevol.* Material from this publication is included in Chapters II, IV and VII.

Gatta M., Giaccio B., Marra F., Rolfo M.F., Jicha B. 2017. Trace-element fingerprinting of the 69–36 ka Colli Albani eruptive units: A preliminary dataset for archaeological and tephra studies in central-southern Italy, *Journal of Archaeological Science: Reports*. Material from this publication is included in Chapters II and IV.

Gatta M., Marra F. 2017. Tephrostratigraphic database of Late Pleistocene landscapes of Central Italy, *Quaternary Newsletter* 141, 40–42. Material from this publication is included in Chapters II and IV.

Pandolfi L., Boscato P., **Gatta M**., Rolfo M., Tagliacozzo A., 2016. Late Quaternary extinction of the narrow-nosed rhinoceros *Stephanorhinus hemitoechus* (Mammalia, Perissodactyla) in Italy. Poster presentation. XVI Edizione delle Giornate di Paleontologia, Faenza 25-27 Maggio 2016. Material from this publication is included in Chapter VII.

Pandolfi L., Boscato P., Crezzini J., **Gatta M**., Moroni A., Rolfo M.F., Tagliacozzo A. 2017. Late occurrences of the narrow-nosed rhinoceros *Stephanorhinus hemitoechus* (Mammalia, Perissodactyla) in Italy, *Research in Paleontology and Stratigraphy* 123 (2), 177–190. Material from this publication is included in Chapter VII.

Chapter I

Research Framework and Aims

It is not an easy task to explore palaeoecological aspects of a distant past or to understand how these have affected the life and death of a territory. The first chapter will explain how this target will be addressed in this thesis. The aims and structure will then be described, together with a summary of each chapter. The Middle-Upper Palaeolithic transition in Europe and Italy will be introduced to provide the chronological background to this thesis. The second section will be dedicated to the research background. Two concepts are extremely important in this thesis and deserve to be introduced: the first is the concept of *refugia* and the characteristics that define them and the second is that of environmental archaeology and palaeoenvironmental reconstructions. The last section is about the key issue of time and space scale, an important question to address when integrating different kinds of evidence into a coherent understanding of a region.

1.1 Thesis aims and objectives

The aim of this research is to formulate a palaeoenvironmental reconstruction of the Pontine Plain region (south-west Latium) between 44–34 ka BP, filling a gap in the knowledge of prehistoric archaeology of Central Italy. The identification of this region as a naturally bounded environmental refuge, in which human and animal species found necessary survival conditions, will be addressed. The concept of *refugium* that is being developed in this research, however, is not particularly connected to human survival in the area, as to the understanding of the environment itself. Did this region offer, during millennia of intense climate change, a stable and favourable microclimate for life? A multidisciplinary approach, incorporating archaeozoological, palaeoecological, geological and anthropological data, has been undertaken to investigate this hypothesis in the most thorough manner, as an original contribution of this work to the archaeological knowledge of the territory.

The primary case study of this thesis is the site of "Cava Muracci" (hereinafter CM), a travertine quarry which has been investigated since 2012. This site has provided abundant faunal remains, among the most numerous of the region; a large number of coprolites, particularly of cave hyena; and a discrete lithic assemblage. All the collected material has been carefully analysed, providing essential data for the understanding of the site.

This research has five primary objectives:

1. To suggest a pattern of human exploitation of the Pontine Plain and highlight opportunities and constraints related to the territory. To this purpose the topography of the area, the resources of lithic raw material, the availability of both terrestrial and marine food sources and the presence and distribution of open-air and cave sites will be taken into consideration (see Chapter V).
2. To develop palaeoecological analysis of hyena coprolites from CM as a tool for understanding the vegetational environment and temperature ranges in the past of the region (see Chapter VI). The pollen analysis of fossil faeces represents the first study of this kind carried out in central Italy.
3. To carry out a complete archaeozoological study of the faunal remains (see Chapter VII). Taphonomic and taxonomic analyses will allow the identification of animal species that inhabited the area. The results of these approaches will provide significant environmental inferences.
4. To combine the palaeoecological and archaeozoological data obtained to suggest a palaeoenvironmental reconstruction of central Italy, specifically of the Pontine Plain between 44–34 ka BP (see Chapter VIII).
5. To determine, by comparing the obtained reconstruction with the environmental characteristics of contemporaneous national and Mediterranean contexts, whether the Pontine Plain can be considered a *refugium*, i.e. a well-delimited area where environmental conditions were stable and favourable for human and animal life (see Chapters VIII).

In particular, information obtained from the archaeozoological and palaeoecological studies has enabled a thorough and reliable environmental study. This is essential, as the present territory went through substantial geomorphological changes. Climate significantly affected not only the vegetation and the animal species but also sea level change and fluvial configuration, changing the morphology of the entire region. The question of how reliable is an assumption of past environments based on present day conditions has already been raised (Bailey, 2005) as it is now recognised that regions can completely change their characteristics over time.

This thesis does not represent the end of this project, but is part of an ongoing research programme. Results obtained so far have yielded a palaeoecological reconstruction of CM, with wider reaching implications for the re-interpretation of other sites within the Pontine macro area. The approach of this research is also significant on a wider scale, as multidisciplinary studies such as those carried out here can be applied to other contexts, providing additional comparisons in the Mediterranean area.

1.1.1 Chapter outlines

This PhD is structured as a linear and continuous thesis. However, parts of it have already been published as articles or conference proceedings. This approach was chosen to allow the dissemination of preliminary results before the completion of the PhD. Sections submitted for publications or already published have been re-written in accordance with the standards of this manuscript to give consistency to the thesis as a whole.

The **second chapter** has two fundamental tasks. The first is to provide a detailed description of the geography, geology and climate of the Pontine Plain, both at present and during the Late Pleistocene, providing an overview of its geomorphological evolution. The second task is to introduce the findings collected from the case site of CM and their great archaeological interest granted by their quantities and the quality of preservation, rare in the area due to the acidity of the volcanic soil. The cave hyena coprolites have been of particular interest since they provided unique information for the final interpretation of the region.

The **third chapter** presents an evaluation of the archaeological literature. A critical approach has proved essential in evaluating the relevance of studies amongst the large amount of available material. Many publications have proven to be unreliable or scientifically worthless and have therefore been excluded from the review.

The **fourth chapter** contains an outline of the materials and methods, explaining the subsequent analyses carried out. The purpose of this chapter is to permit estimation of the validity of the research. It is divided into sections based on the various studies carried out on the coprolites, faunal remains and lithic industry. Each of these sections is further subdivided into subsections which address the appropriateness of the research design, the pilot study when present, instrumentation, procedures, data processing and data analysis.

The **fifth chapter** is dedicated to the human exploitation of the region. The aim of this chapter is to highlight opportunities and constraints of this region as a territory. A broad overview of both open-air and cave archaeological sites in the Pontine Plain during the Pleistocene will be provided for this purpose. Further evidence of human occupation is now available due to the discovery of the lithic assemblage at CM. These industries, relevant due to their presence further inland than the common coastal sites, have been techno-typologically studied in this thesis. A use-wear study of these implements was also carried out and provided useful information on the modality of deposition of the artefacts. Finally, a reconstruction of the human presence in the area and subsistence between the Late Middle and Early Upper Palaeolithic is proposed based on previous analyses of faunal remains, flint raw material, water supply and availability of caves and shelters.

The subsequent **chapter six** is entirely committed to the study of the coprolites, which represents an original and unique contribution to the knowledge of the region during the Pleistocene. Whilst coprolites have been collected from various sites in the region, their potential for pollen analysis has not previously been exploited. This is particularly vital in the area as coring of lake sediments, such as at the site of Mezzaluna (Eisner et al. 1984; Voorrips et al. 1991; Eisner & Kamermans 2004; and also see Chapter III), has previously proved of limited value. Additionally, coprolites provide a more localised climatic reconstruction than materials derived from analysis of lake or river sediments, which contain pollen derived from a much broader catchment, in turn providing a more reliable picture of the local environment. The coprolites, which have also been subjected to a proteomics assessment in the laboratories of Thermo Fisher Scientific, were analysed at the department of Environmental Biology at the University of Rome La Sapienza. The results are highly satisfactory and have permitted a reliable reconstruction of the local flora, despite the difficulties arising from the minimal exposure to pollen of hyenas, which live part of their life in underground environments, and travertine minerals that triggered a mineralised fossilisation of the coprolites which could have destroyed the pollen grains inside them.

The **seventh chapter** introduces results obtained from the study of the faunal remains, including taphonomic and taxonomic information from the identified bones. The taxonomic study of most of the remains was undertaken during a PhD internship in archaeozoology at the Department of Physical Sciences, Earth and Environment at the University of Siena. The study of the remaining assemblage and all further taphonomic studies has been achieved through a scientific collaboration at the University of Rome La Sapienza.

This chapter will highlight factors such as the variety of wildlife and environmental conditions in which these species thrived, the age at death and occasional biometric differences compared with the same species elsewhere. Attention will also be given to identified gnawing marks and the predominance of some anatomical parts over others, key indicators for evaluating the interpretation of the site as a den of *Crocuta crocuta spelaea* (cave hyena). A brief discussion is also dedicated to two bones marked by the presence of rare pupal chambers, cocoons typical of necrophagous insects (see section 7.3.4). The collection of this information, and the comparison with the faunas of sites of the same region, provides additional environmental information.

Chapter eight will draw these various studies together into the discussion, interlinking all of the information and data obtained to propose a palaeoenvironmental reconstruction of the Pontine Plain during the 44–34 ka BP interval. The resulting picture is then compared with the few previous ecological inferences, with the aim to highlight differences of interpretation. Subsequently, the question whether the Pontine Plain can be considered a *refugium* will be addressed, basing on both evidence of this research and correlations with other known European *refugia*. Finally, a section is then committed to recognise significance and implications of this thesis on various scales but also to consider its limitations.

The **final chapter** will propose a summary of the entire research. Afterwards, directions for future research will be considered in order to improve results of this research and overcome some of its weaknesses. Finally, the conclusions and the achievement of aims will be set out, reiterating the contribution of this work to the knowledge of prehistoric central Italy, in its national and international context.

1.1.2 Appendices

Further data and lists of materials have been detailed in the Appendices to aid a fluent reading of the thesis. The faunal, lithic and coprolite datasets are included with descriptive characteristics of the findings. This supplementary material is not crucial for the understanding of the work done but completes it, providing details that support the analyses and interpretations presented in the text.

1.2 Chronological background: The Middle-Upper Palaeolithic transition

The chronological context in which this thesis belongs is that of the 'Middle-Upper Palaeolithic transition', a stage of MIS 3 during which crucial changes in global prehistory took place. This therefore needs to be introduced.

In this time frame, primarily known for the extinction of the Neanderthals and the subsequent advent of *H. sapiens* (AMH) in Europe, major behavioural and cultural changes occurred around the conventional date of 40 ka BP (Camps, 2009). The nature and timing of this transition is one of the most debated archaeological topics and still needs further exploration. An overview of the current knowledge and the latest theories will be outlined in this section. Although we are still far from a unanimous interpretation of this phenomenon, it is now widely agreed that the transition was not a rapid and abrupt event. It occurred, instead, in a varied spatio-temporal scale across Europe, and in a complex biocultural framework (Higham *et al.*, 2006; Carrión *et al.*, 2008). The extinction of *H. neanderthalensis* itself took place over an extended time ranging between 40–26 ka BP, with the underlying causes still strongly debated (Finlayson *et al.*, 2006). Due to the ecological focus of this thesis, it is important to state that the highly unstable environmental conditions are often considered a leading cause of this extinction (Stewart, 2005). It is difficult to fully understand the extent of climatic influence on human groups at the time, as those environmental conditions are not present in any part of the earth today (*ibidem*). Nevertheless, studies of climatic changes in the Mediterranean area during Heinrich Event 5 showed how these might have favoured AMH in the European replacement of Neanderthals (Müller *et al.*, 2011). The climate factor will be discussed in detail in section 2.2.

Despite the many aspects of human life that underwent some changes, archaeological research about the Transition is mainly focused on specialised techno-typological studies of lithic industries. This choice is clearly dictated by the good preservation of this material class, more numerous than any other archaeological find. During the Transition, a change took place in the morphology and manufacture of instruments, with new features replacing the earlier Mousterian ones, thus starting the so-called Aurignacian with the Protoaurignacian culture in its earliest Mediterranean form (Mellars, 2004). This culture appeared in south-central Europe about 42 ka cal BP (Higham *et al.*, 2009; Douka *et al.*, 2012), and lastly in Iberia at 37 ka cal BP (Zilhão and D'Errico, 2003; Camps and Higham, 2012). For a long time, the association between these industries and AMH remains had not been identified in sites prior to 34 ka BP (Dujardin, 2003; Henry-Gambier, Maureille and White, 2004). This controversial evidence could not allow archaeologists to clarify whether the AMH was responsible for Protoaurignacian assemblages dated to the earlier millennia, or the Neanderthal (Higham *et al.*, 2006; Hublin, 2015). Now this industry it is attributed to AMH, and it represents a distinctive feature between the two species (Benazzi *et al.*, 2015).

Outside of Italy, which will be discussed in the following sub-chapter, the earliest AMH remains of Europe were found at Peştera cu Oase in Romania (40 ka cal BP), La Quina-Aval and Brassempouy in France (<40 ka cal BP) and in the Kostenki valley in Russia (38 ka cal BP) (Hublin, 2015). The chrono-geographical distribution of human remains and lithic industries, however, seems to suggest that AMH became widespread just before 40 ka BP in an east-to-west spreading trend, systematically replacing the Neanderthal presence. This phenomenon ends with the arrival of AMH in the Iberian Peninsula at 30 ka BP, with the full disappearance of Neanderthals (Higham *et al.*, 2006). This journey may have occurred mainly via two routes, a northern one through the Danube corridor and a southern one along the Mediterranean coast (Fig. 1.1) (Conard and Bolus, 2003; Mellars, 2005). This theory, although not agreed on by all, is supported by a comparison with the same two routes later followed by the first Neolithic farmers communities coming from the east (10–6 ka BP) (Mellars, 2004).

Despite the simultaneous presence of Neanderthals and AMH in Eurasia for about 2,600–5,400 years (Higham *et al.*, 2014) that would imply the occurrence of repeated contacts between the two species, as well as the genetically proved interbreeding out of

Africa (Green *et al.*, 2010; Prüfer *et al.*, 2014; Vernot and Akey, 2014), a coexistence in central and western Europe is not yet demonstrated (Camps and Higham, 2012). The absence of archaeological contexts in which both cultures are contemporaneous or alternating may indicate a gradual shift of Neanderthals towards western areas leaving the field open to the incoming *H. sapiens*. Nevertheless, many scientifically unproved cases of hybridization have been suggested in Europe (Duarte *et al.*, 1999; Frayer *et al.*, 2006), with the only genetic confirmation coming from the site of Peştera cu Oase (Fu *et al.*, 2014).

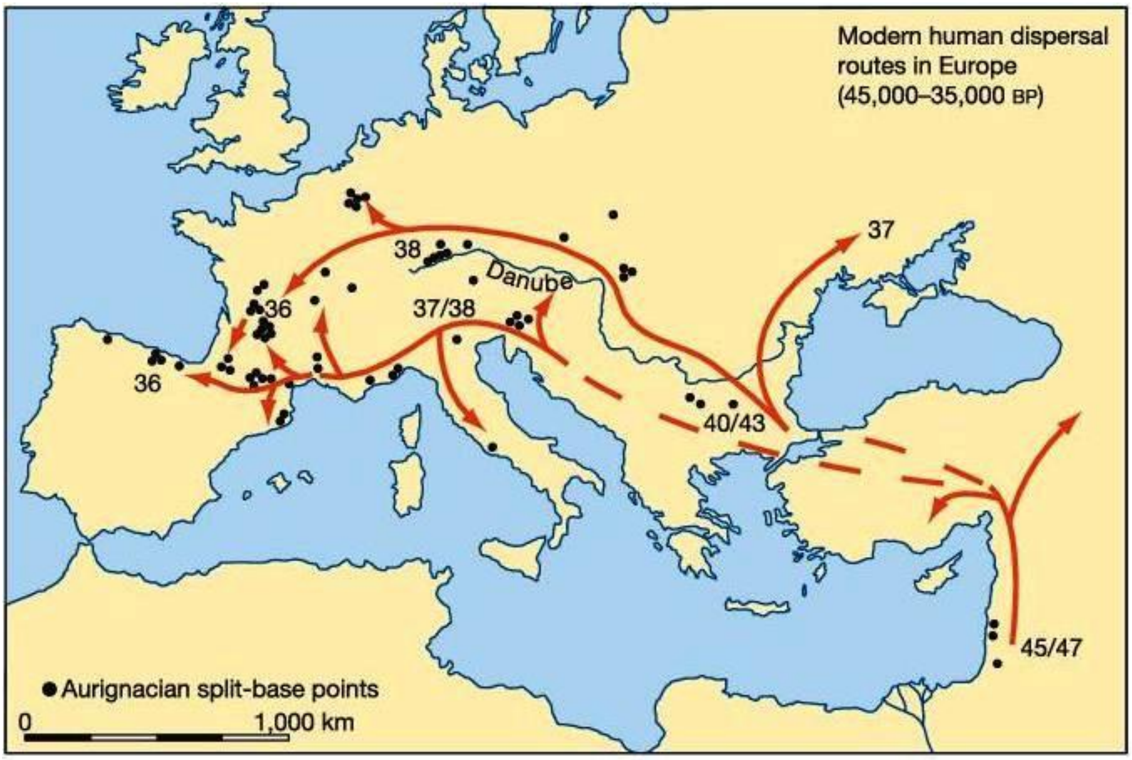


Fig. 1.1 Map showing two potential dispersal routes of AMH across Europe. The figure has been adapted from Mellars (2004), with latest discovered/re-dated sites being therefore absent. However, the model remains valid.

1.2.1 The transition in Italy

The transition in Italy is possibly an even more complex topic to resolve than in the rest of Europe. This is mainly due to the small number of investigated sites. It is possible that Italy was actually less intensely inhabited than other regions during 40 ka BP. However, other factors, mainly historical and cultural, should be also considered. Italy indeed shows a high imbalance in the distribution of the sites, especially along the Adriatic coast, mainly due to the lack of archaeological excavations in some regions. In addition, a large number of sites have been discovered and investigated in the early 20th century, when excavation methods and subsequent analyses were less accurate.

Unfortunately, little attention is given today to new research and revision of previously excavated sites, whilst the main source of data are still local studies produced in Italian, which remain largely unknown to international scholars. These are general considerations contributing to the scarcity of archaeological evidence in Italy.

However, there are a few exceptions of well-executed research that have allowed scholars to identify the earliest European occurrence of AMH remains combined with Aurignacian industries in the Italian peninsula. These are the sites of Riparo Bombrini (35–40 ka cal BP) and Grotta di Fumane (38–41 ka cal BP) (Benazzi *et al.*, 2015). This role had been previously assigned to two other European sites. The first is Kent's Cavern (UK). A maxilla, attributed to AMH since its discovery in 1927, has been recently dated, basing on the *terminus ante/post quem* yielded by faunal remains layered above and below the specimen, to 44.2–41.5 ka cal BP (Higham, Compton, *et al.*, 2011). Both the chronological and morphological revisions were widely criticised and rejected, as well as the stratigraphic reliability of the findings, due to the poor accuracy of the 1820s excavations (White and Pettitt, 2012). The second site is Grotta del Cavallo (43–45 ka cal BP) in southern Italy (Benazzi *et al.*, 2011). After an intense debate (Banks, D'Errico and Zilhão, 2013; Ronchitelli *et al.*, 2014), recent morphological observations have finally assigned the remains to the Neanderthals, and as such these are the latest Italian known (Fabbri *et al.*, 2016). Protoaurignacian industries have been found in slightly more recent layers but no human remains were related to these.

Aurignacian sites without human remains are certainly more common. In addition to the aforementioned Grotta del Cavallo, a number of cave sites in southern Italy such as Castelcivita, Uluzzo Cave, Bernardini Cave and the open-air site of Serino contained Protoaurignacian layers. These sites are poorly dated, but are certainly known to be prior to 39.3 ka BP due to the well-dated Campanian Ignimbrite tephra that seals all of these deposits (Giaccio *et al.*, 2008). One of the most important sites is again in northern Italy. Riparo Mochi (42.7–41.6 ka cal BP) has been recently dated and it appears to be the most ancient Italian Aurignacian context (Douka *et al.*, 2012). Regrettably, there are not reliable transitional sites with recent and accurate dating from the centre of the peninsula, where the case study analysed in this thesis is located. The only two transitional sites reported, both along the Tyrrhenian coast, a few kilometres from CM site, are Grotta Breuil (see section 5.1.2) and Grotta del Fossellone (see section 5.1.4). Here, lithic industries with both Mousterian and Aurignacian characteristics have been found and defined 'transitional' (Alhaique *et al.*, 2000). However, these sites, as well as others of the Monte Circeo area, were discovered and investigated about a century ago and dated by inaccurate U-series and ESR methods; therefore they are to be considered unreliable.

The available data seem to show a spread of this culture from the north to the south of the peninsula. This direction had to be influenced by the geographical constraints even in glacial periods, during which the marine regression made the east side of the peninsula more accessible. The role of Italy in the broader European context is less certain. Those in favour of the Aurignacian spread along the Mediterranean coast claim that this culture came into Italy from Austria via the Balkans and subsequently continued its diffusion into France and finally Spain (Mellars, 2005). In contrast, those who support a spread along the north of the Danube (Conard and Bolus, 2003), identified two different Aurignacian infiltration phases: A first one from central Europe into the Veneto region (e.g. Grotta delle Fumane) (Palma di Cesnola, 1993; Milliken, 2007); and another one from the south of France into Liguria (e.g. Riparo Bombrini and Riparo Mochi) (Broglio, 1994, 1995; Mellars, 2005).

Italy thus seems to have had an important role in this cultural change, but understanding the national framework as a whole is not yet simple. The number of sites, although of extraordinary importance, is extremely low in comparison to other European countries where systematic archaeological investigations have been carried out with accuracy.

1.3 Research background

Reconstructing the environment is a key step for a complete understanding of the dynamics which influenced the human and animal life of the territory. Nevertheless, palaeoecological studies, such as this thesis, present a number of issues including conceptual ones. In this section, two conceptual aspects will be addressed.

This thesis aims to investigate whether the Pontine Plain was a *refugium*, therefore it is necessary to introduce this concept and its significance. The word *refugium* has a long history and application in several fields. It generally describes the area of isolation of a species, once more widespread, the cause of which can vary. In archaeology, this definition is clearly centred on humans and in the last two decades it seems to have been mainly used to describe the supposed local survival of late Neanderthals groups after the species became extinct elsewhere. A brief overview of its significance and of the already known refuge areas of Europe and Italy will be discussed in section 1.3.1.

The next concepts to address are those of environmental archaeology and palaeoenvironmental reconstructions. The first is the subdiscipline of archaeology to which this research belongs, the second is the approach chosen to achieve it. A brief but complete introduction to these is, therefore, necessary in order to understand how they have developed and why they have been chosen in the attempt to achieve the broadest and most comprehensive picture of the region. This will be discussed in section 1.3.2.

1.3.1 The concept of refugium

This thesis aims to address the situation of the Pontine Plain as a potential refuge area. Before we investigate this further, it is important to comprehend what the term *refugium* means in the literature and what it indicates in this work.

The word *refugium* was used for the first time in palynology to describe the survival of some plant species in restricted areas during the Last Glacial (Heusser, 1955). Since then it started to be commonly used in other scientific fields such as botany, biology, zoology and ecological sciences generally, to express the habitat fragmentation, demographic decline of a species and its survival near the range limit in an area with less severe environmental conditions, which effectively plays the role of refuge. The term was initially used in the archaeological literature to define restricted areas of southern Europe where certain species took refuge during a glacial cycle (Hewitt, 1996, 2000; Taberlet *et al.*, 1998). However, since then it has been often used with different meanings and to denote a wide variety of environmental contexts, causing confusion (Bennett and Provan, 2008). In order to prevent confusion with the meaning that the term holds in other disciplines, it has been proposed to replace it with the “concept of bottlenecks" in archaeology (*ibidem*). This term would denote a temporary population contraction into restricted areas in genetic studies (Hawks *et al.*, 2000). However, *refugium* remains the most utilised term to describe this concept. In recent decades, the term has taken on a more specific meaning, being used almost exclusively regarding the controversial survival of small Neanderthal groups during the Middle-Upper Palaeolithic transition. During the Last Ice Age, small-scale open areas between the widespread snow and glaciers would have offered refuge to this human species, potentially allowing for its survival for several thousand years. Therefore, the archaeological definition of the *refugium* became that of a geographical area occupied by a species during its period of maximum contraction, specifically during the glacial cycles of the Quaternary (Stewart *et al.*, 2010).

The concept is still under debate. Some scholars consider the ways in which species respond to climate and environmental changes too complex and individual to be summarised in a single concept (Bennett and Provan, 2008). In support of this position, it has been proven that during the Last Glacial in western Europe the distribution of the sites did not seem to respect climate predictions (Davies and Gollop, 2003). Vice versa, the climate stability in short time-scale seems to be a more critical controlling factor of human distribution (Stewart *et al.*, 2003b; Stewart, 2004; Burke *et al.*, 2014). In fact, according to the Variability Selection Hypothesis, the hominids would develop a complex environmental plasticity and tendency to adapt to long-term environmental changes such as the Last Glacial (Potts, 1998).

The use of the term with the exclusive meaning of glacial refuge is another cause for criticism. The universality of the concept of refuge by which during a glacial phase species moved south, as proposed in earlier work, is dysfunctional when applied to cold-adapted species, since they do not have the same environmental requirements. It has been claimed that cold-adapted species now restricted to northern latitudes were distributed across much wider areas during glacial stages (Markova *et al.*, 2002; Stewart, 2003). In this perspective, these species are bound in a refuge condition during an interglacial period (Stewart and Lister, 2001; Stewart and Dalén, 2008).

The concept of *refugium*, therefore, needed revisiting. There would not be one but at least three types of refuge, where temperate, cold and warm taxa have been able to survive through the different climatic oscillations (Stewart *et al.*, 2010). The long-established southern glacial *refugia* for warm-temperate species, which are mostly situated in Iberia, Italy and the Balkans, had to be integrated with *cryptic refugia* in the northern latitudes and interglacial *refugia.* The first represents areas of glacial refuge where temperate species persisted farther north than previously supposed, hence the name ‘cryptic’ (Stewart and Lister, 2001; Stewart, 2003; Stewart *et al.*, 2010). This typology of *refugia* is well supported by a wide range of studies demonstrating a broad spectrum of southern European faunal and floral species have survived in areas where they were not supposed to be able to (Stewart et al. 2010 and references therein). The concept of cryptic *refugia* is widely accepted although has required some enhancements, and this category now also includes southern montane areas, such as the Alps and Pyrenees, where cold-adapted taxa survived during interglacial periods. The interglacial *refugia*, more rarely termed *polar refugia*, are high latitude areas where cold-adapted species contracted when warm oscillations took place (i.e. interglacials) (Stewart, 2003; Stewart *et al.*, 2010). The latter are the very opposite of the southern glacial *refugia*.

In this thesis, *refugium* is used with significance closer to its original ecological definition. Here, this term does not indicate an area with evidence of late Neanderthals but argues if the environmental pressures were milder in the Pontine Plain then hominins, animals and plants could persist during the harsh climate of Heinrich 5 and 4. This role is now thought to belong to regions whose main features consist of relative geographical isolation, high environmental variability within a small areas, proximity to sources of raw materials and climatic stability.

The Iberian Peninsula (Finlayson *et al.*, 2006), the Balkans (Higham *et al.*, 2006) and the Italian peninsula have been identified as potential human glacial *refugia* during MIS 3 in Europe (Jimenez Espejo *et al.*, 2007; Stewart and Stringer, 2012), a possibility supported by various phylogeographic studies (Taberlet *et al.*, 1998; Hewitt, 1999) (Fig. 1.2). The influence of past ecological studies has created a general association of high latitude with unfavourable-to-life environments during glacial periods, suggesting advantages to living in the warmest southern areas (Huntley and Birks, 1983; Bennett, Tzedakis and Willis, 1991). Nevertheless, the presence of Neanderthals in Belgium led to the hypothesis that areas of human refuge were scattered in Europe. The increasing fossil animal and plant evidence in northern Europe during the Late Pleistocene seems to support such an interpretation (Stewart and Lister, 2001; Stewart *et al.*, 2003a). The recent identification of Beringia as a LGM *refugium* is the most striking demonstration of how a region at high latitude is not necessarily incompatible with the existence of a refuge (Hoffecker, Elias and O’Rourke, 2014).

For the purposes of this thesis, in view of the completely different geographical and climatic conditions, refuges outside Europe will not be explored. The European and specifically the Italian framework will be introduced in the next section.

1.3.1.1 European refugia

The Iberian Peninsula is undoubtedly the glacial refuge region par excellence (Carrión and Leroy, 2010; González-Sampériz *et al.*, 2010; Rodrìguez-Sànchez *et al.*, 2010). The geographic position between the Atlantic Ocean and the Mediterranean Sea gives the territory a varied climate and vegetation (O’Regan, 2008) that would offer stability to the north-west European populations during glacial stages (Straus, Bicho and Winegardner, 2000; d'Errico and Sánchez Goñi, 2003; Gamble *et al.*, 2004; Verpoorte, 2009). The southern part of the region in particular would offer conditions to Neanderthals for isolated survival (Stewart, 2005; Finlayson *et al.*, 2006, 2008; Finlayson and Carrión, 2007), while AMH took possession of the north of the peninsula (Zilhão and D'Errico, 1999; Zilhão, 2000, 2006; Zilhão *et al.*, 2010). South Spain, offering a wide variety of natural resources, acted as a refuge for many other animal species. The striking identification of 140 occupied caves testifies to the intensive human exploitation of the coastal area, which also provided a wide coastal corridor for movement avoiding the interior mountains (Carrión *et al.*, 2008).

The latest Neanderthal evidence has been found in the inner layers of Gorham's Cave dated to 23,780 uncal BP (Finlayson *et al.*, 2006), about 4 ky after the latest attestation elsewhere in Europe (Carrión *et al.*, 2008) and 10 ky after the disappearance of the species from most of the continent (Finlayson *et al.*, 2008). The site would be an extraordinary example from the Late Middle Palaeolithic, but these dates have been harshly criticised since these are in strong contrast with archaeological and stratigraphic evidence (Zilhão and Pettitt, 2006). The latter suggests dating should not be later than 32–30 ka BP (*ibidem*), chronologies which would compare to other late Neanderthal sites widespread in southern Spain and Portugal (Hublin *et al.*, 1995; Pettitt and Bailey, 2000; Walker, 2001).

In this regard, it is necessary to mention some Iberian refuges previously considered to be late Neanderthal sites that have recently been re-dated to earlier phases losing this exceptional role (Vaquero *et al.*, 2002; Wood *et al.*, 2012; Higham *et al.*, 2014). Despite this re-dating resulting in considerable and widespread scepticism about the existence of the other *refugia*, the concept is still widely accepted. A major element to be considered is the demonstrated refuge role of the Iberian Peninsula for *H. sapiens* during the Last Glacial Maximum. Genetic studies have indeed made it possible to recognise that the haplogroup H, having arrived in Europe about 25 ka BP from the Near East, took refuge in Iberia until the retreat of the ice (e.g. 15 ka BP) when its subgroups returned to spread out and colonise the continent (Pereira *et al.*, 2004).

The Neanderthals survived over the Middle-Upper Palaeolithic transition not only in western Europe but also towards the eastern boundaries of the continent. The Vindija Cave site in Croatia is an exceptional case. Over one hundred fragments of Neanderthal remains were discovered, in association with both Middle and Upper Palaeolithic stone tools in two stratigraphic units, between 1974 and 1986 (Karavanić and Smith, 2013). The remains from the first layer (i.e. Level G3) have been dated to 38–44 ka BP (Krings *et al.*, 2000; Serre *et al.*, 2004; Green *et al.*, 2010) but it is the Level G1 which yielded the most interesting chronology. The first direct dating (28–29 ka BP) of Neanderthal remains from G1 made them the supposedly most recent individuals of the species (Smith *et al.*, 1999). However, accurate re-dating with ultra-filtration pre-treatment yielded a date range of 33–34 ka BP, highlighting the importance of new chronological analysis for previously dated Middle Palaeolithic contexts (Higham *et al.*, 2006). Even this dating and the taxonomic assignment to Neanderthals have been criticised (Zilhão, 2009; Pacher, 2010), although these are results from accurate and reliable analyses (Karavanić and Smith, 2013). Nevertheless, the latest dating does not diminish the importance of these remains. As well as being among the most recent European Neanderthal remains, they also show important morphological features similar to those of AMH, more than any other Neanderthal discovered so far. The Neanderthals of Vindija Cave could be a key source of evidence of interbreeding and be the first population in which the influence of AMH has been clearly identified (*ibidem*).

1.3.1.2 Italian refugia

During Quaternary cold stages, most of Italy maintained, in comparison to higher latitudes in Europe, a relatively mild climate and a high ecological diversity (Riel-Salvatore and Negrino, 2009). The geomorphology of the peninsula, naturally constrained by the sea and the Alps, not only insulates the landscape but also constrains movements and contacts to along the north-south axis. These features, allowing an easier study of migrations and interactions in the area, make Italy the perfect place to identify potential *refugia* during the Würm glaciation (Riel-Salvatore and Negrino, 2009). The varied geography of Italy also led to climatically and ecologically unique regions throughout its territory during glacial stages, with cold mountains near to temperate woodlands in coastal areas. Hominins and fauna took refuge in the peninsula, moving southward during colder phases, as evidenced by the high density of sites. The geomorphological framework in Italy, especially in the south of the country, appears to be environmentally similar to that documented in Spain, especially in the Strait of Gibraltar (van Andel, Davies and Weninger, 2003; Finlayson, 2004). However, the archaeological evidence in Spain is, to date, much more abundant (Kuhn and Bietti, 2000). This aspect is obviously linked with the same difficulties expressed in section

1.2.1. Several studies on gene diversity confirmed Italy as a refuge area for many animal species, which would later re-colonise the northern territories (Ruedi et al. 2008; Vega et al. 2010 and references therein).

The picture is much more complex on a human level and evidence of late refuges is completely absent. Until not long ago, the shelter of Riparo Mezzena in northern Italy seemed to represent the first true refuge of late Neanderthals. Thirteen specimens, dating 34.5±655 BP, were morphologically and genetically assigned to this human species (Condemi *et al.*, 2013). The chronology, and some of these morphological characteristics tending to AMH, led scholars to argue for interbreeding and a gradual transition between the two species (*ibidem*). In 2016, in an attempt to prove this interbreeding, DNA analysis, ZooMS and isotope analyses were undertaken on the remains along with new dating. The results have caused a surprising reassignment of the remains to a Neolithic individual, bringing to light a severe previous misidentification (Talamo *et al.*, 2016).

At present, the later Neanderthals are considered to be related to the same transitional sites previously mentioned. Grotta delle Fumane, where the first European *H. sapiens* have been found along with transitional Uluzzian industries (see section 1.2.1), is also the site where the latest Italian Neanderthals (44.8–43.95 ka cal BP) have been discovered associated with Mousterian industries. Riparo Bombrini yielded Mousterian layers (i.e. Neanderthals) dating 41.46–40.5 ka cal BP, but unfortunately human remains were not found.

The south of the peninsula, despite the numerous Mousterian sites, returned an even more sparse set of evidence, mainly due to the few dated and stratigraphically reliable contexts. Grotta del Cavallo, one of the few extensively investigated sites, has returned the latest Neanderthals of southern Italy, albeit dated to earlier than 45–43 ka cal BP. Assuming that this is the dating of the local Neanderthal extinction, it suggests an important difference from the north, where the species would survive for several millennia later. This is an important difference in comparison with Iberia, where the concept of Neanderthal *refugium* was born and has found fertile ground in the south of the peninsula.

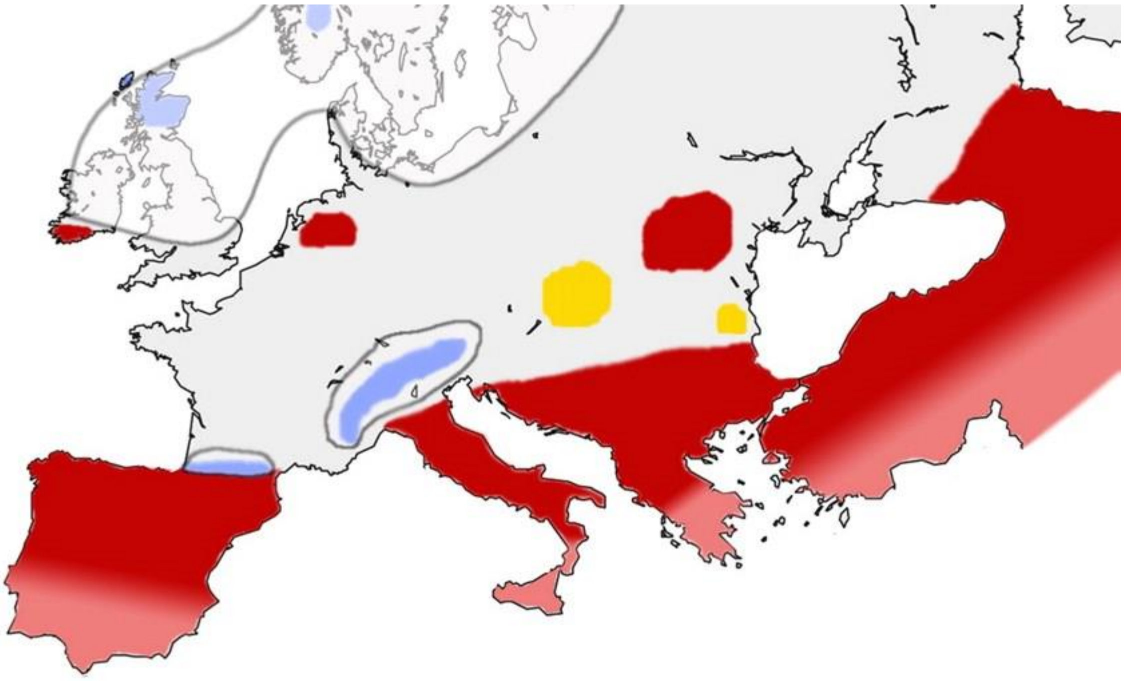


Fig. 1.2 Map of Eurasian continent showing *refugia* areas. Glacial *refugia* for warm-temperate species in red; Cryptic *refugia* for temperate species are shown in yellow; Interglacial *refugia* for cold-adapted species are shown in blue. Adapted from Stewart et al. (2010).

1.3.2 Introduction to environmental archaeology and palaeoenvironmental reconstructions

The ecological approach demanded by this thesis requires an introduction to environmental archaeology and to one of its aims, namely palaeoenvironmental reconstructions.

Environmental archaeology is a subdiscipline of archaeology deeply rooted in the natural sciences, especially biology and earth science, but with its own concepts, methodology and assumptions. Since its first appearance it has been defined in several ways. Although definitions vary according to the different authors and decades, the general purpose of this discipline has always been the study of past environments and their relationships with humans through time (O'Connor and Evans, 1999; Dincauze, 2000; Evans, 2003; Wilkinson and Stevens, 2003; Bell and Walker, 2005; Reitz and Shackley, 2012). Nevertheless, this discipline should not be mistaken for human palaeoecology since it is the natural aspect that is predominant in its investigations. At the basis of environmental archaeology there is the integration of several disciplines, such as anthropology, biology, ecology and geology among others, and its contributions commonly reflect approaches and perspectives of these sciences (Reitz and Shackley, 2012). Some papers emphasise the human interaction, some the biological aspect or the fauna, climate, geology etc., according to the specialisation of the authors, but they are all equally part of this subdiscipline.

The institution of environmental archaeology, or more precisely the first use of this term, occurred back in the 1950s (Wilkinson and Stevens, 2003). However, the first tentative approaches to this aspect of the past can be glimpsed in some studies of natural sciences from the nineteenth century. Prior to the studies of eminent scholars such as Charles Darwin and Alfred Russell Wallace, it was still supposed that the geomorphology and environmental features were unchanged in Earth's history. Only rarely did investigations rely on the natural sciences up to the aforementioned 1950s when deep revisions of archaeological theories and new archaeological techniques, radiocarbon dating above the others, led to the recognition of environmental archaeology. Despite that, before the 1960s the physical environment was seen as a backcloth to human activities. The environment was passive, with humans mapping their activities onto it (Dincauze, 2000). There have been discussions about how effectively the environmental factor affects or determines human life (Binford, 1965), but the great influence of the environment on settlement and economic choices is today recognised also thanks to the influence of processual archaeology.

Landscapes provide both opportunities and obstacles for all species within them, humans included. Nowadays, thanks to technology, people have been able to adapt almost all kinds of landscapes to comfortable life requirements regardless of environmental characteristics, but during prehistoric times the environment was particularly relevant. Indeed, some environmental features were easier to overcome and hardly influenced the life of a region, but others were far more complicated (e.g. harsh climate, volcanism, earthquakes etc.) and led to several challenges for subsistence and persistence of human groups. In the Pontine Plain for example, an important factor of influence on ancient lifeways has been volcanic activity and geomorphology. Similarly, it is unanimously accepted that interactions with different environments played a key role in differentiation within human species but also fauna and flora (Heilen 2005: 32). For these reasons, the ecological perspective of this thesis is the best approach for addressing whether the Pontine Plain was a *refugium* or not.

Reconstructions in environmental archaeology can be carried out using several approaches and concepts such as sedimentology, climatology, palaeontology etc. One of these is palaeoenvironmental reconstruction, as adopted in this thesis. This approach is undertaken to establish what the climate and biota were like at a particular time and place in the past and is used in archaeology to understand the living conditions provided by a site, area or region to past populations (Wilkinson and Stevens, 2003; Bell and Walker, 2005). A wide range of biological (e.g. micro and macrofossils), chemical (e.g. isotopes) and geological (e.g. sediments and deposits) evidence can be exploited to this end. However, plant and animal remains are usually the preferred source of information for these studies, since they well reflect the broad environmental context; that evidence has therefore been chosen for analysis in this thesis. It is evident that this kind of study should not be undertaken in the hope that the environmental reconstruction entirely explains the nature of a region as too many external and undetectable factors could have influenced it. However, bias within the data is something inevitable in archaeology even given the best prospects.

Multidisciplinary studies and particularly palaeoenvironmental reconstructions were considered of little reliability in the past (Thorson 1990 in Dincauze 2000) mainly due to problems of integration of different sources of data. Concerns about the reliability and usefulness of palaeoenvironmental reconstructions are now overcome but it is important to use a time and space scale appropriate to the research context under investigation since the accuracy at which an environment can be examined is extremely variable. This argument will therefore be discussed in the next section.

Environmental reconstruction in the Mediterranean landscape has become more frequent in the last 40 years but struggled earlier when, conversely, these studies obtained great success in America and north European countries (Walsh, 1999). The main reason behind this circumstance is essentially taphonomic. Palaeoecological studies, essentially palynology, are a major tool in environmental archaeology and probably the most widespread at present. However, pollen grain preservation in the Mediterranean basin is not as excellent as it is in more northern latitudes, due to the peculiar climate conditions of the region, reducing opportunities for applicability and subsequent environmental investigations. There is little wonder then that geomorphological studies are the most common approach to environmental research in this area, where geological processes played a significant role during prehistory (*ibidem*). However, Mediterranean palaeoecology has been experiencing an important growth in recent years, despite a remaining broad unwillingness to perform analyses on pollen from archaeological layers which are too easily considered unreliable. This is one of the reasons why this research project has an important role in the Mediterranean scene.

1.4 Time and space scale in archaeological context

A key issue in this thesis, and in all environmental studies that require multiple investigations, is the concept of scale and problems arising from the change of the time and space scale during the integration of different types of data. The discussion about the role of scale in archaeology began over fifty years ago (Spaulding, 1960) and, although theorising about the difficulties of this concept still continues today, archaeologists and ecologists are now aware that the analysis of a process on different scales results in the production of completely different outcomes.

However, according to Dincauze (2000), the problem of scale integrations can be considered an opportunity if properly approached. The key behind a successful multidisciplinary study would be the three C rule: Complementarity, e.g. the different data combined offers an interpretation more complete and reliable than single ones; Consistency, e.g. the final reconstruction has to agree with the indications from all studies involved; Congruency, e.g. data at different scales will need to be mediated (Dincauze 2000).

The questions of spatial and temporal scale demand careful application in this thesis, since it is the integration of archaeological and ecological investigations, which frequently operate on rather different scales. Environmental sciences tend to focus their investigation on a wide scale as changes tend to occur over long terms and on a global scale, such as glacial and interglacial transitions for example. On the other hand, human activities take place mostly on much smaller scales and those are therefore relevant to archaeology.

The palaeoenvironmental reconstruction proposed in Chapter VIII will take into account the problems of integration of time and space data of these two sciences, attempting to suggest a final framework suitable to the aims of this PhD. The main issues to deal have already been identified by Levin (1992):

1- How to identify the appropriate scale to investigate the context;
2- How to combine contexts and processes occurring on different scales without issues of compatibility.

1.4.1 Spatial Scale

Reconstructing the vegetation framework at different scales, depending on how extensive the context to investigate is, is the main aim of palaeoenvironmental archaeology. Megascale (sometimes also called *global*) focuses on the worldwide environment ($\geq 10^7$ km^2); the macroscale relates to the environmental setting of wide geographical areas or continents (10^4–10^7 km^2); environment of a region is explored with the mesoscale (1–10^4 km^2); whilst microscale is necessary to reflect the landscape of small areas or even single sites (<1 km^2) (Dincauze, 2000; Branch *et al.*, 2005).

As a general rule, the smaller the spatial scale (i.e. the area considered for investigation) that is used in a reconstruction, the more accurate the result obtained can be. The accuracy is also called *resolution* and can be defined as the ratio between the distance and the reliability of the data, which increases when the distance is reduced and conversely decreases when the distance increases (Turner and Gardner, 1991; Bottema, 1999; Wu and Qi, 2000; Turner, Gardner and O'Neill, 2001). The concept can be defined with an example appropriate to our study area. We have the environmental data provided by fauna from CM and pollen diagrams from lakes several kilometres north of the site. These lakes are chronologically compatible with it but are geographically distant from CM and lakes are known to catch pollen from large areas via wind and streams (Dincauze, 2000). The pollen diagrams would, therefore, provide information on the CM area but also a wide range of other territories that could have had different ecological characteristics. Using data from both sites in order to obtain a reconstruction of CM's context would result in a distorted image as fauna reflects local data, while the lake sediments reflect this regional or wider context. This is a spatial scale issue. Therefore it is not possible to compare or integrate data obtained from studies with dissimilar scale, because the result would be flawed by a methodological error (Guest, 2003), even if other scholars have proposed methods and formulas which seek to make it possible (O'Neill, Johnson and King, 1989; Turner and Gardner, 1991; Ebert, 1992; Wu and Qi, 2000; Turner, Gardner and O'Neill, 2001; Wu, 2004).

Another issue of scale is the misguided assumption a single dataset is representative of a widespread or even regional context (e.g. macroscale); the more sites that are analysed within a territory, more accurate the reconstruction will be (Dincauze, 1987). Suppose along the banks of a lake there is a small forest of oak; over the wider area, there is an enormous expanse of birch, which is the dominant species. Pollen analysis would reveal a larger quantity of oak, closer to the lake, than birch. An inaccurate reconstruction would then suggest that the zone was densely covered with oaks with few birch trees. This inaccuracy could be likely prevented with the availability of other datasets and, considering the "complementarity" rule, the different data combined would offer a more complete and reliable interpretation.

In conclusion, the correct spatial scale is critical to an accurate understanding of the region and its choice is related to the type of analyses carried out (Heilen, 2005). This thesis aims to carry out the palaeoenvironmental reconstruction of the Pontine Plain, which has an area of 1,180 km^2 and occupies a well-delimited land approximately 50km long and 17-25km wide. The dimensions of this region demand a spatial mesoscale (1–10^4 km^2) and data of an appropriate scale to investigate it. The complementary faunal and pollen data studied, on which this thesis is based, will support a more realistic evaluation of past environment. The faunal assemblage is composed of species well known for the entire Pontine Plain, as their presence is supported by previous literature and remains from other local sites (see Chapter III), and therefore it is perfectly compatible with the selected scale. Pollen from fossil faeces offers data at an excellent resolution reflecting the environments visited by the hyena which cover daily distances of 15–50km (details on pollen inclusion are described in Chapter VI), a distance which comfortably lies in the mesoscale range. Moreover, considering the Pontine Plain dimensions (50×25 km at maximum width) it is straightforward the pollen data from CM confidently reflects the local environment of the landscape.

1.4.2 Temporal Scale

Time is an essential aspect when attempting environmental reconstructions, since the factors (i.e. temperature, vegetation, fauna, hydrogeology etc.) that characterise landscapes exceptionally are stable through time, especially when investigating extremely long time spans such as prehistory. The time issues involved in environmental reconstructions are the same mentioned for space: scale and resolution. However, time issues are likely to have a heavier impact than space on the final result of any research.

"Any inquiry into the past which does not reckon with the dimension of time is obviously nonsense; the past *is* the past by virtue of the place it occupies in the time-scale." (Piggott 1959: 63). Over the past three decades many researchers have written about the role of time scale in archaeological interpretation (Bailey 1983; Gosden 1994;

Hodder 1991; Knapp 1992; Lucas 2005; Murray 1999; Trigger 1989). However, it is a notion which remains somehow ambiguous. What is of interest to this thesis is that perception of events is conditioned according to the time scale in which a context is analysed, as explicated by the concept of time perspectivism by Bailey (1981; 1983), Binford (1981) and Foley (1981a; 1981b), although this concept has been much debated to varying extents (Dunnell, 1982; Shanks and Tilley, 1987; Fletcher, 1992; Murray, 1999; Hull, 2005) .

Applied to the environmental archaeology, and specifically to this thesis, the main concern regarding time scale is its congruency (e.g. referring to the three C rule) with the spatial scale in operation. To reiterate, the congruency of data can be evaluated paying attention to the same issues previously considered for space: scale and resolution.

Temporal scales are by no means different from spatial ones. A megascale is applied to carry out investigations of phenomena enduring longer than 1 million years, such as evolution of plants and animals; a macroscale is necessary to infer changes which took place across a time span ranging between 10 000 and 1 million years; a mesoscale is commonly used to explore vegetation migration and covers a time span of 100 to 10 000 years; finally the microscale examine short time changes over 1 and up to 100 years (Branch *et al.*, 2005). The chronology of CM covers a time span of about 10 000 years (see section 2.3.3) which is compatible with the mesoscale range and suggests its usefulness for investigating vegetation migration.

Archaeology is a science that deals with a long timeframe, however the smaller the study frames are, the higher the resolution of the study. For this reason, great importance has been assigned to radiocarbon dating which, however, especially for prehistoric time, loses accuracy and sometimes reliability (see section 4.1). The result is that environmental reconstructions of prehistoric landscapes, most of the time, provide useful climatic information for the long term but are not effective for understanding how it may have influenced human actions within the span of a single lifetime since its resolution is unlikely so detailed. It has been argued that the low-frequency processes, consequences of which are tangible within a longer period of time, had a higher impact on behavioural changes than those within a life span (i.e. high-frequency processes) (Gumerman and Dean, 1989), so that crucial events for human life are known. This view clearly does not take into account the trauma of fast-acting events, which usually leave little to no room for gradual adaptive responses, which may have been equally significant. The perception that time is quality as much as quantity, and a few hours of activity can create a deposit that may subsequently persist for millennia whilst whole centuries leave no trace in the archaeological record must then also be observed.

It is within this complex temporal assumption that this research will take place. The coprolites have a uniquely accurate temporal resolution, since pollen is assimilated in a daily time scale (see Chapter VI), but it cannot be fully exploited in the absence of accurate dating which is almost impossible to obtain for fossil faeces (Diedrich, 2012c). Therefore, albeit the faeces from CM appertain to a short time scale and are likely almost contemporary, pollen and its environmental indications must be set on the wider time span of 10 000 years yielded by the faunal remains, which also contribute to the reconstruction.

1.5 Conclusions

Was the Pontine Plain a refuge for human, animal and plant species between 44–34 ka BP? This is the question that this thesis will attempt to answer. The aim will firstly be pursued through the study of the unpublished site of Cava Muracci (Latium, central Italy), for which the first modern multidisciplinary analysis ever undertaken in the region will be carried out, and secondly through a review of previously published sites.

The chronological framework to which this case study belongs is that of the Middle-Upper Palaeolithic transition. This is a period of intense changes, within which occurs the extinction of the Neanderthals and the emergence of AMH, an intensely discussed topic whose understanding is still far from being achieved. This seems to be spatio-temporally discontinuous, starting about 42 ka BP in central Europe and coming to conclusion in Iberia at 28 ka BP.

The picture about the transition is not clearer in Italy, where the small number of sites with systematic archaeological investigations makes the understanding of the dynamics behind it challenging. Despite this, the Italian peninsula seems to have been part of AMH diffusion having returned the earliest currently known AMH remains associated with Aurignacian industries (i.e. Upper Palaeolithic culture) in Europe (Benazzi *et al.*, 2015). New research is needed in Italy to confirm or deny this important role. It is in this complex chrono-cultural framework that CM is located.

The transition from *H. neanderthalensis* to *H. sapiens* leads the discussion on the *refugium* argument in areas where the former would survive simultaneously with the continuous expansion of the latter. The refuge, as the definition in biology implies, must offer support to its inhabitants with the perspective of a future new spread. It is clear that its application to Neanderthals did not fulfil this purpose. In fact, they went through a widespread extinction starting from 45 ka BP, which reduced the population and resulted in isolation in a few regions (e.g. *refugia*), mainly distributed along coastal areas (Bailey *et al.*, 2008). Eventually, the last Neanderthals became extinct in southern Spain at 28 ka BP (Finlayson *et al.*, 2006), without being able to overcome this period of stress. Despite that, the concept of *refugium* is still valid. The Neanderthal extinction dynamics are still not completely clear but seem to have been induced by a combination of factors, not only environmental. It is, therefore, impossible to determine if and how much responsibility for this extinction lies with refuges, in the case these areas did not provide enough benefits to overcome these severe periods (Bailey *et al.*, 2008). On the other hand, refuges have successfully performed the role of AMH protection in the next Last Glacial Maximum until the retreat of the ice when a new human spread took place (Pereira *et al.*, 2004). Considering this, the aim of this thesis is not to suggest new evidence of late Neanderthal but to propose a well-delimited area in which climatic pressures were mild and some species did, others could, survive through these climatic extremes.

Italy has been exploited as a refuge by many animal species, as demonstrated by several genetic studies, but evidence of late Neanderthals are completely absent. Nevertheless, the geomorphological and climate framework is very similar to that of other *refugia* (e.g. south Iberia and the Balkans), so the absence of these contexts could then be due to the submergence of sites due to the marine regression. The few known sites seem to establish the extinction of the Neanderthals initially took place earlier in the south of the peninsula and then in the north, surprisingly ignoring the cul-de-sac theory (Straus, 1999). This archaeological data also shows the extinction was not contemporary across all parts of northern Italy, it was gradual but with a rapid exchange with AMH.

In summary, we probably only have a very partial view of the actual Neanderthal-Sapiens transition. Theories and refutations follow each other in an endless circle, often fuelled by unreliable archaeological data and scientific innovations (new dating methods, molecular analysis for taxonomic assignments etc.) which can revolutionise previously accepted assertions. Because of this, new detailed studies from stratigraphically and chronologically well-investigated sites are needed. At the same time, a wider review of previously investigated sites needs to be undertaken, considering the very real possibility that conclusions may have been influenced by obsolete methodologies. Finally, the growing desire to find a solution to an important question of archaeology has led to a huge amount of dubious publications that have complicated this confusing puzzle. A better understanding of the Middle-Upper Palaeolithic transition and survival of Neanderthals, either late or not, certainly passes through these steps.

This thesis, due to its aims and the methodologies applied to achieve them, clearly belongs to the environmental archaeology subdiscipline. This field of study, albeit its late institution during the 1950s, led a profound change in archaeological research, enhancing the role of the physical environment in past interpretations. One way for this discipline to investigate the past is that of palaeoenvironmental reconstructions. This approach makes use of a broad range of evidence to understand both the climate and the biota of a region and because the general picture it offers is a convenient tool for interpreting whether an area is a *refugium*, it is adopted in this thesis.

The usefulness of palaeoenvironmental reconstructions is widely recognised by scholars but they have to overcome various hurdles to be considered trustworthy. One of the main issues concerns time and space scales. In archaeology, there are various processes to be considered but time and space scale can strongly affect a study, providing different perceptions of events and causing compatibility problems of data from different scales of analysis. The aim of this project, as explained in the above sections of this chapter, is to overcome the problems of scale integration by respecting the complementarity, consistency and congruency of the data combined.

Overall, the dataset for this thesis seems to be perfectly suitable for a reliable mesoscale reconstruction of the Pontine Plain. Small scale reconstructions such this one can offer very detailed frameworks for local landscapes but, on the other hand, inaccuracies with this scale are far more evident and severe therefore requiring greater attention.

Chapter II

Introduction to the Pontine Plain

It is impossible to address and understand the past environment of a region, such as the one proposed in this thesis, without a precise geographical and geological study of the present area. The aim of this chapter is therefore to provide, through a geographical and climatic framework, a basic knowledge of the area under investigation in order to understand how it has evolved and infer its past appearance.

Particular significance will be attributed to climate change through the Marine Isotope Stages (hereinafter MIS) 3 on a regional scale, due to its influence on wildlife, ecology and human life. It has already been demonstrated that the proximity of the sea and the particular mountain structure surrounding the Pontine Plain acted as mitigating agents causing the presence of favourable weather conditions in which the struggle for survival would have been easier (Barker, 1981). This presents a comparable situation to the Andalusia coast in southern Spain discussed later (see Chapter VIII).

The final section will be dedicated to the introduction of the case study of Cava Muracci (hereinafter CM), a version of this section has been published as Gatta & Rolfo 2017. This site, with its complex history of archaeological investigation, has proved to be crucial in many ways. The first benefit is purely material, due to the extraordinary richness and relevance of the finds unearthed, which allow for a multidisciplinary study of the site. This has provided an opportunity for a broader understanding of the Pontine Plain, previously known for the high concentration of the Late Pleistocene cave sites along the coastline with just a few close to the Lepini-Ausoni Mountains. At present, CM provides a source of information for the wider plain in the centre of this area. The second benefit of the site relates to having had the opportunity, in an area where most of the prehistoric archaeological excavations took place over fifty years ago, to investigate using modern methods of excavation and run laboratory studies of the finds with technological tools not previously available. This has provided access to a whole series of new information which forms the basis of this research.

2.1 Geographical background

The Latium region is located at the centre of the Italian peninsula, bordered by the Apennine Mountains to the east and the Tyrrhenian Sea to the west, and is characterised by lithological and geomorphological diversity associated with a wide variety of natural environments. These environments range from coastal dunes and river valleys, to volcanic cones and karst plateaus. Altitude above sea level varies considerably, ranging from more than two thousand metres in the mountains down to zero metres along the coastline. Along the coast, the landscape is characterised by narrow plains with marine and continental Plio-Quaternary deposits. The area is mainly composed of two types of formation, those associated with volcanic rocks and those associated with the Apennine Mountains. Volcanic formations, which developed during the Pliocene, constitute approximately 33% of the region (Accordi and Carbone, 1988; Amodio and Bovina, 2006). While the large Apennine ridge, formed by carbonate sediments of Mesozoic age, occupies about 30% (Amodio and Bovina, 2006). The remaining territory consists of lower hills and a small percentage of lowlands.

The geological history of the region can be divided into four main phases. The first of these is the Oligocene in which we see a significant remodelling of the landscape by the tectonic plates to the west pushing up the ridge which formed the Apennines. Secondly, the volcanic activity during the Late Miocene triggered the creation of the hilly formations characteristic of the territories to the west of the Apennines. The third main phase occurred during the Pliocene when rising sea levels engulfed much of the territory. Only the mountain chain to the east, and an archipelago of small islands to the west, were left visible. During this phase, a large amount of sediment was deposited on the seabed, forming an important stratigraphic layer which is widely spread over the modern region.

Finally, during the Quaternary, the four main ice ages (Günz, Mindel, Riss, Würm) modified land forms again by releasing new alluvial deposits with each retreat of the ice. It is important to note that the glacial phases in the Latium region have always been less intense than those in more northern territories and as a result, the area has served as an ecological *refugium* in which animals, floral species, and humans have found the best environment in which to overcome the climatic difficulties (Barker, 1981).

The heterogeneity of the geological region is among the most prominent of the peninsula; a geo-diversity that is best understood by regions. It is the first region of this complex geological framework which is the main concern of this thesis; the Pontine Plain or Agro Pontino, literally translating as the Pontine Marshes. The Pontine Plain is a flat area on the edge of the Lepino-Ausona ridge, with a topographic altitude of less than 100 m a.s.l. It occupies a 50 km stretch of the Tyrrhenian coast, reaching a width of 20 km wide in the NW–SE direction. This area has undergone radical changes during its history due to both natural and anthropological processes. It is enough to consider the natural transformation from gulf to coastal lowland in the age of the Pliocene, let alone its evolution from swamp to agricultural land following the reclamation works which have occurred more recently. The Lepino-Ausoni ridge to the north-east, the southern slopes of the volcanic Alban Hills to the north-west, and Monte Circeo to the south, enclose the study area (Fig. 2.1). Before focusing on the heart of the region a brief description of these prominent features in the landscape, which mark its perimetre, will be outlined.

Fig. 2.1 The natural boundaries of Pontine Plain: The Lepino-Ausoni ridge to the north-east, the southern slopes of the volcanic Alban Hills to the north-west and Monte Circeo to the south.

2.1.1 The Lepino-Ausoni ridge

The Lepini and Ausoni mountains belong to a mountain range which is part of the Latial Antiapennine. These mountains run parallel to the Tyrrhenian coast in the NW–SE direction, delimiting the east border of the Pontine Plain, separating the latter from the Liri Valley. The mountain range was formed in a marine environment during the Mesozoic Era and is considered a probable continuation of the internal Campanian platform (D'Argenio, Pescatore and Scandone, 1973; Parotto and Praturlon, 1975). This carbonate chain about 80 km in length is, except for the Amaseno valley which provides a passage through the ridge and a complex set of minor faults, a unitary geological structure (Accordi, 1966). From a geomorphological perspective, the Lepini and Ausoni mountains are characterised by a very intense and prolonged karst development which gave rise to the formation of numerous caves; some of which are also of archaeological interest.

The Lepino-Ausoni ridge is a very rich ecological area (Guarrera, 1996; Rosati et al., 2006). The low altitude tree cover is mainly characterised by holm oak (*Q. ilex*) and other evergreen plants, while deciduous and mesophilous vegetation, such as Turkey oak (*Q. cerris*), the European hop hornbeam (*Ostrya carpinifolia* Scopoli, 1760) and the Bosnian maple (*Acer opalus subsp. obtusatum* (Waldstein & Kitaibel ex Willdenow) Gams), replace them at higher altitude (Gatta, Sinopoli, *et al.*, 2016). Above 1200 m the vegetation is composed of beech (*Fagus sylvatica* L., 1753), yew (*Taxus baccata* L., 1753) and holly (*Ilex aquifolium* L., 1753) (Gatta, Sinopoli, *et al.*, 2016).

2.1.2 The Alban Hills

The Alban Hills are a group of hills situated in the volcanic district of southern Latium. They are situated in the countryside south-east of Rome, and consist of the caldera and the internal cones of a dormant volcano (Funiciello, Giordano and De Rita, 2003), the so-called Latium Volcano. This Quaternary volcano, which became active around 600 ka (De Rita *et al.*, 1995), is poorly understood despite many scientists having studied its history and structure (Fornaseri, 1963; Funiciello and Parotto, 1978; Rosa, 1995; Villa *et al.*, 1999; Giordano *et al.*, 2006). The volcano, oriented to the north-west, is part of the 250 km long Pleistocene Peri-Tyrrhenian recent volcanic belt ending with Mount Vesuvius at the southern end (Conticelli and Peccerillo, 1992; Barberi *et al.*, 1994). Its ridges, which reach 1000 m in height, form the limit to the north-west of the region under analysis in this thesis, the Pontine Plain. During the three main phases of volcanic activity, a huge volume of pyroclastic materials erupted and the plains below were filled with 290 km³ of volcanic material, significantly changing the environment. The first phase of activity, known as Tuscolano – Artemisio Phase (ca. 355–<180 ka BP) (Karner, Marra and Renne, 2001; Giordano *et al.*, 2010) (Fig. 2.2–2.3), occupies almost half the life of the volcano. It has been by far the most productive phase, with the explosive eruption of 200 km³ of material, about 70% of the total erupted. This was followed by the phase of Campi Di Annibale or Faete (355–250 ka BP) (Marra *et al.*, 2003; Giordano *et al.*, 2010) (Fig. 2.4) with an eruption of 2 km³ of volcanic material. The final phase is known as the Late Hydromagmatic Phase (ca 200–36 ka BP) (Marra *et al.*, 2003) (Fig. 2.5) which during violent explosions, caused by interaction between the residual magma and water, produced a series of craters that have greatly changed the landscape profile of the area and are still visible today (Amodio and Bovina, 2006). The most intense activity of this final phase took place between 70–36 ka BP (Freda *et al.*, 2006).

A study of the possible relationships between the tectonic and volcanic processes revealed that both the morphological appearance and the evolutionary history of the volcano have been strongly controlled by tectonic forces. Specifically, the geodynamics at the base of the volcanism of Latium would be connected to the post-Miocene extensional tectonic activity. This determined the formation of a series of uplifts and subsidences in the substrate, oriented in the NW-SE direction, intersected by transverse faults. At the intersections of these faults volcanic structures have developed (Caputo *et al.*, 1993). It is clear that the Alban Hills are the peripheral structure of the Pontine Plain which is the most affected the region. This was especially so during its greatest period of activity in the Middle and Upper Pleistocene (Parotto and Praturlon, 1975), when the volcano affected a wide surrounding area depositing a thick layer of tuff.

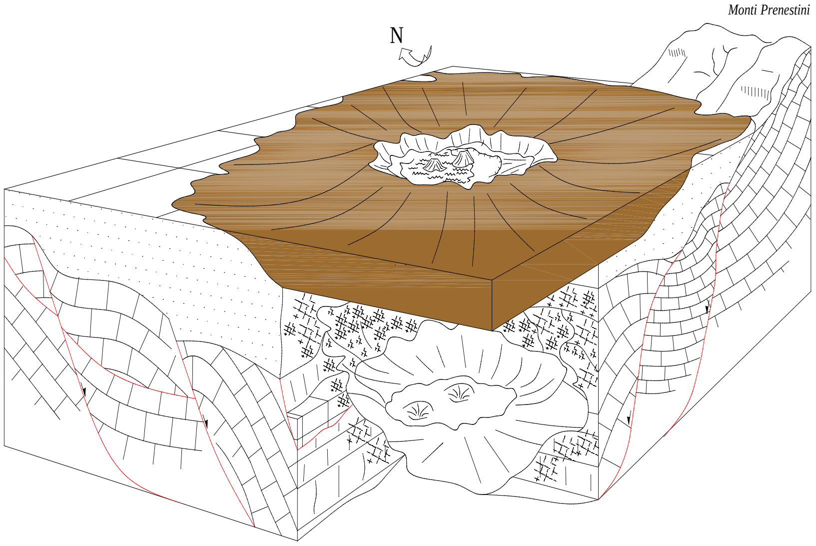


Fig. 2.2 Reconstruction of the structure of the Vulcano Laziale lithosome (ca. 600–355 ka BP), characterised by a central piecemeal caldera surrounded by a 1600 km^2 ignimbrite plateau. The magma chamber volume, hosted by Mesozoic–Cenozoic carbonatic rocks, was ca. 102–103 km^3. Progressive collapse involved significant volumes of carbonate assimilated in the magma chamber. Volcanic activity between paroxysmal eruptions was confined inside the collapse caldera. From Giordano et al. (2006).

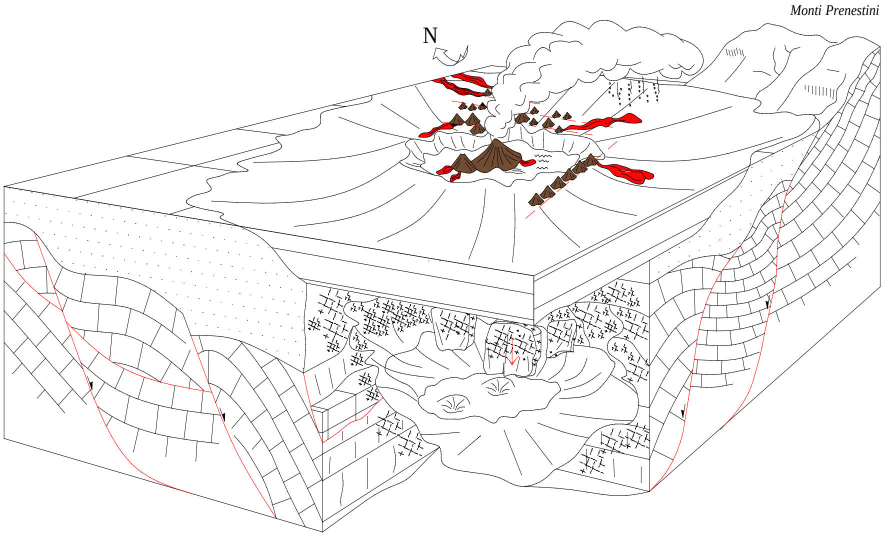


Fig. 2.3 Reconstruction of the structure of the Tuscolano-Artemisio lithosome between ca. 355 and 180 ka BP. After the Villa Senni ignimbrites caldera collapsed in 355 ka BP, the caldera floor underwent continuous down-sagging, with a significant reduction in the recharge of the magma chamber. The deflation promoted the progressive outward activation of peri-caldera fissures, controlled by the structure of the basement. From Giordano et al. (2006).

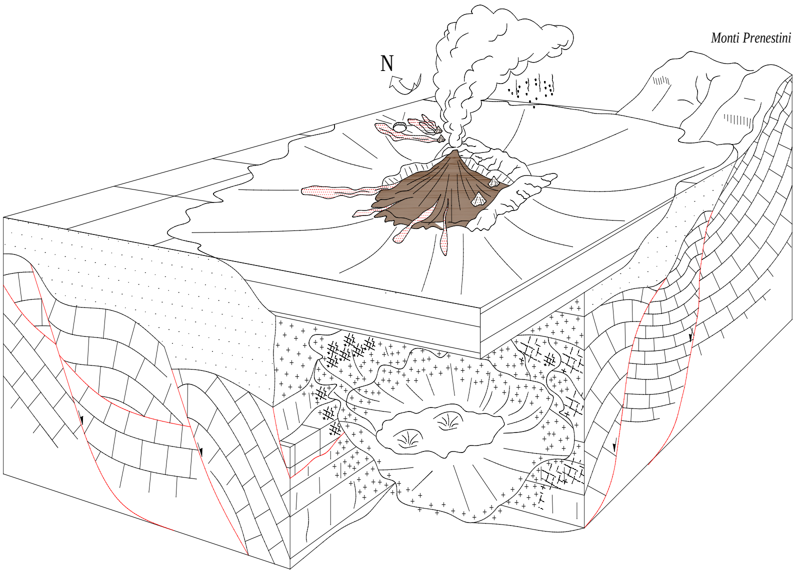


Fig. 2.4 Reconstruction of the structure of the Faete lithosome (355–250 ka BP), characterised by the formation of the central stratovolcano within the caldera, with effusive to strombolian to sub-plinian activity. The final stage was characterised by summit phreatomagmatic eruptions and scoria cones. The reduction of magma recharge most likely promoted the progressive crystallisation of the magma chamber. From Giordano et al. (2006).

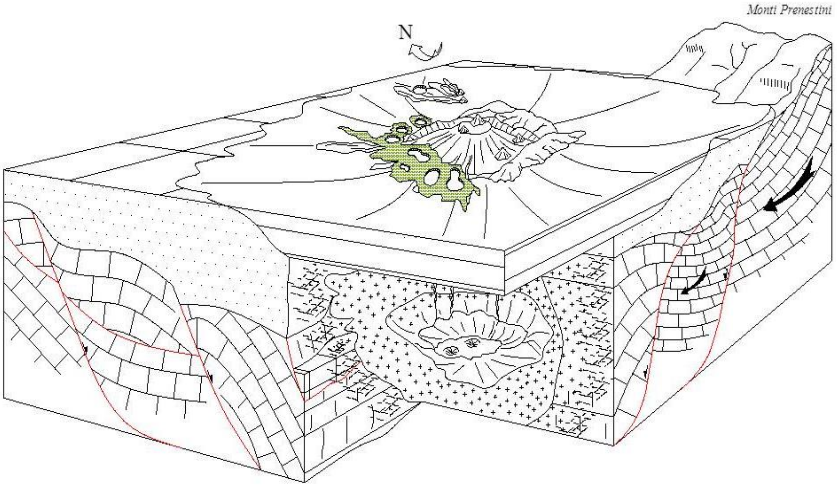


Fig. 2.5 Reconstruction of the structure of the Via dei Laghi lithosome (ca. 200 ka BP-Holocene). Activity became eccentric and was characterised by small volume eruptions forming phreatomagmatic maar localised above the subdued carbonatic horst of Ciampino, which hosts a substantial aquifer recharged at depth from the Apennines (Monti Prenestini). The main magma chamber was mostly crystallised at this stage. From Giordano et al. (2006).

2.1.3 The Circeo promontory

The Circeo promontory, at the southern limit of the Pontine Plain, is a carbonate structure which originated in the Mesozoic Era; as evidenced by the discovery of fossils from the Liassic period. Fossils from Plio-Quaternary deposits characterise the Pontine Plain depressions in the ground. The promontory is structured by three tectonic slivers of “Limestone Massif" that cross each other and are superimposed on Oligo-Miocene deposits (Accordi, 1966; Boni *et al.*, 1980). The mountain extends linearly in the direction NW–SE to a maximum length of 5 km, a width of 2 km, and a height of 541 m a.s.l. During the Pliocene, with the submersion of the Pontine Plain by the sea, the mountain chain became an island separated from the mainland in the centre of what is now called the Pontine Gulf. It has been the subject of numerous archaeological investigations along its southern side, which is characterised as we shall see below, by numerous caves and shelters (Sevink, Remmelzwaal and Spaargaren, 1984).

2.1.4 The Pontine Plain

The Pontine Plain is markedly influenced by the different geological environments that characterise it. The morphology changes from a relatively flat plain, to the hills and gentle valley forms at the foothills of the Alban Hills, to steep limestone slopes. The plain is located about 100 m a.s.l. and occupies a 50 km long stretch of the Tyrrhenian coast, extending for 17-25 km inland towards the Lepini Mountains. The topographic and geological history of the Pontine Plain is relatively well known, having been examined several times in recent decades (Sevink, Duivenvoorden and Kamermans, 1991). The geomorphology has changed considerably in the Quaternary due to severe climatic oscillations (Fig. 2.6).

The territory has always been affected by water, both in the origin of the sediments (marine, fluvial-lacustrine and marsh) and the shaping of the landscape by processes that continue to affect it. One of the most evident examples, morphologically speaking, is the discontinuous dune belts that run parallel to the coastline today. Four sand dunes, formed in correspondence with the different sea levels over millennia, have given rise to the formation of as many terraces and saltwater lagoons that still characterise the coastline (Kamermans, 1991). The oldest of these terraces, the Latina level (560 ka BP), is at 25 m a.s.l.; the Minturno level (125 ka BP) now lies about 16 m a.s.l.; the Borgo Ermada level (90 ka BP) at about 6 m a.s.l.; the last terrace which is still active, the so-called Terracina level, originated in the post-glacial (Eisner and Kamermans, 2004). In addition to the natural features of the Pontine Plain, a dense network of channels and other artificial waterways has been created through the ages, allowing for swamp drainage and reclamation of the area. Furthermore, the geometric shapes of thousands of agricultural fields and lines of the road systems are an important man-made feature of the landscape. The landscape has therefore been largely transformed by an ordered structure of human activity. This had a big impact on the differential survival and visibility of prehistoric and especially Palaeolithic archaeology.

Geologically the territory of the Pontine Plain is characterised by superficial Plio-Quaternary deposits that extend from the Lepino-Ausoni mountains to the current line of the coast and mask the complex structures that form the substrate (Boni *et al.*, 1980). The deposit was reconstructed from numerous drilling and geophysical studies made over the last 50 years by various scholars (Mouton, 1973; di Filippo and Toro, 1980; Barbieri *et al.*, 1999; Capelli and Salvati, 2002). The sedimentary sequence shows a transition from a marine depositional environment, to a transitional coastal environment, and subsequently to a continental system of fluvial-lacustrine type. This evolution of the deposits is reflected in the large vertical and lateral variability. The gravimetric data have shown a deep groove that runs along the alignment Cisterna di Latina - S. Donato separating the platform of the Lepino-Ausoni Ridge by a strong gravimetric anomaly extending to the Tyrrhenian margin along the alignment Tor Caldara - Torre Astura - Fogliano and Circeo. This groove, partially filled by an Oligo-Miocene Flysch and chaotic deposits, was then affected by further tectonic compression and stretching. Consequently, the Pontine Plain is situated within a wide area of transition and marked tectonic instability, dividing the Lepini Platform from the pelagic Tyrrhenian basin throughout the Mesozoic and Cenozoic (Amaldi, Segre and Tribalto, 1965).

During the Pliocene, tectonic phases gave the region horst and graben features. This was followed by a tectonic phase characterised by shortening and compression. In the Plio-Pleistocene a new stretching phase produced a new state of tension in the karstic masses, giving the region the current structural setting. With the reactivation of ancient tectonic faults, there has been a discontinuous rejuvenation of the Pontine sulcus, probably not yet exhausted (Boni *et al.*, 1980). The Pontine sulcus has not yet been well defined in the transition zone which connects the Lepini ridge with buried structures along the Tyrrhenian coast, because of the paucity of elements analysed, although many hypotheses have been put forward (Ippolito and Sgrosso, 1972; Manfredini, 1977;

Funiciello and Parotto, 1978). This condition of instability persisted in the region even in later times, which is shown by the large variability of the Plio-Pleistocene sedimentary environments and current structural conditions of the region (Fig. 2.6) (Segre, 1983). These sedimentary environments consist mostly of fluvial-lacustrine, wind-blown, pyroclastic, and coastal sediments which, thanks to composition and method of deposition, can be grouped and ordered chronologically. The combination of forces that have acted upon the Pontine Plain area is part of the impressive uplift which affected Tyrrhenian central Italy during the Quaternary. Before these phenomena, the sea level was relatively higher than today and the plain was submerged, forming a gulf bordered by the chain of Lepini Mountains (Fig. 2.6b). Evidence of this can be found in the fossil beaches, marine erosion and remains of Pliocene fauna left by the sea (Blanc and Segre, 1953; Blanc, 1957; Sevink *et al.*, 1982).

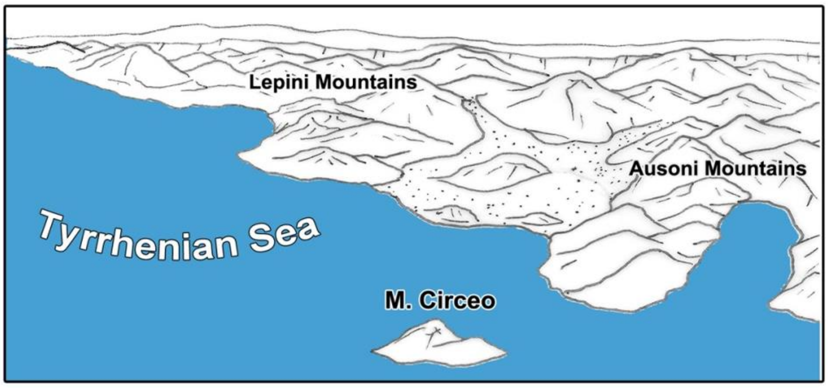
The situation radically changed in the Pleistocene when the sea retreated and left the plain behind. The subsequent uneven lifting of the territory led to the formation of the natural ridge along the coast which, as mentioned above, still characterises the coastal morphology today. The extension of the dune from Torre Astura to Circeo prevented the flow of water into the sea, creating a territory that was in places below sea level and rich in swamps. This low altitude lagoon area has characterised the region since prehistoric times until the last century, and the soils of the region yield ample stratigraphic evidence of this morphological evolution. Pliocene marine debris, during which the sea deposited a thick layer of clay marl formed in a pelagic environment, is followed by blue clays with Plio-Pleistocene sand embedded. This Plio-Pleistocene marine deposit continues along the coastal region of the plain. It is followed by a layer of pyroclastic and other volcanic materials created by the Albano volcanism, and new Middle Pleistocene outcrops of sandy-loam transitional deposits which concentrate along the edge of the Lepini relief and within internal depressions. Peat soils of fluvial-lacustrine origin are attributable to the current Holocene (Nardin, 2010).

To expand upon the aforementioned reference to volcanic activity, it is necessary to make a clarification. Among the numerous outcrops of pyroclastic material, there are some, particularly among those belonging to the most recent phase of activity, which cannot be attributed to the regional pyroclastic blanket. With regard to their sedimentological characters, these products seem to relate instead to a peripheral explosive eruption. All of these factors therefore lead to the hypothesis that the region was home to a highly developed volcano which greatly influenced the character of the Pontine Plain.

The hydrogeology of the plain is also very complex and has been thoroughly studied by many scientists (De Vito, 1977; Manfredini, 1977; Camponeschi and Nolasco, 1983; Capelli *et al.*, 2004; Marinucci, Alimonti and Gazzetti, 2006). The hydrology is powered by two main sources. The first of these is the karst aquifer of the Lepini Mountains, where water infiltrates extensively through sinkholes and swallows. The second of these is a shallow aquifer in the Quaternary deposits of the Pontine Plain, varying greatly in accordance with the heterogeneity of the lithological types.

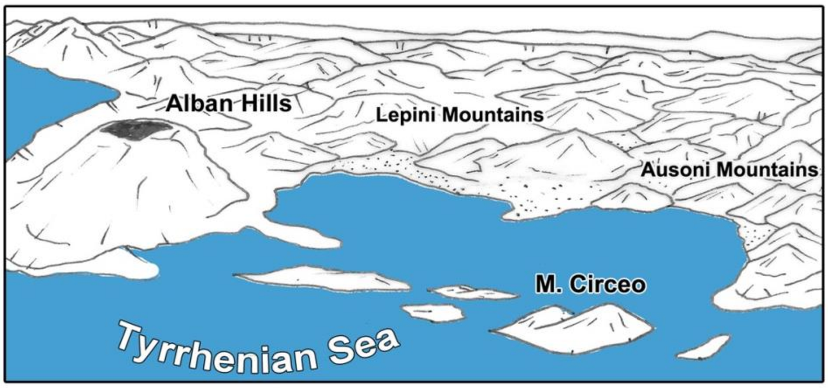
Below the plain there are also some buried ridges which serve as thermal traps, whilst numerous faults also promote circulation of water. Hydrothermal manifestations seem to be particularly concentrated in the region where ancient tectonic Liassic faults have been affected by recent extensional tectonics, and are therefore strongly controlled by structural geological features. To be precise, the contribution of hot water mineralized through a system of fractures in the subsoil caused the formation of travertines both deep in the strata and outcropping in the region, and especially in the area of CM. Lower travertines are visible generally resting on sandy clays of Calabrian age (0.781–1.806 Ma), and above which the upper travertine of Tyrrhenian age. These correspond to the Riss-Würm interglacial, within which sporadic faunal remains can be found. The sources by which the travertine layers were deposited became extinct during the post-Tyrrhenian regression, during glacial Würm I, at the same time as the rapid karst processes began (Segre and Ascenzi, 1956).

The present day arboreal vegetation of the plain is mainly olives (*Olea europaea* L., 1753) and chestnuts (*Castanea sativa* Miller, 1754) and the natural coverage is now restricted to small isolated woods (*ibidem*). The seafront is characterised by steppe vegetation such as the common grass (*Hyparrhenia hirta* (L.) Stapf, 1919) and the large Mauritanian grass (*Ampelodesmos mauritanicus* (Poiret) Durand & Schinz, 1894) (Pignatti, Pedrotti and Lorenzoni, 1961; di Pietro and Blasi, 2002; Gatta, Sinopoli, *et al.*, 2016).



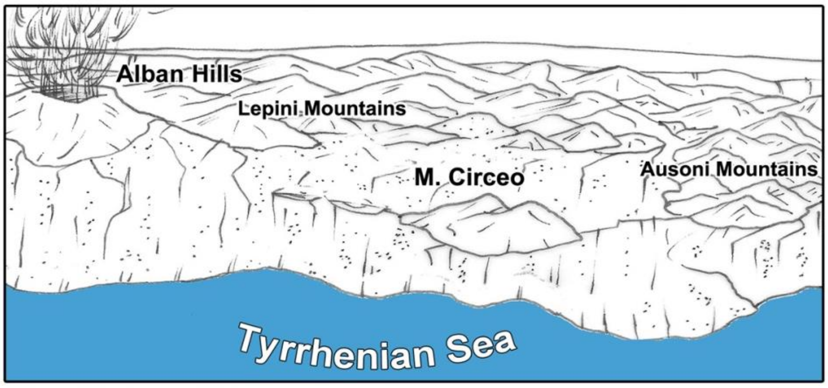
a) Pliocene (3 Mya)

a) During the Pliocene Age (3 Mya), the shore line reached the Lepini and Ausoni carbonate mountains. Mount Circeo was an island separated from the mainland by a wide sea channel.



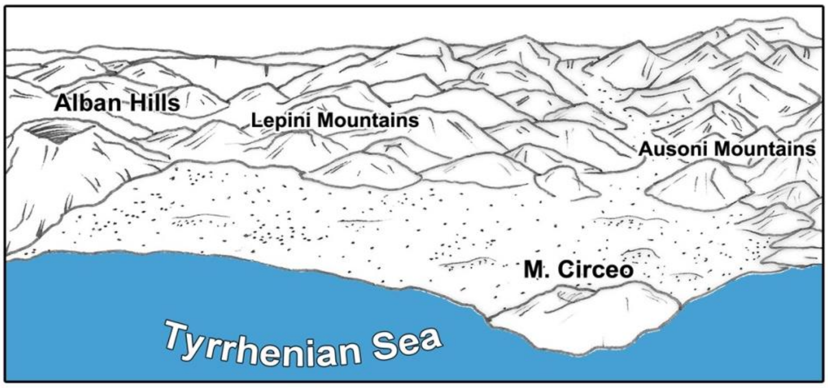
b) Middle-Upper Pleistocene (200 ka)

b) The supply of sediments from the rivers that flow into the sea, and especially the contribution of clastic materials related to the activity of the Volcano Laziale, cause the first partial filling of the sea basin, and the formation of a series of sandbars during the Middle-Upper Pleistocene (200 ka).



c) Late Pleistocene (50 ka)

c) The drop in sea level, linked to the onset of cold climatic phases of the Late Pleistocene (50 ka), led to an advancement of the shore line by tens of kilometres. The whole area turned into a swamp zone, with some streams that reached the sea forming deep valleys.



d) Holocene (10 ka)

d) During the sea-level rise, which occurred at the end of the last Würm glacial phase 10 ka BP, there was a retreat of the coastline, which with the deposition of new sandbars became straighter.

Fig. 2.6 Geomorphological evolution of the Pontine Plain between the Pliocene and the Holocene. Re-elaborated from (Cipollari & Cosentino 1993).

2.2 The climate: opportunity or constraint factor?

The climate is undoubtedly the natural element that most affects a territory. It affects the flora and fauna, and can even change the physical landforms during long periods of time. In regard to its impact on humans, the role played in the development of the social, technological and cultural innovations has already been discussed in the scientific literature, with the transition between Neanderthals and AMH (Burroughs, 2005; Potts, 2012; Evans, Flatman and Flemming, 2014).

Climate during MIS 3 is poorly understood in the area under investigation. For this reason, the European climate standards, which among other things are well known through generic knowledge thanks to the abundant literature on the subject, will be used to better define and guide the environmental reconstruction. However, the climate is not central in this research. What is significant is the plant and faunal biodiversity of the Pontine Plain, and the adaptation and exploitation of this by humans and animals. The aim is to understand whether, and to what extent in the context of south-western Latium local variability has been an advantage or a limitation for both animal and human species.

The current climate of central Italy is generally influenced by warm summers and wet winters, but the region includes 15 different phytoclimatic classes (Blasi, 1994). Hills and mountains of the inland peninsula and the Apennine area are characterised by a sub-Alpine weather, with chilly springs and summers, and extremely cold and snowy winter months (Gatta, Sinopoli, *et al.*, 2016). The coastline, where the Pontine Plain is situated, has a typical Mediterranean climate with dry and warm summers and mild-temperate winters which exceptionally reach 0 ºC. Moreover, a highly diverse landscape with shoreline, extensive plains and mountains within around 25 km, cause a mosaic and patchy vegetation framework.

This situation is very different from that during the Upper Pleistocene during the last Ice Age, the period within which extends the time range dealt with in this thesis. During MIS 3 the climate was relatively mild, characterised by numerous oscillations. These oscillations produced a temperate forest first stage called "Moershoofd", which was followed by a series of cooler and drier stages that induced a steppe environment with *Artemisia* grass. With the last fluctuation of this stage, the oscillation of Arcy and the subsequent improvement of the climate, the region came to be characterised by grasslands with an increase in steppe plants.

The climate deteriorated again with the MIS 2, and cold and aridity characterised the region with extensive *Artemisia* steppe (Caloi and Palombo, 1992). The instability of the climate in the northern hemisphere during the Last Glacial, with alternating temperate-humid and cold-arid stages, is also confirmed by studies carried out in the late nineties on the Greenland ice cores and marine sediments of the north Atlantic (Bond *et al.*, 1993; Dansgaard *et al.*, 1993; Voelker, 2002). Also more recently, from the pollen and marine analysis of the Mediterranean (Allen *et al.*, 1999; Sánchez Goñi *et al.*, 2000, 2002; Tzedakis, 2005).

These discoveries have led to a reconsideration of the traditional model of ice ages interspersed with longer warm periods, called interglacials, previously accepted without disagreement. Although scientists originally maintained that there were four major ice ages (Günz, Mindel, Riss, Würm), today the climate is viewed as a complex sequence of warm and cold fluctuations of varying duration.

The environmental situation of the Tyrrhenian Latium during the late Quaternary may therefore, be summarised with two vegetation stages that have alternated in the succession of climatic oscillations: one characterised by the presence of forests during temperate stages; the other characterised by open grasslands and steppe during colder phases. It is necessary to emphasise that during only 1/10th of this period the conditions for a forested environment were present, and that for the majority the extensive coastal plains were not dissimilar from today and characterised by wide open spaces (Follieri and Magri, 2001).

The Würm glaciation in Latium was therefore characterised by aridity and low temperature but not by high levels of snowfall as previously thought. Average temperatures were around 9 °C lower than the present, both in summer and winter (Frank, 1969). Obviously during the latter it is likely a reasonable snowfall was going to cover areas 500 m a.s.l., substantially reducing the regions available for use. Moreover, during this glacial stage there was an increase in the volume of ice caps, which triggered a marine regression. The marine regression during the glacial maximum led to a lowering of the sea level considered in the past to be between 130 m (Milliman and Emery, 1968) and 120 m (Shackleton, 1987; Fairbanks, 1989; Bard, Hamelin and Fairbanks, 1990; Perissoratis and Conispoliatis, 2003). This would have created a second plain at the foot of Monte Circeo extending between 20–30 km (Barker, 1981). Modern estimates have reduced this regression to between 70–100 m (Antonioli, 2012), significantly diminishing the amount of land that was released from the sea to approximately 7–11 km (Stiner 1994: 27). Nevertheless, it would still have been enough to provide an uninterrupted passage from the north to the south of the peninsula.

The pollen records

The pollen sequences of certain volcanic lakes, some of which are now dry, indicate that even during the Glacial Maximum the Latium has always maintained milder climatic conditions than the surrounding regions. Similarly, the Pleistocene faunal remains from the Tyrrhenian region also indicate how this area was climatically a gentle region compared to the side of central Italy exposed to the Adriatic Sea (Caloi and Palombo, 1992). Not only that, due to the warm currents from the Mediterranean Sea, the conditions of the coast of Latium were significantly less extreme than most of continental Europe.

Geographically from north to south, the sites which have provided these sequences are Lago di Mezzano (Sadori *et al.*, 2004); Lago di Lagaccione (Magri, 1999); Lago di Vico (Magri and Sadori, 1999); Valle di Stracciacappa (Giardini, 2007); Valle di Baccano (Ciuffarella, 1996); Valle di Castiglione (Follieri, Magri and Sadori, 1988, 1989) (Fig. 2.7). These sites, precisely locatable due to their lake origin, have provided useful information to reconstruct changes in the climate and vegetation throughout the chronological zone of our interest. On the other hand, it is necessary to highlight that even between these relatively closely located sites it is possible to denote a discrepancy in the data. These differences are due to climate conditions on a small, local scale (Gatta, Sinopoli, *et al.*, 2016). It is precisely for this reason that this research along the Pontine Plain will not only provide further evidence of a particular environmental situation, but will also provide useful microclimatic information for an area not previously investigated (*ibidem*). The palaeoenvironmental record of the coastal area is currently very limited indeed, consisting only of the many macro-botanical remains discovered in Canale delle Acque Alte (previously named Canale Mussolini until the end of the World War II) during the reclamation of the area during the last century. These however have not been studied in great detail (Blanc, 1935a). The only pollen analysis to be carried out along the coast (e.g. the Mezzaluna core) does not extend earlier than 16 ka (Hunt and Eisner, 1991) and is therefore far too recent to be of any use in this study.

Reconstructions of the vegetation of the region, made through the analysis of the lake pollen sequences above, have shown that this region has been particularly sensitive to climate change (Follieri and Magri, 2001). Even weak temperature fluctuations have been able to trigger expansion and contraction of plant communities that were significant on a regional scale (*ibidem*). This indicates how in the last one hundred thousand years the territory was particularly rich and characterised by a high biodiversity, serving as a climatic refuge which allowed the survival of thermophile and mesophile plant species even during the glacial period (Follieri *et al.*, 1995, 1998). This briefly sums up the climatic situation of the Latium region during the Würm glaciation, particularly during MIS 3, which is the most relevant stage for this thesis.

The significance of this environmental framework in relation to the flora and fauna of the Pontine Plain will be discussed later in Chapters VI and VII. In these chapters, the results of the pollen and faunal analyses from CM's samples will be integrated with the assertions stated here. These analyses will also offer a higher resolution on the Pontine Plain and the Middle-Upper Palaeolithic transition chronologies.

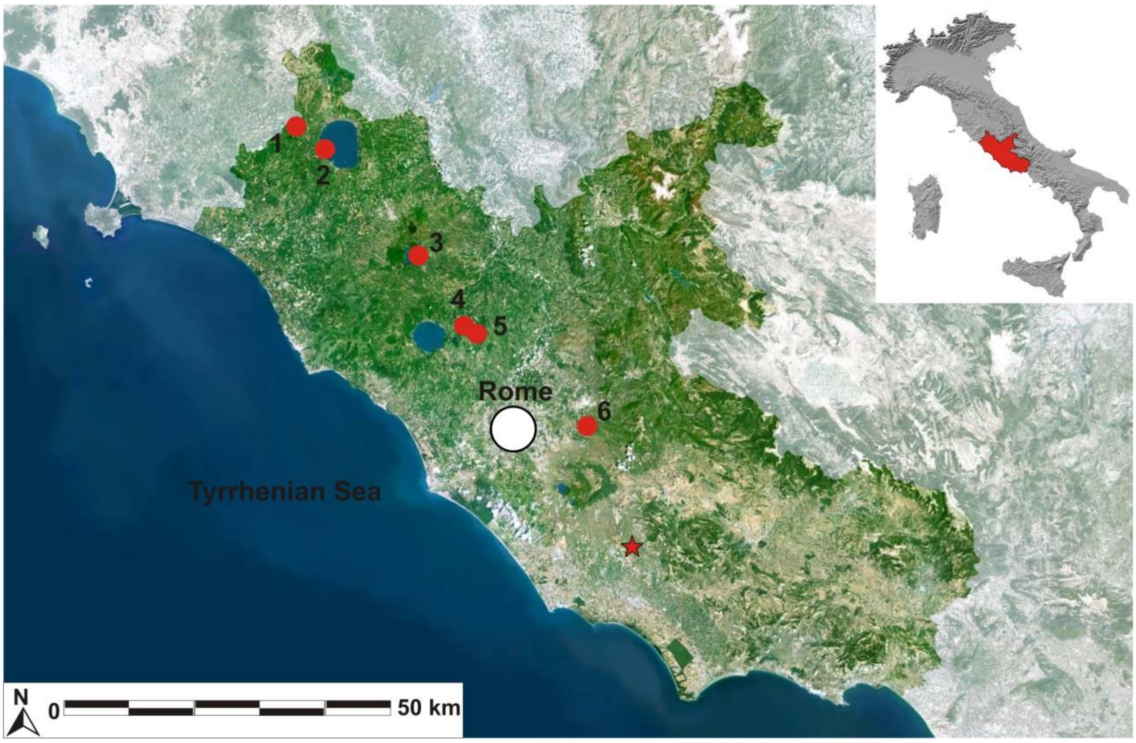


Fig. 2.7 Location of Pleistocene pollen records of Latium: 1- Lago di Mezzano; 2- Lago di Lagaccione; 3- Lago di Vico; 4- Valle di Stracciacappa; 5- Valle di Baccano; 6- Valle di Castiglione; Red Star – Cava Muracci.

2.3 Cisterna di Latina: the case study

Cisterna di Latina lies north-east of the Pontine Plain. The area under consideration is included in sheet 400 of the Istituto Geografico Militare (IGM) series 50 and 50/L, identified as "Latina", and in the sheet 388 Section II of the series 25 as "Cori". The territory is bordered to the north by Velletri (Rm), north-east by Artena (Rm) and Cori (Lt), to the east by Norma (Lt) and Sermoneta (Lt), to the south by Latina and by Aprilia to the west (Lt). It features topographic elevations just above sea level, but never exceeding 77 m a.s.l., and covers an area of 144 km². To the east of the town of CM is a vast expanse of Quaternary travertine situated on the furthest foothills of the Vulcano Laziale and Pontine lowlands up to the base of the Lepine Mountains. Several quarries have been opened, abandoned and re-opened here since Roman times.

The presence of Pleistocene fauna, stone tools and prehistoric human remains has been highlighted during quarry works during the last century when a natural cave was discovered at the quarry "Muracci" (GPS: 41°35'53.4" N 12°51'23.4" E) in 1956. Extraction activities brought to light a cave partially filled by debris material mixed with archaeological remains, which fell into the underground environment through a surface crack (Segre and Ascenzi, 1956). This is confirmed by the discovery of archaeological materials dating to different periods, scattered in disorderly positions (*ibidem*). Many human remains have also been recovered from the site and a minimum number of four individuals were identified (see Appendix 2.1). The recovery of ceramic fragments made of a rough-coarse mixture of local origin attributable to the Late Bronze Age, suggests that these remains may be datable to the same period. To confirm this hypothesis the anthropological analyses identified similar characteristics to Early Neolithic and Italian Bronze Age individuals. The faunal remains and lithic industries were instead attributed to the Pleistocene; abundant bones of *Equus ferus* (wild horse), *Bos primigenius* (auroch), *Sus scrofa* (wild boar), *Cervus elaphus* (red deer), *Dama dama* (fallow deer), various microfauna, and a lower premolar attested the presence of *Crocuta crocuta spelaea* (cave hyena). The most important observation to make with regard to the bones, is the presence of cut marks from butchery which appear on numerous bone fragments but mostly cattle. Samples of stone tools made from pebbles have been discovered, such as reverse retouched blades and blades of the type *La Gravette* have been noted. In addition to these, a core of obsidian, two classic Aurignacian scrapers, and a retouched curved blade were discovered. Overall, comparing the characteristics of the Gravettian at Grotta Romanelli (Blanc,

1930) and the Aurignacian in the Pontine region (Blanc, Segre and Tongiorgi, 1953), this industry can be classified as Gravettian (Segre and Ascenzi, 1956).

The CM cave was destroyed by the advancement of the quarry front following these studies. However, a local enthusiast recovered further human and animal remains within a conical slit of the travertine along the northern side of the quarry in the early 1990s. The most important of these finds was the discovery of an adult male skull, in an excellent state of fossilised preservation, placed on top of a tortoise shell. This occurrence is suggestive of a deliberate ritual deposition. The skull is now in the museum of the city of Velletri (Rm).

Similar contexts were reported by Segre (1956) from Finocchietto and Cotronia quarries in the surrounding area. The large extractions of stone from these sites made it possible to further clarify the geological history of the area, as well as allowing for the collection of abundant finds of lithics and bones; including rare human remains. This has enabled a strong and direct approach to the study of archaeology in the local area and of some of its subdisciplines such as palaeoenvironmental, archaeozoological and techno-lithic considerations.

Further investigations were not carried out during last century due to the collapse risk of the travertine walls, however the same enthusiast discovered an additional fragment of human skull in the cave in 2000. This was followed up with an inspection by the 'Soprintendenza per i beni archeologici del Lazio'. The remains of this second individual, attributable to an adult of indefinable sex, along with the first skull were radiocarbon dated to the Middle-Late Neolithic (3620–3590 BC) (Angle and Germano, 2003).

In the summer of 2012 abundant bones, several coprolites, and rare lithics, were handed by the owner of the quarry to the laboratory of archaeology at the University of Rome Tor Vergata, following sporadic surface collection along a deactivated zone of extraction. After a preliminary review of the finds, and noting the excellent state of preservation and the high archaeological potential recorded by past analyses, a new investigation was started (Gatta and Rolfo, 2017a).

In a geo-archaeological situation not dissimilar to the one that appeared in 1956, the first operation of recovery was implemented to preserve the archaeological finds from quarrying and exposure to climatic stress. Furthermore, there was an attempt to identify the slope with the cave investigated over fifty years before by Segre (1956), in the remote possibility of finding archaeological material to connect with his studies.

However, due to the limited information available and the constant change in the morphology of the site, this proved unsuccessful.

Seven karst caves of various sizes, ranging from pockets of a few metres to large caves, have been investigated returning abundant faunal remains along with rare lithic industry and coprolites (Gatta and Rolfo, 2017a). Excavation of the caves commenced in September 2012 and was concluded in 2016, whilst survey work and collection of material along other areas of the quarry continues to the present day.

2.3.1 The main research context: Area 3

The main area of research is a limestone cave along the north face of the quarry (Area 3 Fig. 2.9), severely damaged by quarrying that occurred about three decades ago. Unfortunately, the cave's destruction was so advanced that its original morphology and extent were impossible to establish (Gatta and Rolfo, 2017a). At the start of the investigation, only a 6 m-long wall and part of the ceiling of the original cave were left, conferring to the site the morphology of a rock-shelter (*ibidem*). Nevertheless, from the remaining section of the cave and through comparison with numerous others along the quarry, it can be ascertained that the cave was a large natural pocket in travertine with at least one access, probably vertically, in the roof of the den leading to the above ground surface. Despite the extended destruction, the high potential of this cave was already revealed during preliminary surveys in the area, when a great number of extraordinarily preserved finds were collected. In view of this, a careful stratigraphic excavation of Area 3 was performed (Gatta and Rolfo, 2017a).

The inner archaeological deposit was mostly intact, but the front part was an altered and weathered slope to the floor level 3 m below. The first phase involved the excavation of the unaltered *in-situ* cave deposit. The stratigraphic investigation involved an area corresponding to c. 20 m², in order to acquire as much information as possible useful to the interpretation of the context. This choice can now be defined as fundamental, as it has supplied information for research in palaeoenvironmental, palaeoecological, archaeozoological and stratigraphic studies of the region.

The cave was obstructed in its entirety by continental alluvial soils, seven stratigraphic levels have been recognised (Gatta and Rolfo, 2017a) (see Fig. 2.8):

- SU7: This layer is the modern walking surface, made up of mixed material but mainly soil and gravel, with which the quarry is paved. The thickness of this surface varies between 10–25 cm.

- SU8: This represents the ceiling of the cave, with a thickness ranging from 40–80 cm, which is currently below the walking surface of the quarry.

- SU11: This consists of a highly consolidated red-brown clay soil, measuring between 45–100 cm, including rare volcanic products from the near Vulcano Laziale and calcareous clasts. Abundant remains of large mammals, coprolites and rare lithics of various lithotechnical facies were also discovered in this layer.

- SU12: This layer is made up of 20–40 cm thick very compact reddish brown clay containing a much greater number of volcanic products than the SU11 above it. Rare lithic industries have been found, while fauna and coprolites are completely absent.

- SU13: This appears to be a homogeneous green copper-coloured layer of compact volcanic tephra and a high number of volcanic products. This revealed to be a completely sterile geological layer and undoubtedly testifies to the main eruptive phase of the Vulcano Laziale complex dating at 70±2 ka (Gatta and Marra, 2017; Gatta *et al.*, 2017).

- SU14: This consists of strongly consolidated reddish clay with a thickness ranging 50–100 cm. The light widespread patina of manganese is characteristic of the layer and indicates the possible presence of recurrent water. Sporadic lithic and bone remains have been found.

- SU15: This layer is made up of a calcareous encrustation and rocks with diffused patinas of manganese. It represents the natural floor of the cave.

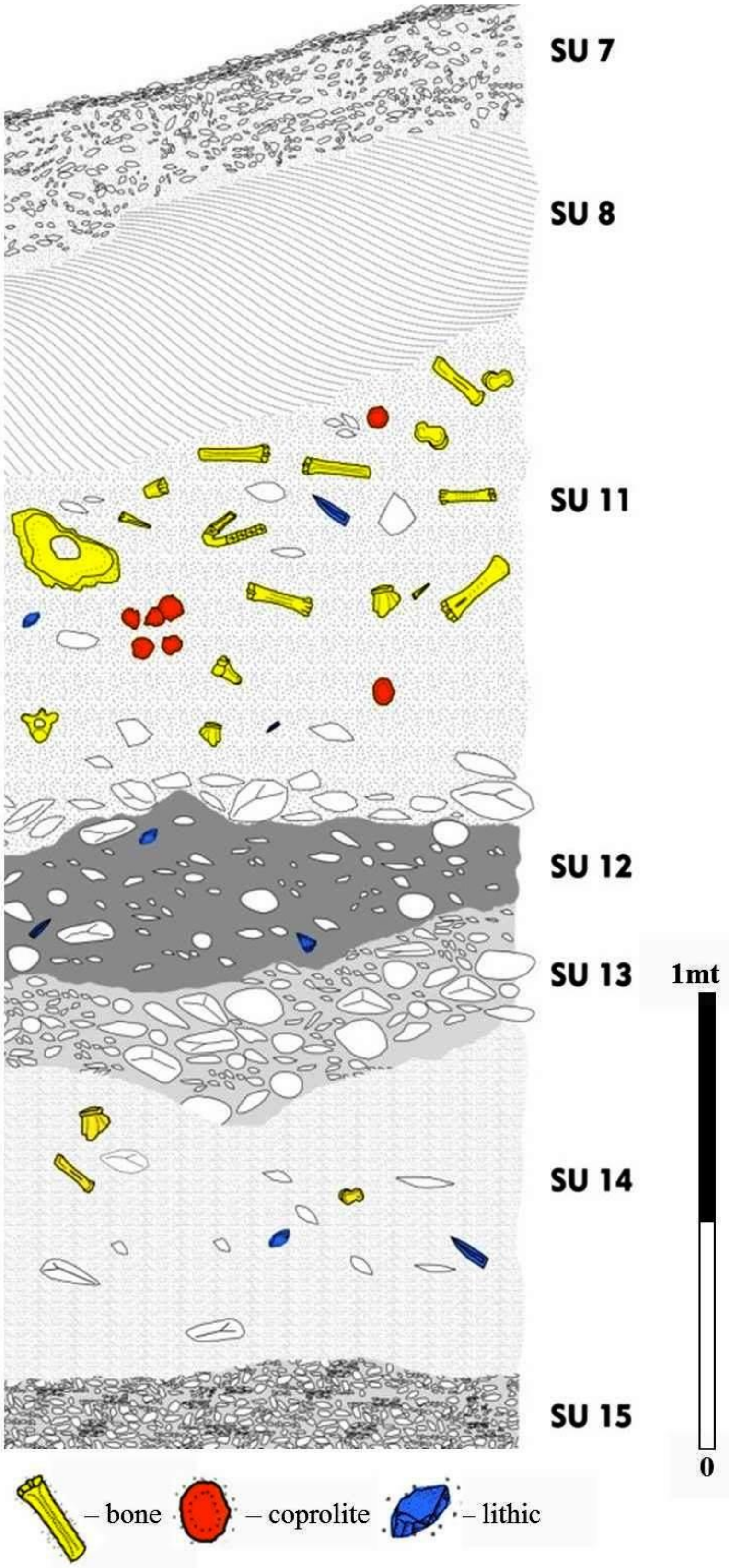


Fig. 2.8 Stratigraphic sequence of the excavation area named Point 3; SU7: Modern surface composed of soil and gravel; SU8: Upper edge of the cave in travertine; SU11: Brown occupation layer with archaeological remains; SU12: Reddish brown layer with volcanic products and occasional finds of stone artefacts; SU13: Sterile layer composed of volcanic tephra; SU14: Reddish layer with sporadic lithic and faunal remains. From Gatta and Rolfo, 2015; Gatta, Kotsakis, et al. 2017.

SU11 is the main archaeological layer of the Area 3. This is demonstrated by the abundant fauna remains collected, around one thousand bones, together with a discrete lithic collection of 38 implements and 48 coprolites (Gatta and Rolfo, 2017a). This stratigraphic unit appears to correlate with the description of a layer at Canale delle Acque Alte (Le Briglie), the only Pleistocene site stratigraphically excavated. The so-called 'layer A' (Blanc, 1935a) or 'layer C2' of a second more accurate stratigraphic reconstruction, in which Blanc (1957) recovered mammals and Mousterian industry. Unfortunately, it is no longer possible to make a direct comparison with this stratigraphy since the site has been destroyed during the work for the creation of a drainage channel.

In the early stages of the investigation, the cave was assumed to be naturally filled by soil and remains through a natural chimney, or vertical entrance, over an indefinite period of time (Gatta and Rolfo, 2017a). Once the excavation started however, a new series of evidences were noticed. A mandible of hyena was visible in the surface layer among further remains of the carnivore and other mammals bones, many of which exhibited gnawing marks (Gatta and Rolfo, 2017a). It became clear that the bone accumulation was not accidental but rather the result of carnivore activity. The site has therefore been identified as a hyena den (*ibidem*). Despite that, the potential for human frequentation remained, linked to the small number of lithic tools found. Due to the extremely low number of flints discovered, it did not appear to represent a primary exploitation of the cave by people, either before or after the cave hyena. Further investigation of the human introduction to the cave was therefore carried out (see section 5.2).

The distribution of finds in SU11 is clearly concentrated in a few square metres of palaeosol, an accumulation which could be the result of one or multiple factors (Gatta and Rolfo, 2017a). The first factor to consider is the action of carnivores. Modern zoological behavioural studies, considered a suitable comparative model, show that a hyena transports not only its prey but also sporadic bones inside dens for personal sustenance and maintenance of other pack members (Stiner 1994, 221–224). The areas of intense accumulation could therefore, indicate where prey were consumed inside the den. A second factor to consider is that of hydrogeology, as the possibility that the flow of water played a role in the deposition and dispersion of the faunal record inside the cave cannot be excluded (Gatta and Rolfo, 2017a). The whole area of CM, like the rest of the Pontine Plain, was subject to flooding and swamping and remained so until the middle of last century when reclamation work altered the region's drainage (*ibidem*). Although it is clear that the majority of the faunal deposit represents primary deposition by hyenas it is still possible that water transported additional elements (Gatta and Rolfo, 2017a). This is particularly relevant regarding the presence of lithic industries from different chrono-cultural phases within the same stratigraphic unit (see section 5.2).

The investigation of the slope was carried out simultaneously with the inner excavation and returned a large quantity of finds and information useful to the interpretation of slope formation. The archaeological remains recovered are the same as those within SU11 (i.e. bone remains, coprolites and lithic industry) and also displayed gnawing marks. Climatic markers (i.e. patinas and cracks) were also widespread. Furthermore, the stratigraphic excavation revealed that the soil forming the slide, although heavily weathered, showed the same geomorphological characteristics (i.e. colour, texture and composition) of SU11. Therefore the formation of the slope can be interpreted as the collapse of part of SU11 due to weathering (Gatta and Rolfo, 2017a).

2.3.2 Cava Muracci: The other collection areas

Area 3 is not the only area of the quarry to have returned archaeological material. In order to obtain a complete picture of the context, collections have been recovered from other six areas spread along the front of the quarry, sampling all perimetres of the site (Gatta and Rolfo, 2017a, 2017b, in press a; Fig. 2.9).

Areas 1 and 2 are located in immediate proximity to Area 3. Area 1 was chosen as the site where the Neolithic human skull was found in 2000 (Angle and Germano, 2003), however, only a few findings were recovered here, probably due to the careful collection during the previous investigation. Most finds consisted of faunal remains, including aurochs, red deer and fallow deer. It is, therefore, possible that this fauna is attributable to Palaeolithic layers below the previously discovered cranium.

Area 2 is essentially an underground tunnel that joins Area 1 to the main area of excavation (e.g. Area 3). The aim of the investigation here was to establish if a relationship existed between the two zones. Unfortunately, it was not possible to clarify this with certainty, although during the excavation those species attesting to the Palaeolithic were found again, including the mandible of a cave hyena. Whilst this data is not helpful in comprehending the actual extent of the cave, it does help to confirm an extensive presence of hyena.

Area 4, located along the east wall of the quarry, appeared to be a narrow, deep pocket in the travertine. A large part of the deposit, containing a huge amount of animal remains, was eroded away by weathering. Hundreds of bones were collected from the surface in total and reflect the same species found in Area 3. The presence of the hyena, attested by the discovery of a canine and some coprolites, leads us to consider this as a natural deposit not dissimilar to Area 3. This area may therefore potentially represent another hyena den, and subject to a more thorough investigation, could be of great importance in the preliminary conclusions concerning the presence of Hyaenidae in the territory of CM.

Area 5, located on the southern side of the quarry, is another large pocket of travertine. Most of the filling soil had also slipped, revealing abundant faunal remains. Among these there are a molar and a premolar belonging to *Stephanorhinus hemitoechus* (narrow-nosed rhinoceros).

Area 6 is located along the west face of the quarry. Although not much was recovered from the area, it was selected to complete the series of surveys around the perimetre of the quarry. Along this side of the quarry the caves are now completely empty and their filling accumulated in several mounds at the edge of the quarry; explaining the absence of finds.

The investigation of Area 7 was carried out at a later date after a new, destructive, progression of extraction work along the east front. What appeared to have been a large cave, has now mostly been destroyed. Along a travertine wall around 7 m long, identified as an inner edge of this cave, a partially concreted layer of soil was preserved along the edge of the rock. Within this soil, a rich filling of remains was visible which, both for the impossibility of an appropriate excavation and for the fear that this material would be lost with successive quarrying, was retrieved under rescue circumstances. Abundant fauna, among which cave hyena remains, and dozens of coprolites testify that the cave would have been intensively populated.

In conclusion, faunal species, taphonomy of remains, and geomorphology of sediments from Areas 2; 4 and 7, reflect the same features of Area 3 and seem to suggest all of them were contemporaneous hyena dens (Gatta and Rolfo, 2017a). Collection Area(s) 1; 5; 6 are instead natural caves and pockets filled with soil and sporadic finds transported by water flooding, as the commingling within the same layers of Middle and Upper Palaeolithic lithic industries and bone remains within different stages of fossilisation, seems to corroborate (Gatta and Rolfo, 2017a).

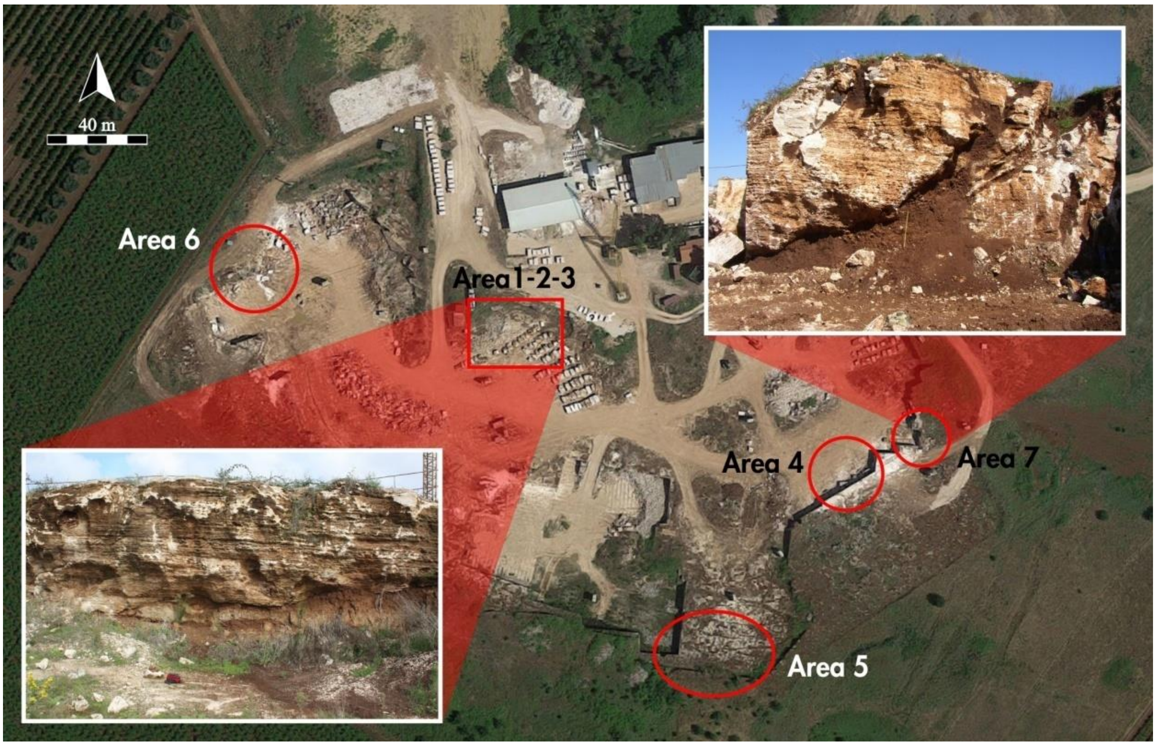


Fig. 2.9 Location of collection and excavation areas within the quarry. From Gatta, Sinopoli, et al. (2016); Gatta et al. (2017); Gatta & Rolfo (2017).

2.3.3 Chronology

It is beneficial for the interpretation of a site to already have an understanding of its chronology before excavation begins. However, establishing the chronology of this site, or a relative date, was not immediately possible. The first attempts at radiometric dating by ^{14}C, made by the Beta Analytic Inc. of Miami (USA), have failed due to a lack of collagen in the bones. Collagen, a protein on which this method of dating is based, is highly dependent on the preservation of the find. The action of travertine in particular, while allowing an optimal fossilisation of the bones with important implications for taphonomy, it has on the other hand a destructive role on the organic component (see 4.1.1).

Further attempts to obtain absolute dating were made with the Uranium-Thorium method on two finds; a molar of narrow-nosed rhinoceros and a molar of wild horse. These yielded results with the rhinoceros dated to 26,300±2600 BP and the wild horse dated to 26,700±3400 BP but their reliability is strongly doubted. Current research concerning the extinction of the rhinoceros in central Italy has suggested they went extinct as early as 45 ka BP (Palombo, 2004; Petronio, di Canzio and Salari, 2007; Petronio and Pandolfi, 2008). Until recently, it was thought the survival of the species was prolonged in south Italy up to 29 ka BP (e.g. Grotta della Cala, Salerno) (Benini, Boscato and Gambassini, 1997). However, during comparisons for the study of CM's rhino, the opportunity became available to verify how the size and proportions compare with the only find coming from Grotta della Cala, and it was discovered that it was closer to the species *Coelodonta antiquitatis* (woolly rhinoceros) and not narrow-nosed rhinoceros (Pandolfi *et al.*, 2016). For this reason, the latter dating and extinction of the species at 29 ka BP should no longer be considered valid and will be extensively discussed later (see Chapter VII).

In order to achieve the chronological framework, four calibrated ^{14}C dates were collected from bones, and they have yielded a Late Pleistocene chronology for the quarry, between 34,810 cal BP (ETH-66210) and 44,054 cal BP (LTL15758A); with particular interest in the date of 36,885±350 (LTL15760A) on a tooth of narrow-nosed rhinoceros (results summarised in section 4.1 and Tab. 4.1). The latter shows a clear difference to the previous dating of the same sample, and highlights the limits of U-Th method dating in karst environments. Therefore the dating achieved at CM requires careful consideration, with the potential to set a new lower limit for the extinction of the rhinoceros (Pandolfi *et al.*, 2017) and provide further evidence in support of the Pontine Plain as a climatic *refugium*.

When dating contexts close to the age limit of the radiocarbon method, the use of Ultra Filtration pre-treatment is highly recommended to strengthen the reliability of age obtained (Higham, Jacobi and Bronk Ramsey, 2006; Jacobi, Higham and Bronk Ramsey, 2006). Although this is the case, the application of this method failed at CM due to the lack of collagen (see section 4.1). Trace element composition analyses and 40Ar/39Ar dating of the SU13 have been then carried out with the aim to provide an age for this volcanic layer and, therefore, a chronological constraint (e.g. a *terminus post quem*) to compare and integrate age by ^{14}C method of SU11 (Gatta and Marra, 2017; Gatta *et al.*, 2017). Results of analyses indicate a strong correlation between SU13 with the Albano 3 eruption unit dating at 69 ka BP, which perfectly fits with the previous dating of the site and sensibly reduces concerns (Gatta and Marra, 2017; Gatta *et al.*, 2017) (see 4.1.3 for methodology).

In summary, the chronological range 44–34 ka BP achieved for the SU11 seems to be reliable. It also matches with the palaeoenvironmental reconstruction permitted by the study of the fauna. The wildlife indicators highlighted suggest a habitat with a cool but not extreme temperate climate. This framework fits between 60–20 BP in central Italy, with the exception of a few millennia which saw the slightly colder fluctuations of MIS 3. It should be noted however, that this faunal assemblage is ubiquitous in the Italian lowlands during most phases of this stage and the first half of MIS 2, finding comparisons with the fauna of other sites in the Latium region such as Grotta Breuil (Bietti *et al.*, 1988; Stiner, 1990), and in the surrounding regions such as Buca della Iena (Pitti and Tozzi, 1971; Stiner, 1990), with chronologies of 45–27 ka BP.

In conclusion, the site is best interpreted as a Late Pleistocene hyena den. A human presence before or after cannot currently be excluded, but the absence of cut marks and the small number of lithics found exclude with certainty human presence during SU11 (Gatta and Rolfo, 2017a).

2.3.4 Concluding remarks

Overall the site of CM seems to be a large, flat landscape characterised by an extraordinary presence of natural travertine caves. These caves contain abundant evidence of archaeological, palaeoecological and archaeozoological remains, through both primary and secondary actions. A wide range of information essential for developing the understanding of the site was obtained. The foundations have been laid for a new study of a wider context, covering the Pontine Plain region, in order to specifically understand how and to what extent environmental factors have favoured the prehistoric presence in the region.

The coprolites found at the site represent a unique resource to study the environment of the Pontine Plain; a valuable opportunity considering that previous palaeoenvironmental reconstructions were made on the basis of fauna from the coastal caves of Monte Circeo. Also, studies based on open sites are essentially absent in the region and so, the current reconstruction helps to enrich the knowledge with a context located more towards the hinterland, close to the Monti Lepini. Pollen analyses of coprolites have not been carried out at all, although these have been found in large numbers in Monte Circeo’s sites for over seventy years. As stated above, the only study of the pollen carried out, achieved through the analysis of core drilling, has a time gap in the millennia to which this site is estimated to belong, and therefore the analysis of the oldest layers seems to be not totally reliable.

In conclusion, useful information has been obtained from this new dataset which holds important implications for the region during the Late Pleistocene.

2.4 Conclusions

The Latium region is an extremely active zone from a geological view, with tectonic and volcanic forces consistently and continuously modifying its shape. The actions of ice and marine regressions triggered by the Quaternary Ice Ages were the last major natural transformations of the region, excluding the massive man-made reclamation of recent times. During the last Ice Age the territory had assumed its current structure and the Pontine Plain, protected by the Apennines from the cold coming from the north-east and warmed by the currents of the Mediterranean Sea, was an extremely hospitable environment and provided an important passage between the north and the south of Italy for both hominin and fauna (Gatta and Rolfo, 2015).

The region is a highly fascinating and complex subject area. The geological and climatic history of the area is unique, with various natural forces continually shaping the fauna and flora environments which vary greatly even within a small area. The richness and variety of this area of the Italian peninsula seem to have offered ideal environmental characteristics for the survival of some animal and human species in the Late Pleistocene, as evidenced by numerous archaeological finds. This leads to the main concern of the thesis: To consider whether the Pontine Plain acted as an area of refuge on a par with other sub-regions of Europe. The actions of many natural factors, including volcanic, hydrogeological, geological, marine and climatic processes have caused the partial disappearance or destruction of valuable archaeological material, such as sites buried under ash and volcanic lava on the slopes of the Albano volcano (Rolfo, Giaccio and Sposato, 2006), the submergence of coastal sites and the erosion of organic material in the acidic soil (Gordon and Buikstra, 1981; Nicholson, 1996). Each problem presents further challenges that have had to be overcome in completing a full and accurate study of the region.

Finally, the difficulties of investigating the CM context have been heavily emphasised. To begin an excavation in an already disturbed context, partially destroyed by quarrying which remains active at the site, presents a great challenge. The archaeological campaigns carried out can be considered as rescue excavations, seeking to limit further the loss of the research potential of the archaeological deposits. The site was extensively damaged and the excavation was conducted to limit the already perpetrated damage by human activity. Area 3, abandoned for decades, has fortunately been subject only to partial destruction and has allowed for a long and detailed excavation. On the other hand, the peculiarity of the archaeological layer, suspended halfway above an almost vertical wall, made the extensional stratigraphic excavation highly complicated. To pre-empt the potential destruction and loss of the site in the future, as has occurred previously in the quarry (Segre and Ascenzi, 1956), extensive archaeological documentation has been recorded in order to allow future reviews.

The other areas from which material was collected were subject to almost daily extraction of stone, allowing for only brief recovery interventions of archaeological materials that were accidentally discovered during the process of work. For this reason their documentation is much sparser than for Area 3, with no stratigraphic correlation between the areas being possible. Nevertheless, in some cases, a chronological correlation has been possible due to radiometric dating, as in the case of the narrow-nosed rhinoceros remains (see Chapter VII). Because of this the environmental reconstruction has been based mainly but not solely on the analyses of Area 3's findings. The finds from other areas also contributed to the interpretation for a better understanding of the development and distribution of the whole complex of caves.

Chapter III

Previous and Ongoing Prehistoric Research in Latium

The purpose of this chapter is to present a synthesised review of the most relevant archaeological literature. As such, many of the early studies which first interpreted the lithic assemblages and fauna over fifty years ago will, therefore, be excluded, as they are no longer scientifically valid.

The first subchapter considers previous environmental studies of the pollen resources from the Late Pleistocene. This is undoubtedly the least studied scientific aspect of the Pontine Plain. To date, no regional studies have been performed of pollen from coprolites, either from hyena or other animal species. This makes the innovative exploitation of this resource for the first time in the territory as difficult as it is fascinating. In addition, those palynological studies that have been carried out on cores extracted in the area are extremely poor due to the low quality of data. At present, there is in fact just a single palynological study in the Pontine Plain from the 1980s which covers a limited portion of the relevant chronological range (Eisner, Kamermans and Loving, 1984; Eisner, Kamermans and Wymstra, 1986; Hunt and Eisner, 1991; Eisner and Kamermans, 2004). For this reason, it is necessary to extend the limits of the research beyond the Pontine Plain and cover the entire landscape of Latium, accessing those pollen analyses from core samples of dried-up volcanic lakes mentioned in the second chapter (Follieri, Magri and Sadori, 1988, 1989; Ciuffarella, 1996; Magri, 1999; Magri and Sadori, 1999; Sadori *et al.*, 2004; Giardini, 2007).

The second subchapter discusses the studies carried out on the Pleistocene faunas of the Pontine Plain and in particular the cave sites of Monte Circeo. Particular importance is given to the work conducted mainly in the 1990s by Mary C. Stiner (Stiner, 1991d, 1991e, 1994), who studied exhaustively as never before all of the fauna from the main archaeological excavations in the region, offering a broad picture of animal life. However, on a scientific level, the large number of discoveries that occurred during the construction of the drainage canal "Canale Mussolini", renamed the “Canale delle Acque Alte”, are equally important. Unfortunately these faunas, whilst covering a very broad period of time, have been mainly accumulated through the fluvial action of water. Subsequently, the possible associations between the fauna and sporadic stone tools are not believed to be reliable.

The third subchapter will focus on the lithic products as direct evidence of human presence in the region. The lithic technology of Latium, particularly that of the Mousterian, has attracted the attention of many scholars in the field since before World War II, when Carlo Alberto Blanc (Blanc, 1939d) first studied its atypical characteristics and recognised it as a regional facies named "Pontinian". Since then, studies on the subject continued at varying rates until the monographic work by Steven Kuhn (Kuhn, 1995). This elaborate study, defined by the author as an investigation seeking to reveal the ecological significance behind the development of the Pontinian, has a key role in the field and in this research. Not only it is a relatively recent and comprehensive study but it also explores issues such as the relationship between tool-making and food-getting, and the influence that some models of subsistence may have had on the system of production and use of stone tools. This has been extremely useful in helping develop the understanding of the unknown factors underlying this research, i.e. the comprehension of the landscape of Latium. In addition to the Pontinian, the assemblage recovered from the site of Cava Muracci (hereinafter CM) is mixed with some tools possibly attributable to the post-transitional period of the Aurignacian. Whilst this period is nonetheless much more poorly evidenced in the region than those prior to it, with a limited number of subsequent studies, a brief examination of it will be provided.

Before addressing these sections a more general history of studies and excavations made in the region will be offered below. This section is of great importance to understand from which context and from what type of excavation most of the data previously studied by Kuhn, Stiner and other researchers, originated.

Remaining focused on prehistory and in particular on the Palaeolithic, the first real archaeological excavations of the Pontine Plain occurred shortly before the World War II. It is from these more organised and interdisciplinary studies that the chronological story of the investigation of the territory will be outlined. However, it is necessary to specify that, at least with regard to the lithic industry, news of reports and systematic collections exist from the mid-19th Century (Bleicher, 1866; Ceselli, 1866; Ponzi, 1866a, 1866b, 1870; De Rossi, 1867; Indes, 1875; Pinza, 1905).

Since the 1930s there has been a strong interest in the prehistory of Latium with studies from the Istituto Italiano di Paleontologia Umana (hereinafter IIPU), the University of Rome La Sapienza and the highly-regarded Alberto Carlo Blanc. The opportunity for this resumption of studies arose from the impressive reclamation works made between 1928–1939. The extensive excavations, and the fortunate discovery of fossil strata along the route, presented a unique opportunity to carry out archaeological, geological and environmental studies never produced before (Blanc, 1935a, 1935b, 1935c, 1936). Subsequently, a series of research programs began a study of the area which continues successfully to the present day, albeit more slowly. Between 1936 and 1938 a campaign survey was carried out by IIPU along the Latium coast between Rome and Terracina, organised and directed by Blanc and the geologist Segre. It was during this period that the majority of caves and shelters of the Monte Circeo were found, reported and in some cases surveyed in order to understand their archaeological potential (Blanc, 1937a). In total, this campaign highlighted the presence of 31 caves and saw the start of archaeological excavations in the Grotta delle Capre, Grotta del Fossellone, Grotta Breuil and Grotta Elena (Blanc, 1938; Blanc and Segre, 1953; Blanc, Segre and Tongiorgi, 1953).

In 1939 Grotta Guattari was discovered by chance, without any doubt the most important cave of the Latium coast, bringing international scientific attention to the area. During construction works in a private property on Monte Circeo the narrow entrance of the site was revealed, within which the workers found the infamous Neanderthal skull which for decades has been falsely referred to as evidence for the practice of cannibalism (Blanc 1940; Blanc 1958; Blanc 1961; Piperno 1977; see also Chapter V). In the same year, the excavations of the site began led once again by Blanc and a member of the IIPU, Luigi Cardini (Taschini, 1979). However, the two alternated the role of director between them, with each employing different methods of excavation. This was a serious mistake which compromised an immediate correct interpretation of the context and contributed to the general confusion that has been created around one of the most important sites in Italian prehistory.

In 1950 Segre carried out further excavations (Taschini, 1979, p. 184), reconstructing the stratigraphic sequence of the site and at least partially correcting the flaws of previous studies, publishing the results together with Blanc (Blanc and Segre, 1953). The great interest which focused on the supposed Neanderthal cannibalism, the forced suspension of the excavations during the World War II and the untimely death of A. C. Blanc just over a decade later, ensured that the site was never studied in its entirety. In fact, a comprehensive study of stone tools was only published forty years after the discovery of the cave (Taschini, 1979), the results of which were not fully supported by the subsequent technological re-analysis of the artefacts by Kuhn (1995: 56). A complete study of the fauna was not achieved until even later, having previously been published only in the form of short reports.

In the late 1980s, Stiner and Piperno & Giacobini worked independently with different methodological approaches (Stiner, 1991e) on the materials of Grotta Guattari, publishing a few years after the first complete results (Piperno and Giacobini, 1991; Stiner, 1991d, 1991e, 1994). Despite the important information that has been delivered with a critical approach, the archaeological potential of the site has not yet been fully exploited. The choice of an excavation in trenches, in addition to the different methods employed by the directors, was undoubtedly dictated by the excavation methods typical of past decades. Moreover, the position of the dug trenches was established in order to reach the innermost point of the cave where the human skull had been found on the surface. This is an extremely questionable choice when it is considered that the area investigated, based on the drawings of Taschini (1979), does not cover even 30% of the total paleosurface. Another cause of regret is the perpetual plundering and re-shuffle of surface finds, a deplorable action which initiated from the time of the discovery of the site. Blanc, in a first report presented to the Accademia Nazionale dei Lincei, stated that the skull and a human mandible were collected by a private individual and later handed over to him, whilst other onlookers had penetrated the cave before his arrival and removed several bones. It is certainly not quantifiable how much archaeological material has been lost, potentially including additional human remains, and what valuable information it may have provided. It is however reasonable to question whether, with a more prudent archaeological investigation of the site, it would have been possible to interpret the context from the very beginning for what it was, a den of hyenas, and thus avoid the huge debate on rituals and Neanderthal cannibalism in Monte Circeo which lasted for over fifty years.

Between 1947 and 1949 a new series of IIPU surveys were undertaken, this time slightly south of Monte Circeo along the coast between Sperlonga and Gaeta, which facilitated the discovery of an additional 113 cave and shelter sites. Many of these contained only residual layers of the Quaternary (Blanc and Segre, 1947), probably leached from the marine action, whilst ten caves returned archaeological material (Blanc and Segre, 1947; Blanc, 1955). At the end of the survey campaign the two most promising sites were chosen for excavation, the Grotta dei Moscerini and Grotta Sant'Agostino.

Grotta dei Moscerini is an exceptional Mousterian site containing one of the widest varieties of animal remains of the Pontine Plain coastal area. The archaeological material covers a period between 120–60 ka BP, the oldest cultural Mousterian deposit of the region. The site, which is no longer accessible due to a landslide that occurred during the construction of a road a little higher up along the side of the mountain, was excavated in 1949 by several members of IIPU including the aforementioned Blanc and Segre. The archaeological excavation was carried out in two trenches, at the entrance and at the furthest end of the cave. Incredibly, despite the challenging excavation and the large amount of documentation collected, a complete monograph of the work carried out here was never published, although the lithic materials found were published thirty-five years after the end of the excavations (Vitagliano, 1984).

Grotta Sant'Agostino was excavated in the two consecutive years of 1947 and 1948 by IIPU, under the direction of E. Tongiorgi (Tozzi, 1970; Kuhn, 1995). The excavations were also completed here in the form of two trenches at the entrance and the back end of the cave. Despite stratigraphic difficulties that made it impossible to connect the stratigraphy of the two trenches (Kuhn 1995: 58), it was possible to chronologically assign the site to a period between 55–40 ka BP. Initially, only a study of the lithic material from the excavation was carried out (Laj-Pannocchia, 1950) and it was another two decades until a complete study of lithics and fauna was published (Tozzi, 1970). The lithic assemblage of this cave is also, by virtue of nearly 8000 collected pieces, the largest Mousterian collection of coastal Latium and thus an excellent comparison site.

Unfortunately, some of the issues highlighted at Grotta Guattari reoccur in these caves. Both sites have been investigated using double trenches positioned so far apart from each other as to make a stratigraphic connection complicated, leaving a large part of the archaeological record untouched. This problem is reflected in the assemblage collected from Grotta dei Moscerini which consists of a rather poor selection of lithic material, further hindering an in-depth study (Kuhn 1995: 59). Moreover, as a result of illegal excavations witnessed by Stiner at Grotta Sant'Agostino (Stiner 1994: 49), a vast amount of archaeological data has been lost forever. Grotta dei Moscerini has been spared a similar fate by the landslide which obliterated the entrance, preserving the archaeological potential. Its large size and stratigraphy of over 8 m thick means the site should be an ideal consideration for a new archaeological excavation using modern techniques. The potential already shown by the site during the first excavation, now more than sixty years ago, could now be fully exploited, providing valuable new information for the understanding of this period of regional prehistory. Finally, the attention has to be focused on the late and partial study of the finds from the excavations, carried out up to a few decades after the excavations took place.

The decades to follow saw a diminishing of interest in the final stages of the Palaeolithic to the benefit of the oldest chronologies, with the excavation of several deposits dated to the Middle Pleistocene, referred to in the bibliography (Biddittu, 1971; Longo and Radmilli, 1972; Malatesta, 1978; Biddittu *et al.*, 1979; Longo *et al.*, 1981; Anzidei *et al.*, 1989). Since the late 1960s a new series of surveys of the area took place in the region, drawing attention to the phases of the Middle and Upper Palaeolithic, undertaken by both professional archaeologists and also amateurs (Cardini and Biddittu, 1967; Bietti, 1969; Zei, 1970; Mussi and Zampetti, 1978; Malpieri, Patriarchi and Zei, 1981; Mussi, 1982).

Additional surveys, carried out by Dutch scholars and universities, have had an important impact on the research of the Pontine Plain with several campaigns of study that lasted for many years. The first period of study in the region concerned a geomorphological study of the territory by the University of Amsterdam, directed by J. Sevink. This had a duration of eighteen years, beginning in 1966 and ending only in 1984 (Sevink *et al.*, 1982; Sevink, Remmelzwaal and Spaargaren, 1984; Sevink, Duivenvoorden and Kamermans, 1991).

"The Agro Pontino archaeological Survey" followed with a heavier emphasis on archaeological over geological interest and represents a masterful job, both in scope and for the quality of the studies. The project was developed for ten years between 1979 and 1989 by University of Amsterdam, collaborating in the final four years with the University of Leiden. It was the original intent of the project leaders, S.H. Loving, H. Kamermans and A. Voorrips, that a methodology of systematic surveys would facilitate a better understanding of the archaeological evidence already known in the territory, ranging from the Middle Palaeolithic to the Bronze Age. The main aim of this program was to consider changes in land use in order to understand how far they could be explained by alterations in socio-cultural patterns or in the environment. However, this project also included specific studies of stone tools and ceramic finds, as well as two pollen analyses which have proven to be extremely profitable in the scientific field. The thorough publications that stemmed from this work have contributed significantly to the knowledge of the Pontine Plain as a whole (Voorrips, Loving and Kamermans, 1991; Holstrom, Voorrips and Kamermans, 2004).

In the mid-1980s new investigations into the caves of Monte Circeo also began. Amilcare Bietti, professor at La Sapienza University of Rome, previously involved with the excavations of the Epigravettian shelter of Riparo Salvini (Bietti, 1984; Avellino *et al.*, 1989; Bietti and Stiner, 1992), initiated a new excavation of Grotta Breuil in collaboration with Kuhn and Stiner. The cave, already the subject of test excavations since the year of its discovery, continued to be investigated until 1998. At present investigations are suspended to complete the study and publication of the materials collected during the most recent excavations while the findings collected during the previous phases have already been studied and published (Bietti *et al.*, 1988, 1991). The study of this cave was carried out with an integrated approach. Utilising experts in both lithic and archaeozoology has helped to interpret the large amount of lithic and faunal remains, contextualising the site within the Monte Circeo and Pontine Plain. Moreover, it has resulted in a clear stratigraphic reconstruction, despite the difficulties presented by the sloping floor of the site. At the same time as the previous study, another scholar of the same university, M. Mussi, began her investigations into one of the few caves of the promontory not noted by Blanc during his surveys, the Grotta Barbara (Mussi and Zampetti, 1990, 1991). This small site, just a few metres above sea level, was initially investigated with a number of test excavations positioned in the filling of the cave. These covered a total area of c. 12 m^2, although they did not stretch to the base of the deposit. Nevertheless, the fauna recovered has provided interesting palaeoenvironmental and palaeoeconomic information for the Late Mousterian coast of Latium (Caloi and Palombo, 1989a, 1989b, 1991).

During the 1990s major studies of the materials collected in previous decades, including the aforementioned Kuhn (Kuhn, 1995) and Stiner (Stiner, 1994), were conducted with a high level of detail. In 1999 the University of Rome Tor Vergata, working with the Istituto di Geologia Ambientale e Geoingegneria del Consiglio Nazionale delle Ricerche (CNR-IGAG), aimed to improve the knowledge of the Palaeolithic population with a program of surveys to identify and record new sites near the caldera Albana. This area, not previously known for collections of lithic material (Rolfo and Giaccio, 2000; Rolfo, Giaccio and Sposato, 2006), has facilitated the observation of the direct relationship between the outcrop of lithic material and the known volcanic geomorphological contexts. This has offered the possibility to establish a time frame for the surface sites which are otherwise unquantifiable, furthering the knowledge on the techno-cultural phenomenon known as the Pontinian.

Born from the need to provide more in-depth answers to some questions still posed by this culture, a research project was begun in 2013; "Il Pontiniano di *plein air"* (Rolfo *et al.*, 2013; Gatta, Achino, *et al.*, 2016). The main objectives of this project were to conduct a census of all the surface collections made to date and to implement a series of new surveys, with the aim of identifying the exact geographical limits of the distribution of Pontinian sites. In addition, the study aimed to define the relationship between open sites with the cave sites along the Latium coast, whose stone industries are currently being studied by another international project "Stability and Innovation in Neanderthal technology from MIS 9 to MIS 3 in central Italy " (Villa and Soriano, 2013).

However both studies, especially the first, have had to face bureaucratic problems in the performance of their work. A major organisational fault apparent in the region is, as mentioned previously (Rolfo *et al.*, 2013), the dispersion and in some cases the disappearance of many lithic collections, forgotten over time and divided among various museums and institutions. This research will, therefore, be useful not only in the study of the materials but also in the creation of a new classification of the assemblages currently dispersed throughout the territory.

This concludes the brief but comprehensive overview of the history of the excavations and surveys in the territory of Latium, allowing the focus to shift onto those specific studies of the materials recovered from these studies, which will be of most interest to the environmental issues addressed in this thesis.

3.1 Previous environmental studies on the Late Pleistocene central Italy

Since the pollen analysis of the Pontine Plain is a fundamental step in this research, it is absolutely necessary to show in more detail the history of the studies and environmental reconstructions based on pollen sequences concerning the Late Pleistocene. In Italy, palynological research reached its peak during the last decade; suffice it to say that of the 94 sites that returned Late Quaternary pollen sequences as many as 73 had been studied in the previous decade. Over 40 pollen diagrams containing information about the Last Glacial period reveal a picture of extremely complex and diverse vegetation, mainly due to climatic conditions and the highly varied physiography of the peninsula

(Magri, 2007).

Nevertheless, this aspect of the Pontine Plain past has so far hardly been investigated. Apart from the discussion of a study of pollen from coprolites, of which the one presented in this thesis is the first one to be realised, I will present here the studies based on the analysis of sediment cores. These are the only ones that have been carried out and are insufficient in number to outline a framework for the environment. Consequently, it is necessary to extend the study area to include the entire Latium region. It is well known that the pollen spectra obtained from lacustrine environments can accurately reflect some valid elements on a regional scale (see Chapter I). Therefore, whilst located at a great distance from the primary study area, these sites remain relevant and factual comparisons.

Firstly, to begin with those investigations located in the Pontine Plain (Fig. 3.1), pollen has been extracted and analysed from at least seven places in the area, three of which are located near the sea:

- Campoverde (41°32'10.3"N 12°43'55.2"E): the core was extracted from a dry lake and shows chronologies between 4690±70 BP and 1915±145 BP (Veenman, 1996; Sevink *et al.*, 2013).
- Colle San Lorenzo (41°35'10.0"N 12°32'07.0"E): in 1998 a core of 265 cm was extracted by Delvigne, Woldring and van Joolen in this town south of Ardea. It contained layers between 4560±60 BP and 2950±60 BP (van Joolen, 2003).
- Lago di Fogliano (41°23'55.1"N 12°54'10.6"E): a core of approximately 8 m containing layers ranging between 3590±100 BP and 2360±60 BP was extracted by Woldring, Veenman and Haagsma along the perimetre of this lake, located on the Tyrrhenian coast (van Joolen, 2003; Sevink *et al.*, 2013).

An additional four pollen samples have been taken from around the edge of the Lepini Mountains:

- Monticchio (41°32'35.4"N 12°58'47.3"E): a long core of about 11 m, dated to the first millennium BC, was extracted from this town near Sermoneta (Haagsma, 1993).
- Via Migliaria 47 (41°26'23.1"N 13°03'59.3"E): 13 km from the present coast, two cores reaching a depth of more than 30 m were extracted. Samples provided important geological and palaeoenvironmental information of the area for a period between the Middle Pleistocene and the beginning of the Last Glacial (Barbieri *et al.*, 1999).
- Laghi di Vescovo (41°27′15″ N 13°7′25″ E): In 1998 a core of about 355 cm in length was taken from one of the sulphuric lakes at the base of the Lepini Mountains, with

layers ranging between 2,680±70 BP and 2290±100 BP (van Joolen, 2003; Sevink *et al.*, 2013).

- Mezzaluna (41°27'44.0"N 13°05'59.1"E): a core drilling of 9 m revealed chronologies covering, albeit discontinuously, the last 35 ka years. It was extracted in 1981, not far from Laghi di Vescovo (Eisner, Kamermans and Loving, 1984).

From this list of pollen analyses conducted so far, two key pieces of information can be deduced. The first relates to the geographical distribution of the sites listed, of which a good portion are distributed along the coast and the rest are situated more to the interior, at the foot of the mountains (Fig. 3.1). The site of CM, with its location between the sea and the mountains, therefore potentially offers new information.

The second key point is related to chronology. Five of the seven cores are indeed chronologies which relate to Protohistoric phases or, at most, the late Neolithic. The one from Via Migliaria 47 has been the object of a multidisciplinary study which permitted an extremely comprehensive geological and palaeoenvironmental reconstruction. However, the layers identified are significantly older than those discussed here and are therefore of limited use in reconstructing the environmental evolution of the territory.

The only information directly comparable is from the cores of Mezzaluna, represented by the first two levels of the drilling. This core drilling was carried out as part of the extensive aforementioned Dutch research project "The Pontine Archaeological Survey". Although previously praised for the quality of the work in general, the palynological aspect is unfortunately incomplete and unreliable. The first published report lacked detail but presented the stratigraphic, chronology of the samples and palynological results (Eisner, Kamermans and Loving, 1984). Although the lowest sediment of the core was analysed, "Zone A" (910–842 cm) rich in Poaceae and *Artemisia* and pollen of fresh water plants, this layer was not carbon dated. The next level "Zone B" (841–770 cm), in which shells and remains of Hystrichosphaeridae were considered as indicators of a marine environment, has also not been carbon dated. Probably at that time the chronologies of these layers had not been even deduced because the publication speaks of Late Glacial, and such lower limit of the sample and successive layers actually showed chronologies ranging from about 16–4,7 ka BP. When the full study analysis was presented in 1986 previous interpretations of the two lower levels were confirmed and a new date of 34.650±950 was assigned to Zone A (Eisner, Kamermans and Wymstra, 1986). An initial, simple reconstruction of the local environment was also proposed as it was considered that additional core samples would be required in order to build an accurate regional reconstruction.

Following the conclusion of the project a monograph was published containing the results of a decade's worth of studies (Voorrips, Loving and Kamermans, 1991). On this occasion, the final palynological study of the site of Mezzaluna was presented, providing a full description and a detailed interpretation of the data obtained. Unfortunately, the report contains serious errors with the pollen diagram, the stratigraphy and its relative depth was reported incorrectly (Eisner and Kamermans, 2004, p. 1). In addition, the first two Pleistocene levels were not even described. It was not until 2004, over twenty years after the extraction of the core, that a final revised report of the Mezzaluna Core was published (Eisner and Kamermans, 2004), and it is from this paper that the following information has been obtained.

The stratigraphic sequence of Mezzaluna appears as a continuous sediment of great environmental interest, especially in the chronological range of 16–4 ka BP. The Pleistocene stratigraphic levels A and B, on the other hand, are rather detached and are therefore difficult to interpret. Zone A is dominated by Gramineae, Cyperaceae, *Artemisia* and Chenopodiaceae which make up more than 80% of the sample. Tree pollen is represented mainly by *Quercus* and *Pinus*, with small percentages of *Fagus*, *Ulmus*, *Fraxinus*, *Picea*, *Pistacia*, *Betula* and *Juniperus*. From this layer there was also a high percentage of pollen from fresh water plants such as *Myriophyllum* and *Alnus*. The pollen assemblage, therefore, characterises a regional environment of a freshwater lake with a landscape of dry herb steppe and mesic woodland dominating the surrounding area. The highest proportions of *Quercus* and *Pinus* are well suited to the framework provided. However, the small percentages of *Fagus* and *Ulmus* require a more humid environment, especially the latter, and could be indications of a different habitat within the region. For this level radiocarbon dates of c. 34650±950 BP were obtained but in the final report this dating was identified as problematic due to the low concentrations of carbon in the sample (Eisner and Kamermans, 2004, p. 5;7). Zone B, a sandy layer in which pollen assemblages were absent, was considered of possible marine formation in the first publication of results due to the presence of Hystrichosphaeridae. Nevertheless, Kamermans (1991) and Sevink et al. (1991) afterwards demonstrated that a marine regression phase did not occur. This layer may therefore alternatively be the result of a massive erosion subsequent to the first draining of the lake, which occurred at some time between 35–16 ka BP. Similar problems have been encountered by other authors during the study of Pleniglacial sediments from other regional volcanic lakes (Magri, 1999; Magri and Sadori, 1999, p. 256), suggesting that this problem could be a response to a specific event which affected a much wider distribution area of the Pontine Plain.

In summary, this analysis cannot be considered reliable as a comparable dataset. However, the existence of a lake during the Pleniglacial and persistence of mesic species during this period of the Late Pleistocene indicate the presence of a mild environment.

Looking outside the Pontine Plain it has been possible to identify at least five sites that have produced pollen analyses involving the Late Pleistocene period of relevance to our site (Fig. 3.2). These are lakes or dried up lakes in volcanic complexes, studied mainly over the last twenty years. From north to south the sites presented here are: Lagaccione in the volcanic district of Vulsini (42°33'49.0"N 11°51'19.8"E) (Magri, 1999), Lago di Vico in the volcanic Vico-Cimini district (42°18'49.1"N 12°10'36.9"E) (Magri and Sadori, 1999), Stracciacappa in the volcanic district of Sabatini (42°07'49.9"N 12°19'21.9"E) (Giardini, 1993, 2007), Valle di Baccano in the same above district (42°07'00.2"N 12°21'13.6"E) (Ciuffarella, 1996), Valle di Castiglione in the volcanic district of Colli Albani (41°53'32.7"N 12°42'44.0"E) (Follieri, Magri and Sadori, 1988, 1989) and Lago Grande di Monticchio (40°55'52.0"N 15°36'19.4"E) (Watts, Allen and Huntley, 1996, 2000; Allen, Watts and Huntley, 2000). In addition to these there are other volcanic lakes from which core samples were extracted, such as Lago di Monterosi (42°12'21.8"N 12°18'06.9"E) (Bonatti, 1970), Lago di Nemi (41°42'43.7"N 12°42'12.8"E) (Lowe *et al.*, 1996) and Lago di Martignano (42°06'45.2"N 12°18'52.0"E) (Kelly and Huntley, 1991). These, however, have Holocene chronologies and will therefore not be discussed below. Similarly, Lago di Mezzano (42°36'43.2"N 11°46'15.1"E) will also be excluded despite containing core sediments dated up to 34 ka BP (Ramrath, Nowaczyk and Negendank, 1999) as the pollen sequence has been studied only up to the Bronze Age so far (Sadori *et al.*, 2004). Although these sites are located close to each other and are all within volcanic environmental contexts, correlating them is not simple due to the variation in local sedimentation processes. In fact, the complex sedimentation of glacial periods is a factor which concerns all Italian volcanic lakes. A series of geological processes such as emersions, pedogenesis, erosions and collapses related to climatic fluctuation and Pleistocene tectonic instability characteristic of these volcanic areas has indeed heavily influenced the formation of local geological sediments (Magri and Sadori, 1999, p. 256). Despite these challenges, the sequences obtained from the five sites appear to demonstrate a good degree of correlation. Consequently, they serve to present a common environmental framework which should reflect regional climatic patterns, useful to later contextualise the reconstruction of CM. Moreover, whilst only the information referring to the period known as Würm III is taken into account here, these cores represent far more extensive chronologies. The core of Castiglione covers more than 250 ka years, Stracciacappa the last 60 ka years, Lagaccione around 100 ka years and Lago di Vico 90 ka years. The environmental situation highlighted by these sites is extremely complex and characterised by a large number of arboreal oscillations that, for the particular regional frequency, have been grouped into the so-called "Lazio Complex" (Follieri *et al.*, 1998). These fluctuations may reflect changes in vegetation related to the climatic oscillations of MIS 3.

The last ice age of Latium is characterised by alternating steppe and grassland environments and a dominance of *Artemisia*, *Gramineae* (or *Poaceae*) and *Chenopodiaceae* (now included within the family of the *Amaranthaceae*). Brief periods of trees see a dominance of *Pinus* and *Juniper*, with percentages of pollen reaching 60%, especially between 35–30 ka BP, millennia in which are located the last three oscillations of Lazio Complex. Other tree species worth mentioning include the *Picea* which, although variable as a percentage, is always present to some extent in all of the sites. *Quercus*, *Corylus* and *Ulmus* are also always present in the arboreal fluctuations, of which *Quercus* yields the highest percentages. The percentage level of *Fagus*, however, varies considerably from site to site, indicating a high sensitivity of the species even with minimal environmental differences. In general, the flora of Latium shows an alternation of major forested and steppe periods. This seems to align relatively well with the sequences collected in the rest of Europe, however there appear to be minor fluctuations. This highlights a greater regional climatic sensitivity and frequent variation in vegetation, despite there being no significant changes demonstrated across the rest of Europe in those periods. For this reason, a more detailed correlation between the sequences from central Italy and for the rest of Europe does not seem possible. A further difficulty is also dictated by the pollen record of central and northern Europe, often intermittent or incomplete due to the ice that covered the territory in colder glacial phases. Moreover, Latium is located on the border between the Mediterranean and the temperate zone, meaning it is possible to find elements belonging to both floras, escalating an already complex environmental situation.

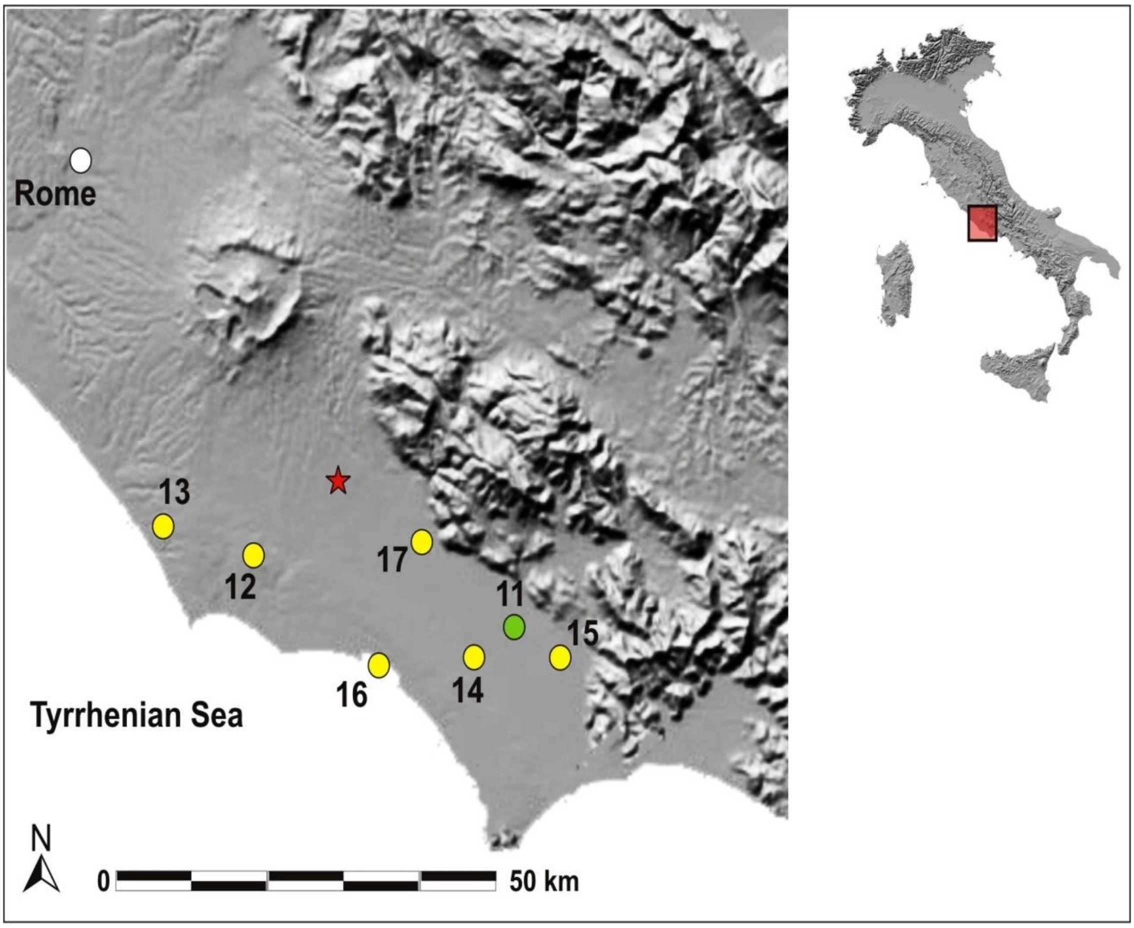


Fig. 3.1 Location of the main cores in the Pontine Plain: Yellow – Cores without MIS 3 sediments; Green – Cores with MIS 3 sediments; Red star – Cava Muracci site.

11- Mezzaluna; 12- Campoverde; 13- Colle San Lorenzo; 14- Via Migliaria 47; 15- Laghi di Vescovo; 16- Lago di Fogliano; 17- Monticchio.

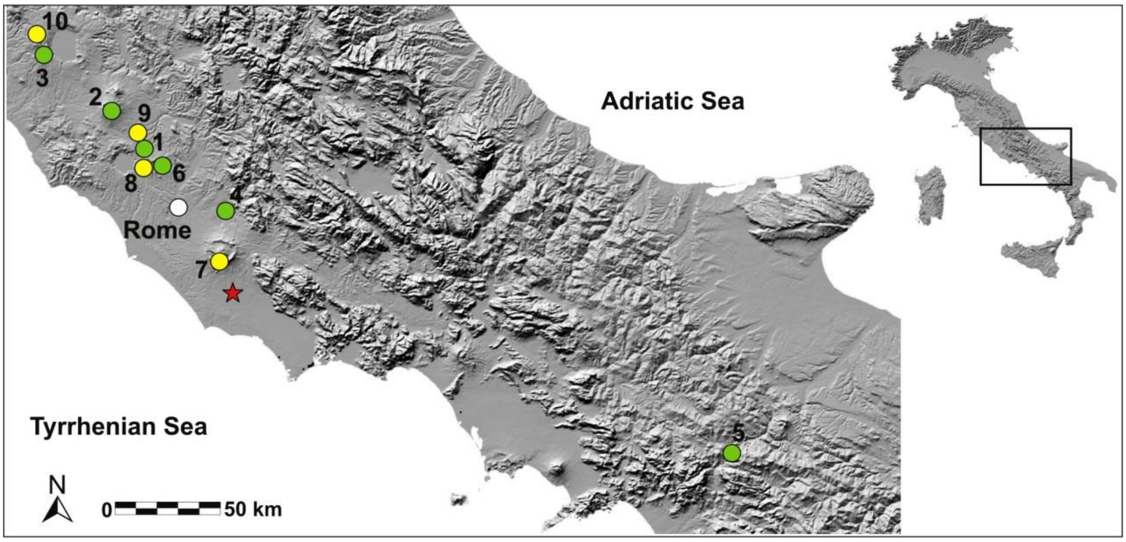


Fig. 3.2 Location of main cores in Central Italy: Yellow – Cores without MIS 3 sediments; Green – Cores with MIS 3 sediments; Red star – Cava Muracci site.

1- Stracciacappa; 2- Lago di Vico; 3- Lagaccione; 4- Valle di Castiglione; 5- Lago Grande di Monticchio; 6- Valle di Baccano; 7- Lago di Nemi; 8- Lago di Martignano; 9- Lago di Monterosi; 10- Lago di Mezzano

3.2 The archaeozoological studies of the regional fauna

The history of archaeozoological studies in the Pontine Plain region is extremely interesting and complex. As a general principle, faunal assemblages of the area do not differ from the many findings in the rest of the region. Nevertheless, their chronological assignment in the coastal area is more complicated. Essentially two types of Upper Pleistocene deposits are attested, in caves and open air. The latter type can be reduced to the fauna of Canale delle Acque Alte only, as in the present state of research there are no other open air deposits with faunas from MIS 3, although deposits with fauna from the Middle Pleistocene are abundant. The limited presence or complete absence of faunal deposits in the territory has often been the subject of debate among scholars. This phenomenon, also evidenced in various other areas and sub-regions of the world, is currently attributed to the destructive role of the volcanic soil which is particularly acidic in the Latium region (see Chapter II).

This unique collection of fauna has therefore been interpreted differently by various authors, whose discordant chronological assignments make it difficult to reach an exact classification. Behind these different opinions, there is on the one hand the human factor, with the fortuitous discovery of the deposit in the first half of last century that led to the subsequent excavation and collection of material without specific stratigraphic references. On the other hand, the previously discussed climatic complexity of Latium has an equally influential effect. Canale delle Acque Alte was excavated in 1935 by Alberto Carlo Blanc and published in numerous studies, hailed for providing a large number of finds and the first, and still most complete, Late Pleistocene open air stratigraphic sequence for the Pontine Plain (Blanc, 1935a, 1935b, 1935c, 1936). Despite the recognition of a detailed stratigraphy, only a handful of the c. 500 finds collected were recorded according to the layer in which they were found. The majority were instead generically labelled as "Canale Mussolini". This, unfortunately, resulted in the loss of a large amount of information, especially chronological, which has caused further difficulties in the recent reviews of the artefacts, now preserved at the Museum of Natural History and the University of Pisa. Nevertheless, the abundance of species found and recent attempts to reassign the finds to their layers through the observation of taphonomic conditions has allowed a tentative reconstruction of the environment and chronology (Farina, 2006, 2011). The stratigraphy covers an uninterrupted period from the end of MIS 5a to MIS 3, has a vacuum throughout the Last Glacial Maximum (MIS 2) and then presents new Holocene fossils layers. The lack of deposit related solely to the MIS 2 presents interesting questions worthy of further study.

However, layer B encapsulates the end of MIS 3 and is of great interest because contains fauna from cold steppe periods which are nevertheless warmer than the previous MIS 4. This confirms that the period of population by Neanderthals and Early Modern Humans in the Pontine Plain saw ideal, mild environmental conditions for the survival of a wide range of fauna, as already suggested by the regional pollen information, and will be discussed in the chapters on palaeoecological and faunal studies (see Chapters VI and VII).

The cave deposits come from four sites in Monte Circeo: Grotta Guattari, Grotta Breuil, Grotta Barbara and Grotta del Fossellone, and two a little further south in the Fondi Plain, Grotta Sant'Agostino and Grotta dei Moscerini. Although all of these sites were discovered and often investigated for the first time during the middle of last century, more detailed studies of animal remains have been realised only in the last decade of the last century (Bietti *et al.*, 1988; Caloi and Palombo, 1989b; Kotsakis, 1991; Mussi and Zampetti, 1991; Stiner, 1991e, 1994). These sites cover a wide timeline between 120 ka BP (Grotta dei Moscerini) and 10 ka BP (Grotta del Fossellone) but have all yielded abundant material accumulated both by humans and carnivores, especially cave hyena and wolf. In addition to providing interesting information on the eating habits of these species, it was possible to reconstruct the surrounding environment through the knowledge of the typical species' habitats. However, these layers suffer from an important preliminary filter as the assemblage is based on the preference of carnivores/humans for a particular food source. This may strongly bias the correct interpretation of the context and it should, therefore, be considered with caution. On the other hand, it is necessary to emphasise that the fauna of the various stratigraphic levels of these caves seems to accurately reflect the various climatic oscillations of MIS 3 which occurred between 55–30 ka BP (Caloi and Palombo, 1992).

In conclusion, whilst the fauna of the Pontine Plain have been thoroughly studied, it is extremely difficult to assign these collections to certain chronologies without the support of additional information such as dating or stone tools. The main difficulty is presented by the relative uniformity of wildlife throughout most of the MIS 3–2, stages during which the influence of local factors has kept the climate and the environment relatively stable. This stability has prevented the alternation of fauna typical of extreme environments, giving rise to a simultaneous exploitation of the region by both warm and cold fauna. In addition, the lack of deposits with long stratigraphic sequences is problematic, hindering the identification of changes and evolution of the fauna. Whilst the sequences from the caves of Monte Circeo are fairly long they are subject to the selective factors of the humans and carnivores which inhabited the shelters. Canale delle Acque Alte, the only natural open air deposit of the entire region with a complete stratigraphic sequence, was excavated nearly a century ago and neglects valuable information. Other collections have been extensively studied in recent decades with poor results, therefore, only the discovery of new deposits would provide essential new information to fill this gap of knowledge.

In general, the faunal data collected so far seems to confirm the climatological information already known for the Late Pleistocene of Latium. The short and frequent investigated fluctuations were never strong enough to trigger sudden changes of fauna, and the environmental and geographic features of the area did not allow the establishment of selective climates (Caloi and Palombo, 1992).

3.3 The lithic technology of Tyrrhenian Latium

As stated, the first collections and studies of the lithic industry of the western region of Latium began in the mid-19th century and continued, on and off, to the present day. Whilst these collections have allowed the accumulation of thousands of elements and careful typological studies, they have also impeded the interpretation of the context of recovery. Two local technological cultures are evidenced, the Pontinian corresponding to the European Mousterian and the Circeiano, corresponding to the Aurignacian, now called the Latial Aurignacian.

The Mousterian is well distributed in the Italian peninsula, with both open-air and cave sites from altitudes above 2000 m down to sea level. Indeed, it is precisely at the coastline along the Tyrrhenian side of the peninsula that Middle Palaeolithic sites are most densely concentrated. According to the interpretative model proposed by A. Palma Di Cesnola (2001, p.183), the Middle Palaeolithic in Italy and in particular the Mousterian "*seems to have created on Italian territory a sort of mosaic landscape. Indeed, to our knowledge on the basis of the data in our possession so far, each Mousterian complex would follow, in the different areas of the peninsula, its own evolutionary path, [. . .] And would have stably retained its territory, without sharing it with other complexes.*"

In accordance with this theory, the Pontinian would not be an autonomous culture but represent a specialised adaptation of a Mousterian facies that arrived in central Italy, utilising the raw material of pebbles available in the coastal zone (Tozzi, 1970, p. 83). Professor Alberto Carlo Blanc first coined the “Pontinian” term in 1939, together with the term "Coastal Mousterian", to describe those artefacts initially found in the caves of Monte Circeo and subsequently across the surrounding area. The term has since been adopted to indicate this particular complex. This phenomenon was initially ascribed geographically to the coastal plain bounded on the north by the river Tiber and to the south from the territory of Gaeta. However recent systematic surface collections have facilitated a more precise geographical constraint. The research carried out in the Alban Hills area has extended the limits of the Pontinian phenomenon outside the Pontine area itself, with lithics found along the northern slope of the caldera Albana (D’Ambrosio *et al.*, 2010). Chronologically, this raw material processing technique was developed by Neanderthals in a time span ranging between 100–35 ka ago. The main feature of this technology is the use of siliceous pebbles, fractured by bipolar percussion to produce various elements with the form of a "slice of tangerine", and retouched to form the necessary corticated flake tools (or caps). Because of the size of the raw material, all the products of this industry are very small compared to contemporaneous European Mousterian products, with an average size of about 3 cm. Size has played a key role in identifying the typology, allowing easier production of simple, transverse and nosed side scrapers of any kind. These represent on average 70% of the total implements found across the sites. For the same reason, the points are extremely scarce. During the Mousterian, the transportation of raw material from long distances is not documented in the Pontine Plain. Neanderthals of Latium appear to have preferred to adapt to their immediate environment, developing a different manufacturing technique using local stone rather than travelling long distances to collect better flint. Essentially, the distinctive features of this culture are the result of the adaptation of production techniques that were typical of Middle Palaeolithic, applied instead to raw material not ideal for those same techniques (Bietti, 1991).

During the different stages of the Palaeolithic various populations have used pebbles to manufacture necessary tools. However the Pontinian culture, apart from simple size similarities with these other assemblages, has always been highlighted because of its different techniques and types of tools. The best example is the subsequent Aurignacian lithic technology of the Pontine Plain, which, despite the use of the same raw materials has clearly led to the convergence of several characteristics, is a clearly distinct facies and no evolutionary relationship with previous Pontinian can be attributed.

In addition to Blanc, who made a first cultural, spatial and chronological definition, other scholars have played a key role in the study of the Pontinian. Following the death of Blanc, a typological and technological definition of this culture was made by Taschini based on pieces from Grotta Guattari and the nearby Grotta Breuil (1970; 1979). This initiated the interpretative debate, which saw, on the one hand, the Pontinian described as an autonomous culture (Piperno and Biddittu, 1978) and on the other those who interpreted it as an adaptation of the European Mousterian (Tozzi, 1970; Taschini, 1972). In the 1980s new studies of these industries were carried out by Bietti (Bietti, 1981, 1989; Bietti and Grimaldi, 1993), which highlighted not only new typological information but opened the quest for understanding the cultural and behavioural aspects. Finally, in the 1990s Kuhn dedicated an entire monograph to the analysis of the Mousterian industries of Latium, with a particular interest in the palaeoecological implications (1995). The recent 2000s have seen a renewed interest to search for Pontinian sites, especially open air locations, which during seventy years of surveys (Fig. 3.3) have exponentially grown in number, now totalling eighty-three (Fig. 3.4) (Gatta, Achino, *et al.*, 2016). Of primary importance in future research will be the attempt to answer some questions of great relevance, such as whether the sites can be defined as primary living sites or production locations of stone tools. Moreover, their chronological intervals, absolutely undetectable for this industry if taken out of their original context, can be established. A further question is raised in terms of defining the relationship which connects the open sites with caves. This extraordinary number of sites situated within a clearly defined region, characterised by an environment with geographical features that offer very different ecosystems suitable for diverse methods of subsistence of the Neanderthal population, is a framework unique in Italy. This is a quality that other scholars have already recognised in this area: “The Pontine Plain presents a relatively unique context for the study of distributional patterns in Palaeolithic surface archaeological remains… the Palaeolithic surface archaeology is relatively intact compared with other parts of Europe.” (Kuhn, 1990, p. 67).

The situation differs with the arrival of the Protoaurignacian in Italy 40 ka BP. It is attested to by between thirty (Mussi, 2001a) and forty-five sites (Chilardi *et al.*, 1996). These are distributed across Italy, both in the open plains and in caves in the mountains. Latium itself is host to the coastal sites of Grotta del Fossellone and Grotta Barbara. As demonstrated in the previous Mousterian phase, most of the lithic industry is manufactured from small sea pebbles of good quality, rarely exceeding 6 cm in length. It is highly likely that many Aurignacian sites, established during the marine regression, are now lost below the water level.

In this cultural facies nosed and carinated end scrapers predominate, with 900 out of a total of 1,400 instruments identified as such at the Grotta del Fossellone (Blanc and Segre, 1953). However, notches, burins, denticulates and Aurignacian blades are also common. The small size of the pebbles used in the Pontinian has encouraged a bipolar technique of percussion, with retouching and processing based on the removal of small blades. Bone tools are also associated with the Aurignacian, although these will not be discussed in this thesis. Although these pebbles are not an obvious first choice as a raw material due to their small size, and in fact imported stone is documented for tool use throughout the stages of the Upper Palaeolithic, it is interesting that the discovery of nosed end scrapers made from marine pebbles in sites of the hinterland (Biddittu and Segre, 1977) documents a displacement of at least 50 km for the procurement of this raw material. This may indicate that, during regional shifts, the early *Homo sapiens* were choosing to transport small amounts of these pebbles into areas where alternative raw materials were present. In conclusion, whilst the type of raw material obligates the maintenance of the same Pontinian technique of percussion and consequently the production of tools on fully or semi-corticated flint, the first lithics produced by *Homo sapiens* shows a transition to both more complex instruments and a greater degree of efficiency. The sharp decline in the number of sites located in the territory during this final phase of the Palaeolithic, potentially caused by marine regression, remains as yet insufficiently explained.

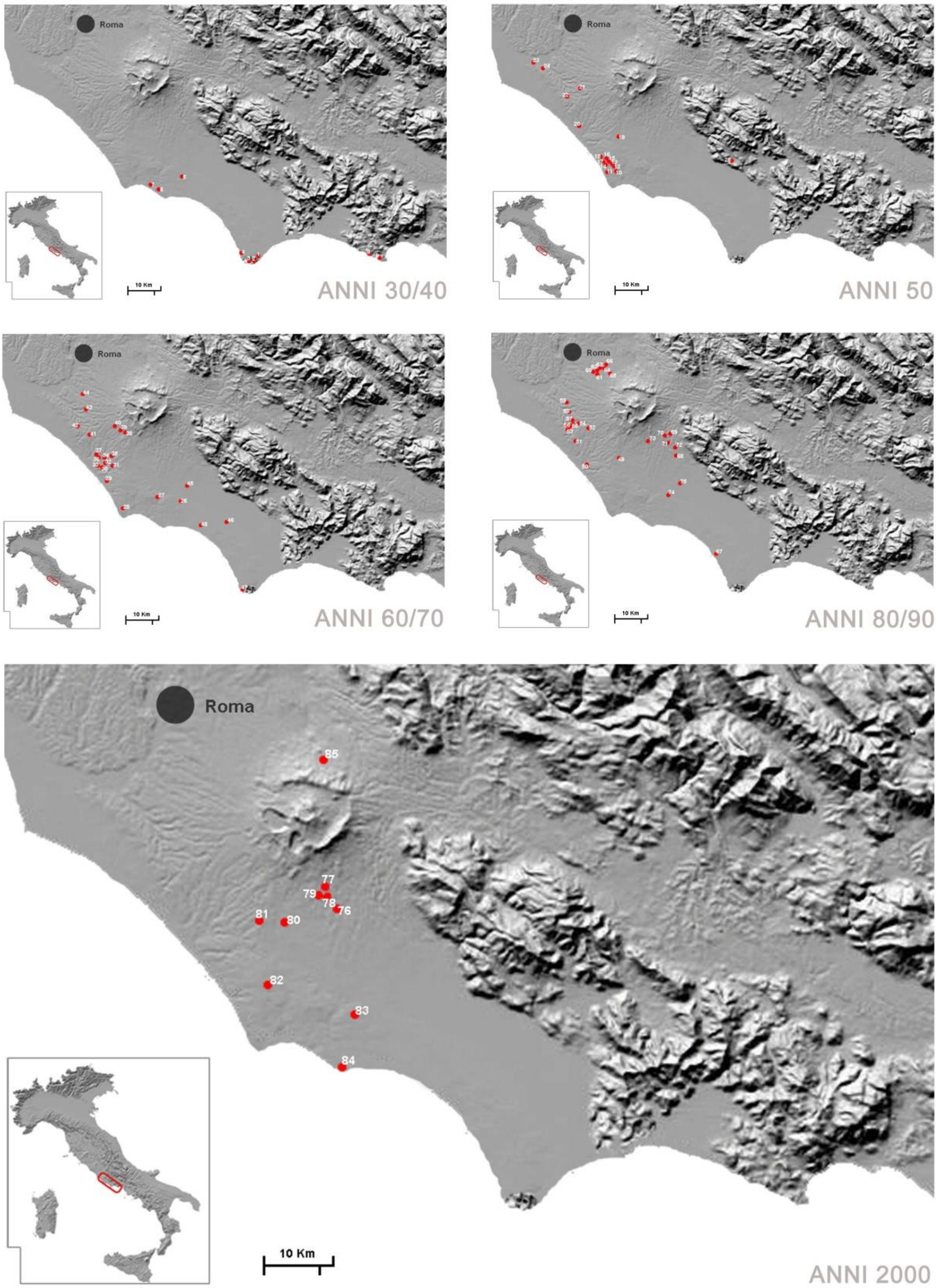


Fig. 3.3 Timeline of the Pontinian archaeological discoveries in coastal Latium (From Rolfo & Aureli 2012).

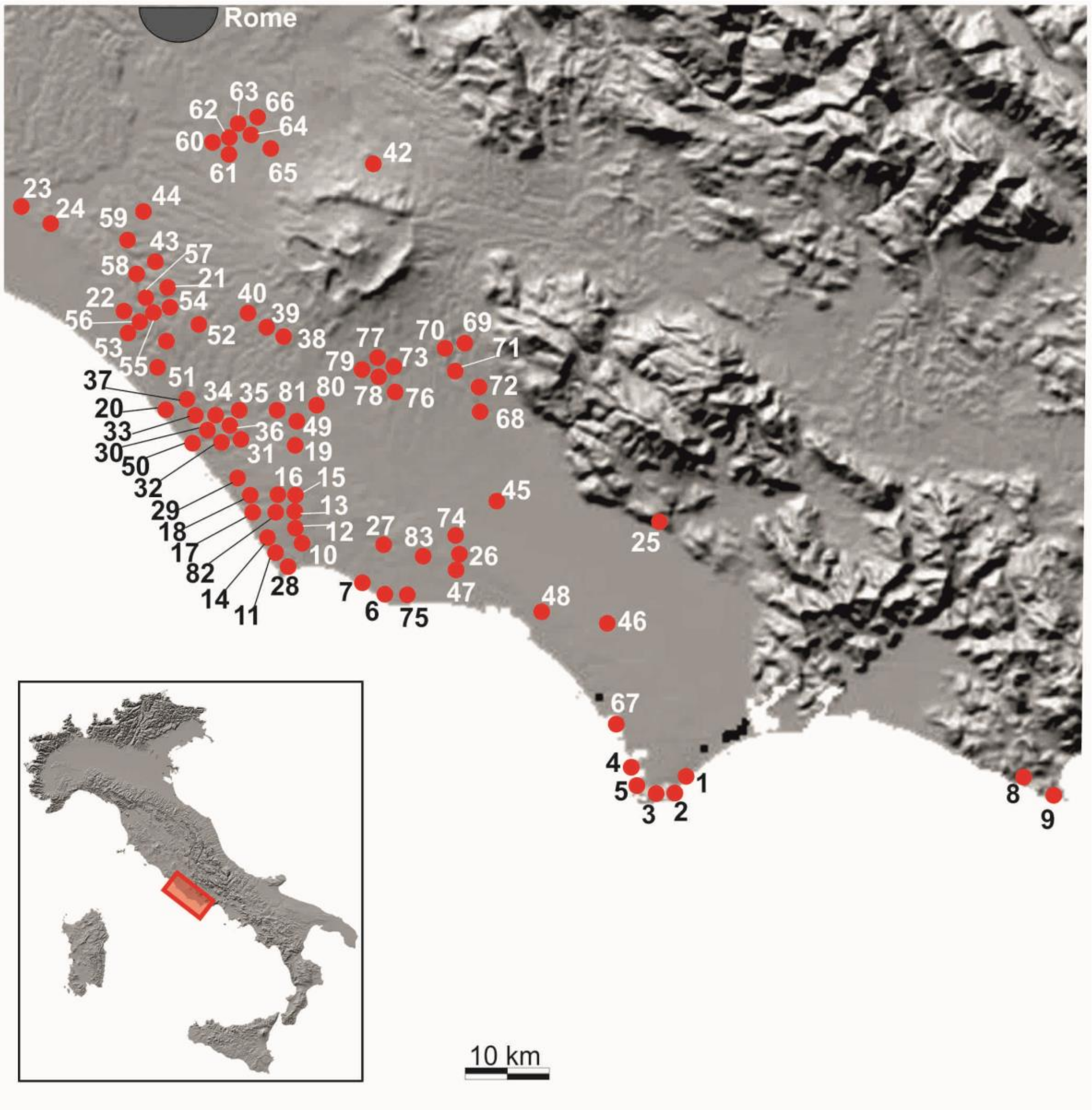


Fig. 3.4 Geographical distribution of the Middle Palaeolithic Pontinian sites known at present. From Gatta, Achino, et al., 2016, updated after Rolfo & Aureli 2012.

1. Grotta Guattari; 2. Grotta delle Capre; 3. Grotta del Fossellone; 4. Grotta Breuil; 5. Grotta Barbara; 6. Vallone Carnevale; 7. S. Rocco – Foglino; 8. Moscerini; 9. S. Agostino; 10. Ris. Abbruciati; 11. Tor Caldara; 12. Pantano – Riserva S. Olivo; 13. Valle dello Schiavo; 14. Stazione di Nardo; 15. Torre S. Anastasia; 16. Km. 9 – Valle Maggio; 17. Km 10,500; 18. Fosso Secco; 19. Carroceto – Carrocetello; 20. Campo Iemini; 21. Monte Migliore; 22. Podere Carafa 1-2; 23. Acilia Castel Porziano – Tre Confini; 24. Ficana; 25. Grotta della Cava; 26. B.go S. Maria; 27. Bosco di Nettuno; 28. Fornace Paiella; 29. Nuova California; 30. Valle del Serpentario (1-2) – Capanna Cesavero; 31. Acquasolfa – Fossignano – Rimessone; 32. Vallegrande; 33. Fosso Grande; 34. Ardea; 35. Casalazzara; 36. Cava di Pietra – Nuova Florida; 37. Loc. Piangimino – Campo Sportivo – Cava bosco; 38. Montagnano; 39. Valle Caia – Quarto Montagnello; 40. S. Palomba; 41. Petronella; 42. Colonna; 43. Mandriola; 44. Tenuta Acquacetosa; 45. Borgo Pogdora 1-2; 46. Portosello; 47. Gnif Gnaf; 48. Colle Parito; 49. Casale Pazienti; 50. La Fossa; 51. Pratica di Mare; 52. Zolforata; 53. Quartaccio; 54. Fosso di Leva; 55. Quarto del Cuore; 56. Il Frasso; 57. I Quaranta Rubbii; 58. Monti della Caccia; 59. Tenuta della Perna; 60. Roma Vecchia; 61. Fattoria di Donna Lucrezia; 62. Torre Spaccata; 63. Via del Fosso di S. Maura; 64. Orti Poli; 65. Unità Anagnina; 66. Fattoria Due Torri; 67. S. Andrea; 68. Via di Cori; 69. Lupacchiotti – Malatesta; 70. Colle Ercole; 71. Castel Ginetti; 72. Torrecchia Nuova; 73. Centocolonne; 74. Podere 797; 75. Torre Astura; 76. Lazzaria; 77. Colli di Cicerone; 78. Via di Vigne Nuove; 79. La Parata; 80. Federici; 81. Campo Leone – Casale Arganini; 82. Colle Rotondo; 83. Piano Rosso;

3.4 Conclusions

The Pontine Plain has seen numerous excavations and surveys concerned with prehistory, mainly due to the extraordinarily high presence of evidence from this period, among the highest in the whole of Italy. The interest of scholars such as Blanc, as well as the intrigue created by the discovery of the famous skull at Grotta Guattari, also fuelled investigations. However, this led to the compulsive excavation of a myriad of sites, with thousands of artefacts collected but only studied and published many years later. Now divided among museums, institutions, “Soprintendenza per i beni culturali” stores and private collectors, many of these finds are hard to trace (Rolfo *et al.*, 2013). Another clear issue is the contrast between excavation standards, with past excavations utilising often significantly different procedures from those of today (Rigaud and Simek, 1987). For example, documentation was certainly less meticulous, with no plans of artefact deposition and only a brief note of the area, trench or geological level from which an artefact came (Stiner, 1994, p. 11; Kuhn, 1995, p. 79). Moreover, it is a known fact that post-excavation processes in the past selected only the "best" pieces to preserve. However, after conducting meticulous screening techniques on the materials collected in the most recent excavation of the Grotta Breuil, no distinct differences could be found in the percentage of tools present in each collection. The only minor difference is a drop in the number of pieces smaller than 1 cm, suggesting that sieves of a larger mesh were used in the past but not suggesting any processes of selection (Kuhn, 1995, p. 79).

As Stiner points out, even present excavations will appear deficient in the future; as advancement is a continuous process only the most meticulous studies available at the time can be applied. Obviously, it makes no sense to suspend the archaeological excavations waiting for a methodological perfection that will never come. The only way to overcome this problem is then to perform work as meticulously as possible, in this case create a documentation of the excavation so as to facilitate future re-study.

Considering the relevant environmental studies, there is only one reliable sequence from the Pontine Plain which contains the chronologies applicable to CM. Fortunately, generic environmental information can be deduced from pollen sequences sourced from greater distances in order to supplement this deficit, creating a good timeline within which the data retrieved from the analysis of the coprolites from CM can be inserted and compared. From a critical point of view, it should be emphasised how the absence of palynological studies of the last ice age in a territory rich in archaeological remains such as the coastal Latium is a big gap in the knowledge and interpretation of territory. On the other hand, the sequence obtained at CM will offer a new and indispensable contribution to the environmental reconstruction, at least partially filling this current gap.

The numerous and intensive studies of the faunal remains have demonstrated that in the Pontine Plain, since the beginning of the Last Pleniglacial, the animal species that frequented the area remained relatively stable, surviving the various climatic oscillations. These faunal groups have formed the basis of an environmental reconstruction in accordance with the information obtained from the palynological studies made elsewhere in Latium. Although it must be emphasised that there is a significant shortage of natural fossil deposits, hindering these studies with the selection bias of predators, mostly humans and cave hyenas.

The study of the only open air site, Canale delle Acque Alte, provided interesting environmental information and presented an extremely interesting database. The stratigraphic studies have shown that in an exceptionally complete sequence it is entirely missing a level estimated to belong to the MIS 2. This absence could be due to many taphonomic factors or the original formation of the layer, but that assumes extremely interesting aspects when compared with the palynological data of the Mezzaluna core, where this layer was always difficult to interpret. It is possible that these two pieces of information are not random and that the region during this phase presented specific climatic or environmental conditions which influenced the formation of the stratigraphic and archaeological record.

The lithic technology present in the area during both the Middle and Upper Palaeolithic has been identified as a particular local adaptation to the European Mousterian and Aurignacian cultures. The Pontinian (i.e. the local Mousterian) and the Circeiano (i.e. the local Aurignacian) show similarities in the exploitation of raw materials by groups of Neanderthals and *H. Sapiens* as well. Nevertheless, the more recent industries seem to demonstrate much more complex processing and, for the first time, reveal the practice of importing and exporting raw materials covering a radius of about 50 km. Some key questions relating to the frequency of coastal sites, much higher in the Mousterian, remain unanswered, with the as yet unconfirmed hypothesis that Aurignacian coastal sites have been lost due to marine transgression.

Chapter IV

Materials and Methods

This chapter deals with various key topics for a multidisciplinary archaeological study, i.e. materials and methods used to perform the analyses, including dating that in this study has provided various issues.

A chronological reference is essential to ensure that any archaeological evidence or discovery does not remain suspended in an indefinite time scale and lose its significance. Despite modern methods of dating, establishing a chronological reference for the site of Cava Muracci (hereinafter CM) has been one of the most difficult issues to address. Several dating attempts were made with three different methods (standard ^{14}C, Ultra-filtration ^{14}C and U-Series). However the results were not always consistent with the chronological time-span suggested by lithic industry and faunal remains collected. This section explores the difficulties encountered in this research and shows how some methods or dating of specific samples (i.e. coprolites) can easily fail and be extremely misleading in some archaeological contexts. However, a reliable assignment to the Late Pleistocene, perfectly compatible with the archaeological remains found, has been possible through standard ^{14}C dating, although numerous attempts have been necessary due to the absence of collagen caused by fossilisation of the finds.

Materials and methods that have been used in this PhD thesis to analyse the archaeological finds are discussed in the second part of the chapter. Its purpose, rather than proving such methods fully successful, is to provide enough information to the scientific community to replicate or verify their efficacy. The results of the analysis described here will be discussed in the following chapters.

4.1 Dating: methods and issues encountered

The dating of a site is crucial for its proper interpretation. However, the dating of Late Pleistocene archaeological sites is a challenge, since even small amounts of modern contamination may cause major errors in the results. An incorrect chronological reference can turn an important archaeological discovery into a scientific falsehood. In the worst case it can misleadingly feed a theory and place under discussion its own integrity. The concept of *refugium* is a topic that has been highly affected by this. Many sites have been defined as a refuge for the last Neanderthal, especially in Spain, only to be reconsidered in light of new thorough dating (Vaquero *et al.*, 2002; Wood *et al.*, 2012). For this reason, unquestionable dating was a major priority of this thesis.

CM, as briefly mentioned (see section 2.3), is reliably attributed to a period of the Late Pleistocene approximately ranging between 44–34 ka cal BP (see Tab 4.1) (Gatta, Sinopoli, *et al.*, 2016). This chronological assignment was made possible by dating three animal bones at the Centro di Datazione e Diagnostica (CEDAD) of the Università del Salento. The samples were tested for dating with the radiocarbon method by means of the high-resolution mass spectrometry technique (AMS). The macro-contaminants found in the samples were identified by observation under an optical microscope and removed mechanically. An acid-alkaline-acid chemical attack assured the removal of contamination. The extracted material was subsequently converted into carbon dioxide by acidification and then into graphite by reduction. H_2 has been used as a reducing agent and iron powder as catalyst. The amount of graphite extracted from samples was sufficient for the accurate experimental determination of age. The concentration of radiocarbon was determined by comparing the measured ^{12}C, ^{13}C and ^{14}C counts with comparative values obtained from standard samples of C6 Saccharose provided by the IAEA (International Atomic Energy Agency). The radiocarbon dating was corrected for the effects of isotopic fractionation through the measurement of $\delta^{13}C$.

Samples of oxalic acid of known concentration provided by NIST (National Institute of Standard and Technology) have been used to check the quality of the results. The determination of the experimental error in the radiocarbon dating has been established taking into account the scatter of data around the average value and the statistical error arising from the ^{14}C count. The uncalibrated and calibrated radiocarbon dating for the samples with the indication of the absolute error of the dating is shown in Table 4.1.

The achievement of a chronological reference, however, has been far from easy. Various attempts using different techniques were realised within the project. The results proved unreliable on several occasions. Three dating attempts by U-Series yielded dates too recent due to environmental contamination (see section 4.1.1).

Three previous attempts through ^{14}C standard procedure at the laboratories of the Beta Analytic in Miami have been unsuccessful due to lack of collagen. Furthermore, four ^{14}C dates with the application of Ultra Filtration protocol (Brown *et al.*, 1988; Higham, Jacobi and Bronk Ramsey, 2006) have failed for the same reason at the ETH Zürich laboratories. The latter had been attempted to get additional chronological constraints, in light of recent re-dating that the application of this method yielded in other contexts (Higham, Jacobi, *et al.*, 2011; Wood *et al.*, 2012; Jackes, Lubell and Crann, 2015). In Italy, the application of this method has revealed how more than 70% of past ages were incorrectly young at Grotta di Fumane (Higham *et al.*, 2009).

Radiocarbon dating is generally the first technique employed when dating bone. However, this method has a chronological limit of about 45 ka, beyond which it cannot obtain reliable results, although the application of ultrafiltration pre-treatment makes it possible to overcome some problems of contamination and to extend the limit of the method to about 50–60 ka (Higham, Jacobi and Bronk Ramsey, 2006; Jacobi, Higham and Bronk Ramsey, 2006).

The use of ultrafiltration, an improvement on Longin's bone pre-treatment method (1971), is a protocol useful to identify the original collagen of bones, separating low-weight molecules and altered proteins which are more likely contaminant (Hedges and Law, 1989; Hajdas *et al.*, 2009; Minami *et al.*, 2013). It allows a purification of the collagen gelatine in the bones and can be used to obtain accurate ^{14}C dates (Minami *et al.*, 2013). This technique highlights its importance especially for remains with chronologies near or beyond the limit of the radiocarbon method (Higham, Jacobi and Bronk Ramsey, 2006; Hajdas *et al.*, 2009; Talamo and Richards, 2011), where the presence of well-preserved organic matter is rare. Unfortunately, this pre-treatment can result in significant loss of carbon, and therefore also in the yield of collagen, especially in poorly preserved fossils (Minami, Muto and Nakamura, 2004; Fulop *et al.*, 2013), such as those of CM, or introduce new contaminants (Bronk Ramsey *et al.*, 2004; Brock, Bronk Ramsey and Higham, 2007; Huls, Grootes and Nadeau, 2007, 2009; Santos *et al.*, 2010). The problem of collagen degradation in mineralised samples is addressed in section 4.1.1.

Finally, two radiocarbon dates were obtained from two coprolites at the ETH Zürich laboratories. Unfortunately, these were found to be invalid due to contamination by modern carbon and therefore not taken into account for the dating of the site (see section 4.1.2). The dating of coprolites is often a poor choice, as these are particularly prone to contamination (Bon *et al.*, 2012; Diedrich, 2012c, p. 372). In this case the attempt was justified by the aim to obtain a direct dating for the samples on which subsequent pollen analysis has been carried out.

Table 4.1
Results of AMS radiocarbon dating from Cava Muracci.

Sample	**Laboratory No.**	**14C age yr BP**	**Calibrated age yr BP***
Bos primigenius bone	LTL15758A	39417±450	44054–42523
Cervus elaphus bone	LTL15759A	35231±350	40658–38945
S. hemitoechus tooth	LTL15760A	36885±350	42054–40804
Crocuta crocuta sp. bone	ETH-66210	31339±168	35638–34810
Coprolite	ETH-66212	16141±42	19640–19292
Coprolite	ETH-66213	18313±51	22378–21952

*OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal13 atmospheric curve (Reimer et al 2013)

4.1.1 Bone diagenesis in karst environments: Radiocarbon and U-series

Obtaining reliable dating is not always possible. This section shows the difficulties experienced in the context of CM. Karst environments involve specific natural bone diagenesis. The following overview is a summary meant to explain how and why this happens, but will not address the intricate chemical perspective that would be more appropriate in a geo-chemical thesis. For a chemical approach to the discussion please refer to the numerous references in the following text.

The physical-chemical taphonomic change of bones enables these remains to survive in the archaeological record for millennia and, sometimes, millions of years. The mineral components of skeletons are indeed subject to dissolution and re-crystallization in a wide variety of environmental conditions. Since the bones are largely composed of minerals, their degradation involves the deterioration and progressive dissolution of the bone remains.

Therefore, when fossilised bones are discovered, it means that these have gone through a process of stabilisation during which most of the organic material has been replaced by a mineralogical compound (Grun, 2006). This process enhances the preservation but, on the other hand, it hinders the possibility to obtain the many types of information that the original macromolecular components may have contained. The original amount and/or composition of some of these are a key resource but are subject to deterioration due to the deposition environment during fossilisation (Berna, Matthews and Weiner, 2004). Radiocarbon dating is one of the fundamental instruments affected by bone diagenesis. Bones are the category of remains on which this dating method is performed more frequently, as they are commonly found on archaeological sites and can provide, if preserved, direct chronological reference. Their dating is generally achieved by the extraction of collagen, a prominent and highly repetitive protein of bones (Longin, 1971; Collins *et al.*, 2002).

Bone preservation is related to a large number of taphonomic factors mainly associated with the depositional background and particularly with the geological context, as has already been demonstrated elsewhere (Stiner *et al.*, 2001; Bocherens *et al.*, 2008). The correct interpretation of data obtained from bone remains, such as chronologies, is therefore closely linked to the understanding of the natural setting and how it affects the diagenesis of bone remains. Unfortunately collagen, which in ideal preserving conditions can survive over 100,000 yr (Jones *et al.*, 2001), suffers bone diagenesis that leads it to denature and dissolve (Collins *et al.*, 2002; Higham, Jacobi and Bronk Ramsey, 2006; Lee-Thorp and Sealy, 2008; Dobberstein *et al.*, 2009), making its use for dating impossible. Several factors play an important role in collagen degradation (Collins, Walton and King, 1998). The diagenetic processes in prehistoric caves, in particular, can be harsher than other environments and compromise the interpretation of biomolecular features (Karkanas *et al.*, 1999). It is a long known problem that minerals have an influence on remains within these environments (Martini and Kavalieris, 1978).

Karst environments, such as the one studied in this thesis, often allow excellent morphological preservation of the bones, but also increase the constraints related to collagen preservation. The calcium carbonate, which moulds the limestone walls of caves at CM, is constantly altered, dissolving and percolating in the underlying layer. In this process, the calcite stabilises the pH of the soil (Stiner *et al.*, 2001), reducing the acidity and the consequent bone destruction, simultaneously calcifying deposed bones and their organic content (Karkanas *et al.*, 2000), which results in a loss of collagen. A similar pattern for bone diagenesis in karst contexts has been documented (Bocherens *et al.*, 2008). When collagen is absent or low and insufficient to produce reliable dating, as in the context of CM, other methods may be attempted such as electronic spin resonance (ESR), amino acid racemisation (AAR) and U-series (Grun, 2006). Before being able to obtain the ^{14}C dates, which allowed a final chronological assignment of the site, some of these alternative methods have been used at CM.

U-series has recently become the most used and accurate method among the three aforementioned ones, allowing dates up to about 500 ka for closed systems and over 1 Ma for open systems (Grun, 2006; Grun *et al.*, 2010). It nevertheless has complications. This method is based on measuring disequilibrium in the natural decay of the element uranium. Measuring the progressive uptake of uranium by bones resulting from the deposition and calculating absorption times, the time of deposition can be traced back. For more details on this method please refer to literature (Bourdon *et al.*, 2003; Pike and Pettitt, 2003). This method provides very accurate dating for uranium closed systems such as calcite (calcium carbonate) and, on the rare occasions when layers of this mineral covered cave fossils, it was possible to obtain useful archaeological information. An example from the Pontine Plain comes from the nearby Grotta Guattari where incrustations on some human bones have been dated (Schwarcz, Bietti, *et al.*, 1991). Unfortunately, bones are open systems to uranium (U) migration, a geochemical event not predictable and computable, which means that the bones continue to absorb uranium for long periods after deposition. As a result, fossil bones have high amounts of uranium in comparison with modern bones (Grun *et al.*, 2010; Sambridge, Grun and Eggins, 2012). The uptake may be affected by various factors, thus further analysis may return an incorrect chronology (Sambridge, Grun and Eggins, 2012). For this reason, open systems are usually avoided by geochronologists (Grun, 2006). Many predictive models have been developed in recent decades to obtain reliable dating. Even in these cases, however, the method is still not totally reliable (Pike, Hedges and van Calsteren, 2002; Grun, 2006; Grun *et al.*, 2008; Sambridge, Grun and Eggins, 2012; Hercman, 2014). As a rule, it can be said that if uranium uptake was the dominating geochemical process to act on the bones, as seems to be the case given the higher uranium concentration in fossil bones compared to modern ones, younger dates than the correct age of the bones would be obtained.

The calcium carbonate, which largely constitutes karst caves, besides providing palaeoclimate information, can be a valuable geochronological resource. Stalagmites, calcite and flowstones can return high-resolution dating if uncontaminated. Unfortunately, the calcium carbonate has also an important role in the aforementioned uranium migration in bones, complicating subsequent dating.

This is exactly what happened with the four dates yielded, three in beta spectrometry and one in alpha, from three samples of CM (Tab. 4.2). It is necessary to specify that the specimens were collected from the same SU11 of Area 3. Despite the fact that the values of U content were not very high for a karst environment, they have yielded three incoherent dates, too young when compared with the reliable radiocarbon dating. For this reason, these were rejected.

Sample	**Alpha spectrometry**				**Beta Spectrometry**		
	^{230}Th/^{234}U	^{234}230Th/^{234U}	U content	Age (ka)	^{226}Ra/^{238}U	U content	Age (ka)
Bone	0.188±0.012	1.137±0.042	1.91 ppm	22.5±1.6	0.194±0.021		19.6±2.4
Bone					0.251±0.026	2.53 ppm	26.7±3.4
Bone					0.245±0.019	10.3 ppm	26.3±2.6

Table 4.2 U-series dating from Cisterna di Latina.

In addition to the geological factors, it is necessary to mention how the chemical processes of the sediments can also be severely influenced by organic material such as guano and faeces, which can release high amounts of phosphate (Karkanas *et al.*, 2000). Furthermore, phosphates have a strong chemical reaction when in contact with carbonates, triggering a series of chain reactions (Karkanas *et al.*, 2000). These processes obviously affect the radioactive element distributions, and therefore the dating obtained from these layers and finds therein (Mercier *et al.*, 1995). Because of this it was not possible to establish whether and to what extent the large number of phosphatic hyena coprolites unearthed at CM have altered the sediments.

In conclusion, the impact that the karst environment of CM has had on bones, in particular the calcium carbonate of travertine, is high. While the calcium carbonate has allowed an excellent fossilisation of the finds, on the other hand this mineralisation has heavily affected the biological compound of the bones themselves. Therefore, certain analyses, including the two types of dating mentioned above, have proved unsuccessful.

4.1.2 Radiocarbon dating of hyena coprolites

Two coprolites from SU11 at CM (specimens 423; 542) were processed with an acid wash and organic carbon was analysed for ^{14}C content (Gatta, Sinopoli, *et al.*, 2016). The intention was to obtain dating of specimens from which the pollen analysis would be carried out. The procedure, carried out at the ETH laboratories of Zürich, has returned two dates. Sample 423 yielded 16,141±42 ^{14}C BP (19640–19292 cal BP)

(ETH-66212) while specimen 542 yielded 18,313±51 ^{14}C BP (22378–21952 cal BP) (ETH-66213) (Gatta, Sinopoli, *et al.*, 2016).

Considering the faunal assemblage and the chronological discrepancy nearly 15 ka with the previous radiocarbon dates (Tab. 4.1), it seems likely that these ages are abnormally young. The main reason for this is a very low (approximately 1%) organic carbon content of the coprolites, and an already known high tendency of coprolites to be contaminated by recent carbon assimilation (Bon *et al.*, 2012; Diedrich, 2012c, p. 372). These dates have been considered unreliable and therefore discarded.

4.1.3 Trace element composition of SU13

The stratigraphy of CM included a thick volcanic layer (SU13) composed of weathered tephra (see Fig. 2.14). It has been analysed for trace-element composition and dated 19 times through ^{40}Ar/^{39}Ar method, along with a reference set of ten samples from the eruptive units of the Albano activity, for tephrochronological purposes (Gatta *et al.*, 2017).

Ten samples, representative of the whole Albano crater eruptive activity, and one sample of the CM tephra layer were analysed for major and trace element composition at Activation Laboratories (Canada). Age determination was carried out on sanidine grains extracted from CM sample at the Oregon State University (Jicha et al., 2016).

The combined ^{40}Ar/^{39}Ar dating and trace-element composition of the tephra layer made it possible to gain an accurate comparison of CM’s sample with the robust database of the Volcano Albano eruptive activity (Gatta and Marra, 2017; Gatta *et al.*, 2017). Trace element composition provided a confident correlation with Unit 3 dating at 69±1 ka (Freda et al., 2006; Giaccio et al., 2009), a correlation confirmed by the ^{40}Ar/^{39}Ar age of 70±2 ka (Gatta and Marra, 2017; Gatta *et al.*, 2017). This method provided a valid alternative to conventional dating methods, which were not available in this sterile volcanic layer, and permitted to achieve a *terminus post quem* for the SU11 of CM.

4.2 Morpho-technical and use-wear analysis on lithic industry

The lithic industry analysis was carried out at the University of Rome Tor Vergata, where the material is currently stored, under the expert guidance of Prof. Mario F.

Rolfo, who has studied many of the surface sites recently discovered in the Pontine Plain (Gatta, Achino, *et al.*, 2016).

Materials and methods

The lithic collection analysed is quite modest in quantity (*n* = 60) and includes artefacts from six of the seven areas investigated, since this study was realised before the investigation of "Area 7", which is therefore excluded (see Appendix A). The industries are particularly concentrated in "Area 3" of the site, however, the technology seems consistent in all of the investigated areas. The morpho-technical study was performed by the naked eye or with support of low-power magnification (10–20X). The lithic industry has been oriented and documented according to Inizan et al. (1995) and assigned to specific typological categories (Tab. 5.3). The results and further details of the lithic study are presented later in section 5.2.

For each item several descriptive attributes (see Appendix A) have been recorded: technology; typology; raw material quality, colour and patina; butt and bulb morphology; blank morphology; cortex presence; damage and wear traces; knapping quality; retouch type; size. Technological and typological assignments were based on Bordes's (1961) and Bietti's typology (1977). These typologies proved to be the most appropriate to the local Pontinian industries. The quality of raw material was based on the presence/absence of specific properties necessary to ensure that the product maintained a high standard and was suitable for its purpose. The properties have been defined according to macroscopic characteristics such as grain size, inclusions and cortex structure (Roebroeks, 1988). High-quality flint was obviously more attractive to prehistoric humans. Colours were determined by comparison of every flint with a Munsell colour system. The patina, if present, has been observed to identify special taphonomic events (e.g. fire action, water flow etc…) or recycling of previously discarded artefacts. The latter is a provisioning strategy attested in the ethnographic and archaeological record (Binford, 1977; Camilli and Ebert, 1992; Amick, 2007; Vaquero, 2011) but not yet documented, although noted in various collections (Mario F. Rolfo, pers. comm.), in the Pontine Plain. Butt and bulb morphology were analysed to provide evidence for the use of soft/hard hammers. Blank morphology and cortex percentage were also recorded, being specific features appropriate for the assignment of a collection to the Pontinian facies, as well as useful techniques for the identification of the pebbles' source from the marine coast, in order to exclude the presence of exotic raw material. Post-depositional damage and wear traces were distinguished by looking at retouch, based on the criteria of regularity and uniformity of scars. Knapping quality was rated on a scale consisting of poor, mediocre, fair and good quality, with the intent to deduce information on the human groups which produced these industries, firstly with regard to their ability in stone processing, and secondly to understand whether particular artefacts reflect a greater effort or skill by producers. Retouch type was classified taking into account a combination of scar features such as localisation and position, distribution, extent and angle. Size (length, width and thickness) was measured with vernier digital callipers with an error range of 0.01 mm.

The measurements and attributes were used for comparisons with other industries. Because of the particular characteristics of the Pontinian industry, it was possible to make comparisons only with collections from the same region, especially with cave industries recovered from Monte Circeo (Laj-Pannocchia, 1950; Taschini, 1970, 1979; Vitagliano, 1984; Bietti and Kuhn, 1991; Mussi and Zampetti, 1991; Vitagliano and Piperno, 1991; Alhaique and Lemorini, 1996; Alhaique *et al.*, 1996). A comparison was also made with several collections stored at Tor Vergata University, permitting a direct comparison of the CM finds with those from numerous coastal surface sites. The evident recurrence in the CM industries of the same raw materials and features highlighted by scholars in Pontinian lithic products from other sites in the region allows us to affirm with certainty the local production of this collection.

A preliminary wear trace analysis was carried out by low and high power microscopes at the University of York, with the valuable support of Dr. Aimée Little. The study, based on two of the best preserved samples, selected through a visual evaluation, was carried out in order to shed light on the use of lithic tools and possible post-depositional processes. The results presented encouraged us to broaden the analysis to the entire collection to obtain more detailed and reliable conclusions (see section 5.2.3). All implements were then further analysed with a stereomicroscope (Nikon SMZ-2T stereomicroscope, magnifications 10-63) thanks to support of Dr. Virginia Garcia Diaz at Leiden University (NL). After that, a sample of implements from CM were examined under a metallographic microscope (Leica DM6000M (50-1000x). Implements were additionally cleaned with alcohol or lighter fluid to remove occasional dirt and finger grease while pictures of the possible micro-traces of use were taken with a Leica DFC450 camera. Results of the analysis are presented in the next chapter (see section 5.2.3).

4.3 Palaeoecological analysis

Coprolite sampling is a destructive process, therefore it is important to record as much information as possible on each sample before performing analysis. The first phase was then to create a database (see Appendix B) in which details of the samples, including the weight, measurements and photographic documentation, were recorded based on standardised criteria (Jouy-Avantin *et al.*, 2003).

Materials and methods adopted for the pilot study of the biological evaluation of samples and subsequent pollen analyses are described below. The latter has been carried out at the Department of Environmental Biology at Sapienza University of Rome following a training course under the guidance of Prof. Laura Sadori, an internationally renowned Mediterranean palynologist.

Maximum attention has been paid to both studies, so that the result of the analyses and subsequent interpretations were as reliable as possible. The results will be described in Chapter VI.

4.3.1 Pilot study

Aims

The detailed pollen analysis of coprolites has been preceded by a preliminary pilot study of the samples, following the general guidelines on the subject of scientific studies. The main purpose of this study was to assess the palaeoecological potential of the samples. This included: (i) assessing the archaeological integrity of the coprolite samples; (ii) detecting possible taphonomic contamination of the finds; (iii) assessing survival of different lines of evidence (e.g. pollen, ova parasites, phytoliths and other remains) and their proportion; (iv) ensuring that organic material suitable for analysis was still present; (v) identifying the best extraction procedure, the sample size and preparation methods, with the intent to identify possible difficulties in data collection or in the subsequent analysis. In particular, it was necessary to establish if hydrofluoric acid (HF) treatment was necessary. Since such protocol is not practicable at the University of York, an external collaboration for this procedure was thus required.

Material

The coprolites on which the study has been undertaken all belong to the cave hyena species. The samples come from Area 3 layer 11 of CM site (see section 3.4), a hyena den, and are in good state of preservation, with a compact texture due to fossilisation by mineralisation.

For the purposes of this pilot study, it was decided to work on a sample of ten coprolites (samples numbers 11; 21; 22; 316; 478; 504; 505; 507; 508; 524). The choice of sample size was due to two major decisions: (i) a percentage of about 10% was estimated to be representative of the entire collection (e.g. at time of analysis, during subsequent excavations the number of coprolites found increased significantly); (ii) the intention to maintain a reference sample for future studies. The selection of coprolites was based on two morphological criteria, size and state of preservation of the external surface. It was decided to choose samples with a minimum diametre of four centimetres. This constraint was due to the necessity to destroy part of the sample for the analysis. The selection of bigger coprolites made it possible to save a large part of each sample for future and more advanced analyses. A selection based on the preservation of the external surface has been carried out in order to exclude, as far as possible, those samples with fractures or cracks that may have favoured penetration of contaminants within the coprolites. This choice has not imposed great limitations, as the surfaces of almost all the samples were solid and compact (Gatta, Sinopoli, *et al.*, 2016).

Method

The procedures used for palaeoecological analysis on coprolites are rarely described or reported in detail. Protocols on how to conduct the analyses, however, are general and usually customised to the specific needs of individual studies (Wood and Wilmshurst, 2016). This study has adopted an approach able to minimise the risks of contamination and grant the realisation of sensitive analyses.

The contamination of a biological sample can occur in three distinct phases: (i) during the deposition of the sample; (ii) at any time after the deposition, including the excavation and storage of samples; (iii) in the laboratory during the time necessary to perform the analysis. The first is a relative contamination, because contaminants would offer an environmental picture coeval to hyena life. Therefore post-depositional and laboratory contamination of the samples are the only ones to concern the successful outcome of the study.

Every coprolite sample was individually collected immediately after discovery in disposable paper envelopes on which every detail relevant to their location in the excavation was reported. This choice was based on the need to prevent cross-contamination between samples and at the same time to help the moist samples to dry spontaneously, avoiding mould formation and subsequent contamination. Once dried the samples were transferred into individual plastic zip-lock bags and stored in a cool stable temperature room at the University of Rome Tor Vergata, to avoid rapid degradation of the organic material inside the samples. The batch of samples on which this pilot study has been realised was transported in sealed containers to the University of York, where it was again stored in a cool stable temperature room until the beginning of the analysis.

Prior to the actual beginning of the assessment, a test of the exterior of all samples was undertaken in order to evaluate the extent of surface contamination. A few grams of material, from an area no more than two centimetres wide, were scraped off from each sample. A portion was then preserved for future analysis and another dissolved in hydrochloric acid (HCl). The latter solution has been used to produce the slides. A consequent microscope check showed the absence of any modern pollution.

The whole analysis was carried out using sterile materials and disposables, in a sterile environment in which modern contaminants are routinely monitored for with dust samples.

Extraction procedure

At this stage, the greatest risk was to run into recent contamination of pollen during the analysis and not recognise it. This could falsify the interpretation of samples and consequently the entire context. In this specific case, to not recognise any pollen contamination would result in pollen diagrams that do not reflect the actual vegetation of the studied area. The result would be an environmental reconstruction that would take account of floral species actually not present at the time in which the coprolites have been produced with serious consequences for the final interpretation of the region.

To prevent this hypothesis the utmost attention possible was paid. Lab coats, facemasks and gloves were worn at all times and changed at every step. The equipment utilised include sterilised scalpels with replaceable blades, aluminium foil, paper towels, ultra pure water, detergent (e.g. 10% Decon) Eppendorf pipettes and Falcon tubes and a circular table saw with a sterile water pump.

The extraction procedure was carried out in four distinct phases. Firstly all samples were subjected to a deep cleaning using ultra pure water to remove any remaining soil or other contaminants from the external surface. The latter was then scraped off to remove at least 2 mm of the outer surface. This operation was carried out to ensure removal of all modern soil contaminants. The removed material has been preserved for future studies. The next step was cutting the coprolites, however, because of the fossilisation by mineralisation, these coprolites are extremely hard and this process was not achieved by hand-tools. The coprolites were then dissected into two halves, as precise as possible, by means of a circular table saw with a sterile water pump. Once again, half of each sample was carefully preserved for future studies or result verification while the remainder was used for sampling. In the third phase, a sample of 5 g was scraped from the centre of each half, where no trace of penetration of soil or contamination was visible (Fig. 4.1), onto a piece of aluminium foil. The powder was then disaggregated with a sterile mortar and pestle, in a controlled environment. The final phase of this procedure was to transfer the disaggregated coprolite powder into Falcon tubes and let it dissolve for 48 hours with HCl at 20% (Gatta, Sinopoli, *et al.*, 2016).

Once the HCl acid dissolved all carbonates in the samples, often resulting in a loose matrix at the bottom of the tube, a portion of the residue was siphoned out with the use of an Eppendorf pipette. A drop of the solution was placed on a sterile glass slide. A further drop of a mixture 50:50 glycerol and water was also added, and a cover slip placed on top of the mixture. The corners of the slides were then sealed using transparent nail polish. The surplus material of each tube has been retained as a reference sample. The slides were then scanned in their entirety using an Olympus inverted microscope, at magnification of 400x and 630x. The presence of debris of various types, including silica and other minerals, and a broad typology of biological remains such as pollen, fibres, fungal spores, phytoliths was detected (Gatta, Sinopoli, *et al.*, 2016).

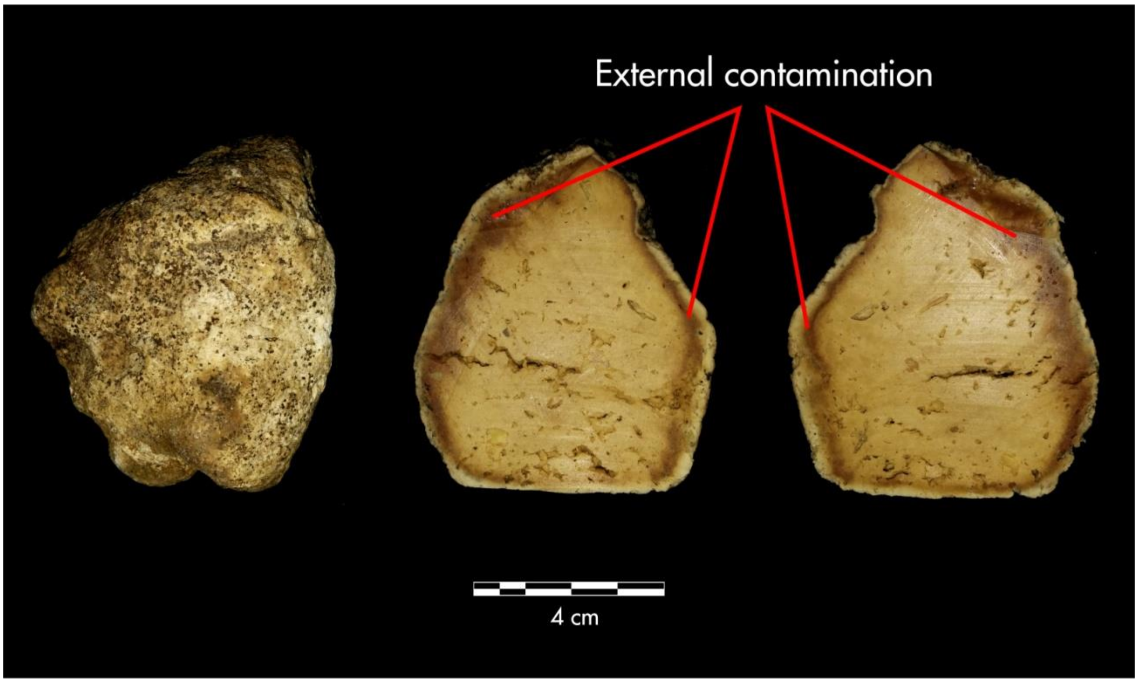


Fig. 4.1 A dissected coprolite. It is possible to note the penetration of external contamination in the two halves (From Gatta et al. 2016).

Results and discussion

The analysis yielded a variety of micro-remains, including pollen, micro-charcoal, bone fragments, phytoliths, hairs, fungal debris, plant tissues of low diagnostic nature and a parasite, proving the potential of the coprolites to retain a wealth of palaeoenvironmental data. It was clear since the scanning of the first slide, that such remains were diluted in a matrix of silica, and other mineralised organic residues, that the HCl had not dissolved (Fig. 4.2a-b).

The majority of biological remains were represented by pollen. The low concentration of non-pollen remains and their low diagnostic nature justified the choice of prioritising pollen analysis over other lines of evidence, which would be less productive. Nevertheless, the coprolites were also subject to further assessments that will be briefly discussed below, and future additional attempts to exploit these remains are not excluded.

A valuable outcome of this pilot study is the need for coprolites to undergo a more aggressive procedure in order to retrieve and concentrate biological remains and carry out a detailed pollen study. It was then decided to proceed with a complete and exhaustive analysis at the Sapienza University of Rome.

Summary conclusions

This study was necessary to determine the palaeo-archaeological potential of coprolites and in some sense preliminary to actual pollen analyses. It was therefore necessary to: (i) verify the survival and the quantity of organic waste; (ii) to determine the possible presence of contamination of the samples and extent of diffusion; (iii) identify the best method to process the coprolites, in order to achieve the subsequent pollen analyses in the best possible way. Ten coprolites have been selected among those collected in the stratigraphic unit of hyena occupation (SU11) of Area 3 at CM. The number of samples was determined to represent a large percentage (about 10%) of the entire collection. The samples were chosen according to their size, in order to assure the survival of a reference sample for subsequent checks, and the preservation of the external surface, to reduce the risk of modern contaminant penetration. The procedure performed follows the generic protocols for this type of analysis with some minor modifications due to the features of the samples (e.g., hardness, excavation context, air travel). The extraction of the matrix was performed next to an examination of the surface, which has returned the absence of modern contamination (Gatta, Sinopoli, *et al.*, 2016). The extraction was performed in four steps: (i) washing of the samples and removal of 2 mm of surface; (ii) dissecting the samples in two equal parts; (iii) sampling and the disaggregation of 5 g of coprolites; (iv) leaving the samples to dissolve for 48 hours with HCl at 20% (Gatta, Sinopoli, *et al.*, 2016).

The slides were examined revealing the frequent presence of pollen, confirming the coprolites validity for further analyses (Gatta, Sinopoli, *et al.*, 2016). It was also possible to verify how HCl acid was not sufficient to dissolve the high amounts of calcium carbonate and silica inside them, hindering the microscope analysis. The use of HF acid was therefore essential. Since this procedure is not executable for safety reasons at the University of York, a new partnership was established with the Sapienza University of Rome in which it was possible to perform the pollen analysis described below.

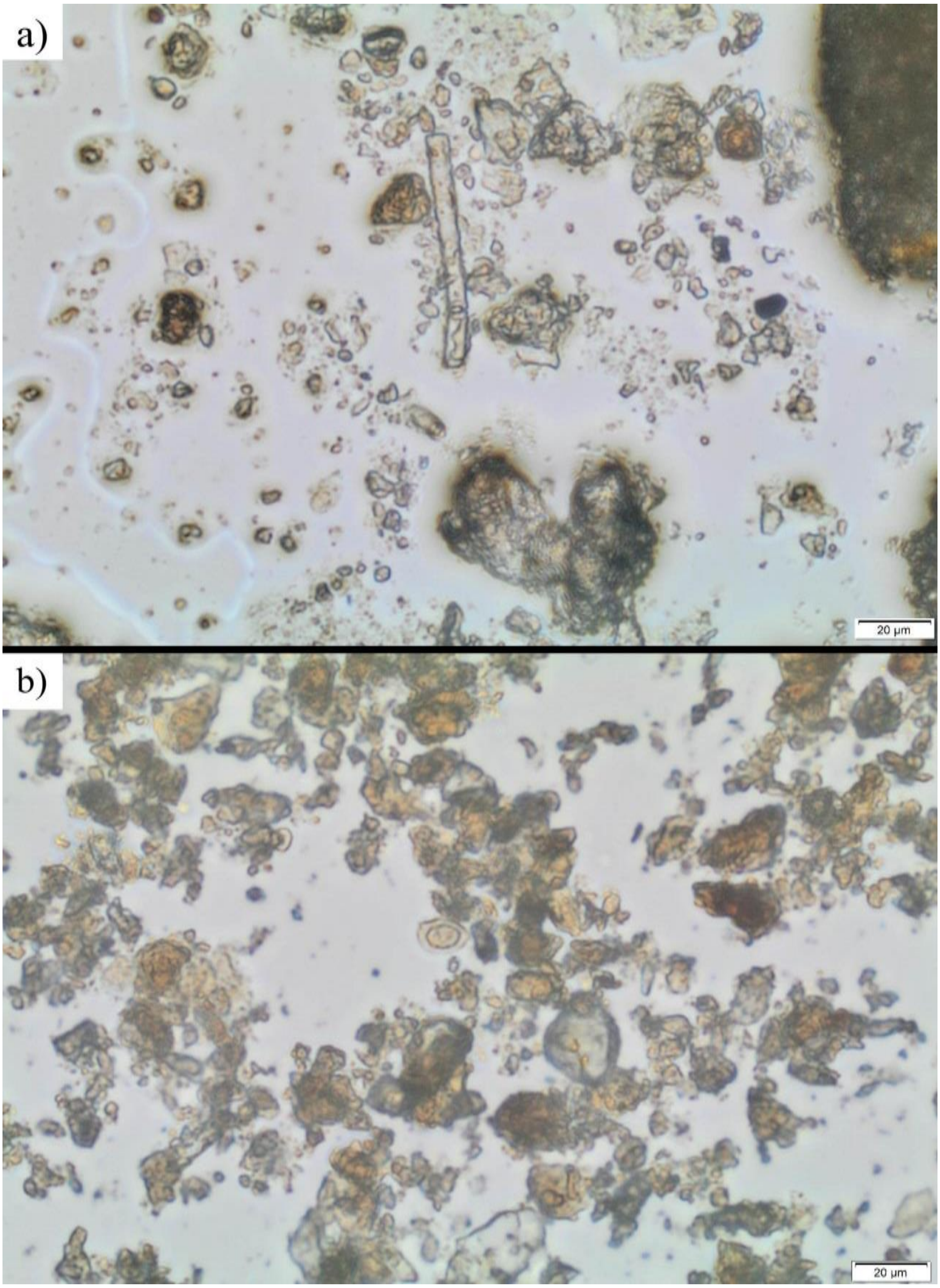


Fig. 4.2 a-b) The resulting matrix after the first treatment with HCl.

4.3.2 Pollen analysis method

The coprolite selection was based on their state of preservation, avoiding specimens with eroded surface or cracks, and size, with a weight between 33–196 g. A total of sixteen coprolites from Area 3 (samples numbers 13; 14; 16; 20; 23; 354; 423; 474; 476; 479; 542; 731; 814; 815; 817; 823) have been chemically processed in the pollen sterile laboratory of Sapienza University (Gatta, Sinopoli, *et al.*, 2016).

Before proceeding with the microscopic examination, it was necessary to prepare the samples. The same method described in the previous section has been applied for the extraction of coprolite powder (see section 4.3.1). The subsequent treatment of the sediment to extract the pollen instead differed, as suggested by the pilot study, to trigger higher dissolution of calcium carbonate. The analysis, which was performed by alternating treatments with acids and treatments with bases, was designed to destroy everything other than pollen or spores. Despite this, a small percentage of the sediments, including the organic material, can sometimes withstand the procedure. The physical-chemical treatment follows the three-day procedure, although slightly revised, indicated by Faegri & Iversen (1989). After a distilled-water wash of coprolites, a sample of wet sediment of about 7–8 g, weighed with a precision scale, was collected from the core of each sample, and left to dehydrate at 60 ºC for 12 hours in a sterile stove. For successful implementation of pollen analysis, at least 5 g of dry sediment was necessary. Samples which were lighter when dry have undergone an addition of sediment to make their weight fall within the aforementioned range. Hereinafter all the samples were placed in Falcon tubes, which resist attack by strong acids and bases and by high temperatures. Within each tube 25 ml of HCl (37%) was added, in order to remove the carbonate component of the sediment, and a known number of lycopodium spores (*Lycopodium clavatum*). A carbonate tablet of lycopodium spores (*Lycopodium clavatum*), which releases the spores in contact with the acid, is used to estimate the pollen concentration compared to sediment (Stockmarr, 1971). Each tablet contains a statistically estimated quantity of about 13,911 spores. For this study, two tablets of lycopodium were added for a total of 27,822 spores for each sample. Tubes were thoroughly shaken using a stirrer to make HCl react with the sediment. Due to the high amount of calcium carbonate in the samples, a violent reaction occurred characterised by effervescence. After running in a centrifuge at 3600 rpm for 6 minutes, a further 5 ml of HCl (37%) were added to dissolve further carbonates and the spin cycle was repeated. Afterwards the solute was decanted. The centrifuge and decantation are required for the removal of the liquid component. These steps are repeated after each addition of fluid. In this paragraph these steps will be omitted to prevent redundancy. 25 ml of HF (40%), which has the function of degrading the silicates, was added to the samples. The acid is left to operate for 12 hours. 5 more ml of HCl was added to remove residues of carbonates. The samples were boiled in soda (NaOH 10%) for 10 minutes to remove humic acids. After the basic attack, another 5 ml of HCl was added, to remove the remaining carbonates previously trapped in the organic matrix. At this stage, the entire carbonate and silica component of the sediment should be eliminated. Cold NaOH (10%) is added to raise the pH and induce acid neutrality in samples. Several "washes" at 70º C with distilled water were necessary to complete the neutralisation process. Tubes were shaken and centrifuged during every wash. The washes were repeated until reaching the neutrality, evaluated by pouring the supernatant of each sample on a litmus test. Finally, the samples were mixed with glycerol in sterile tubes, ready to be mounted on sterile glass slides and studied microscopically.

4.3.3 Further assessments on coprolites

Recognising the great palaeoecological value represented by coprolites and the rarity of the same in the region under investigation, it was decided to carry out further assessments to quantify the potential of these finds for future studies. The samples underwent proteomic analysis at Thermo Fisher Scientific and Fourier transform infrared spectroscopy (FTIR) at the University of York.

The first one was carried out, on a coprolite (R. 726) from the Area 3 at CM, with the aim to identify peptide sequences belonging to the unfortunate prey of the hyena within the coprolites. The result would provide direct information about the carnivore diet but also the opportunity to identify additional animal taxa whose remains could not have been preserved in the archaeological record. Unfortunately, only short fragments (about 8%) of the peptide sequences were preserved and the collagen was of very low quality. The poor quality of surviving peptides has allowed the identification of a ruminant and a carnivore but taxonomical assignments to species have proved to be impossible.

After such poor results, it was wondered if other coprolites could present a better preservation and thus provide better results. For this purpose FTIR was performed on ten coprolites (samples number: 11; 21; 22; 316; 478; 504; 505; 507; 508; 524) coming from the SU11 at CM. A minimum quantity of each coprolite was removed and analysed by returning IR-SR and C/P poor values (see Appendix 4.1). A similar alteration is unfortunately evidence of a harsh diagenesis that has been a problem for the survival of archaeological information.

Despite these discouraging results, coprolites are a resource worthy of being further exploited in the future. Tests to assure their preservation can be extended to samples from different areas of excavation with, presumably, a different diagenesis.

4.4 Archaezoological analysis

The study was partially carried out at the Laboratory of Environmental Sciences, University of Siena, following an internship in Archaeozoology organised by Dr Paolo Boscato, and at the Laboratory of Prehistory of the University of Rome Tor Vergata with the support of Prof. Carmelo Petronio and Drs Luca Pandolfi and Leonardo Salari. The number of remains from CM is constantly growing with the progression of the archaeological investigations. A database of finds is included in the appendices of this thesis (see Appendix C and D). The results and further details on the faunal assemblage from CM are described in Chapter VII.

Aims

The faunal analysis had multiple results. Interesting information on individual taxa was obtained, nevertheless its main purpose for the thesis was certainly to obtain indications that could, together with the pollen data, offer a reliable environmental framework. To achieve this aim a detailed study of the fossil remains was necessary, which included: (i) taxonomic and taphonomic analysis; (ii) determination of the main cause of deposit formation; (iii) NISP and MNI estimates; (iv) age class at death estimation.

Materials and Methods

The bones analysed in this thesis have been excavated between 2012 and early 2016 and are currently preserved at the Laboratory of Prehistory of the University of Rome Tor Vergata. This study involved 1346 fossilised macro-remains from Area 3, of which about 656 (48.7%) were taxonomically classified (Tab. 7.1), and several hundred bones of small vertebrates of which only 58 were taxonomically classified (Gatta *et al.*, in press a).

The preservation is extremely variable. Short and long bones are found both whole and fragmented ranging from 1 cm to a few decimetres in size. The texture and patina are also variable, especially among those recovered deep in the archaeological layers and those found on the surface, exposed during time to severe local climate factors such as warm summer sun and prolonged winter rains. The indeterminate material includes bone fragments, whose size ranges between 1–10 cm, which could not be attributed to any faunal taxa or anatomical part. The degree of fragmentation of the bones falls within the standard set for Pleistocene and modern hyena dens.

A find number was assigned to each bone, which was recorded with its grid coordinates and depth within a 1 x 1 m excavation grid system. The soil was fully sieved with a 2 mm mesh in the field to ensure that microfauna was also recovered. Finds were mostly concentrated in the excavation area called “Area 3”.

The comparative samples were sourced from the Laboratory of Environmental Sciences, University of Siena; University of Tor Vergata; the Sapienza University of Rome.

Further assessments on fauna

The potential of this fossil deposit is remarkable. However, in the short time period of this PhD research it was not possible to study all its features. For this reason, priority was given to analyses with specific environmental implications. However, it is highly recommended that other studies are carried out in the future.

The large quantity and extraordinary preservation of bones for each taxon, but also the discovery of uncommon species in the area during the Middle-Upper Palaeolithic transition, such as *Stephanorhinus hemitoechus*, makes an in depth study of specific taxa possible and highly interesting. This will help to improve the understanding of many of these extinct animals and show possible regional environmental adaptations through the comparison of these specimens with contemporaneous ones from elsewhere in the Mediterranean area. Some of these studies have already been published (Pandolfi *et al.*, 2016, 2017) while others are ongoing.

Despite the excellent preservation, a large number of bones, about 810 (51.3% of total), presented a high fragmentation rate as the result of carnivore activity and taphonomic processes. For this reason, these were not morphologically referable to any taxon (Gatta *et al.*, in press a). Nevertheless progress in the branch of bio-archaeology now makes it possible to obtain taxonomic information from small/minute fragments, as demonstrated with the application of ZooMS (Welker *et al.*, 2015). ZooMS is a molecular barcode method, which uses peptide mass fingerprinting of collagen, highly present in bone, to differentiate fauna to a genus level. Previous studies demonstrate that ZooMS in combination with morphological identification is capable of providing a complete understanding of fauna composition, considerably increasing the number of identified specimens but also increasing supplementary taxa not previously identified (Collins *et al.*, 2002). The combination of these taxa could obviously have ecological implications, confirming or refining the picture proposed (see Chapter VIII). Due to poor collagen preservation of CM's remains, the realisation of these analyses could not be achieved.

Summary Conclusions

The faunal assemblage of CM is one of the largest of the Pontine Plain. Due to the preservation conditions and the inland location and typology (e.g. a group of hyena dens in a karst environment), it is perfect for an environmental reconstruction of the region. In addition, its excavation, which took place over seventy years after the discovery of the neighbouring cave deposits of Monte Circeo, offered the possibility to use both excavation and analysis methods and resources not available in the past, creating a unique framework.

Chapter V

Human Exploitation of the Landscape

The aim of this chapter is to shed light on the human exploitation of the Pontine territory, examining the existing archaeological evidence and local features to provide the context for the subsequent chapters. In order to do so, opportunities and constraints related to this territory need to be highlighted. To this purpose, the most influential archaeological features in the Pontine region will be outlined. These are the topography of the area, the resources of lithic raw material, the availability of both terrestrial and marine food sources and the presence and spread of open-air and cave sites in the region.

The first section will provide a broad overview of the Pleistocene evidence in the area, including the Lower Palaeolithic, and will focus on the high presence of open-air sites scattered along the Pontine Plain. Whether these sites played the role of primary settlements or of areas of tool production is still unclear; similarly, their significance in terms of economy and human exploitation of raw materials, has never been fully revealed. This issue will be addressed more thoroughly at the end of the chapter, after an analysis of the use of raw materials, which will enable a deeper understanding of the topic.

In this region, numerous cave sites are concentrated in the Monte Circeo, some of which have been studied with particular attention in the past (see Tab. 5.1). A selection of these, based on their compatibility with the archaeological site of Cava Muracci (hereinafter CM), will be described in greater detail as they will constitute the comparative basis for this thesis.

Further evidence of human occupation in this territory is provided by the lithic artefacts from CM. The second section of this chapter will therefore be dedicated to the techno-typological study of these finds. A typological study on such an assemblage can provide meaningful information, even though limited by the small sample size. One key aspect is the presence of lithic industry itself in this region. Most of the open-air or cave sites with human presence are located along the present coastline, while CM is much more inland, close to the Apennines. Although the industries retrieved (i.e. mostly unretouched and broken flakes) have not received as much focus in techno-typological studies as retouched tools or cores, it has been proved that they can provide important details as well (Holdaway and Douglass, 2011). An assessment of the wear traces was carried out, which helped clarify both the modalities of deposition of these finds and their use. It has been thus revealed that in the Pontinian, similarly to the rest of the Italian and European industries, not only tools but also the *débitage* resulting from their production were exploited.

The third section will attempt to understand the reason behind human exploitation of the region and the relationship of humans with fauna, natural resources and mobility strategies. Taking all these factors into account, a reconstruction of the human presence in the territory during the entire Palaeolithic can be built up, with particular emphasis on the Late Middle and Early Upper stages. The real challenge will be to tie the archaeological record to the surrounding environment, understanding how, and to what extent, it has affected human and animal life in the territory and, in turn, how people were relying on the environment for subsistence.

From the palaeoecological point of view of this thesis, answering this question will help understand how the environment affected human strategies and whether it offered the "ideal" conditions for life that are often attributed to the so-called *refugia*. The differences highlighted in the choices perpetrated by *H. neanderthalensis* and AMH are also very interesting. These can be attributed to different abilities of the two hominins and to the mental and physical development of the AMH species, as well as, in this case, to an environmental change which would have triggered different land use dynamics.

In the following chapters, this outline will be used as a background and starting point for the interpretation of the available archaeological data from CM.

5.1 The human presence in the region

In order to complete the contextualisation of this study, it is important to present a picture of the human presence in the region. Both *Homo neanderthalensis* and *Homo sapiens* lived in the Pontine Plain within the period discussed in this thesis. These hominins’ exploitation strategies in this territory will be discussed in further detail later in this chapter.

In Italy, archaeological research applied to prehistory developed in the early decades of last century, focusing mainly on the extraordinary number of caves. These natural shelters sometimes feature complex stratigraphic sequences with preserved finds ranging from the Middle to the Upper Palaeolithic, reflecting their long continuity of use. Since human remains are not very numerous, the human presence is often inferred from the sole presence of stone tools.

Latium is one of the richest regions in Palaeolithic sites (Fig. 5.1), many of which have yielded remains of Neanderthals (Manzi and Passarello, 1989) and even earlier hominin species (Fig. 5.2). The sites are concentrated in three areas: north of Rome, in the Aniene Valley and particularly in the Pontine Plain. This evidence covers a wide chronological span, ranging from the earliest human presence in Italy to the final Upper Palaeolithic.

Human presence in the region is attested since the Lower Palaeolithic, most probably with the species *Homo heidelbergensis*, based on the discovery of stone tools made from simply shaped pebbles, choppers or chopping tools which characterise their material culture. Among the few known sites, Valloncello and Campoverde are of particular interest: here, large accumulations of faunal remains associated with stone tools attributable to the Recent Acheulean were found. The site of Quarto delle Cinfonare, along the banks of the river Astura, where pebble industries attributable to a period ranging from 500–300 ka BP were found, is of equal importance. Finally, in the coastal area, are the site of Tor Caldara, with a complete stratigraphic sequence spanning from the Lower to the Middle Palaeolithic, and Le Ferriere, with industries including Acheulean bifacials.

Around 250 ka BP, during MIS 7, an expansion of the Neanderthals is attested, widely documented in Latium (Marra *et al.*, 2015). In addition to the stratigraphically complex sites around Monte Circeo are numerous surface collections, recovered along the Pontine and Roman Plains. The earliest recovery of these lithic products dates back to 1936, when Alberto Carlo Blanc first attributed them to the work of Neanderthals, defining the type with the name "Pontinian" (featured in detail in Chapter 3). This cultural facies will be discussed again in the section of this chapter on the stone tools found during the investigation.

Thanks to its geomorphological characteristics and its climatic conditions, the Pontine territory would have represented an ideal place to inhabit for prehistoric people, especially if compared to other areas of Italy. This region provided a wide range of resources, from the shorelines on the warm Tyrrhenian Sea to the cold peaks of Lepini and Aurunci mountains with milder climates in the foothills, all within a radius of 10–30 km. In between these extremes, a wide plain offered the perfect setting for large herds of animals. Due to its unique ecological diversity, the area could be defined as an eco-region, which has enabled the survival of human groups, even during periods of adverse climate. The picture that emerges is, therefore, that of a widespread human presence in an area of about 4,200 km^2, where Neanderthal people found the best survival conditions for more than 200 ka. For these reasons this phase is regionally called the Pontine period (Rolfo, 2009; Martone, 2012).

With the Upper Palaeolithic and the spread of *Homo sapiens*, the human distribution within the Pontine Plain changes (Fig. 5.3). Although, in the early stages of the Aurignacian and Gravettian, some sites were still frequented, a preference for inland areas became more pronounced, to the detriment of the coastal ones. In the Epigravettian, the area of the Circeo is almost completely abandoned. It is unclear whether this phenomenon was a result of a search for new shelters in which to settle, or if it consisted of sporadic visits due to new forms of subsistence. Nevertheless, far from the coast, numerous open sites have yielded large quantities of lithics, although sites of the Middle Palaeolithic remain much more numerous. Consequently, several theories on the settlement dynamics of coastal Latium can be drawn.

Firstly, a change in the economic activities and hunting strategies might have caused this radical change of settlement patterns, as undoubtedly indicated by the archaeozoological studies on the faunal remains procured by *Homo sapiens*. These seem to place the new human groups in the inland areas of the peninsula (Rolfo 2008). Furthermore, climatic reasons may also have had an impact, as the last glacial maximum and the last explosive activity of the Vulcano Laziale took place in this period (25–15 ka BP). It should be noted that during this phase a major marine regression took place, triggering the extension of the coastal plain, some of the Upper Palaeolithic sites could then have been submerged by subsequent sea-level rise.

Around the Middle and Upper Palaeolithic, prehistoric people frequented the numerous caves of Monte Circeo and the coast of Latium, later submerged by the sea during the end of MIS 2. They also visited the hinterland of the plain, as evidenced by the numerous lithics found. However, as these finds only consist of flint tools with no evidence of food remains or other human activities, these findspots might belong to secondary sites.

The occurrence of stone tools, even if concentrated, is not necessarily a sign of the presence of organised sites. In a possible attempt to justify this distribution of lithic material, it may be suggested that prehistoric hunters, moving in search of food, brought with them only the tools which were absolutely necessary and subsequently abandoned them after use. These sites appear instead to represent areas of procurement and acquisition of food resources, such as the slaughter of prey, which were then consumed elsewhere.

As Binford (1990) argues, evidence of Neanderthal hunters abandoning the stone tools does not necessarily reflect long-term planning and an "economic" behaviour, but may reflect instead a "noncurated" conduct, in which people found it more advantageous to produce new expedient tools, rather than to maintain and transport previously made tools. The consequence is that they would be forced to search for raw materials in their surroundings and even use artefacts manufactured by previous visitors. If this large presence of lithic products spread with great frequency along the plain is to be related to the system of hunting proposed by Binford, then carcases of animals may be expected to be found in association with stone tools, even sporadically. Similar circumstances can be found in the case studies of Carrière Thomasson (France) and Neumark-Nord (Germany), where a few stone tools surrounded the remains of a slaughtered animal. However, similar associations within our region have never been recovered. In the rare open-air sites in which faunal remains have been preserved, the contexts are fluvial lacustrine or lagoon and the findings cannot be associated in a primary context.

As such, the absence of animal remains in association with stone tools at open-air sites in the region of Latium has often been questioned, producing varied theories on the subsistence practices. In recent years, however, the idea that the notoriously acidic volcanic soil of the territory has prevented the preservation of perishable materials such as bones, has begun to be taken into account, and archaeologists have noted the same problem in other regions with dominance of volcanic and acidic soils (Fiorenza et al. 2015, p. 50; Linse 1991).

The application of a model based on the percentage of finished lithic tools and production waste found in individual sites, combined with a topographic analysis of their distribution, has allowed for a fairly structured view of the area and the dynamics of activities inside it.

In order to properly contextualise the site of CM, a detailed consideration of local sites provides some important insights. Comparative sites have been selected not only due to their similar geographical locations and/or chronologies with CM, but also due to the thoroughness of the related studies and their subsequent usefulness in this research. Although this comparative study will include relevant extra-regional examples, only the sites with the greatest affinities to CM, which as expected are located in the vicinity of our key site, will be described in detail.

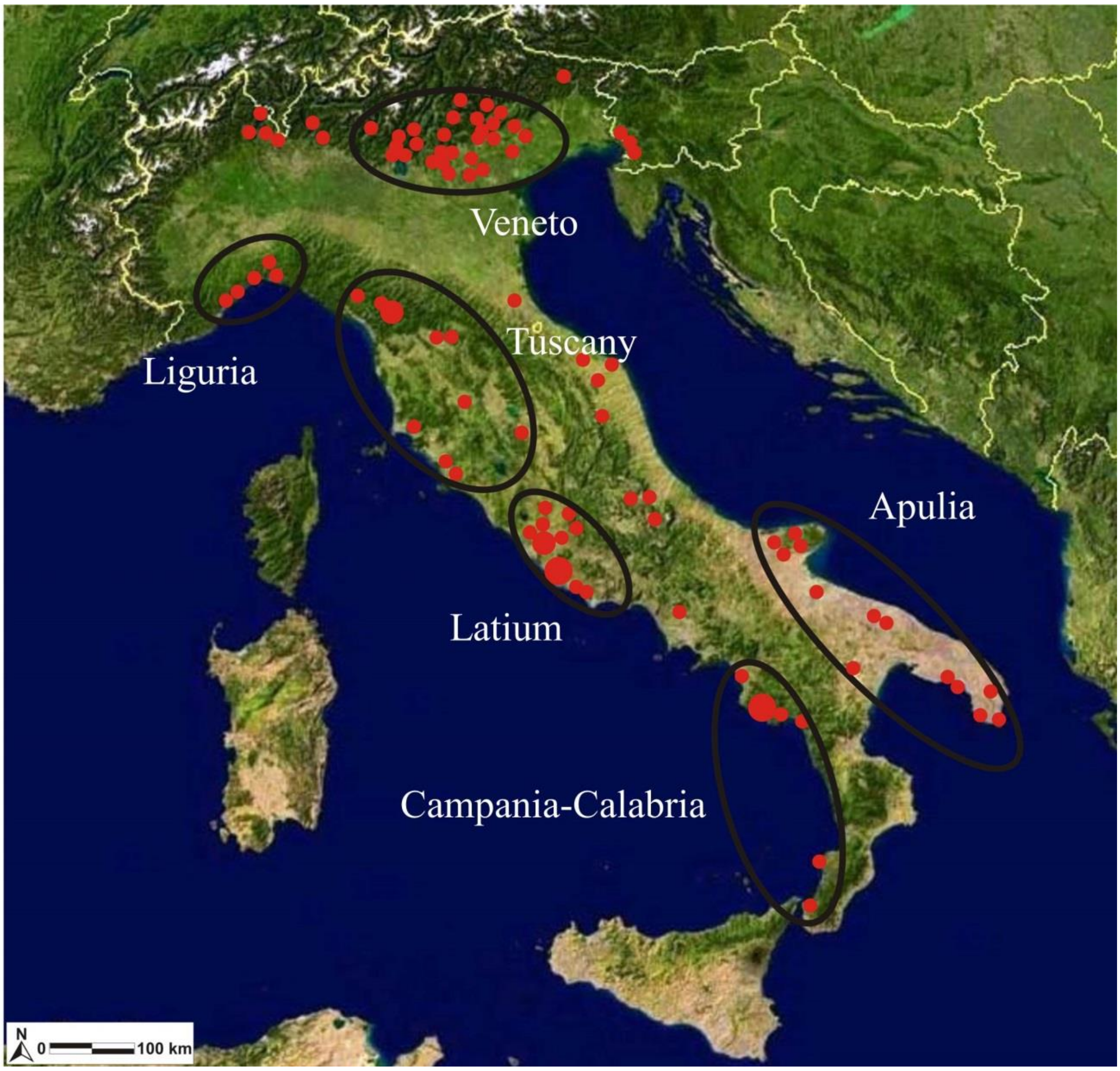


Fig. 5.1 Six areas of Italy with the highest concentrations of Middle Palaeolithic sites. Re-elaborated from Fiore et al. (2004).

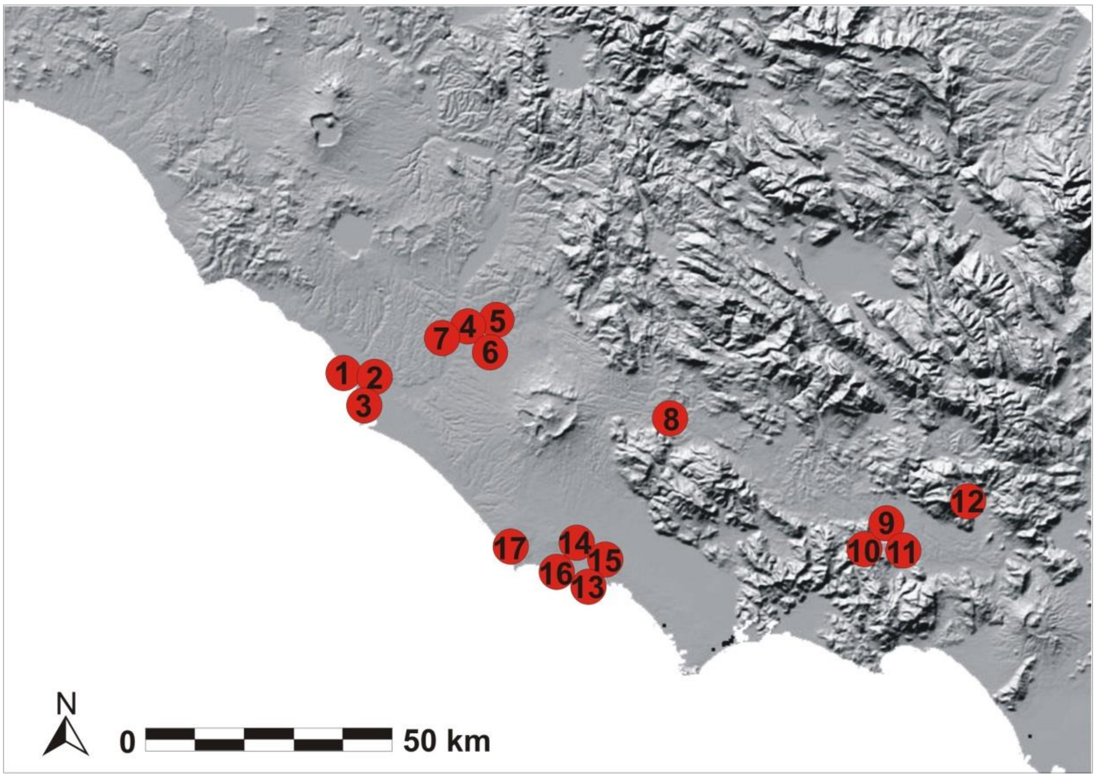


Fig. 5.2 Most important Lower Palaeolithic sites of Latium: 1) Torre in Pietra 2) Castel di Guido, La Polledrara 3) Malagrotta 4) Casal de' Pazzi 5) Monte delle Gioie, Sedia del Diavolo 6) Ponte Mammolo 7) Valchetta Cartoni 8) Fontana Ranuccio, Colle Marino 9) Cava Pompi 10) Castro dei Volsci 11) Ceprano 12) Arce, Fontana Liri 13) Quarto delle Cinfonare 14) Campoverde 15) Valloncello 16) Le Ferriere 17) Tor Caldara. Re-elaborated from Rolfo (2008).

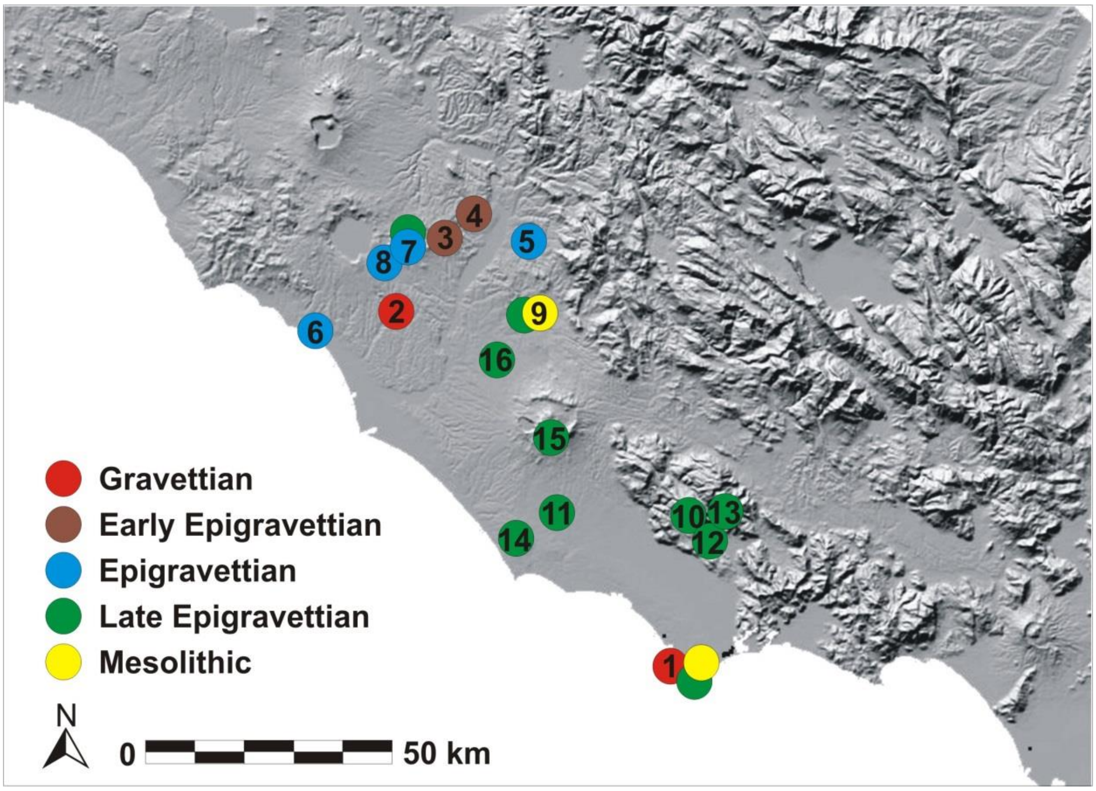


Fig. 5.3 Most important Upper Palaeolithic sites of Latium: 1) Grotta del Fossellone, Grotta Barbara, Riparo Blanc; 2) Castelmanome 3) Riparo Lattanzi 4) Grotta del Sambuco 5) Valle Ottara 6) Palidoro 7) Cenciano Diruto 8) Riparo Biedano 9) Grotta Polesini 10) Grotta del Peschio Ranaro 11) Cisterna 12) Grotta Jolanda 13) Riparo Arnalo dei Bufali 14) Torre del Giglio 15) Pratoni del Vivaro 16) Tor Vergata 17) Riparo Salvini. Re-elaborated from Rolfo (2008).

5.1.1 Grotta Guattari

This relatively small cave (15 m deep and 12 m wide), located less than 10m above the modern sea level, is undoubtedly the best known of the Circeo sites, and has attracted the attention of many archaeologists. The cave, composed of a discrete number of chambers of various sizes, was sealed by colluvium approximately 50 ka BP. Discovered accidentally in 1939, the cave was excavated digging a narrow trench, which made impossible to thoroughly investigate the deposit and understand the stratigraphy. The notoriety of the site is mainly due to the over fifty-year-long conviction that it contained evidence of Neanderthal cannibalism (Blanc, 1961, pp. 124–126; Marshack, 1989). At the time of the discovery of the cave, the workers had apparently unearthed a Neanderthal skull with an unnatural enlargement of the foramen magnum, placed at the centre of a circle of stones and surrounded by a great number of deer antlers (Blanc, 1939a, 1939b, 1939c). This was interpreted as a certain indication of human, possibly ritual activity. In addition to the skull, two Neanderthal mandibles were also found, from different sectors of the cave (Sergi, 1954; Sergi and Ascenzi, 1955). In the 1990s, the skull was re-examined and it was demonstrated that the traces of this enlargement were typical of those which would have been produced by the action of a hyena, which would expand the foramen in an attempt to reach the soft tissues of the brain (Piperno and Giacobini, 1991; Stiner, 1991a; Toth and White, 1991; White and Toth, 1991). Similar traces had already been identified elsewhere on human remains, confirming this behaviour by the hyena (Horwitz and Smith, 1988). It is interesting to note, however, that many years before, during the first analysis of the human remains found, the investigators had already highlighted traces of hyena activities (Sergi, 1954), but ignored these completely in the final interpretation of the remains. This does not mean that hyena was necessarily responsible for the killing of the Neanderthals discovered. The carnivores could have gathered the remains of the hominins already dead, even dismembered, and introduced them inside the cave. This practice has been also observed in modern hyena when burials do not occur in deep or protected pits (Skinner, Davis and Llani, 1980).

The stratigraphic sequence of the cave ranges between 78–51 ka BP. The lower U-series date was estimated using the thin layers of calcite that began to cover the palaeosurfaces soon after the collapse of the entrance (Schwarcz, Bietti, *et al.*, 1991). For 20 ka the cave was occupied by the Neanderthals, attested by the two mandibles and the famous skull, while the latter stages of the sequence and the palaeosurfaces are currently interpreted as hyena dens (Stiner, 1991a) and not as evidence of human presence or even "place of worship" (Piperno, 1977).

5.1.2 Grotta Breuil

This important prehistoric cave, located just a few kilometres from Grotta Guattari, is now accessible only via the sea. Although it was discovered prior to the aforementioned site, archaeological excavations did not begin until the end of the 1980s and the research is still ongoing. Albeit its deposit is dated by U-series to approximately ±36,600 BP (Schwarcz, Buhay, *et al.*, 1991), four Neanderthal remains have been discovered inside the cave (Manzi and Passarello, 1991, 1995; Grimaldi and Spinapolice, 2010), as well as a discrete assemblage of Pontinian stone tools which are technologically attributable to the Middle Palaeolithic (Grimaldi and Spinapolice, 2010). These elements may provide definite evidence of how the last Neanderthals in Tyrrhenian central Italy persisted even when *Homo sapiens* had already expanded across northern Italy, suggesting a cautious comparison with the south of Spain and the *refugium* area of Gibraltar. It is necessary to specify that, as a result of the dating carried out for this PhD, and having found the unreliability of the U-series method (see Chapter IV), I personally do not consider the dating yielded about twenty-five years ago by Schwarcz for Grotta Breuil and the other sites to be trustworthy.

The study of the faunal remains, and particularly the age at death of some species, revealed human exploitation of the shelter during winter months only, while providing information about a worsening climate, which was becoming more arid and colder during these millennia (Stiner and Kuhn, 1992; Stiner, 1994). This possibility is perhaps confirmed by the significantly decreased presence of human activity in the most recent levels, in favour of the large carnivores typical of a cold climate, including hyenas, bears and wolves.

5.1.3 Grotta Barbara

This small cave at Monte Circeo is the first of two shelters on the coast which also contains evidence of Aurignacian stages. The deposit, dated to the first cold oscillations of MIS 3, contains lithics and fauna attributable to the action of both *Homo neanderthalensis* and *Homo sapiens*. The faunas from the Mousterian age also indicate an environment that was not particularly cold, with mixed grasslands and forest.

5.1.4 Grotta del Fossellone

Both Middle and Upper Palaeolithic levels are present at Grotta del Fossellone. Human presence at the site is testified by a Neanderthal jawbone (Blanc, 1954) and Mousterian (layers 41–23) and Aurignacian (layer 21) stone tool finds, as well as typical bone points in the second facies. Scant Gravettian tools have also been found in the upper levels of the stratigraphy (layers 19–1). The importance of the site, the subject of continuing research, lies in the continuity of its occupation, which provides the opportunity to highlight both climatic and cultural differences between the Mousterian and Aurignacian layers. In the later layers, species have been identified that are most suitable to a cold arid climate and open-air habitats. The faunal assemblage suggests more selective hunting tactics during the Mousterian stages where remains are more numerous but less varied compared to those in the Aurignacian.

5.1.5 Grotta di Sant'Agostino

This cave is located in the Plain of Fondi, 40 km south of the Pontine Plain, between the former and the Aurunci Mountains. It is situated 25 m a.s.l. and is easily reachable from the current coastline. Despite the distance from the main study area of this work, the cave clearly demonstrates the typical cultural characteristics of the Pontinian sites. Furthermore, the geomorphological features of the territory are similar to those of the north. For these reasons, this plain can be considered as an appendage of the Pontine Plain.

The cave has a single chamber, slightly bigger than Grotta Guattari, and yielded archaeological deposits dated between 55–43 ka BP (Schwarcz, Buhay, *et al.*, 1991). Human presence in the site is attested by the recovery of the largest assemblage of a Mousterian lithic industry from a cave site in central Italy (Tozzi, 1970). Based on age at death of fauna recovered, this occupation occurred in the winter months, whereas during the summer months the cave was occupied by other animals, especially wolves (Alhaique and Tagliacozzo, 2000). The fauna from this site has been studied in depth and constitutes a good comparative source.

5.1.6 Grotta dei Moscerini

Located a few kilometres north of Grotta di S. Agostino, between the towns of Sperlonga and Gaeta, with the entrance lying 2–3 metres above the modern sea level, this is the largest Mousterian cave of the Latium coast. A huge deposit, over eight metres thick, unfortunately only partially excavated, ranges from 120–60 ka BP. Pontinian lithic industries have been found throughout the entire sequence but in very small quantities. Alongside a broader array of faunal species with clear signs of human predation, a seasonal and sporadic level of hominin occupation is also documented. Interestingly, unlike the sites of Grotta Breuil and Grotta di S. Agostino, studies of age at death of fauna seem to attribute the human presence to the summer months, possibly due to a different mobility strategy in the earlier stages of the Middle Palaeolithic.

Faunal assemblages show a predominant presence of hyena, which apparently visited the site throughout the year. The remains of abundant marine animals and shellfish represent one of the oldest examples of human exploitation of marine resources. Among about 200 bivalves, found especially in layer G but also in layers H, M and N, *Callista chione*, *Glycymeris* sp. and *Mytilus galloprovincialis* specimens are predominant (Vitagliano, 1984). An extremely interesting aspect of the exploitation of these resources is the manufacture of shell tools, made with similar techniques to those of stone tools, as is also found at sites along the coast of Liguria and Apulia (Cristiani *et al.*, 2005).

5.1.7 Canale delle Acque Alte (Canale Mussolini)

This site includes all the archaeological remains discovered during the construction of the drainage water channel across the Pontine Plain. A large amount of lithic artefacts, faunal remains and organic macro-remains, such as tree stumps, have been found along the path of the channel. These finds, having been deposited mostly by natural agents, have not proved of great archaeological interest. Nevertheless, the site has been of great environmental importance, providing the most complete natural stratigraphic sequence of the Pontine Plain, as well as useful information on environmental changes which have occurred in the territory.

Archaeological Site	Chronology	Type of activity	Typology of findings	Essential Bibliography
Grotta Guattari	78–55 ka BP (level 5-2)	Neanderthals	Lithic industry	(Blanc, 1939b, 1939c, Sergi, 1954, 1974; Sergi and Ascenzi, 1955; Piperno, 1977; Taschini, 1979; Stiner, 1991d, 1991e, 1994; Toth and White, 1991; White and Toth, 1991; Giacobini, 1991; Piperno and Giacobini, 1991; Schwarcz, Bietti, *et al.*, 1991; Schwarcz, Buhay, *et al.*, 1991)
	55–51 ka BP (level 1-0)	Hyena	Fauna, coprolites Neanderthal’s remains	
Grotta Breuil	±36.600 BP (Late Mousterian)	Neanderthals (winter months)	Lithic industry Fauna	(Bietti *et al.*, 1988, 1991; Bietti, Manzi and Zei, 1988; Manzi and Passarello, 1991, 1995; Schwarcz, Buhay, *et al.*, 1991; Stiner, 1994; Alhaique and Lemorini, 1996; Alhaique *et al.*, 1996; Alhaique, Bietti, *et al.*, 1998; Lemorini and Alhaique, 1998)
		Large Carnivores	Fauna	
Grotta Barbara	MIS 3	Neanderthals	Lithic industry	(Caloi and Palombo, 1989a, 1991, Mussi and Zampetti, 1990, 1991)
		Homo sapiens	Lithic industry Bone points	
Grotta del Fossellone	39–10 ka BP	Neanderthals	Lithic industry	(Alhaique, Biondi, *et al.*, 1998; Alhaique and Tagliacozzo, 2000)
		Homo sapiens	Lithic industry Bone points	
		Hyena	Fauna, coprolites	
Grotta Sant’Agostino	55–43 ka BP	Neanderthals (winter months)	Lithic industry Fauna	(Tozzi, 1970; Schwarcz, Buhay, *et al.*, 1991; Stiner, 1994)
		Wolf (Summer months)	Fauna	
Grotta dei Moscerini	120–60 ka BP	Neanderthals (Summer months)	Lithic industry, Shell tools, Fauna	(Vitagliano, 1984; Schwarcz, Buhay, *et al.*, 1991; Stiner, 1994)
		Hyena	Fauna	
Canale delle Acque Alte (Canale Mussolini)	MIS 5a – Holocene	--------	Fauna, lithic industry, Macrobotanical materials	(Blanc, 1935a, 1937b; Taschini, 1972; Caloi and Palombo, 1992)

Tab. 5.1 Summary table of the main Palaeolithic sites of the Latium coast.

5.2 The lithic industry from Cava Muracci

A new contribution to the human framework described above is provided by the site of CM. The collection of artefacts recovered is limited and does not point to an intense human occupation, but nonetheless provides useful insights.

From a morpho-typological point of view, this material does not show any particular difference from all the other industries of the Pontine Plain, including the raw material, originating in both cases from the fossil beaches of the coast. The small size of the dataset and of identifiable Mousterian or Aurignacian features prevents us from assigning this collection to a single cultural facies. Despite this, the study exposes interesting information about the functionality of the tools and their deposition within the archaeological context.

5.2.1 Material for the present study

The study is focussed on the lithic material retrieved from the quarry to date (up to the writing of this chapter) from six of the seven sectors investigated (Tab. 5.2 and Appendix A). The few lithic finds from "Area 7" have not been covered in this work, due to the advanced stage of the thesis at the time of the investigation of that sector. These and the other remains found in this area will be part of a follow-up study. This small set anyway does not appear to be dissimilar from the lithics analysed from the main assemblage, so its not being studied does not affect the interpretation of the area as a whole.

The spatial analysis shows a higher concentration of artefacts in Area 3 (Tab. 5.2), which must be analysed from a taphonomic perspective. Such a difference in the distribution of the lithic industry among very close areas sharing the same geological conditions is unlikely to be due to natural factors only, such as water action. It can be interpreted considering two key factors. The first is the size of Area 3 of about 20 m^2, much larger than the other areas investigated. The second is due to the survey methodology. Area 3 is the only area in which an extended stratigraphic excavation was possible, ensuring finer archaeological reliability.

The lithic assemblage recovered is composed of 60 pieces, 23 retouched tools, 37 blanks, 1 residual core (see Appendix A, Tab. 5.3 and Fig. 5.4).

The list of the tools found is as follows.

End-scrapers: 19. Eleven are simple, straight or convex. All tools, except a sample showing Levallois technique, have large areas of cortex. At least seven blanks are derived from caps or edges of pebbles. Retouch is stepped in four specimens, as in *La Quina* technique. On another six specimens, retouch is simple, mostly marginal. Five scrapers are transverse, blanks are almost all corticated except in a broken one. Retouch is stepped in three examples, while simple in the remaining pieces. Two carinated scrapers were also found, one of them manufactured on a pebble cap. Retouch is marginal on both. A *déjété* scraper has also been found.

Points: 3. One is an elongated Levallois point with simple flat reverse retouch on both sides. The other two are a carinated and a curved point. Retouch in both cases is stepped with secondary retouch on the opposite side.

Notch: 1. Obtained with bipolar processing from a cap.

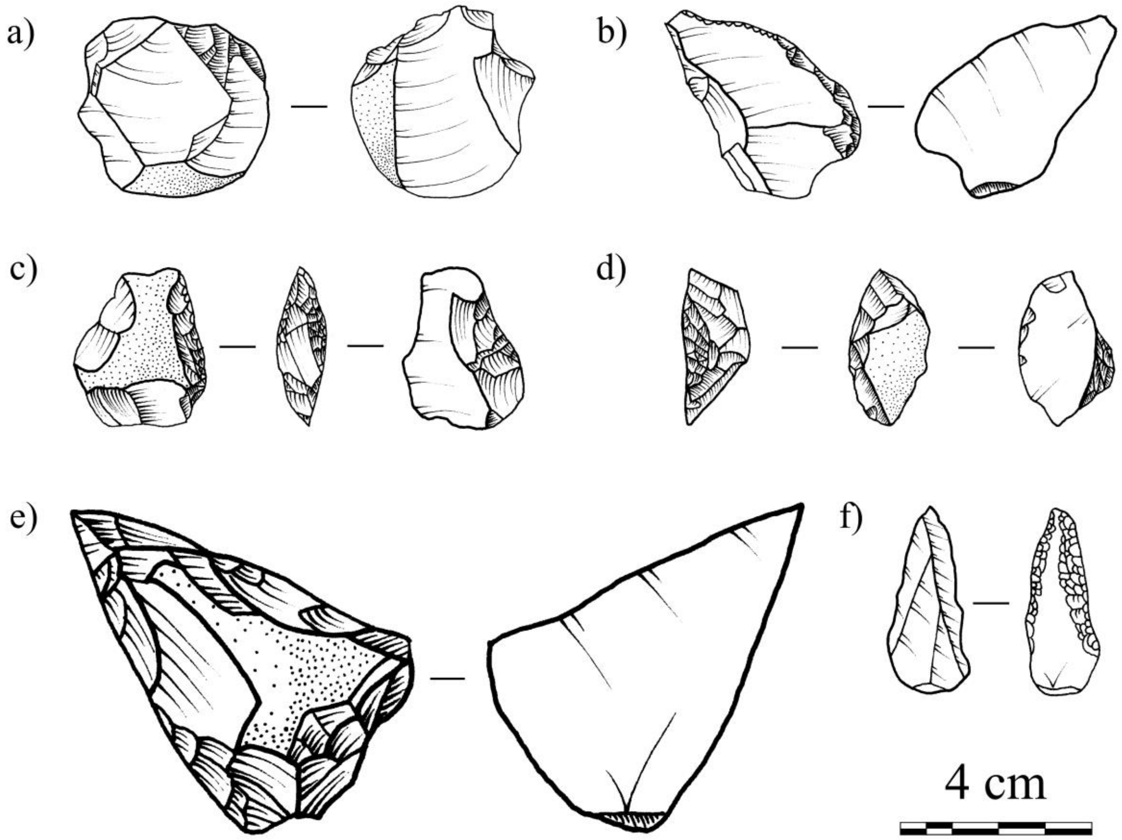


Fig. 5.4 Lithic industries from SU11 (Area 3): a) Residual core; b) Pontinian transverse scraper; c) Pontinian straight scraper; d) Aurignacian carenated point; e) Pontinian transverse scraper; f) Aurignacian Levallois point. From Gatta & Rolfo (2017).

Lithic Assemblage												
	Area 1		Area 2		Area 3		Area 4		Area 5		Area 6	
	N°	%	N°	%	N°	%	N°	%	N°	%	N°	%
Total	1	1.7	3	5	49	81.6	3	5	1	1.7	3	5

Tab. 5.2 Distribution of the lithic industry found in Località Muracci's quarry.

	Area 1	**Area 2**	**Area 3**	**Area 4**	**Area 5**	**Area 6**	**Total**
End-scrapers							
Simple straight			8	1			9
Simple convex			2				2
Transverse straight			3				3
Transverse convex			2				2
Carenated			2				2
Déjété						1	1
Points							
Levallois point			1				1
Carené point			1				1
Curved point			1				1
Hammer	1						1
Flakes							
Simple marginal		1					1
Steep marginal						1	1
Notch			1				1
Cores							
Residual			1				1
Debris		1	4		1	1	7
Total	1	2	26	1	1	3	34

Tab. 5.3 General breakdown of the lithic industry from Località Muracci's quarry.

5.2.2 Techno-typological analysis

The analysis and classification of the lithic assemblage was carried out through the most suitable typology considered appropriate to this study. Bordes's typology (1961) is commonly used for Middle Palaeolithic industries, while, for the subsequent Upper Palaeolithic, the typology of Laplace (1964) is the most adopted in Italy. In this respect, it is necessary to note the very peculiar lithic industry of Latium, particularly that of the Pontine area, which has led Bietti (1977), one of the foremost Italian specialists of lithic typology, to adapt the methods of De Sonneville-Bordes and Perrot (1956), previously implemented in France, to the local Italian industry. This typology has proven appropriate to regional studies, as it can classify a larger number of tools than the other methods (Kamermans, 1984).

The lithic collection is divided almost equally into retouched and non-retouched blanks. The presence of flakes from cortex removal and a residual core suggest that every step of the *chaîne opératoire* was carried out at the site. The exploitation and abandonment of the industry is also reflected by the wear traces (see next section). However, the absence of refitting suggests that the industries probably were not in a primary deposit, having been transported there from nearby.

The main feature of the assemblage is the generally small size of pebbles (microlithic or hypermicrolithic), with only three specimens of larger size – still within 5.2cm – due to the small size of the raw material. The percentage of cortex on blanks is high, in accordance with the industry found elsewhere in the coastal area. The raw material, as is often noted for the lithic industries of the Pontine Plain, is obtained by processing of pebbles collected along the fossil beaches, which are characterised by a wide variety of rock types. The use of exotic raw material is not attested. The presence of impact traces produced by natural secondary deposition, characteristic of sources of raw material such as the coastal beaches and river beds, are visible at a macroscopic level on most of the analysed artefacts. The flint consistency is compact with a fine to medium grain, with a rare occurrence of coarser textures and radiolarites. The colours range from white to grey and pale yellow, with substantial differences in the shades even within the same specimen.

It is common knowledge that the raw material was at the base of the technological choices and artefact distribution in the region (Taschini, 1970). Therefore, details about the supply areas and the quality of the stone itself will be now explored.

The pebbles found in the Latium coast are generally oval or rounded and of small size, not exceeding ten centimetres in length and five in width, with a shape varying from flat to spheroid. The quality of these stones is highly variable, from poor to excellent (Grimaldi and Santaniello, 2014, p. 118). The pebbles were collected in prehistoric times along the coastline between the Tiber and Sabaudia, where fossil beaches were numerous. During the glacial marine regressions such beaches were clearly on the surface (Bietti and Grimaldi, 1995), while currently located about ten metres below the sea level. A proof of the availability of these resources are the Eemian beach ridges west of Latina, where pebbles are still emerging (Kamermans and Sevink, 2009, p. 46). The provenance of these fossil deposits is not yet ascertained, but can be probably referred to the materials transported by ancient rivers flowing down from the Apennine mountains and cutting the Pontine Plain to flow into the sea. Although the exact deposit from which the raw material would have come is impossible to trace, due to the close similarity of all the fossil beaches, the nearest procurement source to the site of CM would have been about 20 km westwards.

Carrying out a typological study of this sample is extremely difficult. The collection is quantitatively and qualitatively inadequate for a statistical study: for example, only a residual core – a most important element of production – is present in the dataset. Coarse raw material and size left no doubt about the local origins of the stone. The core seems to be a "tester", which is a bipolar percussion of a core in which the knapping was necessary to define the quality of flint, abandoned once the low quality of the material was identified. The use of platform core technique is predominant in the Pontine sites, although the use of centripetal core reduction is separately attested by Kuhn up to about 55 ka BP (Stiner and Kuhn, 1992). It is interesting to note that in these sites the percentage use of the two techniques varies substantially, although the platform technique remains the most frequent, probably due to the shape of the pebbles available in the immediate proximity of each site (Stiner and Kuhn, 1992). These two techniques tend to prefer pebbles of different shapes, circular for the centripetal and oval for the platform one (Fig. 5.5), with the latter morphology being most common among the pebbles of the Latium coast. It is thus valid to assume that this type of core reduction was prevalent also in the context of CM.

The number of retouched tools is just over 38% of the total assemblage. This is a rather high percentage, assuming that many flakes could also be used without retouching (see wear traces section). A possible explanation of this occurrence could be the transport in the area of many finished tools and only a few cores. This evidence is in contrast to the expedient technology that often occurred in the region. This difference may be explained by the more inland location of the site, in comparison to the already known coastal sites, and therefore being a greater distance from sources of the raw material.

The most attested knapping technique is bipolar on an anvil, a production technique that makes it possible to fully exploit the quality and size of local raw materials, while the Levallois technique is visible only on two elements. The most frequent tools are end-scrapers on blanks shaped like a "slice of tangerine". The retouch is mostly simple or scalariform Quina type, with a manufacturing technology that ranges from poor to good. Due to the large majority of end-scrapers identified among the tools and the low incidence of Levallois technique, scholars generally agreed to consider the “Pontinian” as a Quina-type Mousterian (Laj-Pannocchia, 1950).

The Middle and Upper Palaeolithic of the Latium region share raw material, knapping technique, blanks and typology of tools. The assignment of an assemblage to one or the other facies is based on the type of retouching (see section 2.3). In this assemblage, simple and scalariform retouch predominates, typical of the Pontinian, although the presence of tools with laminar retouch makes an assignment to a single cultural or chronological facies much more uncertain.

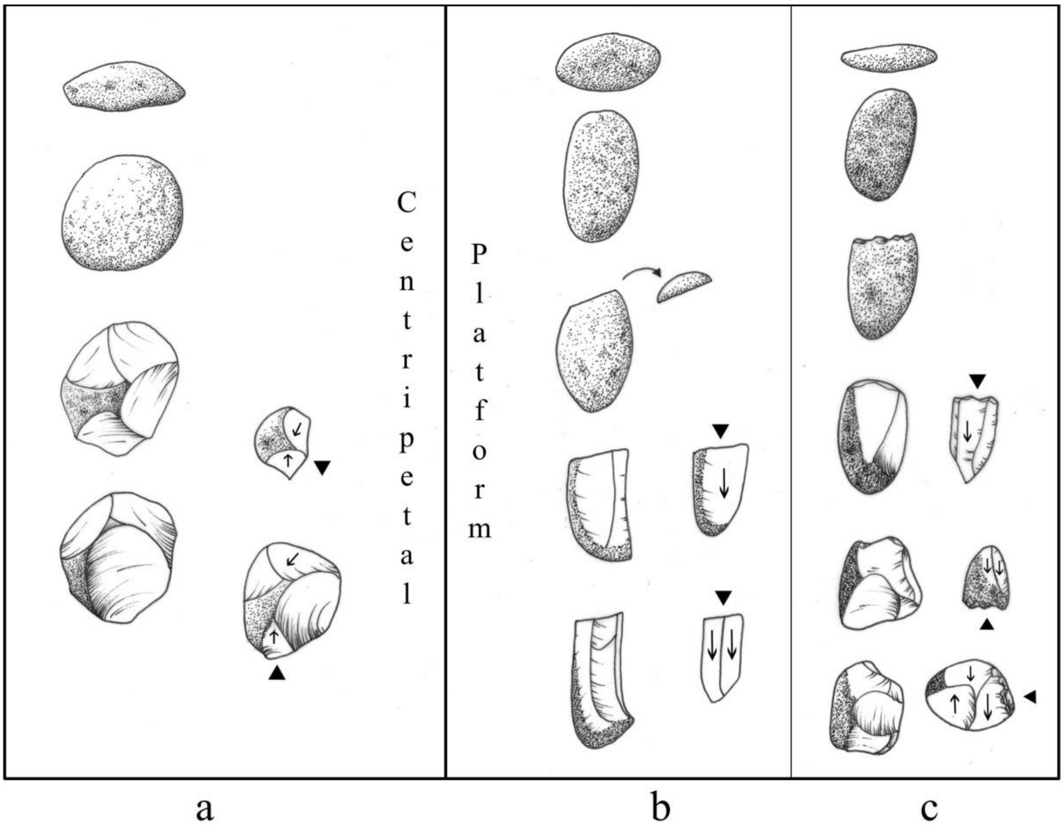


Fig. 5.5 a) Centripetal core technique; b) and c) Platform core technique.

This type of retouching is spread along the coastal area with the locally called "Circeiano", which ranges between 38–30 ka BP (Mussi, Gioia and Negrino, 2002), corresponding to the European Aurignacian. It can be therefore hypothesised that the industries studied belong to both facies and that they have reached the cave during different times of the formation of the deposit and over a broad period.

5.2.3 Use-wear assessment and analysis of the lithic collection

The deposition of the lithic industry in the areas investigated is not fully understood, as mentioned in Chapter II. Preliminary observations of the topography of the area indicate that water action may have been a potential agent of accumulation. Water action is difficult to identify but, in many cases, it appears to have affected prehistoric contexts, especially cave sites with vertical entrances or natural chimneys.

When it is possible to stratigraphically investigate sites with a large number of lithic finds, a rearrangement of the stone artefacts caused by water action can be observed through their orientations and distributions in the layer (McPherron, 2005; Enloe, 2006; Bertran *et al.*, 2012) or by sedimentological analysis (Sitzia *et al.*, 2012). However, sometimes it is necessary to study assemblages from contexts lacking a detailed sedimentological analysis. In such cases, macroscopic signs of water action can be researched on flints, such as damage or rounded edges (Burroni *et al.*, 2002; Howard, 2002; Hosfield and Chambers, 2005a), although these are present only in cases of significant water force (Hosfield and Chambers, 2005b). These marks can also be misinterpreted as the result of other taphonomic factors (Miller *et al.*, 2009; Bertran *et al.*, 2010; Eren *et al.*, 2010). In recent years, microscopic analysis has proved highly effective in the identification of abrasions caused by the interaction of stone tools with water (Fernandes *et al.*, 2007; Chu, Thompson and Hosfield, 2015). An analysis of wear traces on flints was then considered necessary to possibly clarify both the taphonomic activities but also the exploitation of CM site.

Observation of the abrasions on the lithic surface may indeed provide valuable information on life of the industry, i.e. on their main use as a tool, but also about the next phase, when flints were discarded and became part of the archaeological deposit. The latter is known as the taphonomy of the stone tools: "*we define flaked stone taphonomy as the subfield identifying and analyzing the processes affecting the appearance and context of lithic artefacts subsequent to their cultural use lives*. *Thus, a* *flaked stone taphonomic process is not intentionally cultural, social, or behavioural (e.g. heat treatment, butchery), only geological or natural (e.g. erosion, sediment consolidation, trampling)*" (Eren et al. 2011, p.202; Dibble et al. 1997). Nonetheless, it is necessary to stress that it is not always possible to distinguish between taphonomic and cultural processes (Eren *et al.*, 2011).

The use-wear analysis method was firstly developed by S. A. Semenov (1981). His method was based on the assumption that, if a tool was used, its surface would be modified. This modification could be macroscopic and/or microscopic, and it would be different depending on the material being worked. Semenov (1981) differentiated four types of attributes: micro-retouch or edge damage, edge rounding, polish and striations. The method, however, did not become popular in western Europe and the United States until his book was translated into English in 1964. After the translation of the book, the method spread quickly through western Europe and the United States. Several theses and scientific articles were published during this time trying to consolidate and replicate Semenov's method (Newcomer, 1974; Tringham *et al.*, 1974; Keeley and Newcomer, 1977; Odell, 1977, 1979, Anderson, 1980a, 1980b, 1981, Moss, 1983a, 1983b). On the basis of the methodologies applied to observe the use-wear traces, two different approaches emerged: the low-power approach and the high-power approach. The low-power approach (Tringham *et al.*, 1974; Odell, 1977, 1980) used a stereomicroscope (up to 60x) to examine wear traces such as striations, edge damage and edge rounding. The high-power approach, as developed by Keeley and Newcomer (Keeley, 1974, 1980; Keeley and Newcomer, 1977; Newcomer and Keeley, 1979), involved an incident-light microscope (up to 400x) to observe different wear traces such as striations, edge damage, and edge rounding, but also polish and residues (Shafer and Holloway, 1979; Anderson, 1980b).

Unfortunately, not all assemblages are suitable for micro-wear study. Natural surface alterations can completely obliterate traces of use. These alterations include for example various types of patination, abrasion by the surrounding matrix or dehydration due to long-term exposure to the open air. Some alterations, like patinas, can be seen with the naked eye, but others, like abrasion or gloss patina, are less obvious and can only be observed with the help of a microscope.

5.2.3.1 Assessment of use-wear analysis potential for CM's assemblage

Lithic items from Area 3, for which the stratigraphic excavation permitted the geo-location of the finds, were selected to carry out preliminary use-wear analyses. Two specimens (R. 400 and R. 498) from the cave hyena layer (SU11) were analysed by low and high power microscopes. The choice of the two artefacts was determined by a visual and low power magnification evaluation of the entire collection, which showed that these two specimens are better preserved than the others.

R. 400 is the only Levallois point discovered, produced from fine local flint. The production shows a good lithic technique with a simple reverse flat retouch on both sides. Despite being slightly abraded, micro-wear polish and macro traces on the ventral and dorsal proximal end could be suggestive of hafting (Fig. 5.6a). A black residue, which needs further investigation, could be preliminarily identified as hafting resin or attributed to a post-depositional contaminant (Fig 5.6 b-c).

R. 498 is a broken *débitage* fragment, resulting from tool production. The raw material and the cortex indicate the knapping of a local pebble. It is slightly patinated/abraded but appears to have use-related wear traces along one margin. There are signs of transverse directionality suggesting that this piece was used as a scraper. The object being scraped was compact, possibly a hardwood, resulting in the formation of a series of removals and polishes on the upper edge (Fig. 5.7). Some abrasions are possibly due to water action.

Although this analysis was still to be extended to the rest of the collection, the preliminary geomorphological observations made it possible to identify water action as the main agent for the introduction of at least part of the human artefacts found. Summarising, the poor to fair conditions of the flints collected do not allow an excellent taphonomic study. However, signs of slight patination and abrasions from post-depositional processes have been identified and wear traces shed light on the use of the lithic artefacts by humans.

The information obtained from the wear traces of these two artefacts is interesting. The levallois point revealed traces of hafting, with key implications for the interpretation of tool use and of hunting behaviour in the Pontine Plain. If wear traces were expected on a tool, the traces found on a debris fragment are less obvious. They indicated that even the waste from the production phases was exploited, enabling us to even hypothesise the collision object, in that case hardwood. In-depth analyses of lithic industry have provided a unique basis for further interpretation. Taphonomic agents that acted on the deposit have also been identified.

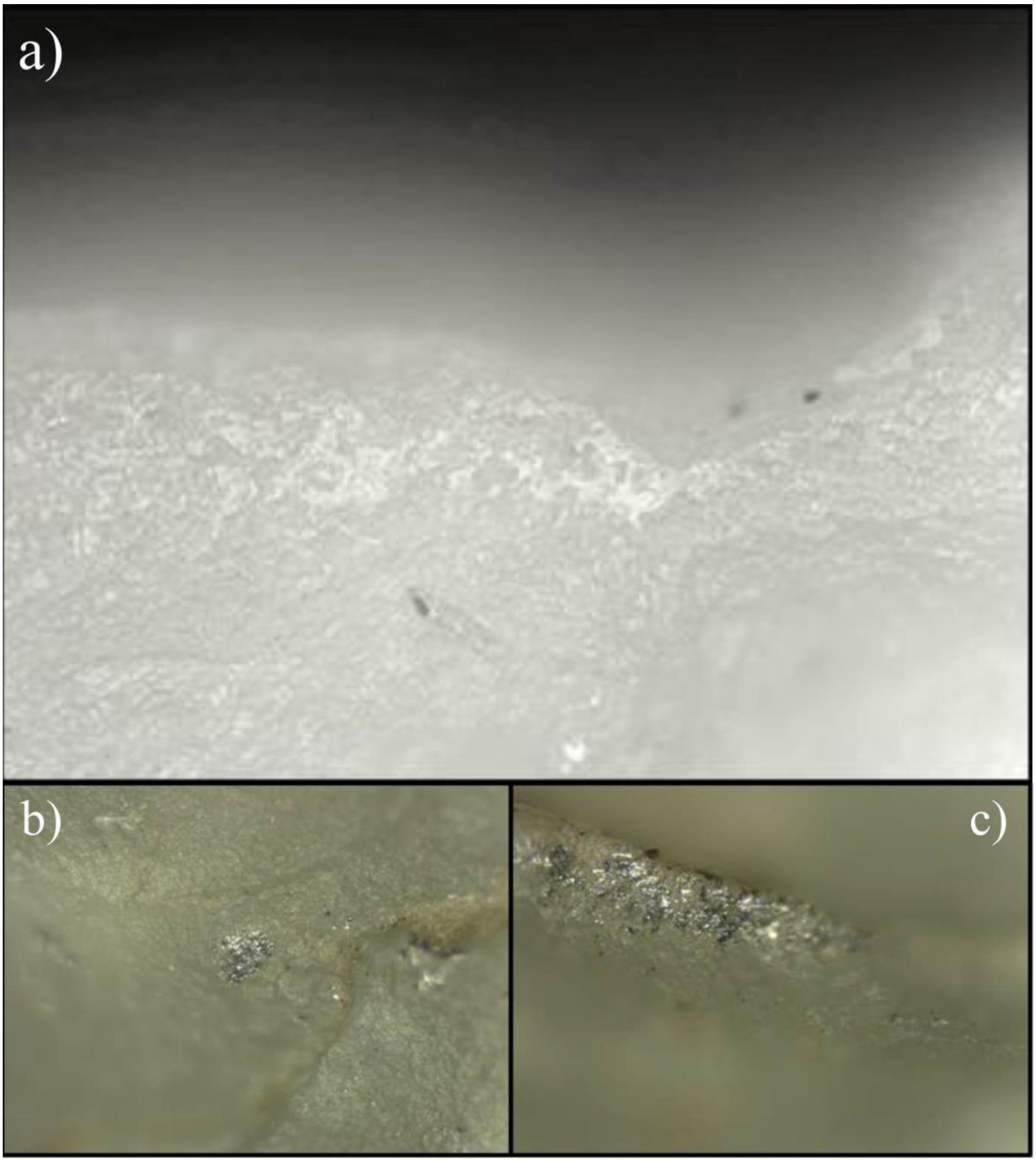


Fig. 5.6 a) Possible hafting-related polish on proximal edge of R. 400; b-c) Black residue on R. 400, it could be hafting adhesive or post-depositional contaminant.

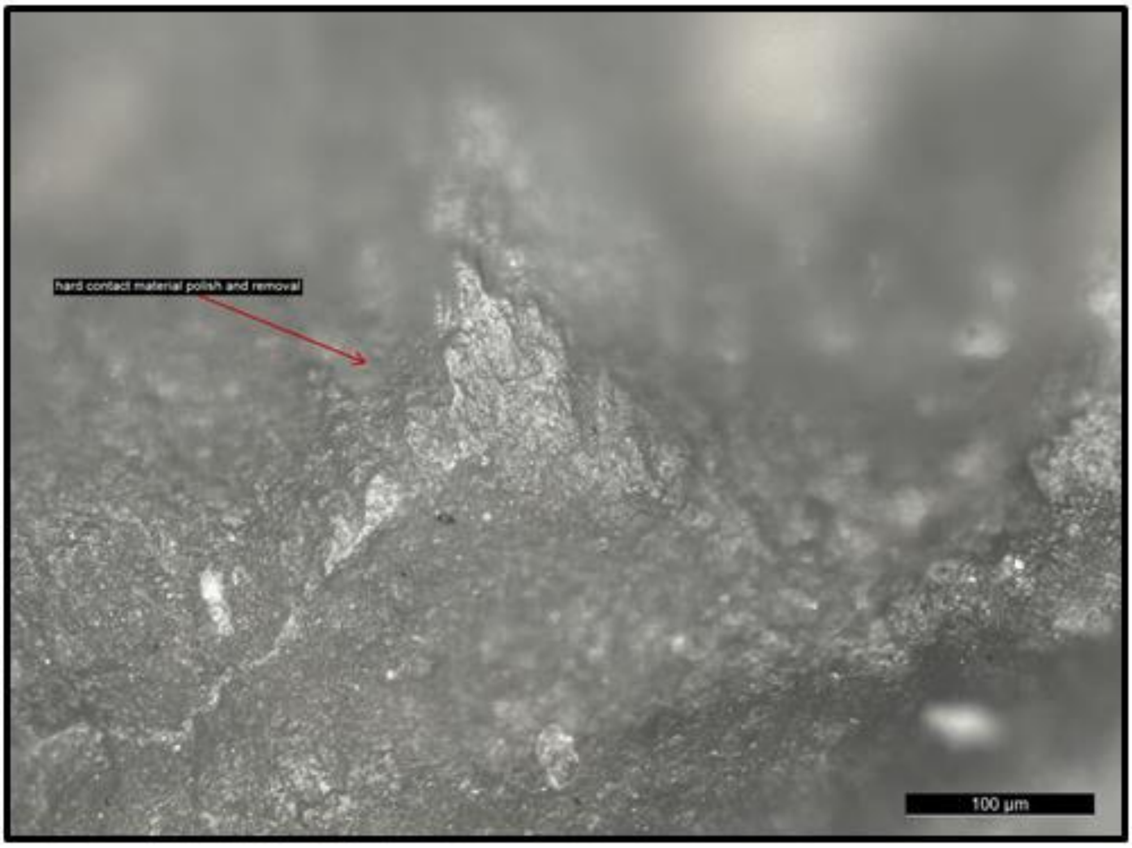


Fig. 5.7 Transverse polish from hard contact material on R. 498.

5.2.3.2 Use-wear analysis of the flint assemblage from CM

The assemblage of CM was first analysed with low magnifications. After this analysis, and based on the preservation of the flint and use-wear attributes, a sample of 22 implements were examined with higher magnifications (up to 500x). Most of the implements analysed under the metallographic microscope were classified as not interpretable (i.e. R. 31; R. 34; R. 35; R. 50; R. 115; R. 253; R. 265; R. 578; R. 579; R. 732; R. 735; R. 800; R. 804), due to the heavy degree of post-depositional modification. Only six implements display traces that could relate to use-wear traces, when more than one use-wear attribute (edge rounding, edge damage, polish and striations) was documented.

Possible traces of use on:

R. 736

On the distal end of the tool, edge rounding and edge damage were recorded. Traces are only visible on the dorsal surface. However, there is a heavy greasy patina that covers the surface of the tool, so other use attributes, such as polish and striations are not observable.

R. 38

On the distal end of the tool, edge rounding and isolated spots of polish were recorded (Fig. 5.8a-b). Traces are only visible on the dorsal surface. However, there is a heavy greasy patina that covers the surface of the tool, so the worked material could not be inferred.

R. 41

On the distal end of the tool, edge rounding and edge damage were recorded. However, the edge is really badly preserved, covered with isolated spots of a hard polish caused probably by the impact of the implements with other stones (Fig. 5.8c-d), making it impossible to interpret if the tool was actually used.

R. 564

On the proximal edge of the tool, possible traces of use were documented. Some edge rounding and edge damage are displayed on the tool. However, the implement is really badly preserved. Some rounding on the retouch is visible, but the surface is covered with a heavy glossy patina and the surface is slightly abraded.

R. 724

The distal edge of the tool displays some edge rounding and edge damage (Fig. 5.8e-f). However, the edge displays a recent fracture and possible traces related to use are not preserved.

R. 33

On the lateral edge of the tool, some rounding associated with the retouch is documented. However, the entire surface of the implement is covered with a heavy abrasion and use-wear traces could not be performed.

In general, the material shows a poor or very poor preservation of the surface. Unfortunately, none of the selected implements show clear traces to infer the worked material or the activity carried out. Several surface alterations were documented during the analysis of the flint. In the first place, an important part of the assemblage shows an abrasion of the surface. This abrasion covers an extensive part of the implements, making use-wear analysis not possible (Fig. 5.9). In addition, different types of patinas were observed on the industries. Patinas are chemical reactions that develop gradually and can cover the entire surface of the implements, making difficult or impossible the analysis (Mansur-Franchomme, 1986; van Gijn, 1990). The more documented patinas are white and heavy glossy patinas (Fig. 5.9). Although, in some cases, it is possible to perform use-wear analysis with the presence of patina, in most of the cases, patinas were heavily developed, obscuring the possible use-wear traces present on the implements. In addition, some lithic industries were exposed to fire, causing a severe thermal alteration. Most of the industries with thermal alteration show a *craquele* and a glossy surface. Thermal alteration of the implements makes difficult, and sometimes impedes, use-wear analysis. In the first place, it reduces the strength of the flint surface, increasing the chances of post-depositional fractures (Bleed and Meier, 1980; Pevny, 2012). In addition, the surface is modified by fire causing not only fractures but colour and texture changes.

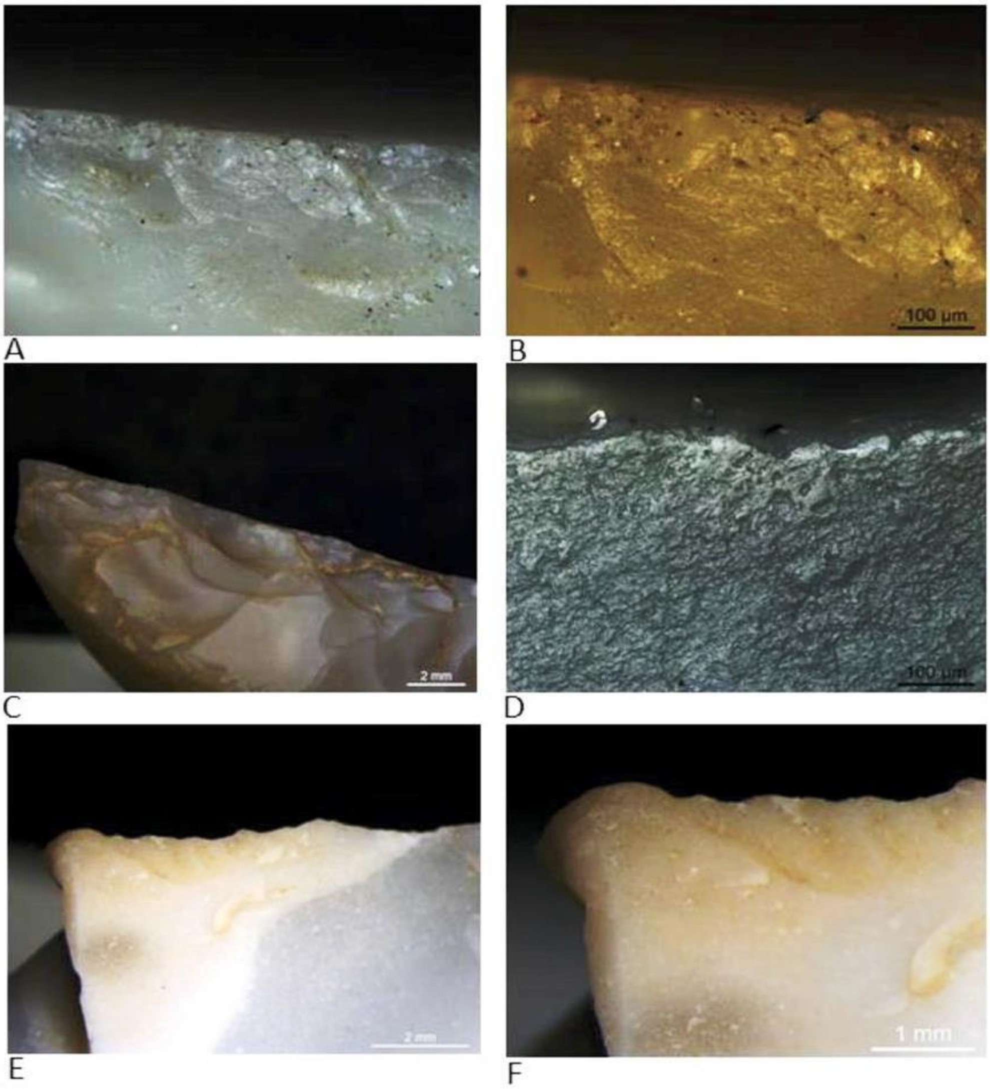


Fig. 5.8 The poor preservation of the implements impeded a proper analysis of the traces. A and B: edge-damage and isolated spots of polish displayed on the distal edge of tool R. 38 (10x and 20x); C and D: edge rounding and edge damage displayed on the distal edge of tool R. 41. Microscopically, the edge shows post-depositional traces in the form of a bright and well developed polish, similar to the one created by the contact with other stones (0.75x and 20x); E and F: edge rounding recorded on tool R. 724 (1.25x and 2.5x).

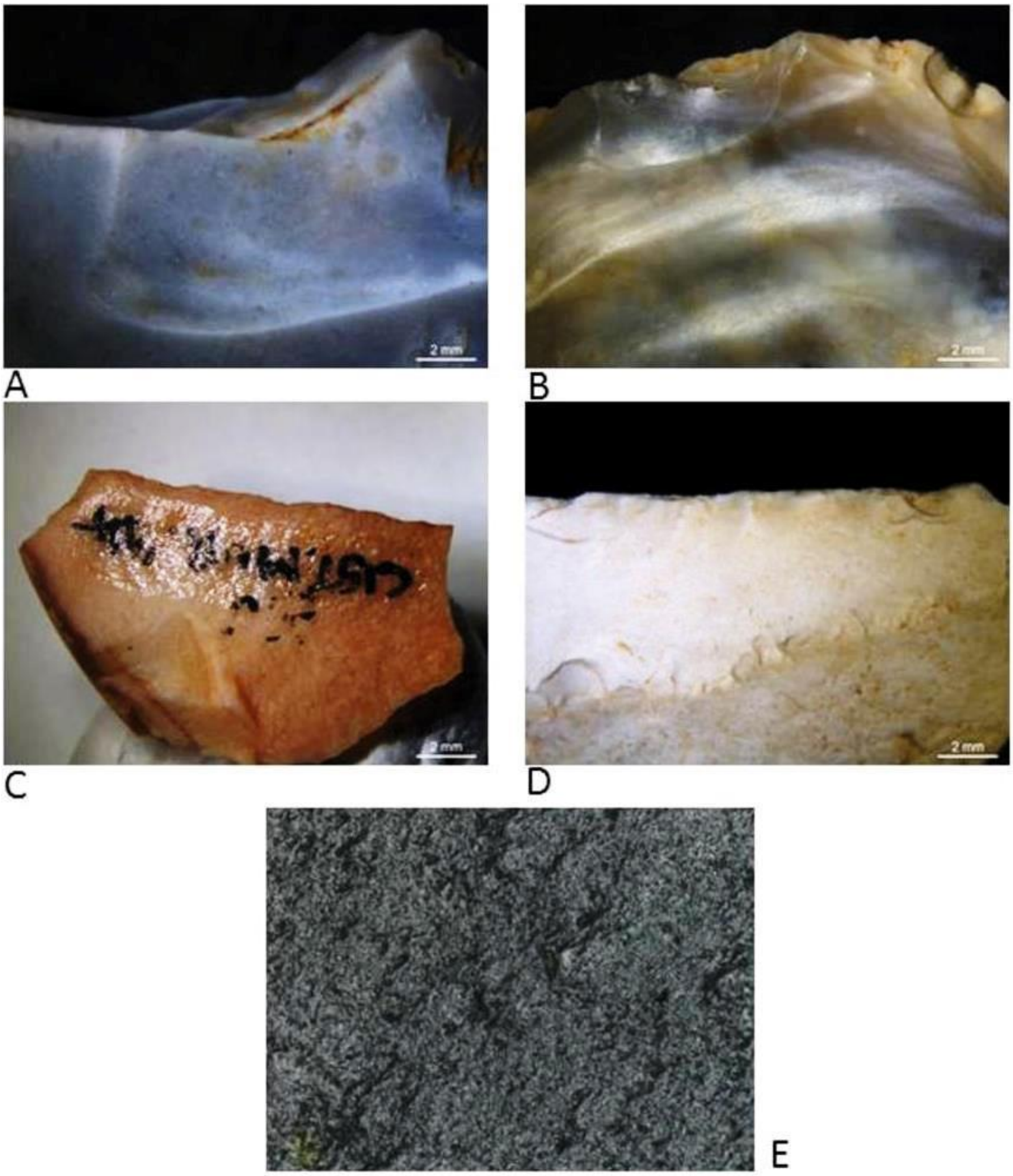


Fig. 5.9 Several macro and micro-alterations were documented that impeded use-wear analysis, as patinas. A): white patina displayed on tool R. 40 (0.75x) and B): glossy patina displayed on tool R. 34 (0.75x); alterations caused by fire. C): change on colour and fracture displayed on tool R. 578 (0.75x) and D): change of colour caused by the dehydration of the implement on tool R. 732 and a heavy abrasion of the surface (0.75x) E): aspect displayed by tool R. 33 and observed in several implements.

5.2.4 Final interpretation

Dating of a lithic industry is difficult even if the typology of knapping is identified, as these technologies usually cover large chronological periods. For example, the identification of Levallois technique or bipolar percussion can only allow assignment of assemblages to the Mousterian or the Aurignacian facies, which correspond to extremely long periods.

Some geographical areas, such as the Pontine region, are even more complicated to interpret as the knapping technique shows no significant change over even longer periods, and stratigraphic data or large collections are often lacking. The finds analysed in this work are affected by such issues. The tools recovered could fit both in the Late Mousterian and in the archaic Aurignacian. The first hypothesis discussed to clarify this problem will be that of the occurrence of a transitional industry. Although the dating of the site, as well as the presence of tools with both Mousterian and Aurignacian characteristics, could point toward such a conclusion, the existence of this lithic typology in Latium has not been unanimously accepted. However, some scholars identified transitional local industries in a few sites, e.g. from layer 7 of Grotta Breuil (Alhaique, Bietti, *et al.*, 1998) and layer 27b of Grotta del Fossellone (Vitagliano and Piperno, 1991), in which many Aurignacian features were common to the local Mousterian, yet with a Levallois index above the average (Alhaique *et al.*, 2000, p. 111).

In this regard, it is necessary to specify that the presence of the Uluzzian, i.e. the Italian transitional industry par excellence, is not at all attested in the Pontine region (Kuhn and Bietti, 2000; Mussi, 2001a). The Uluzzian consists of a Neanderthal industry distinct from the previous Mousterian and the later Aurignacian, which shares the typology of many tools with both facies, although heated debate on its belonging to the first sapiens is still ongoing (Palma di Cesnola, 2001). It is well known in north and south Italy, while scarcely present in central Italy. This facies is characterised by small microliths with a crescent shape and a high rate of splintered tools (Palma di Cesnola, 1993). The industry here discussed does not show sufficient elements to ascribe it to the above mentioned rare “transitional" industries of Monte Circeo nor to the Uluzzian.

Despite the poor preservation, the use-wear analysis of stone tools has helped their understanding in a number of ways. Through the use of low and high power magnification, further and more detailed inferences about the tools’ functions were made, as well as observations about the post-depositional taphonomic processes impacting on the condition of the assemblage. It is possible to conclude that the lithic collection found at CM was introduced into the site by an external agent such as water. This result is extremely important to define the human role in the history of this site. People frequented the surrounding plains rather than the shelter itself.

In conclusion, lithic artefacts found at CM can be interpreted as sporadic archaeological material transported into the site during occasional, but common, flooding events of the area. This assemblage can be divided into two groups: the larger one, of Pontinian facies, was present throughout the Middle Palaeolithic (SU12, SU14) and during the period of hyena occupation (SU11). The second one, smaller and attributed to the Aurignacian facies, rests on layer SU11 and would have been deposited in a period subsequent to the carnivore activity and prior to the filling of the cave.

5.3 Analysis of the human exploitation of the territory

The most important and best stratigraphically preserved sites of the Pontine Plain (see section 5.1) have provided a substantial amount of information on various aspects of prehistory. Regional patterns of land use are closely related to subsistence techniques, raw material procurement and exploitation of the regional topography. In the past, assumptions and reconstructions have always been based on single factors, such as lithic industry (Kuhn, 1991b, 1995; Stiner and Kuhn, 1992), food resources (Stiner, 1990, 1994; Stiner and Kuhn, 1992) or palaeoenvironmental features (Hunt and Eisner, 1991; Eisner and Kamermans, 2004).

The aim of this section is to provide a site exploitation territory analysis (SEA) and outline a complete picture, by integrating all these elements and highlighting limitations and opportunities offered by the area to humans in prehistoric times. The application of this kind of analysis was defined for the first time in the 1970s (Vita-Finzi and Higgs, 1970), with the aim to understand the context from which the finds discovered originated. This can be done either through a study of the landscape to interpret a site therein, defined as Site Territorial Analysis (STA) or through a Site Catchment Analysis (SCA), reconstructing the surrounding landscape according to findings from a site (Vita-Finzi and Higgs, 1970; Higgs, 1972; Bailey, 2005). Both of these methods have been applied successfully in the past, showing their usefulness (Bailey, 2005; Henry, Belmaker and Bergin, 2017). For the purposes of this study, published archaeological records of the region have been reviewed for the construction of a SCA.

Faunal and technological frameworks do not remain stable in the Pontine Plain throughout the Middle Palaeolithic, undergoing changes roughly around 55 ka BP (Stiner and Kuhn, 1992). Greater emphasis will be put on the description of the regional framework and human behaviours between 44–34 ka BP, based on the main focus of this thesis. A brief overview of the earlier phases and the dynamics that may have led to behavioural changes will also be proposed, offering a diachronic perspective on this regional variability.

For the purpose of conciseness and clarity, the factors relevant to this reconstruction, albeit still naturally overlapping with each other, will be examined in separate sections.

5.3.1 The importance of topographic features

While the topography of the Pontine Plain region is described in section 2.1, this section will focus on its impact on the life of humans during prehistory. A crucial role for the survival of human groups was obviously played by the choice of the place to live in. In a world so closely related to natural resources as the prehistoric one, this decision would have been taken in relation to the availability of resources. Key resources include not only food resources but also other resources such as water, which is also difficult to transport, and thus constrains the location of occupation sites. Features of topography can be important. For example, European Upper Palaeolithic hunters tend to locate sites in order to control access to topographically well-delimited plains frequented by large mammals rather than live at their centre (Bailey, 2005). From here it was not only possible to control the movements of herds and ambush them when crossing chokepoints, but also to avoid overcrowding of their living space that would lead them to move towards more peaceful areas, devoid of human presence.

The model of a naturally delimited region with vast plains, frequented by herbivores and with human sites placed on the almost exclusively coastal border, fits perfectly with our study area. All Mousterian sites of the Pontine Plain with a human presence are placed along the Tyrrhenian coast, especially in the area of Monte Circeo. Coastal caves were the only sheltered areas of the plain with access to abundant water and flint sources, and the opportunity to control the movements of animal prey that came into the region from a distance.

Although a large percentage of the Pleistocene coastal sites are now submerged by the sea, with subsequent loss of related information, coastal environments and their role in prehistoric human life have been particularly investigated in the last fifteen years. The LGM marine regression allowed the emergence of vast plains in the Pontine Plain and, in addition to increasing the land area, this has contributed to the drying up of the wetlands, making the area more attractive than the Italian inlands, including the post-glacial Pontine Plain itself.

The study of coastal territories has usually been focused on topics such as the emergence of natural bridges between isolated regions (Stringer, 2000; Walter *et al.*, 2000; Oppenheimer, 2003), the role played by marine resources in subsistence (Erlandson, 2001), the environmental benefits these areas offered (Bailey, 2004; Erlandson and Fitzpatrick, 2006) and others. The hypothesis that some coastal areas may have served as *refugia* for Pleistocene populations will be applied in this work, based on the assumption that the combined features of coastal areas would have offered favourable living conditions in the past (Bailey *et al.*, 2008; Finlayson, 2008). The most obvious and common features are: nearby pure water sources; integration of new food types in subsistence, such as fish, shells but also many species of marine birds; a greater productivity and higher variety of natural products of the soil, due to both marine and land properties, with many micro-environments and high biodiversity in relatively small and very well defined areas.

Some areas of the Mediterranean have already been identified as potential *refugia* through an analysis based on variables such as the effect of ocean currents, connection with the surrounding territories and proximity to the coastlines. According to archaeological data, southern Iberia (Finlayson and Giles Pacheco, 2000), Atlantic Europe (Boyle, 2000) and Black Sea-Aegean (Bar-Yosef, 2000; Panagopoulou *et al.*, 2004) would have made other areas of refuge. All these features characterise the Pontine Plain as well.

Evidence of the importance of coastal areas in the Late Pleistocene also comes from the distribution of sites. Neanderthals, in particular, seem to prefer lowland settlements near the sea. Furthermore, studies related to their extinction suggest that this would have occurred earlier within the continent than along the coast (Finlayson, 2008). Most of the Middle Palaeolithic sites are located in the lowlands of Latium. However, during the beginning of the Upper Palaeolithic, both lowlands and highlands are occupied, with cave sites identified close to the Pontine Plain in the Apennines, especially the Lepini and Ausoni Mountains (Barker, 1999).

In conclusion, all the evidence and comparisons with other contexts seem to confirm that the Pontine Plain offered natural opportunities and favourable conditions for life even during the harshest climate.

5.3.2 The land and marine resources

Drawing information on the subsistence and human strategies of settlement in this context is challenging. This is due to the biased faunal collections available, which were almost exclusively retrieved in caves in the western border of the area, while the rest of the region has provided little evidence. This phenomenon is linked to the fact that during the ice ages, the entire Italian peninsula was subjected to the erosion of the open-air surfaces rather than sedimentation, allowing the preservation of fossils only in cave sites (Mussi, 1999). In addition, these rare cases of open-air fossil deposits are located in fluvial and lacustrine environments, such as the aforementioned Canale delle Acque Alte (see section 5.1.7) and the site of Valle Radice (Biddittu, Cassoli and Malpieri, 1967; Segre, Biddittu and Cassoli, 1984), where lithic industries can hardly be associated with human activity. For this reason, this kind of context belongs to "non-site archaeology", areas in which a great number of artefacts are accumulated by post-depositional factors such as rivers furthest from the original deposition (Alhaique and Bietti, 2007). In the Mediterranean landscape, this kind of context is relatively common and the concept of non-site archaeology has been extensively discussed (Gallant, 1986; Terrenato, 2000; van Leusen, 2002; Cherry, 2003; Given, 2003). In this section, to avoid this kind of site, only faunal assemblages from coastal cave sites extensively studied in the past have been taken into account.

Before going into detail of which animal resources were hunted, and what is their involvement in a study on the exploitation of the territory, a brief summary on the subsistence of both Neanderthals compared to the AMH is needed. The practice of hunting by AMH has never been questioned, whereas the mastering of this technique has only recently been confirmed for Neanderthals. However, the time and modality of this cultural acquisition are still unclear. Although the Neanderthals' relationship with AMH is among the most discussed topics in prehistory, it is only recently with the development of new laboratory analysis that light has been shed on the subsistence of this species (Ready, 2010). This human group was previously thought to rely mostly or only on scavenging, with hunting solely towards small animals (Klein, 1987; Chase, 1988; Stringer and Gamble, 1993; Marean, 1998; Shea, 1998). Later it became clear how Neanderthals practised selective hunting of individual species as well (Mellars, 1989; Gaudzinski, 2006), evidence of a specialised hunting adapted to different environments and the available faunas (Costamagno *et al.*, 2006; Blasco and Fernandez Peris, 2012; Blasco *et al.*, 2013). Only in recent years have studies based on dental wear and calculus shown that a wide variety of food resources were exploited (Stringer *et al.*, 2008; el Zaatari *et al.*, 2011; Henry, Brooks and Piperno, 2011; Salazar-Garcia *et al.*, 2013; Sistiaga *et al.*, 2014; Fiorenza *et al.*, 2015) including plants (Lev et al. 2005; Madella et al. 2002), fish and shellfish (Stringer *et al.*, 2008; Brown *et al.*, 2011; Colonese *et al.*, 2011), although it is still widely discussed what the actual contribution of these resources was to the daily diet (Hockett and Haws, 2005; Richards and Trinkaus, 2009). This shows an organised and specialised subsistence, though perhaps less logistically organised than people in the Upper Palaeolithic (Mellars, 1989). Furthermore, the Neanderthal diet shows a certain flexibility during the climatic oscillations, during which it adapts to animal migrations (Fiorenza *et al.*, 2015).

Key studies of this topic have been carried out for central Italy by Stiner on the fauna and by Kuhn on the lithics (Kuhn, 1990; Stiner, 1994). Mary Stiner, the greatest specialist of the Pontine Plain's faunal record (see section 2.2), offered her own interpretation of how humans procured meat in the Middle Palaeolithic. The analysis of animal bones from Neanderthal layers of caves such as Grotta Guattari, Grotta Sant'Agostino, Grotta Barbara, Grotta Breuil and Grotta dei Moscerini (see section 5.1), enabled her to identify extremely interesting phenomena, including a change in dietary habits that occured roughly about 55 ka BP in the Middle Palaeolithic (Stiner and Kuhn, 1992).

Prior to this time, faunal remains from Grotta Guattari and Grotta dei Moscerini consist mainly of skulls and feet of old individuals, indicating the exploitation of remains of already preyed-on carcases (i.e. scavenging). At Grotta dei Moscerini, faunal remains from more recent layers provide evidence of a different strategy. In particular, the exploitation of marine resources, such as shellfish (bivalves and shells), seals and marine turtles is attested (Vitagliano, 1984; Kuhn, 1995), especially when animal bones resulting from meat consumption are absent. After 55 ka BP, in sites such as Grotta di Sant'Agostino, Grotta Breuil, Grotta Barbara and Grotta del Fossellone all animal body parts are found, indicating that whole carcases were brought into the shelter (Stiner and Kuhn, 1992). The remains belong mostly to prime specimens with a high meat yield, with the entirety of the bones bearing the traces of marrow extraction. The intensive exploitation of carcases is typically associated with infrequent hunting or with the hunting of single individuals rather than herds (Stiner, 1990, 1991b, 1991c). This type of exploitation may indicate seasonal nutritional stress.

The age of death of the fauna also allowed an identification of a seasonal rather than permanent occupation. During such gaps, shelters were occupied by other carnivores, mainly hyena and more rarely wolf, in a typical alternation pattern of the Palaeolithic (Gamble, 1986; Caparròs *et al.,* 2012). In the Pontine Plain, such alternation is more evident in the Middle Palaeolithic than in the Upper Palaeolithic, when human occupations became longer and more intense (Alhaique and Bietti, 2007).

A study extended to cave sites in northern Italy, for a total of about 200 sites, revealed that Neanderthals chose carefully which caves to live in. Caves hosting the two largest Italian carnivores, i.e. *Ursus spelaeus* and *Panthera leo* appeared to have been avoided, while it seems that Neanderthals occasionally occupied shelters contemporaneously with carnivores of smaller sizes (Mussi, 2001b). This might suggest that prehistoric humans did not fear the competition with species such as hyena and wolf for the occupation of a site. Such willingness to compete might have also been valid in hunting the same prey, with important repercussions for human subsistence. The exploitation by Neanderthals of both hunted and accidentally found carcases is expected to be identified, especially in relation to the earliest phases, when hunting was not predominant. This change is not currently attested in other areas of central Italy and it seems that it is a regional variant due to human adaptation to the territory and resources. Hunting appears to have progressively replaced scavenging. The latter, usually considered as a passive practice, is believed to have had a more active connotation in the case of hominins, as it probably implied the act of excluding other predators from carcases instead of waiting for their voluntary departure (Stringer and Gamble, 1993). However, most of the time, scavenging would have provided little meat and, therefore, required more frequent searches. During the early Middle Palaeolithic varied fauna appear to be equally exploited, while in the final stages red deer is by far the most frequent in layers with human activity. Afterwards, this preference seems to become more apparent with AMH, who mainly exploit fallow deer (*Dama dama*) and later *Equus hydruntinus* (Stiner and Kuhn, 1992; Barker, 1999). Ungulates dominate all faunal assemblages until the Late Upper Palaeolithic, when hunting specialisation appears leading to changes in settlement choices, with sites moving closer to the habitats of the hunted species. Deer and horse, among others, alternate the use of the plains during the winter months with the occupation of highlands during the warmer summer months. In order to always have access to these mammals, a seasonal migration of human groups developed, as documented in central Italy by Barker (1981), based on a system of logistical hunting where frequented areas became seasonal kill sites.

It should be noted that this is a very general behavioural framework of the first AMH, since there are many known sites where groups of *Homo sapiens* decided not to leave the plains, preferring to exploit other foods and resources, instead of following those species.

Little can be said about the exploitation of marine resources, which are extremely difficult to preserve due to sea-level change and the size of remains. One of the earliest pieces of evidence for this subsistence practice is provided by Grotta dei Moscerini (see 5.1.6), with turtles possibly harvested or hunted along the seashores but no evidence of fishing practised (Stiner, 1994). The faunal assemblage from this site shows an early exploitation of minor species, as noted in other contexts such as shelters in Gibraltar (Stringer *et al.*, 2008), and testifies to the start of the so-called Broad Spectrum Revolution (Flannery, 1969).

5.3.3 A landscape perspective on the lithic industry

The abundance of raw material, regardless of its quality, has undoubtedly influenced the production technique of lithic industries by human groups in the territory (Kuhn, 1991b). At the same time, the need for constant access to this resource has certainly influenced the settlement choices along the coastal area. The presence of these sources of raw material along a single axis (i.e. the coastline) imposed a linear behaviour for the exploitation of the flint (Rolfo, 2008), opposed to the “star behaviour” in which the residential site is placed at the centre of the exploitation area all around it. The Pontine Plain has a relatively small extension (see section 2.1), the almost unlimited availability of pebbles to knap along the coast should not, therefore, have imposed severe restrictions. The settlement areas would have never been at a distance greater than about 30 km, which falls within the estimated daily range of hunter-gatherers. It was thus possible for humans to practise what Binford (1979) called “expedient technology”, consisting of the collection of raw material and production of tools when required, then abandoning them after use. The very high frequency with which tools are found across the territory would, therefore, be explained by this interpretation.

This practice contrasts with the "curated technology", generally adopted by groups of hunters who had to make vast movements away from sources of raw materials. In that case, they were forced to take particular care of their tools and retouch them until depletion before abandonment (Binford, 1979).

In this respect, the raw material provides important technical information with notable repercussions for the mobility habits of these people. Although scholars have long considered exotic raw material as a rarity (Kuhn, 1991a), it has been now unanimously accepted that this did not appear in the region until the Upper Palaeolithic, when the Apennine red flint is exploited (Alhaique and Bietti, 2007). This could indicate that human groups of central Italy during the Middle Palaeolithic did not travel outside a rather short range and therefore did not establish any contacts with groups from other regions. This behaviour coincides with the movement patterns already documented in the Middle Palaeolithic of many other European regions, according to which long distance movements or goods exchanges were unfrequent (Djindjian, 2012). The sources of raw materials are usually between 5–20 km from the site (Fernandes, Raynal and Moncel, 2008; Féblot-Augustins, 2009; Conard, Bolus and Munzel, 2012), rarely at a greater distance. Despite this, we cannot ignore important exceptions, with raw materials coming from over 100 km (Marwick, 2003) up to incredible distances of 400 km in Cap Grand in south-west France (Slimak and Giraud, 2007). It is still debated whether these cases should be regarded as evidence of networks between distant groups or sporadic cases of personal goods transported across long distances (Féblot-Augustins, 2009; Meignen, Delagnes and Bourguignon, 2009; Sykes, 2012). In the last decade, bioarchaeological analyses, not previously accessible, have yielded important information in support of a not very mobile and socially isolated life of Neanderthal groups, also with regard to reproduction (Prüfer *et al.*, 2014; Sanchez-Quinto and Lalueza-Fox, 2015).

The exotic Upper Palaeolithic flint consists of almost exclusively heavily retouched tool forms and a few exploited cores. This suggests that their production was realised far outside the Pontine Plain and that the tools possibly arrived in the territory by means of exchanges with neighbouring peoples (Renfrew, 1984) or long seasonal movements of the Pontine Plain groups. It has long been debated whether the transport of lithic material was indicative of high mobility behaviour developed during the Upper Palaeolithic (Bar-Yosef, 2002, 2003; Clark, 2002; Henshilwood and Marean, 2003; Mellars, 2005). Exotic material is often present in the Middle Palaeolithic sites in Europe but in lower quantities than the next phase (Féblot-Augustins, 2009), perhaps because of a lower mobility of human groups (Slimak and Giraud, 2007; Riel-Salvatore and Negrino, 2009). Despite the Italian Mousterian sites showing a large majority of local flint exploitation (Alhaique *et al.*, 2000), important exploitation of exotic flint is documented elsewhere (Spinapolice, 2012).

The total absence of this resource in the Pontine area is, therefore, a peculiar aspect of this region. The absence of raw material from the interior uplands of the peninsula during glacial ages and the appearance during the subsequent post-glacial might suggest inaccessibility to these sources of flint because of snow or frozen ground, as proposed by Rolland and Dibble for other countries (Rolland and Dibble, 1990). However, climatic conditions of these areas were never considered to be so restricting, making this hypothesis hard to confirm.

The choices made by these peoples in core and tool processing reflect a number of contingencies and adaptations to the territory under consideration. Due to the application of Levallois technique in all lithic collections in central Italy (Grimaldi, 1995), the use of bipolar knapping technique in the Pontine Plain together with a very low percentage of Levallois technique, never exceeding 11% (Bietti 1980; Bietti 1982; Taschini 1979), were often considered as constraining factors for prehistoric humans of the region. According to this concept, regional lithic production would then be a forced adaptation to the raw material available, i.e. a Neanderthal's adaptation to a flint of low quality with which, when possible, they pursued a Levallois production. This would explain the low incidence of this technique. Recently, a new interpretation has been offered for this issue. The Pontinian industry should not be considered as the result of a limitation of Neanderthal technology but, as an equally predetermined *débitage* sequence, as shown by a study on cortex percentages (Grimaldi and Santaniello, 2014). That means that, when analysed, these lithics should be considered as a series of technological choices made to satisfy the needs of the humans in that particular context.

The studies of the lithic collections from Grotta Guattari, Grotta di Sant'Agostino, Grotta Breuil e Grotta dei Moscerini by Kuhn (Stiner and Kuhn, 1992) have provided information to support a subsistence based on a mix of scavenging and hunting by the human populations. Specifically in its technical study Kuhn identifies a greater rate of curated instruments in the layers of Grotta Guattari and Grotta Breuil, interpreted as suitable for short hunting and slaughter of prey brought into shelters. Conversely, at Grotta di Sant'Agostino and Grotta dei Moscerini, tools seem to show less care and were probably used for the extraction of anatomical parts to carry into the cave from already slaughtered carcases. Considering that Grotta Guattari has a source of raw material in the immediate vicinity (Durante and Settepassi, 1976), contrary to Grotta di Sant'Agostino, where flint deposits are unknown (Kuhn, 1991b), this ratio between curated and non-curated tools in both caves is in perfect agreement with a curated and expedient technology as defined by Binford (1979).

A change in technology and dating is indicated by Kuhn around roughly 55 ka BP, a dating established for consistency with the dating on subsistence discussed above (see 5.3.2) and published in the same article. The lithics show how after this date the expedient technology is preferred although the typology of tools did not change, with end-scrapers remaining dominant. At the same time, raw material, i.e. the local pebbles, was rarely transported over long distances (Stiner and Kuhn, 1992, p. 326). The latest specialised studies of finds from Grotta Breuil confirmed that this dating might be too vague. According to these studies, subsistence and lithic production behaviours changed between the oldest and the most recent layers, but such a change would be placed at about 38 ka BP. The authors have then supposed that the change is attributable to a different use of the shelter and natural resources. Specifically, the oldest layers would reflect a stable and intense occupation throughout the year while the subsequent layers indicate an occasional use of the shelter (Grimaldi and Santaniello, 2014).

Similar conclusions based on the study of only two sites may not be statistically very reliable, however, the lithic assemblages correspond to a series of palimpsests spanning many thousands of years and not corresponding to individual events. In this sense, these deposits are ideal for studying behavioural changes and the use of these contexts during a broader time scale. Comparison with behaviours of other human groups in prehistory can provide critical information to the understanding of land use. The production of large blanks and the presence of tools retouched several times suggest the need to make them last as long as possible. This is particularly true, for example, for mobility over a wide territory, when the time for future access to the raw material is uncertain. Conversely, the recovery of numerous small tools indicates a more sedentary lifestyle near sources of raw materials, where the search for food did not require long journeys, and lightweight tools that would be abandoned after use were preferred. This latter event matches with the picture visible in the Pontine Plain, meaning that the last Neanderthals of the area complied with this behaviour.

This attitude could be detected mainly through studies of surface lithic industry distribution along the Pontine Plain (see section 3.3). This systematic spatial analysis has also permitted us to recognise interesting elements that affect our interpretation of the territory. The number of open-air sites with a lithic industry appears to be more common in the northern coastal plain of the region than the southern (Loving *et al.*, 1991). This difference is not justified by any archaeological reason, therefore possible taphonomic processes were investigated that may have influenced this distribution.

Two factors seem to explain this anomalous distribution. The first one is geological, with stratigraphic studies of the region showing that the most recent aeolian soil formation is far more extensive and widespread in the south of the region (Sevink, Remmelzwaal and Spaargaren, 1984), covering Middle Palaeolithic layers and industries therein contained. The second one relates to the human activities of modern times, particularly the reclamation that required massive excavation and movement of huge amounts of soil and subsequent intense agricultural activities. Both these activities are particularly concentrated in the south of the region and seem the most likely factor to explain the above-mentioned difference.

It has been possible to observe that surface finds of Upper Palaeolithic industries are less prevalent than those of an earlier age. This might demonstrate that AMH preferred to apply a curated technology in contrast to their predecessors.

In addition to this, it is also evident that, with AMH, the number of find spots decreases in the coastal areas to the benefit of the innermost ones close to the mountains. On the other hand, Palaeolithic sites have not been currently identified in the Lepini Mountains (Casto and Zarlenga, 1997; Casto, 2005). This is probably due to the unfavourable conditions offered by that environment, lacking sources of raw material and resources of water, and with some of the big mammals usually hunted only living in the plains (Kamermans and Sevink, 2009). However, intensive research is ongoing in the area, and is likely to reveal many more details.

5.3.4 Elaborating the exploitation of the territory

All relevant factors listed so far have affected the land use. A combined interpretation of them can be used to understand the exploitation of the territory. Changes in lithic technology and in procurement and exploitation of food resources reflect changes in the choice of the shelters, seasonal movements and vice versa. All elements are deeply related and vary according to limits and benefits offered by one or the other. The Neanderthal dynamics in this area are not necessarily valid in any other place or time, as concepts of flexibility and adaptability are indeed crucial for interpretations of the exploitation of territories during the Palaeolithic.

The Pontine Plain can be considered as a coastal area, although its eastern boundary is circumscribed by high Apennine mountains. This is a topographically well-delimited region with transitional landscapes between the inner mountains of the peninsula and the marine resources of the coast, which favoured the intense exploitation by Neanderthals in earlier periods and AMH later. The wealth and variability of resources of this environment allowed subsistence based on short trips. The coastline ensured an easy access between the north and south of the peninsula offsetting risks of isolation of human groups. These kinds of environments have also been recognised as ideal elsewhere, particularly in Mediterranean Spain. Because of their more suitable living conditions during climatically harsh ages such as the LGM, these are commonly known as *refugia* (Jennings *et al.*, 2011). The linear morphology of the territory had, therefore, important implications for the role played by humans. The disposition of sites on the margins of the area and the behaviour of the human groups seem to suggest that the region was not intensely occupied but controlled throughout its access points and exploited with occasional expeditions inside it.

Food resources and the lithic industry habits of prehistoric humans appear to undergo an adaptation after roughly 55 ka BP (Stiner and Kuhn 1992) (see section 5.3.3). The subsistence is essentially based on a combination of hunting and scavenging. The latter appears as the main system for meat procurement before this chronological limit, while hunting dominates the next phase (Stiner and Kuhn, 1992). At the same time, the lithic industry shows a change in the reduction technique, but not in the typology of tools, although an increase of hunting tools would have been expected simultaneously to the intensification of hunting. According to Kuhn (Stiner and Kuhn, 1992, p. 330), this data would demonstrate the ability of these human groups to overcome the lack of hunting equipment with advanced collaboration during the hunt, showing that an intense sociality would characterise the inhabitants of the area. Such a technological and subsistence change is only typical in this regional framework. Very different behaviours are visible in terms of technology in the Mousterian of Europe and Italy, as in the case of Riparo Mochi in Liguria. The Pontine Plain situation thus seems a regional adaptation to local resources. Studies of lithic cores found in the area made it possible to clarify that the presence of abundant raw material has influenced the behaviour and mobility of human groups. According to this, the inhabitants would have found it convenient not to transport the raw material to sites within 6 km from the source, preferring to produce tools directly there and to carry only those end products with them. For settlements between 6–10 km, the raw material was imported as cores, while for greater distances the evidence seems to indicate that only small cores were transported to be processed later (Loving *et al.*, 1991). In general, an expedient technology was applied since the distribution of raw material throughout the territory did not impose great limitations.

A model of land use in Tyrrhenian Latium during the Middle Palaeolithic may, therefore, be suggested. Evidence supports the concept that the last Neanderthals lived in cohesive and compact communities in the few, and grouped, coastal cave shelters, frequenting them in a seasonal pattern. The plain was not densely populated, as a limited amount of open-air sites seems to indicate, but rather was used through numerous and short expeditions. These occurred both for the procurement of flint along the fossil beaches and for hunting of large mammals which lived in the region, especially deer and wild horses. The occasional exploitation of carcases, perhaps turning away the first predators, is also attested after the emergence of hunting. Marine resources were exploited when available, whereas there is no evidence of fishing activities at this period. Expeditions outside the boundaries of the Pontine Plain should not have been frequent, at least according to the lithic tools. However, the marine regression gave access to a wide corridor along the coast through which episodic movements and contact with other populations would have become possible.

5.4 Conclusions

The main aim of this chapter was to understand the human presence and the exploitation of the landscape of the Pontine Plain during the Late Pleistocene. In order to achieve this, the most influential resources in human life have been taken into consideration, e.g. specific environmental requirements and the presence of natural shelters, access to food, water and nearby sources of lithic raw material. The combination of all these has made it possible to reconstruct human lifeways in the territory during the Palaeolithic, with particular emphasis on the Late Middle and Early Upper stages.

Sites located along the Tyrrhenian coast of the region have been selected according to their environmental and archaeological information potential and described, in order to be used later as comparative case studies.

An use-wear analysis of the lithics found at the key site of CM was also provided, establishing the local origin of raw materials, in accordance with the regional

Mousterian, and determining that even the *débitage* was utilised as a "tool". The most important result, however, is the demonstration that the small collection recovered was brought in the cave by natural factors, such as water. This proves humans did not attend the site but the surrounding plains.

The third section, through a territorial analysis of the resources and the distribution of known archaeological sites, proposed a pattern of areas of interest and demonstrated the potential of the related environmental resources. Despite the limited number of sites, it has been possible to draw some conclusions. The picture shows an interesting outline of the region, which features a biodiversity of environments and resources in its topographic compactness.

Some interesting differences in settlement and subsistence choices between AMHs and Neanderthals have been highlighted by this study. Comparing the two species, it was decided not to consider the influence that evolutionary anatomical differences may have had. Although it is now abundantly documented that the two species presented different physiological adaptations to the cold European climate (Facchini & Belcastro 2009; Finlayson 2004; Gilligan 2007), the role of such adaptations in the survival and extinction dynamics of the hominins is still discussed. The environmental conditions of the Pontine Plain territory have never been considered so extreme as to demonstrate this feature. Anatomical differences may have influenced human groups' decisions, but the extent of this influence is not currently quantifiable. The analysis undertaken above is rather based on the different choices made by these hominins to address the same needs, such as finding food, knapping flint, sheltering choices etc. These could perhaps identify an evolution of cognitive abilities but changes in environmental conditions may have also assumed a key role in this process. The environmental conditions hold the greatest interest. May these different choices have not been dictated by a different way of thinking but rather by an environment more favourable for life? The suitable conditions of the Pontine Plain, in which every resource was easily accessible, might have allowed the Neanderthals to lead a life enclosed within these geographical boundaries and without the need to occupy new areas.

An environmental reconstruction of this transitional period, necessary to answer the question above, will be presented in the following chapter, focused on the palaeoecological analysis of hyena coprolites found at the site of CM.

Chapter VI

Palaeoecological Analysis of the Coprolites

The aim of this chapter is to introduce the results of pollen analysis from Cava Muracci’s coprolites (hereinafter CM), a resource that has never been exploited before in the region. The methods and materials used for the realisation of this study were presented in detail in Chapter IV. A representative sample of each specimen has been retained to ensure that repeatability of this study or new analyses can be carried out in the future.

The first section presents an overview of coprolites, their features and usefulness in the archaeological record. This discussion is required in order to motivate some of the methodological and analytical decisions adopted in this study. The next section focuses on the CM samples analysed. Details about their identification, classification and preservation are provided to demonstrate the reliability of the pollen diagrams described below. Finally, a first vegetation framework based on these data is proposed. The pollen results will be then discussed and combined with the faunal data (Chapter VII) in the discussion (Chapter VIII), where a holistic environmental reconstruction will be proposed.

6.1 Introduction to coprolites and pollen analysis

Coprolites are human or animal faeces fossilised through diverse processes, usually mineralisation or desiccation, the name is derived from Greek kopros (dung) and lithos (stone). The word coprolite was first introduced in the 19th century (Buckland, 1824), when Late Pleistocene fossil hyena's faeces were discovered in Kirkland Cave, England, the first den of this carnivore to be described (Buckland, 1822). However, there is evidence of coprolites having been discovered earlier, as demonstrated by several sparse documents, but never interpreted as fossil faeces (Duffin, 2012). The first preliminary studies on fossil dung date back to a few years after the discoveries of Kirkland Cave

(Buckland, 1829). This resource had little success and for a long time was deliberately ignored, or even destroyed, during archaeological excavations (Diedrich 2012, p.369). Incredibly, an intense exploitation of coprolites as fertiliser took place in Europe until the end of the 1800s (O'Connor and Ford, 2001; Ford and O'Connor, 2009; le Loeuff, 2012). Detailed studies began in the mid-1900s (Callen 1969; De Lumley 1969; Hantzschel et al. 1968), when the first analyses were performed on human (Loud and Harrington, 1929; Wakefield and Dellinger, 1936) and animal coprolites, aiming to obtain information about ecology, health and diet of these species (Reinhard, 2006; Bryant Jr. and Reinhard, 2012; Mead and Swift, 2012). Despite technological developments, and the growing importance attached now to the coprolites, these remains are rarely fully exploited even today.

The discovery of coprolites is not a rarity in Europe, but this resource is extremely fragile and in some regions is not common at all (Hunt *et al.*, 2012; Mead and Swift, 2012). Faeces, potential coprolites, were obviously deposited in large quantities wherever there was a human or animal presence. However, the preservation of these materials in modern days is limited by two constraints. The first and probably the biggest difficulty lies in the initial fossilisation of excrement. The decomposition of faeces is actually induced by multiple natural factors, such as temperature, weathering and soil composition (Hollocher and Hollocher, 2012) and by fungi and invertebrates (Hansen, 2001; Wood *et al.*, 2008) which usually disintegrate these remains very quickly. The second is the preservation of coprolites in the archaeological record, which is substantially correlated to their components and the context of deposition. Coprolites can disintegrate even after thousands of years, as a result of erosion or sudden animal activities. Therefore, only a very low percentage of deposited faeces are preserved. Finally, destruction and/or failure to identify the coprolites during excavations must be taken into account. In fact, coprolites rarely maintain their entirety but crumble and are incorporated in the soil, making their identification extremely complex.

One aspect which makes fossil faeces an extraordinary source of information is the tendency to assimilate and preserve pollen grains. Pollen analysis is the best source to infer past vegetation of a region, providing evidence otherwise unavailable in the archaeological record, and led to the development of an independent discipline called palynology. Today it leads in environmental studies since its first development by Lennart von Post in 1916 (Manten, 1967) and permits reconstructions of environmental frameworks over different space and time scales as well as understanding of vegetation evolution through time. The current knowledge of Pleistocene landscapes is mainly based on pollen data. The reasons behind the exploitation of pollen are their ubiquity, due to their distribution over large areas by wind, water and animals, and their remarkable preservation in anaerobic (Bell and Walker, 2005; Reitz and Shackley, 2012) and acidic sediments (pH under 6.0) (Dincauze 2000). However, interpretation of pollen is effective only if carried out in full awareness of its biases. A large part of environmental reconstructions are based on lake sediments, as lakes collect pollen grains from incredibly large distances through pollen rain and water transport via streams yielding a vegetation picture at a regional scale (see space scale issue in Chapter I). A significant bias of sediments is the overrepresentation of airborne pollen and particularly tree taxa since these species developed a high production of air-transportable grains (Faegri and Iversen, 1989; Moore, Webb and Collinson, 1991). Finally, some areas of the world are too acidic to permit pollen preservation in sediments. Nevertheless, most of these limitations do not apply to fossil faeces which may represent a primary resource to impartially investigate such contexts, though of course other issues are present (see section 6.1.1).

Despite that, pollen analysis from coprolites is a little-used resource in Italy. The reason is partly due to the climatic conditions of the peninsula which do not particularly support faeces fossilisation and preservation. The discovery of coprolites has taken place almost exclusively in caves, often sealed by rock collapses or with low air circulation, especially in hot and dry areas of the peninsula.

The pollen from coprolites represents a unique opportunity to understand the vegetation of the Pontine Plain. This region has undergone the most extensive land reclamation in Italian history, and subsequent farming exploitation, which markedly modified the geomorphology and stratigraphic integrity of a large part of it (see Chapter II) hindering the reliability of pollen from sediments. Moreover, the entire volcanic region is characterised by an acidic soil making preservation of biological material difficult. Coprolites are also infrequent in the Pontine Plain. Their finding is restricted to the unstudied samples from Monte Circeo in the 1930s and to those from CM, which therefore assume a great scientific value.

6.1.1 The potential for coprolite studies

The study of coprolites does not belong to a specific discipline. It falls somewhere between palaeoecology, palaeontology and archaeology. This intermediate position results in it not being fully exploited by any of these disciplines. However, the palaeoecological potentiality of fossil faeces has long been acknowledged since the last century (Martin, Sabels and Shutler Jr., 1961; Leroi-Gourhan, 1966; Bryant Jr. and Holloway, 1983; Moe, 1983), although continually underestimated and poorly evaluated. Due to these circumstances, and because of the higher availability of lake and lacustrine sediments, the latter are commonly preferred for vegetation and climatic reconstructions. Nevertheless, the pollen preservation is conditioned by many factors in these sediments (i.e. climatical, chemical, biological, etc.) that can make their reliability for environmental studies uncertain. Therefore coprolites, as this thesis aims to support, offer an important and sometimes unique resource.

Coprolites have achieved greater visibility in recent years and their importance in various scientific fields has been recognised. Pollen analysis has been successfully performed on samples of both living and extinct species, carnivores and herbivores (Carrión, Scott and Vogel, 1999; Carrión *et al.*, 2000; Yll Aguirre, Pantaleòn-Cano and Roure, 2001; Wood *et al.*, 2008). Despite this, many misconceptions on fossil faeces are still widespread. The most common are: (i) faeces are not morphologically recognisable; (ii) faeces do not conserve organic material; (iii) faeces are not scientifically reliable (Hunt *et al.*, 2012).

All these claims are false and unproved: (i) all hyena coprolites are morphologically recognisable if well preserved, those from CM will be discussed in the next section 6.2.1; (ii) coprolites can protect pollen, and other organic matter, partly impeding oxidation (Scott *et al.*, 2003; Gatta, Sinopoli, *et al.*, 2016). This is particularly true for hyena's coprolites, due to their consistency and durability (Bearder, 1977; Larkin, Alexander and Lewis, 2000; Gatta, Sinopoli, *et al.*, 2016). Therefore, taphonomy of pollen from faeces is generally good and pollen grains are taxonomically recognisable (Scott, 1987; Carrión *et al.*, 2001; Scott *et al.*, 2003); (iii) when both coprolites and sediments are available, their analyses return comparable vegetation frameworks, proving the scientific reliability of fossil faeces.

In addition to the already mentioned oxidation, the main cause of pollen degradation is the fluctuation from arid to humid conditions, while digestive acids have no consequences on pollen (Scott *et al.*, 2003). In general, pollen also deteriorates over time and, therefore, it will be easier to find pollen spores in the youngest dated samples (*ibidem*).

Cave sediments can represent an alternative resource to standard core sediments in arid karst environments (Hunt and Fiacconi, 2017). However, cave palynology is not always reliable and is the object of a widespread scepticism (Sanchez Goñi, 1991, 1994; Bottema and Woldring, 1994). The main perplexities are related to pedoturbation in the stratigraphy, easier destruction of pollen grains in loose soil and frequent contamination due to animal activities and percolation (Carrión, 1999; Dincauze, 2000). Although cave deposits are trustworthy if carefully investigated (Carrión, 1999; Navarro *et al.*, 2000; Hunt and Fiacconi, 2017), fossil faeces currently represent a more reliable resource when available. It has been noted indeed that pollen from coprolites is generally the best preserved of pollen from the surrounding sediments (Scott *et al.*, 2003). All these reasons make fossil faeces an helpful standalone resource for those environments in which usual pollen traps such as lakes and swamps are absent (Scott, 2000; González-Sampériz, Montes and Utrilla, 2003) and a solid comparable tool elsewhere.

In regard to coprolite preservation, due to the karst environment of CM, the influence of caves on fossil faeces deserves to be discussed. Travertine, or rather the minerals of which it is composed, has both positive and negative effects on the finds discovered in CM (see Chapter IV). It is then particularly important to understand if there are negative consequences in the preservation of pollen within karst contexts, such as a selective destruction of some taxa, thereby making the pollen analyses and the subsequent vegetation reconstruction unreliable. The taphonomic processes undergone by pollen in travertine contexts are currently poorly investigated. However, it has long been a common idea that the alkalinity of travertine is not favourable for their preservation (Gray and Boucot, 1975). Nevertheless, recent studies have shown that alkalinity of karst environments is not high enough to cause the destruction of pollen grains (Bertini, Minissale and Ricci, 2014). This implies the reliability of CM's samples, while the lack or low concentration of pollen in these samples is therefore mainly due to an original absence, a statement supported by the good preservation of pollen when found.

The number of pollen grains in coprolites is highly variable from zero to hundreds of thousands per gram (Carrión *et al.*, 2001) and is affected by several factors. Season of deposition, age of samples, gastric action, typology of sediment and diet behaviour of producer are the most common (Gatta, Sinopoli, *et al.*, 2016). Pollen analyses of cave hyena coprolites have been profitably carried out in the past (Carrión *et al.*, 2001; Scott *et al.*, 2003; Yll *et al.*, 2006; Argant and Dimitrijevic, 2007) albeit returning rather low pollen concentration compared to herbivore coprolites (González-Sampériz et al., 2003) or core sediments. However, the accuracy of pollen from hyena faeces to reflect detailed vegetational frameworks is proved by close similarities with pollen data from different sources (Argant & Dimitrijevic, 2007; Carrion et al., 2001; González-Sampériz et al., 2003; Scott et al., 2003; Yll et al., 2006).

Pollen from coprolites has significant potential for local environmental reconstructions. Because of their inclusion in the faeces through nutrition, they reflect only the plant species present in the areas visited by the hyena, which is rarely wider than 15 km and never more than 50 km from their den (Scott, 1987; Argant, 2004; Argant and Dimitrijevic, 2007; Gatta, Sinopoli, *et al.*, 2016). It has already been shown that dung pollen offers better resolution due to the presence of those pollen taxa with a narrow distribution at regional level (Carrión *et al.*, 2008), which are often missing in the marine, lake or marsh sediments, but are essential to identify accurately local vegetation assemblages (Carrión, 2002).

In addition to pollen, coprolites can also provide important information on the landscape through the studies of spores and phytoliths. Nevertheless, fossil faeces are a valuable resource to investigate other aspects of prehistory. Genome analyses were successfully carried out on human and animal coprolites in the last 20 years (Poinar *et al.*, 1998; Gilbert *et al.*, 2008) and more recently on cave hyena coprolites (Bon *et al.*, 2012). This first DNA study from hyena coprolites permitted, in addition to demonstrating kinship with contemporary spotted hyena, the identification of DNA fragments belonging to prey, providing extraordinary direct advice about the carnivore diet (*ibidem*). Lipid analyses and Multiple Detector Computed Tomography (MDCT) scans have also been performed (Gill and Bull, 2012; Milàn, Rasmussen and Lynnerup, 2012). Fossil faeces also represent the ideal environment for the survival of some micro-organisms, such as bacteria and parasites, which rarely survive elsewhere (Hunt *et al.*, 2012; Mead and Swift, 2012; Pesquero *et al.*, 2014).

6.2 Cava Muracci’s coprolites

6.2.1 Description of the coprolites

The faeces of carnivores are phosphatic due to the ingestion of bones. This feature makes them hard and compact and easier to fossilise (Hollocher and Hollocher, 2012; Hunt *et al.*, 2012). This property is extremely evident in cave hyena coprolites but it has also been documented in faeces of modern species of dogs (Diedrich 2012, p.372). Bone fragments of variable size are frequently macroscopically visible in hyena coprolites and this feature has also been described for contemporary African hyena (Horwitz and Goldberg, 1989; Larkin, Alexander and Lewis, 2000) as well as Pleistocene *Canis lupus* and *Panthera leo spelaea* (Horwitz & Goldberg 1989). The easier preservation of carnivores' coprolites is also confirmed by archaeological investigations. Despite the world being mainly populated by herbivores, as was also the case in the past, the majority of coprolites discovered belong to carnivores.

The hyena coprolites consist of aggregates made up of several individual elements defined as "pellets". Their internal structure is highly variable depending on the typology of fossilisation achieved, it can be soft and porous if dehydration starts immediately after the deposition of faeces or hard and granular if a high mineralisation of faeces took place. The pellet dimension is extremely variable, depending on size and age of the hyena but mostly on the food ingested. There are only seven different morphologies of pellets, specific to their position in the whole coprolite aggregate (Diedrich 2012) (Fig. 6.3a). The correct identification of the shape thus permits the reconstruction of disjointed faeces, similar to sparse bones of a skeleton. Furthermore, albeit the elongated and cylindrical morphology is typical of many carnivores and seldom sufficient by itself to allow a zoological assignment (Jouy-Avantin *et al.*, 2003), the morphology of the hyena faeces is very peculiar and difficult to confuse with that of other carnivores (Dietrich, 1951).

A total of 107 coprolites have been excavated from CM: 66 of them from the Area 3; 10 from Area 4 and 31 from collection Area 7 (see Appendix 4.1). All of them match the above mentioned features, which made it possible to establish the origin by *Crocuta crocuta spelaea* with certainty (Gatta and Rolfo, 2015; Gatta, Sinopoli, *et al.,* 2016). Moreover, the detection of medium and small fragments of partially digested bones within coprolites (Fig. 6.1) is typical of only a restricted number of Pleistocene carnivores. The size and shape excluded *Canis lupus* (Larkin et al. 2000) while cave lion is not attested in the area.

The coprolites of CM, according to the morphological types proposed by Diedrich (2012), can be classified into seven shapes (Fig. 6.3b-c). The colour varies from light brown-yellow on the external surface to pale yellow internally (Gatta, Sinopoli, *et al.*, 2016). The diametre of the coprolites varies between 15–85 mm (Tab 6.1), with a weight between 4–209 g (*ibidem*). Values shown in table 6.1, demonstrate the mean measurements of CM’s coprolites well compare with that of other Late Pleistocene hyena fossil dung. The only exception is the maximum widest diametre value of CM samples, which is much larger than the others. However, an accurate examination of the full list of measurements (see Appendices 4.1) clearly shows that, except for two exceptionally large coprolites (e.g. # 807; # 23), all others perfectly fit in standard hyena measurements. It is also worth noticing that almost all Pleistocene faeces are bigger than those of modern African spotted hyena, albeit San Teodoro’s coprolites are surprisingly small, suggesting that Pleistocene cave hyena was bigger than its contemporary successor, as already proposed by Carrión et al. (2001).

The coprolites from Area 3, 4 and 7 appear morphologically similar, although showing various degrees of preservation, confirming several hyena dens were present in a small area. The samples show an extremely hard and compact surface which is mostly intact and only a few samples show cracks. The interior is hard and granular due to fossilisation (Gatta, Sinopoli, *et al.*, 2016). The preservation of fossil faeces is considerably related to their phosphate component and to the karstic environment of deposition. The high carbonate values of the cave caused an extreme and rapid mineralisation of organic material (*ibidem*).

During the investigations, the coprolites were mostly found as individual pellets. Nevertheless, aggregates of two or more elements have also been excavated, supporting that a prompt fossilisation took place with little or no post-depositional disturbances (Gatta, Sinopoli, *et al.*, 2016).

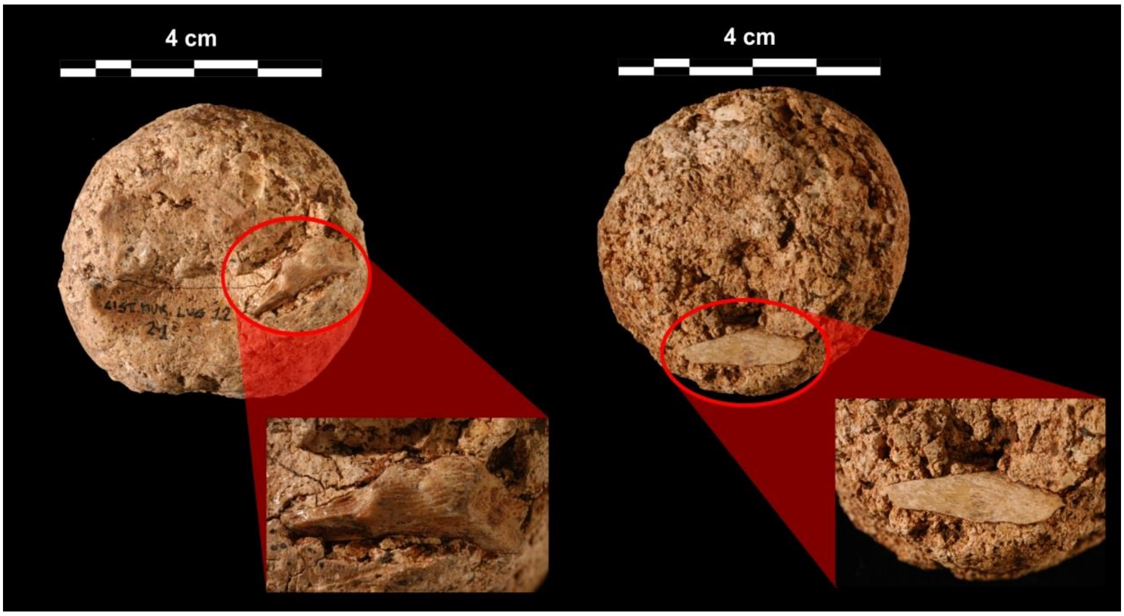


Fig. 6.1 Cave hyena coprolites with digested bone.

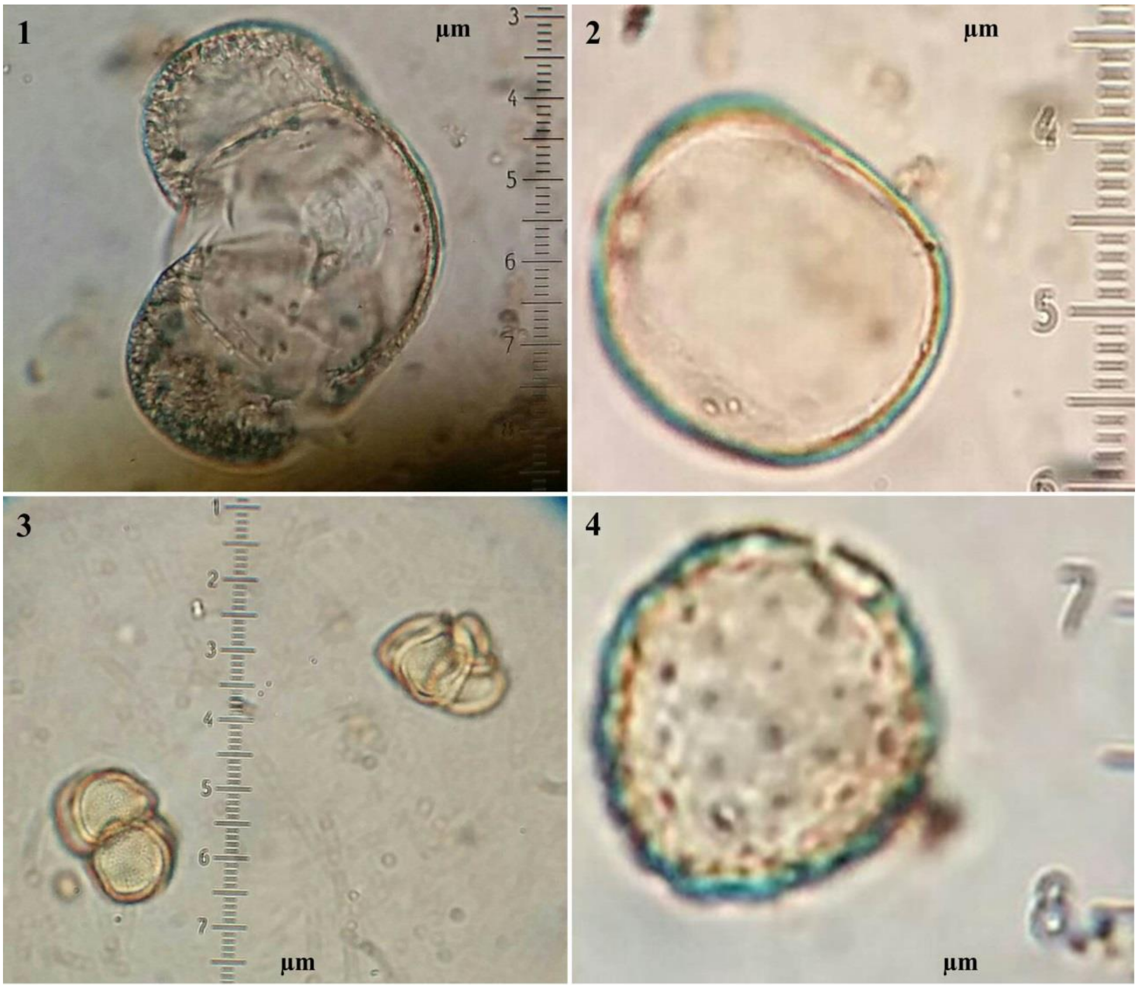


Fig. 6.2 Pollen taxa from CM’s coprolites, showing modest preservation of grains: 1- *Pinus*; 2- Poaceae; 3- *Typha*; 4- Chenopodiaceae.

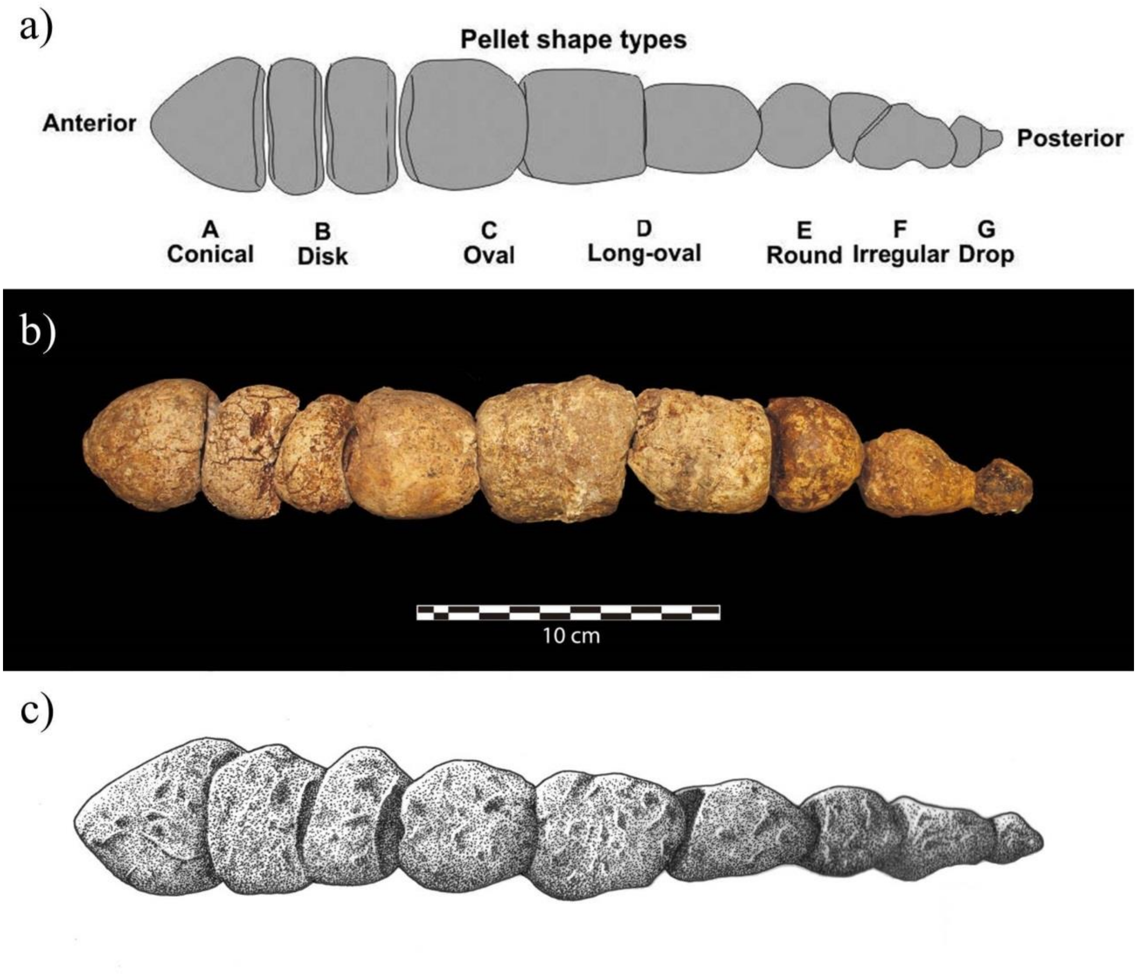


Fig. 6.3 **a)** Morphological types of Pleistocene *Crocuta crocuta spelaea* coprolites from Diedrich (2012); b) Reconstructed cave hyena aggregate from SU11 of Area 3 at Cava Muracci (Cisterna di Latina, Italy); c) Drawing of the reconstructed aggregate from SU11 of Area 3 at Cava Muracci.

Site	Widest diameter (mm)			Shorter diameter (mm)		
	Max	Min	Mean	Max	Min	Mean
Cava Muracci, *Italy*	**85,7**	**20,4**	**40,8**	**55,5**	**12,7**	**29,9**
Colchester Zoo, *UK**	43	17	31	36	12	26
Geula, *Israel*	44	36	40	-	-	-
Kebara, *Israel*	44	38	41	-	-	-
La Valina, *Spain*	-	-	40,5	-	-	-
Las Ventanas, *Spain*	50	31	40,1	49	30	38,7
San Teodoro, *Italy*	41	23	29	35	17	25
West Runton, *UK*	55	27	41	50	19	33

Tab. 6.1 Maximum, minimum and average values of Cava Muracci's coprolites, compared with hyena fossil faeces from several sites. *Colchester Zoo represents values of fresh modern hyena faeces. Measurements of other than CM from Yll et al. (2006).

6.2.2 Results from pollen analysis

There is no general agreement on how many coprolites have to be analysed to obtain a trustworthy environmental reconstruction. In the past, percentages of the total discovered coprolites or a minimum number of samples have been proposed so that the data obtained was reliable, but now these indices are no longer shared and individual considerations must be made for each study. Studies have generally shown so far that the type and amount of pollen are rather uniform in a series of coprolites deposited in the same layer (e.g. contemporary or almost). For this reason, if pilot studies reveal a consistency in the pollen data, a low number of samples are probably sufficient. Complete reconstructions of vegetation were carried out based also on just three samples in the past (Petrucci, Giardini and Sadori, 2005), of course, the larger the number, the more accurate the results would be but large collections or funds are not always available.

A total of 16 of the >100 coprolites from CM were considered representative of the whole collection and 5 g of each sample have been microscopically analysed, revealing a satisfactory number of pollen grains (Gatta, Sinopoli, *et al.*, 2016). Six out of sixteen coprolites from CM were almost pollen-sterile and were discarded, therefore 10 coprolites yielded enough pollen to be reliable for palaeoecological considerations (*ibidem*). The number of pollen taxa from CM is 27, with 15 herbaceous and two aquatic taxa (Fig. 6.4), the concentration varies between 650 and 2200 pollen grains/g (Gatta, Sinopoli, *et al.*, 2016). The preservation of grains is modest, with high percentages of indeterminable pollen (11–24%) (*ibidem*) (Fig. 6.2).

The main taxa are Poaceae (4–34%), Amaranthaceae (1–52%), *Artemisia* (4–39%) and Asteroideae (0–21%) (Gatta, Sinopoli, *et al.*, 2016). Other taxa such as *Typha* and Cichorioideae reach high concentrations in individual samples. *Typha* indicates the existence of ponds or small rivers in the vicinity, while Cichorioideae usually testifies to grazing activities (*ibidem*). Pollen taxa such as *Quercus* deciduous, *Q. cerris/suber*, *Acer*, *Ulmus*, *Fraxinus* cf. *excelsior* and *F.* cf. *ornus* are only occasionally attested, while evergreen species such as *Q. ilex* and *Juniperus* are more frequent. *P. argentea*, *P. bellardii* and *P. lagopus* are included in *Plantago lanceolata* category. Mesophilous trees are consistent, particularly in sample 8 (>13 %) (Gatta, Sinopoli, *et al.*, 2016).

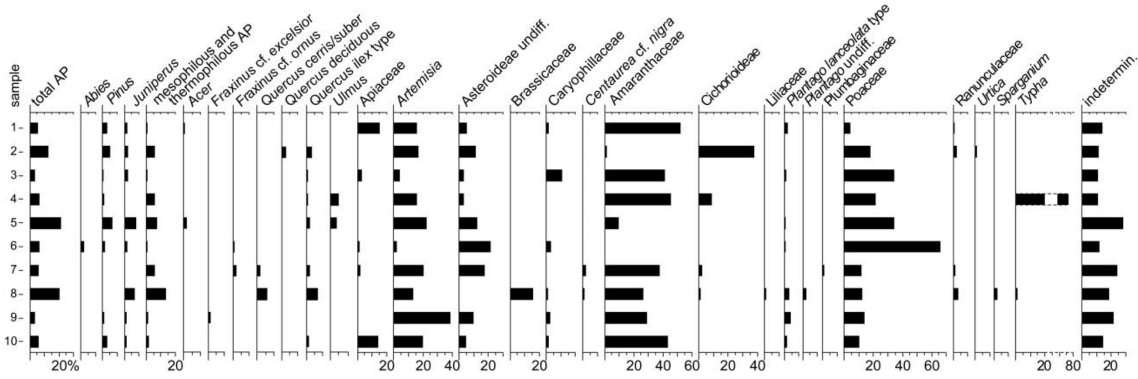


Fig. 6.4 Percentage pollen diagram of coprolites. AP = pollen of all mesophilous and thermophile arboreal plants, minus *Abies*, *Pinus* and *Juniperus*. From Gatta et al. (2016).

6.3 The environmental reconstruction based on pollen data

Pollen results from coprolites are more difficult to interpret than usual core sediments. The main difference is the way pollen grains become included in sediments and faeces. Pollen found in sediments represents a pollen rain due to air transport while coprolites incorporate pollen through several processes that are difficult to quantify. Also, while pollen in sediments is deposited over a long time-span and taxa and concentrations only show long term vegetation changes, the latter commonly shows very different percentages and taxa in each sample, representing the landscapes the animals visited on a daily basis (Gatta, Sinopoli, *et al.*, 2016).

Referring to hyena coprolites, there are three possible ways to absorb pollen grains which greatly influence quantity and variety of taxa found (Scott *et al.*, 2003), and the resulting pollen diagrams are usually a combination of these:

1- Through the ingestion of stomach content of herbivores and/or pelt of prey on which pollen can get trapped;
2- Through the direct ingestion of pollen with other sources of food (e.g. mainly plants and herbs) and water or during self-licking/cleaning of pelt;
3- Due to coprolites coming into contact with elements such as air flows, sediments and water flows or other post-depositional contaminants.

The first two ways concern the well-known intake of pollen during hyena feeding (Argant & Dimitrijevic, 2007; Carrion et al., 2001; Scott et al., 2003), the eating of large herbivore stomachs in particular, containing large amounts of pollen, plays an important role in the assimilation of pollen in faeces (Carrión *et al.*, 2000). However, hyenas are an omnivore and that includes the not unusual eating of plants and grass (Skinner, 1976;

Mills, 1989; Argant and Dimitrijevic, 2007). Doubts have arisen on the reliability of these pollen sources for environmental interpretation, since the vegetation reflected would not be the actual one but that chosen by herbivores and hyena when feeding (Scott, 1987). However, previous studies have revealed that coprolites yield a reliable vegetation framework. The stomach of herbivores is particularly rich in taxa typical of grazing, similar to those of sediment records (Carrión *et al.*, 2001; Scott *et al.*, 2003; Argant, 2004; Argant and Dimitrijevic, 2007).

The third factor regards post-depositional contamination. Air contamination is a minor issue, since pollen would get trapped on faeces only while these are fresh, therefore reflecting vegetation contemporaneous with the coprolites. On the other hand, water flow and sediment transport could take place countless times, also over thousands of years subsequently to coprolite deposition, providing a pollen intake not reliable for an environmental reconstruction (Gatta, Sinopoli, *et al.*, 2016). In order to prevent possible post-depositional pollen intake, a thorough cleaning of sample surfaces and sampling the inner part of pellets, sensibly reduce contamination risks (see Fig. 4.1) (*ibidem*).

Pollen from sediments, usually lakes, is known to provide a vegetation framework on a regional scale due to the long distances which airborne pollen can travel. Differentially, pollen from coprolites reflects vegetation on a small-scale within 50 km or less from hyenas' dens, due to the short distances covered by hyenas on a daily basis (Scott, 1987; Mills, 1989; Argant, 2004; Argant and Dimitrijevic, 2007). Therefore coprolites, because of higher resolution than sediments, offer a valuable resource to investigate local vegetation (Argant and Dimitrijevic, 2007; Djamali *et al.*, 2011; Gatta, Sinopoli, *et al.*, 2016).

The main pollen taxa from CM reflect open environments. *Artemisia*, Amaranthaceae, Poaceae and *Plantago* are all typical of glacial steppe/grassland environments, albeit *Artemisia* indicates strong aridity while Amaranthaceae requires moderate humidity. This feature is also indicated by the values of mesophilous and thermophilous trees and *Typha*, which indicate ponds and wetlands were also present in the area (Gatta, Sinopoli, *et al.*, 2016).

The reconstruction based on pollen analysis suggests the coexistence of extensive steppe and grassland in the plains with numerous rivers and streams in the inland and marshland along the coast and Mediterranean woods, characterised by mesophilous trees in the nearby hills (Gatta, Sinopoli, *et al.*, 2016). Angiosperm trees have already been recorded previously in central Italy during the last Pleniglacial (Follieri *et al.*, 1998; Chiarini *et al.*, 2007). Pollen indicate the climate was rather cool and arid when coprolites were produced albeit slightly warmer and humid oscillations were extremely frequent (Gatta, Sinopoli, *et al.*, 2016).

The complex environmental reconstruction results in a mosaic landscape that perfectly matches with both morphology of the region, which also nowadays is extremely variable, as well as pronounced MIS 3 climatic variability, during which temperature oscillation was extremely frequent (Gatta, Sinopoli, *et al.*, 2016). Unfortunately, since all coprolites are from the same layer (e.g. time-span) with a broad chronological resolution of about 10 ka years, it is impossible to investigate if the pollen analysed returned either diachronic evolution of vegetation or a synchronic mixed environment in the Pontine Plain. A coexistence of both diachrony and synchrony is also possible. Unfortunately, further analyses, which are not currently available for this area, are necessary to solve such uncertainties. Therefore, pollen data from CM represents a valuable comparison database for future studies and a first step towards a more complete knowledge of the territory.

6.4 Conclusions

Coprolites have been introduced in this chapter. Their scientific potential, especially palaeoecological, has been highlighted. Despite that, coprolite studies are still rare and the study proposed in this thesis represents the first ever to be carried out in central Italy.

Fossil faeces from CM have clearly been produced by cave hyenas, according to size and morphological features. The sample preservation is extremely good, suggesting the high concentration of minerals of the cave caused a rapid fossilisation with insignificant post-depositional taphonomy. A representative number of 16 coprolites has therefore been analysed for pollen identification and 10 of them proved to be reliable for an environmental reconstruction.

Vegetation reconstruction based on pollen from coprolites has three particular and valuable features which need to be considered:

1- Pollen from coprolites reflects the feeding and the areas visited by the hyena while hunting. Some of this information can be extremely detailed, such as drinking from a pond highlighted by *Typha* pollen in samples 4 and 8 (see Fig. 6.4).

2- Since hyenas carry out these activities within a short range of kilometres from their den, pollen from faeces yield a local vegetation framework of the dens' surroundings. This unique feature is not achievable with normal sediment analyses, which contain pollen grains airborne over hundreds of kilometres.

3- Pollen inclusion in faeces through daily activities (e.g. feeding and digestion) implies coprolites represent a palimpsest of a few events occurring in a very short time between several droppings. This feature makes every coprolite a unique mirror of an environmental context, such that a large collection of samples allows us to identify many different areas and contexts visited by the carnivore. A remarkable aspect of pollen from faeces is the possibility to identify seasonal alternations (Argant, 1990, 2004; Tomescu, 2006), a result hardly achievable with sediments.

Considering all the coprolites from SU11 of CM belong to the same time span, according to archaeological data, the reconstruction obtained suggests a complex mosaic environment for the Pontine Plain between 44–34 ka BP. The landscape was extremely diverse, with wetland shoreline, extensive steppe plains and wooded areas within a few kilometres and a cool and arid climate (Gatta, Sinopoli, *et al.*, 2016). This reconstruction is consistent with previous sediment analyses of Late Pleistocene central Italy, when extensive steppe and grasslands also characterised the south of the peninsula (Follieri *et al.*, 1998; Allen, Watts and Huntley, 2000; Watts, Allen and Huntley, 2000; Follieri and Magri, 2001).

The successful results of this pollen analysis display a very effective method to obtain detailed local vegetation reconstructions, however, they only return a partial view of the entire landscape. The environmental data from faunal analysis, proposed in the next Chapter VII, will complete the multidisciplinary approach of this thesis and support a conclusive and reliable landscape reconstruction.

Chapter VII

The Archaeozoological Study of Faunal Remains

This chapter describes in detail the faunal analyses carried out on the assemblage from Cava Muracci (hereinafter CM). The study, which involved 1346 fossilised macro-remains and several hundred remains of micro-, avi- and ichthyo- fauna, returned valuable data for the environmental reconstruction and behavioural understanding of some species in the Pontine Plain. Materials and methodology adopted for this study were presented in detail in Chapter IV, whilst the environmental implications of this chapter have been published in a different form as Gatta, Kotsakis, et al. 2018.

The first section lists the faunal taxa discovered at CM, the Number of identified specimens (hereinafter NISP) and the minimal number of individuals (hereinafter MNI). For each taxon, a basic knowledge of their natural habitat and discovery in Italy is also provided. The second section introduces the results of taphonomic analysis. The identification of Area 3 as a cave hyena den has already been anticipated in Chapter II, allowing readers to fully understand the background of this thesis since the beginning, but it is only in this section where I will fully explain how such an interpretation was possible. Moreover, a short digression on two particularities from CM is also present: the first is the dating of rhinoceros remains, of which one at least is the latest occurrence in Italy at present; the second is the discovery of two bone remains with pupal chambers, a rare discovery since these are usually built by insects within soft material (e.g. sediments). These remains are significant ecological indicators but extremely difficult to analyse. The third section compares the assemblage from CM within the wider regional context. Taxa from CM are quite common during the Late Pleistocene, albeit that the size of the assemblage from SU11 is remarkable for a single archaeological layer and among the largest of the Pontine Plain. Finally, the palaeoecological implications of the fauna are discussed in section 7.5. This data will be then integrated together with pollen data (Chapter VI), to suggest a final environmental reconstruction in the next chapter.

7.1 Faunal deposits as indicators of past environments

Animal species have a systematic geographic distribution in the world, some of them are widespread whilst others only live in limited habitats, but none is ubiquitous (Stuart, 1982; Yalden, 1999). Actually, *H. sapiens* is the only past or present species to have reached and colonised, when accessible, every region of the Earth. Therefore, each taxon from an archaeological context permits deductions about the environment in which it lived. An extended fossil assemblage of several taxa, and the habitat inferences of each of them, is capable of returning a more or less reliable ecological framework. The potential of fauna to reconstruct past environments has been known since the nineteenth century, albeit attention has mainly focused on animal bones as a key to investigate human behaviours (i.e. hunting patterns, diet preferences, competition and coexistence etc.) since the late 1960s (Dincauze, 2000). Before then, the emphasis was on bones as evidence of evolutionary history of animals. The role of environmental indicators gained increasing attention since the last decades of the past century and is extensively discussed and theorised at present, with methods which join biological, palaeontological and archaeological sciences. Nevertheless, palaeoenvironmental reconstructions are still widely dominated by palynological data, in comparison to which the potential of fauna remains is highly neglected.

Fauna distribution and dispersal through time and space is regulated by two types of components:

1- The first are the so-called abiotic ones, i.e., the non-living elements of an environment, such as topography, atmospheric conditions, water supply etc, which affect life and functioning of environments. Climate (i.e. temperature and humidity) is the abiotic factor which most of all determines the habitability of a territory (Mainland, 2008), this is the reason why it has a crucial role in all environmental reconstructions;

2- The second are the biotic components, i.e., the living elements that affect the population of another organism or the environment (Krebs, 1994; Dincauze, 2000). These include the double role of producer and exploiter of food resources of which any organism is part (e.g. the so-called ‘food chain’). In the Earth’s history, the biotic components which most influenced life are probably diseases and humans, with the latter being responsible for the extinction of many fauna and flora species.

Abiotic and biotic components act in and on every aspect of environments, sometimes balancing and at others increasing each other, constituting ‘habitats’ (e.g. meant as a set of environmental conditions). Some animals are extremely adaptable to different habitats whilst others demand very specific conditions, therefore a knowledge of the preferred habitat of a species returns insights about the environment in which it occurred. Due to the behavioural analogy with extant species of some species, and increasing knowledge of extinct fauna ecology, fossil remains can be very informative of past environments (*ibidem*).

However, some considerations and constraints are necessary when using fauna to investigate the environment. The first of them is to pay attention to the compatibility of faunal assemblage with the scale of reconstruction. As a general rule, larger species have a higher tolerance of abiotic factors than small ones, which means the first category has a lower resolution than the latter as an environmental indicator (Dincauze, 2000; Mainland, 2008). In an overly simplified concept, it is possible to say animal species can be used to make general observations of the area they lived during their life span. Large and longer-living animals then provide good indications for regional (e.g. mesoscale) reconstructions but their application for larger (e.g. mega- or macro- scales) or smaller (e.g. microscale) environments would produce unreliable frameworks. On the same basis, small-short living vertebrates and insects who are excellent predictors of local environments are of little utility on a larger scale. A second issue to be aware of is that archaeological records will never exactly reflect the faunal diversity or actual population of an area, since both natural and artificial accumulation agents and post-depositional taphonomy will act selectively on remains (Lyman, 1994). Finally, although analogies with extant species have been mentioned as a valuable tool to predict extinct species environments, they should be used with caution since many species deeply modify their natural habitat through time and space (Dincauze, 2000). In this regard, the best example is the striking faunistic revolution (e.g. megafauna extinction) that occurred worldwide during the LGM (Barnowsky *et al.*, 2004; Koch and Barnosky, 2006; Elias and Schreve, 2007; Stuart and Lister, 2007; Sandom *et al.*, 2014). It resulted in a massive redistribution and evolution of most adaptable species which live in very different environments at present, whilst many other species have gone extinct.

7.2 Taxonomic analysis: systematic palaeontology, NISP and MNI

The systematic palaeontology of every species from SU11, and the only *Mustela arvalis* (weasel) from SU12, of Area 3 at CM is provided in this section. In total, 47% of the specimens were taxonomically classified, for the exact number of specimens, individuals and age determination please refer to the appropriate tables in the following pages.

7.2.1 Micro-, avi- and ichthyo- fauna

Osteichthyes indet.

A single vertebra of a fish has been found. Unfortunately, a single specimen such as a vertebra is not significant to classify it to a species level and, therefore, understand if it belongs to a fresh or sea water fish. However, considering the distance of CM site from the coastline, it is highly probable this finding belongs to a fresh water fish.

Bufo bufo (Linnaeus, 1758)

A single specimen of *Bufo bufo* has been collected. These species have lived in Italy since the Late Miocene (Delfino, 2002). The great common toad is present in diverse environments and it is therefore of little ecological help (Böhme *et al.*, 2007).

Bufotes gr. *B. viridis* (Laurenti, 1768)

The Pontine Plain was, and still is, inhabited by the green toad *Bufotes balearicus* Boettger (Balletto, Bologna and Corti, 2007). The urostyle recovered presumably belongs to this species but it does not show characteristics useful for a species classification. Consequently, we have preferred a genus assignment to *Bufotes* gr. *B. viridis*. The green toad usually indicates damp open areas (Balletto, Bologna and Corti, 2007; Böhme *et al.*, 2007).

Rana (s.l.) sp. 1 and *Rana* (s.l.) sp. 2

Three remains of frogs, of which it has been impossible to determine the species, have been discovered and classified as *Rana* (*s.l.*) sp. 1, and a single specimen of a different species has been recovered from SU12 and classified as *Rana* (*s.l.*) sp. 2.

The genus *Rana* (*s.l.*) is present in the Italian territory since the Late Miocene (Delfino, 2002; Kotsakis *et al.*, 2011; Bartolini *et al.*, 2014). The impossibility to determine these remains to a species level makes it impossible to obtain detailed ecological inferences but the presence of humidity or aquatic habitats is implied (Lanza, Nistri and Vanni, 2007).

Podarcis sp.

The presence of lizards is attested by the recovery of a few remains of the genus *Podarcis*. Unfortunately, osteological characteristics do not permit a species classification.

The impossibility to attribute these remains to a species impedes any ecological conclusion, since the genus was widespread during the Pleistocene in Italy (Delfino, 2002; Corbino, 2015).

Anguis veronensis (Pollini, 1818)

Six vertebrae of a slow worm belong to the species *Anguis veronensis*. This species, until recently classified as *Anguis fragilis* (Delfino, 2002, 2004; Delfino and Sala, 2007), only recently has been recognised as a separate taxon living in south France and Italy (Gvoždík *et al.*, 2013).

Plio-Pleistocene remains of this species have been discovered in several sites of the peninsula, due to their adaptability to a wide variety of habitats, with a preference for mesophilous and damp environments (Luiselli, Anibaldi and Capula, 2011).

Natrix natrix (Linnaeus, 1758)

Five vertebrae of grass snake (*Natrix natrix*) have been found. This species is well known in numerous Pleistocene fossil deposits of Italy (Delfino, 2002; Delfino and Atzori, 2013) and it is a good indicator of abundant fresh water (Scali, Gentili and Lanza, 2011).

Hierophis viridiflavus (Lacépéde, 1789)

Two vertebrae of another snake, *Hierophis viridiflavus,* have also been found at CM. This species is widely distributed in all kinds of natural environments (Vanni and Zuffi, 2011) and in several Pleistocene Italian sites and it is, therefore, of little contribution to environmental understanding.

Aves

Birds' vertebrae and other remains have also been collected, however, these are not sufficient to determine the species to which they belonged.

Arvicola italicus (Linnaeus, 1758)

Arvicola italicus represents the most abundant microfauna of the site, being attested in both SU11 and SU12. Several mandibles and diagnostic teeth of this species have been collected, while a large amount of other non-diagnostic teeth probably also belong to *Arvicola italicus,* based on dimensional parameters. The specimens from both SU11 and SU12 returned a SDQ quotient (= Schmelzband-Differenzierungs-Quotient = enamel differentiation quotient, e.g. a method based on variation in the thickness of enamel in lower first molars) of 104, which perfectly fits with the Italian Late Pleistocene SDQ ratio (Maul *et al.*, 1998).

This species of rodent appears in Italy in the Late Pleistocene (Kotsakis *et al.*, 2003; Sala and Masini, 2007) and since then has been almost ubiquitous in archaeological sites with humid conditions such as those situated close to lakes, rivers, swamps (Cagnin, 2008).

Microtus (Terricola) savii (de Selys Longchamps, 1838)

Two species of the genus *Microtus* have been found at CM. The first is *Microtus (Terricola) savii*, the so-called pine vole. At present, it has the most widely distributed range of any rodent in the Italian territory and during warm oscillations of Middle and Late Pleistocene it also had a diffuse range in open areas (Contoli, Nappi and Castiglia, 2008; Kotsakis, 2008; Petruso *et al.*, 2011).

Microtus (Microtus) arvalis (Pallas, 1778)

The common vole is the second taxon of genus *Microtus* recovered at CM, this time in the SU12. This species, also characteristic of open environments (Paolucci and Amori, 2008), was present in central Italy since the Late Middle Pleistocene while it is confined to north Italy at present (Kotsakis *et al.*, 2003; Salari, 2014; López-García *et al.*, 2015; Berto *et al.*, 2016).

Myodes glareolus (Schreber, 1780)

A fourth species of arvicolid, the bank vole *Myodes glareolus*, has been identified by two lower first molars and one lower second molar. It is a species typical of woody habitats (Amori, 2008) which first appeared in Italy in the Middle Pleistocene (Kotsakis, 2008), albeit its presence in fossil assemblages of the Early Pleistocene could be attested by a few specimens (Marchetti, Parolin and Sala, 2000; Marcolini, Masini and Argenti, 2013).

Apodemus gr. *Sylvaticus-flavicollis* (Linnaeus, 1758)

The so-called wood mouse (*Apodemus* gr. *Sylvaticus-flavicollis*) is also present in the SU11. This species is very common in most sites since the Early Pleistocene (Kotsakis, 2008), albeit only two teeth have been found at CM. The wood mouse lives in a wide variety of habitats, especially forested (Capizzi and Filippucci, 2008a).

Glis glis (Linnaeus, 1766)

One tooth of dormouse (*Glis glis*) has been discovered. This species is present since the Middle Pleistocene and particularly frequent in the Late Pleistocene (Kotsakis, 2008; Bona, Laurenti and Delfino, 2009). *Glis glis* indicates the presence of deciduous or mixed forests (Capizzi and Filippucci, 2008b).

7.2.2 Macromammals

Lepus sp.

A few remains of hare were present (Tab. 7.1), however, these were not sufficient for a species classification and, therefore, no environmental indication can be provided.

Mustela nivalis (Linnaeus, 1766)

A single tooth attests the presence of at least one adult weasel (*Mustela nivalis*) in the SU12 (Tab. 7.1). This is an opportunistic species common in Italy since the Middle Pleistocene (Angelici, 2003) and therefore of little support to environmental reconstructions.

Meles meles (Linnaeus, 1758)

A fragmented tibia testifies to the presence of badger (*Meles meles*) among the taxa of this hyena den (Tab. 7.1). This carnivore appeared in the Italian peninsula during the Early Pleistocene and immediately diffused into various habitats (Pigozzi and De Marinis, 2003; Petronio and Marcolini, 2013).

Crocuta crocuta spelaea (Goldfuss, 1823)

The central figure of this site is the cave hyena and therefore a detailed description of this species is provided. Cave hyena, a bigger in size relative of contemporary spotted specimens (i.e. *Crocuta crocuta crocuta*, Erxleben 1773) living in the African territory at present (Kurtén, 1968), was first described among the remains discovered in the Zoolithen Cave in Germany (Esper, 1774). However, its current taxonomic classification as hyena *spelaea* only occurred half a century later by Goldfuss (1823).

Cave hyenas arrived in Europe at least as early as 800 ka (García and Arsuaga, 2001; Martinez-Navarro, Belmaker and Bar-Yosef, 2009) via the Middle East (1.4–1.2 Ma) (Martinez-Navarro, Belmaker and Bar-Yosef, 2009), whilst the earliest records of the genus are from the ca. 3.46 Ma dated deposits of Laetoli (Africa) (O'Regan *et al.*, 2011). Since then and up to the Late Pleistocene, this carnivore was an almost ubiquitous taxon occurring in a wide range of habitats and climatic ranges throughout Europe (Bon *et al.*, 2012; Crezzini *et al.*, 2016), albeit their presence was not uninterrupted but probably characterised by several recolonizations (Stuart and Lister, 2014). Highly debated is the extinction of the species, of which chronology and modes need to be deepened in many regions. At present, it is supposed to have occurred in two phases during MIS 3: A first disappearance took place in central and north-east Europe, up to the Urals and in Siberia around 40 ka BP; The second and final extinction of cave hyenas occurred about 30 ka in north-western and south Europe (Stuart and Lister, 2014), the latest specimens dating to 30,813–30,328 cal BP were found in southern Italy at Grotta Paglicci (Stuart and Lister, 2014; Crezzini *et al.*, 2016). A few sites have been suggested to contain younger specimens which would delay the extinction up to the beginning of the Holocene (Suitcliffe, 1970; Altuna, 1971; Li and Lei, 1980; Delpech, 1983; Ma and Tang, 1992; Cupillard and Welte, 2006; Sirakov *et al.*, 2010), however, cave hyenas' remains from these sites were not directly dated or were collected from stratigraphies which had been disrupted and, therefore, are considered unacceptable (Stuart and Lister, 2014). The causes behind Pleistocene hyena extinction are uncertain but it is now considered part of the so-called "megafaunal extinction" which took place in the late Quaternary (Barnowsky *et al.*, 2004; Stuart and Lister, 2012). A combination of factors which most likely would have triggered the extinction have been recently identified and widely discussed (Stuart and Lister, 2014). Progressive climate cooling of MIS 3 would be the main cause of this event, reducing the population and driving fragmented groups southward. Hyenas would have survived southern Europe for some thousands of years, before large herbivores (e.g. preferred prey) decreased and/or extinction would have increased competition with other predators and a fatal lack of prey (Stuart and Lister, 2014).

A few misconceptions have for a long time affected a complete understanding of the diet of Pleistocene hyenas. Studies of bone deposits and analogies with modern hyenas have now returned a more exhaustive and reliable picture of this subject. The first misconception was the common, but unfounded, idea that both extinct and extant hyenas based their subsistence on scavenging. Actually, recent studies proved extant hyenas hunt 80–95% of their prey (Lansing *et al.*, 2009). Similarly, Pleistocene hyenas are supposed to have been active hunters and only a small percentage of their prey was scavenged (Stiner, 2004; Diedrich, 2010; Stuart and Lister, 2014; Crezzini *et al.*, 2016). In the Pleistocene framework, it can be supposed hyenas could hunt any small and medium sized species (Stuart and Lister, 2014). Group hunting was probably necessary to kill adults of some medium sized prey such as aurochs, fast horses or potentially dangerous red deer, whilst young and senile prey could have been hunted by individual hyenas. Large mammals such as elephants and rhinoceros or extremely dangerous taxa such as cave lion and cave bear could only have been scavenged, albeit isolated juveniles or hibernating bears may have been intentionally hunted (Stuart and Lister, 2014). Another concept which needs revision is that considering Pleistocene hyenas as being exclusively carnivorous. In contrast, a plausible comparison with its extant relative which include vegetable matter and perhaps even grass in their diet (Skinner, 1976; Mills, 1989), suggests that also cave hyenas were completely omnivorous.

Finally, based on partial observation of living hyenas in Africa and several fossil assemblages, it was supposed cave hyenas had a dietary preference for medium-large ungulates (Kruuk, 1972). However, recent ethological studies demonstrated that hyenas hunt an ample selection of prey, with preferred targets varying seasonally and from one area to another (Salnicki *et al.*, 2001). This dietary variability has then been featured in archaeological contexts. Fossil assemblages from cave hyena dens of Saint Césaire, Camiac and La Berbie in France showed horse was the preferred prey (Bocherens *et al.*, 2005), whilst red deer was the main prey of Coumère Cave (France) (Bon *et al.*, 2012). Horses were central in the subsistence of many other dens of central Europe (Diedrich, 2010), whilst in southern Europe *Bos primigenius* acquire a key role (Stiner, 2004).

Crocuta crocuta appeared in Italy during the Middle Pleistocene (Marra *et al.*, 2014), probably during MIS 18) (Sardella and Petrucci, 2012), and it was immediately widespread in different environments and climates of the Peninsula, because of that it is not a diagnostic species for ecological purposes (Conti *et al.*, 2012; Churchill, 2014). The cave hyena had a very diffuse distribution during the Late Pleistocene (Petronio, di Canzio and Salari, 2007) and its presence at CM during the MIS 3 is not, therefore, unusual. *Crocuta crocuta spelaea* went rapidly extinct in Italy around 31 ka (Stuart and Lister, 2012), slightly younger than the upper chronological limit of CM.

The carnivore is mainly represented at CM by cranial bones and teeth (Tab. 7.2) belonging to at least four individuals. The presence of very young individuals in the assemblage, such as a neonatal and two cubs (Tab. 7.3), is typical of Pleistocene hyena dens (Blasco, 1995). It is also worth highlighting that an ulna of a young individual shows gnaw marks (Tab. 7.4) and thus attests cannibalism, an occasional practice already testified among cave hyenas (Cruz-Uribe, 1991; Diedrich, 2012a, 2014).

Canis lupus (Linnaeus, 1758)

The last carnivore of Area 3 is the wolf. The presence of two only remains (Tab 7.1) shows that this species was not among the favourite prey of the hyena albeit it was probably quite numerous in the area. The wolf appears in Italy during the late Middle Pleistocene (Marra *et al.*, 2014; Salari *et al.*, 2017) and is particularly abundant during the entire Late Pleistocene while today it is confined to a few remaining natural habitats (Petronio, di Canzio and Salari, 2007; Petronio *et al.*, 2011; Bertè and Pandolfi, 2014; Sansalone *et al.*, 2015).

Equus ferus (Boddaert, 1785)

The second most abundant taxon at CM is the wild horse, a third of the total bones collected belongs to this species (Tab. 7.1). Cranium, hindlimbs and forelimbs are the most numerous anatomical parts (Tab. 7.2), while age determination of bones shows both adult and senile individuals were preferentially hunted (Tab. 7.3).

This species arrived in Europe from Asia and Mongolia in the Middle Pleistocene and immediately dispersed throughout the continent, undergoing geographical adaptations, such as size and skeletal proportions, considered by several scholars as evidence of subspecies evolution (Conti, Petronio and Salari, 2010). *Equus ferus* arrived in Italy also in the Middle Pleistocene, it was widespread in steppe and prairie lowlands during the Late Pleistocene and, eventually, became extinct in the Early Holocene (Petronio, di Canzio and Salari, 2007; Conti, Petronio and Salari, 2010; Petronio *et al.*, 2011).

Stephanorhinus hemitoechus (Falconer, 1859)

A few remains of rhinoceros of the species *Stephanorhinus hemitoechus* have been collected in the entire area of CM (Tab 7.1) (Gatta and Rolfo, 2015; Gatta, Sinopoli, *et al.*, 2016; Pandolfi *et al.*, 2016, 2017). This species lived only in a few temperate open environments with low vegetation such as steppe or prairie (Fortelius, 1982) and it is, therefore, a good environmental marker.

In regard to this species, however, unlike previously discussed taxa it is its last appearance rather than its first which is of particular interest. *Stephanorhinus hemitoechus* is believed to have gone extinct around 45 ka in north and central Europe and around 41 ka in the Italian territory (Pandolfi *et al.*, 2017). Nevertheless, the specimen from SU11 of Area 3 has been dated to 42,054–40,804 cal BP (Gatta, Sinopoli, *et al.*, 2016) which makes it the youngest known specimen in Italy (see section 7.3.3) (Pandolfi *et al.*, 2017).

Sus scrofa (Linnaeus, 1758)

A few remains of wild boar with gnaw marks have been collected at Area 3 (Tab 7.1). This species appeared in Italy during the Early-Middle Pleistocene transition (Petronio *et al.*, 2011; Marra *et al.*, 2014) and is still common today. *Sus scrofa* is an indicative marker of lacustrine/swampy areas rich in vegetation (Rustioni *et al.*, 2003).

Capreolus capreolus (Linnaeus, 1758)

A fragmented mandible of an adult roe deer is present (Tab 7.1). The gnaw marks (Tab 7.2) clearly indicate it is what is left of hyena feeding, albeit the single specimen suggests this cervid could not be among the preferred prey of the carnivore.

Roe deer lived in forested habitats of Italy since the Middle Pleistocene (Perco, 2003; Marra *et al.*, 2014) and is a common taxon during the Late Pleistocene (Petronio, di Canzio and Salari, 2007).

Cervus elaphus (Linnaeus, 1758)

The red deer is the third most common species (Tab. 1). Most body parts have been found but antlers, mandibles and teeth make a large part of the total (Tab 7.2). Over 40% of total bones shows gnaw marks (Tab 7.4), this is particularly evident on antlers of subadult individuals (Fig. 7.1b) of which 82% shows significant chewing.

The osteological characteristics and morphometric values of remains from CM are similar to those of modern Italian red deer. This species appeared in Italy in the Middle Pleistocene and several subspecies (*C. e. acoronatus, C. e. eostephanoceros, C. e. aretinus* and *C. e. rianensis*) successively evolved up to the Late Pleistocene (di Stefano and Petronio, 1993, 2002; Petronio, di Canzio and Salari, 2007; Petronio *et al.*, 2011; di Stefano *et al.*, 2015). In prehistory as at present this species preferred wooded open areas with abundant glades (Mattioli, 2003).

Dama dama dama (Linnaeus, 1758)

A few remains of fallow deer have been collected (Tab 7.1), as for previous cervids teeth, mandibles and antlers abundantly chewed by hyenas are the majority of findings (Tab 7.4).

The genus *Dama* was present in Italy since MIS 16 (Marra *et al.*, 2014) but the antlers from CM show characteristics typical of the extant fallow deer, which appeared during the Late Pleistocene and went extinct earlier than the LGM (di Stefano and Petronio, 1997; Petronio, di Canzio and Salari, 2007; Petronio *et al.*, 2011; Marra *et al.*, 2014).

This cervid is a good marker of temperate warm woodlands or open woodlands (Apollonio, 2003).

Bos primigenius (Bojanus, 1827)

The most abundant taxon of CM is the auroch, with 275 identified remains and over 40% of total NISP (Tab 7.1). Almost all body parts of this species have been found (Tab. 7.2), these can be referred to at least 14 individuals (Tab 7.3), and almost 50% of them show traces of carnivores activity (Tab. 7.4).

Aurochs have been present in Italy from MIS 15 (Cassoli, di Stefano and Tagliacozzo, 1999; Lefèvre *et al.*, 2010; Marra *et al.*, 2016). From the late Middle Pleistocene to the early Late Pleistocene an increase in size occurs, followed by a decrease probably caused by climatic changes during the Late Pleistocene (Pandolfi, Petronio and Salari, 2011, 2013). The morphometric values of metacarpal bones from CM confirm this trend and show the size of these individuals was similar to those of other Late Pleistocene and Holocene fossil deposits but smaller than those from earlier Pleistocene contexts (Pandolfi, Petronio and Salari, 2013). *Bos primigenius* preferred temperate woodlands with open spaces with abundant grass (van Vuure, 2002; Pandolfi, Petronio and Salari, 2011), despite the common belief that aurochs were not dissimilar from the current oxen, which have been domesticated to live in open grassland.

	NISP	**%**
Osteichthyes indet.	1	0,14
Bufo bufo	1	0,14
Bufotes gr. *B. viridis*	1	0,14
Rana (s.l.) sp. 1	3	0,42
Rana (s.l.) sp. 2	1	0,14
Podarcis sp.	6	0,84
Anguis veronensis	6	0,84
Natrix natrix	5	0,70
Hierophis viridiflavus	2	0,28
Aves	2	0,28
Arvicola italicus	16	2,23
Microtus (Terricola) savii	5	0,70
Microtus (Microtus) arvalis	5	0,70
Myodes glareolus	3	0,42
Apodemus gr. *sylvaticus-flavicollis*	3	0,42
Glis glis	1	0,14
Lepus sp.	18	2,5
Canis lupus	2	0,3
*Mustela nivalis**	1	0,1
Meles meles	1	0,1
Crocuta crocuta	17	2,4
Equus ferus	194	27,1
Stephanorhinus hemitoechus	1	0,1
Sus scrofa	2	0,3
Cervidae	9	1,3
Capreolus capreolus	1	0,1
Cervus elaphus	114	15,9
Dama dama	23	3,2
Bos primigenius	273	38,1
Total identified specimens	**717**	**100,0**
Identified specimens	717	47,0
Indeterminate bones	810	53,0
Total	**1527**	**100,0**

Tab. 7.1 Number of identified specimens (NISP) and indeterminate bones among macromammals taxa from SU11 and SU12 of Area 3. **Mustela nivalis* is the only macromammal from SU12. From Gatta, Kotsakis, et al.

Body Part	*Lepus* sp.	*M. nivalis**	*C. lupus*	*M. meles*	*C. crocuta*	*E. ferus*	*S. hemitoechus*	*S. scrofa*	Cervidae	*C. capreolus*	*C. elaphus*	*D. dama*	*B. primigenius*	**Total**
Horn/Antler									5		40	4	2	**51**
Skull					1						1		2	**4**
Maxillary					1	7					3			**11**
Upper teeth		1			5	57					16	6	35	**120**
Mandible					3	5		1		1	13	1	7	**31**
Lower teeth					2	42	1	1			9	4	23	**82**
Indet. teeth	1				2	11			1				6	**21**
Atlas									1				1	**2**
Epistropheus													1	**1**
Vertebrae													8	**8**
Rib														
Scapula													3	**3**
Humerus	2				1	2					3	1	22	**31**
Radius						2					6	1	5	**14**
Ulna	1				1								2	**4**
Radius+Ulna						2							7	**9**
Carpal bones						1					1			**2**
Metacarpus			1			5					3	2	20	**31**
Pelvis	2					12							11	**25**
Femur	1					2					1		13	**17**
Tibia	1			1		6					5	1	26	**40**
Astragalus	2					6							18	**26**
Calcaneus	2					6							17	**25**
Tarsal bones													5	**5**
Metatarsus	6		1			14			1		10	3	31	**66**
Metapodial bones					1	10			1		2		7	**21**
Phalanx I						1					1		1	**3**
Phalanx II						2								**2**
Phalanx III						1								**1**
Total	**18**	**1**	**2**	**1**	**17**	**194**	**1**	**2**	**9**	**1**	**114**	**23**	**273**	**656**

Tab. 7.2 Taxonomic body parts classification of macromammals remains from SU11 of Area 3. **Mustela nivalis* is the only macromammal from SU12. From Gatta, Kotsakis, et al. (2017).

	Young	**Adult**	**Old**	**Total**
Lepus sp.	1	1		1
*M. nivalis**		1		1
C. lupus		1		1
M. meles	1			1
C. crocuta	3	1		4
E. ferus	3	5	2	10
S. hemitoechus	1			1
S. scrofa	1		1	2
C. capreolus		1		1
C. elaphus	2	3	3	8
D. dama	1	1	1	3
B. primigenius	3	4	7	14
Total	**16**	**18**	**14**	**48**

Tab. 7.3 Minimal number of individuals (MNI) and age class at death estimates of large mammal taxa from SU11 of Area 3. **Mustela nivalis* is the only macromammal from SU12. From Gatta, Kotsakis, et al. (2017).

Gnaw marks	*C. crocuta*	*E. ferus*	Cervidae	*C. capreolus*	*C. elaphus*	*D. dama*	*B. primigenius*	
Horn/Antler			3		33	4	1	
Mandible				1	1		1	
Atlas							1	
Scapula							1	
Humerus		2			1	1	16	
Radius		1			5		3	
Ulna	1							
Radius+Ulna		2					4	
Metacarpus		5			2	1	14	
Pelvis		6					7	
Femur		1			1		11	
Tibia		5			2	1	18	
Astragalus		1					11	
Calcaneus		5					15	
Tarsal bones							1	
Metatarsus		9			5		24	
Metapodial bones		9			1		6	
Phalanx I							1	
Phalanx II		2						
Total	**1**	**48**	**3**	**1**	**51**	**7**	**135**	**245**

Tab. 7.4 Body parts with evident gnaw marks by *Crocuta crocuta spelaea* from SU11 of Area 3. From Gatta, Kotsakis, et al. (2017).

7.3 Taphonomic analysis

7.3.1 The cause of bone accumulations

Chapter II hinted how SU11 in Area 3, as well as bone deposits within Area 2, Area 4 and Area 7, have been interpreted as Late Pleistocene hyena dens. How was this interpretation possible? The opportunity was offered by the suitable preservation of fossilised bones from CM, which made detailed taphonomic analyses possible. Chapter V argued that there was no human contribution to bone accumulations of CM, the cause was, therefore, to be sought among the top carnivores of the region. Ethological studies describe individual behaviours of carnivores, and palaeontological studies demonstrate how thorough study of bone deposits can help to recognise the carnivore responsible for the accumulation (Stiner, 1991a, 2004; Lansing *et al.*, 2009; Camarós *et al.*, 2013). The most common features used for this purpose are patterns of bone modification, prey selection (i.e. taxon and age) and body part abundance. All of these have been taken into consideration in this study and comparable data with that of standard cave hyena behaviour have been reviewed.

However, even before starting the analysis of fossil remains, the main agent of bone accumulation was expected to be cave hyena, based on comparison with other European bone deposits. During the Late Pleistocene of Europe, hyenas were the only large carnivore living within caves to accumulate bones. The reasons behind this behaviour are various and documented with extant specimens as well: firstly, hyena cubs do not leave the den for several months and need to be fed within it (Crezzini *et al.*, 2016); transport of carcasses into dens permits to them to be fed safely from other carnivores (e.g. cave lion) and other hyenas; to store and preserve food within cooler areas of caves (Diedrich, 2010). Cave lions (*Panthera leo spelaea*) had a diet similar to that of cave hyena but, despite their name, did not live in caves but in steppe and open woods (Hublin, 1984; Arduini and Teruzzi, 1993). Moreover, this taxon is less common than hyena in the Pontine Plain. The wolf accumulates bones within caves only seasonally when feeding cubs but these deposits are never large (Crezzini *et al.*, 2016). Badgers and foxes do create substantial accumulations but these deposits mainly consist of birds and small prey and are not comparable with the over 1300 bones from SU11 (*ibidem*).

The first indication to support such a preliminary interpretation was the high number of remains showing gnaw marks typical of a large carnivore (Tab. 7.4). These have been found on 37% of the total NISP; the percentage increases to 56% if teeth, which obviously cannot display this type of mark, are deducted from the assemblage. Chewing and crushing of bones is practised by carnivores with the purpose of feeding on the bone marrow and they have developed a systematic way of doing it in the most efficient and profitable way possible, albeit also being recorded as an occasional pastime especially in young individuals. The Pleistocene cave hyena, due to their incredibly strong jaws, has a very peculiar system to process prey bones which can be traced with careful studies of remains (Pokines and Kerbis Peterhans, 2007; Diedrich, 2012a, 2014). A feasible example is the radii of auroch collected at CM (Fig. 7.1a), all of them have been exploited following the same technique which leads the hyena to chew the soft and fat-rich epiphyses and then crush the diaphysis so as to reach the marrow. This process is clearly different and adapted to each body part and prey species, depending on bone dimensions and hardness. As a general rule, hyenas prefer body parts which return a high quantity of nutrients (e.g. fat) such as ribs, vertebrae and epiphyses and sometimes that leads to the complete destruction of these bones (Camarós *et al.*, 2013). Body part distribution from CM reflects such a pattern, with only a few ribs and vertebrae recovered (Tab. 7.2) and most of the long bone epiphyses eaten (Tab 7.4).

A second feeding behaviour which is only carried out by cave hyenas during the Late Pleistocene is the collection of shed cervid antlers (Diedrich, 2014). Cervids were not the main food resource for Pleistocene hyenas, nevertheless, a large number of antlers is common in their dens (*ibidem*). These were chewed to assimilate the calcium of which they are largely composed and then discarded when the harder part (e.g. the base attaching to the skull) was reached. Antlers are shed and replaced yearly by most cervids, therefore these could be collected in abundance. Moreover, other large carnivores common during the Pleistocene (i.e. cave lion and wolf) were not able to digest horn and antler whilst cave hyenas, as well as extant species, could ingest and assimilate any bone tissue. Antlers with these damage marks, therefore, are a key fossil to attest the presence of cave hyena and are numerous (=49) in the assemblage of CM (Fig. 7.1b).

However, Pleistocene hyenas did not limit themselves to gnaw and crush bones to have access to the marrow but also ingested whole fragments to consume collagen within them (Kolska Horwitz, 1990). This practice is fairly common among carnivores but the cave hyena’s digestive system was predisposed to digestion of big fragments, despite the fact that fragments too big were occasionally regurgitated partially digested (Kolska Horwitz, 1990). The discovery of long fragments (Fig. 7.2) with these characteristics at

CM is then useful for the identification as a hyena den (Kolska Horwitz, 1990; Crezzini *et al.*, 2016).

Further evidence is given by the age at death of hyena remains. The analysis of the seventeen bones attributed to the carnivore permitted estimates of the presence of at least four individuals, among which are a neonatal and two cubs (Tab. 7.3). Cave hyena is, therefore, the only species among the main taxa of CM to return a majority of young individuals. This statistic has obviously no agreement with natural mortality patterns, where old individuals are the majority. Indeed, this data agrees with den contexts, and particularly those of the cave hyena’s (Blasco, 1995), where a percentage of newborns and cubs never reach adulthood while adult and old individuals have higher chances of dying through hunting. The next section will show how also age at death estimates of other taxa from CM also suggests a mortality pattern typical of hyena dens. However, all the evidence above mentioned demonstrates the indubitable role of hyenas as the main agent of accumulation.

Finally, albeit not related to the bone assemblage, we should not forget that a large number of coprolites were discovered in CM. These are used by modern hyenas to mark their territory against other carnivores or other hyena groups and the same use was probable in the past (Diedrich, 2014). The spatial distribution of bone remains is another valuable, but underestimated and marginally debated, element to recognise hyena dens (Crezzini *et al.*, 2016). This analysis demands a well preserved layer, with absent or minimum post-depositional disturbances, which reduces its applicability to archaeological sites. At CM, the quarrying activity and weathering made spatial analysis not applicable.

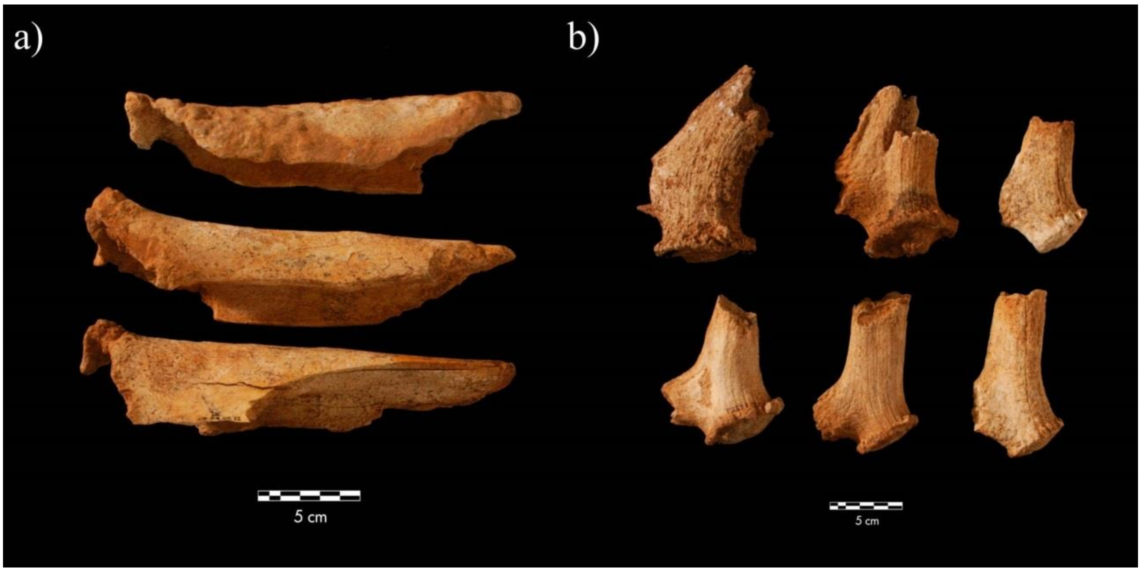


Fig. 7.1 a) Radii of *Cervus elaphus* displaying systematic bone exploitation by cave hyena; b) Shed antlers of *Cervus elaphus* with conspicuous gnaw marks. Re-elaborated from Gatta, Kotsakis, et al. (2017).

Fig. 7.2 Long bone fragment partially digested by cave hyena. From Gatta, Kotsakis, et al. (2017).

7.3.2 Age at death estimation and mortality pattern

The post-depositional fossilisation of bone remains made it possible to estimate the age at death of taxa identified at CM. The results returned the presence of at least 48 individuals, with a majority of adults (≈18) followed by young (≈16) and then old (≈14) ones (Tab. 7.3). Aurochs, wild horses and red deers are again the best represented species, reflecting the abundance of their remains. Shed antlers have not been considered in the count of the MNI, since these were naturally shed by the cervids and then collected by the hyena in the surroundings of the den. Similarly, a large amount of auroch and horse remains are individual teeth which, with the exception of third lower molars, are not particularly suitable for the counting of individuals.

The dominance of young individuals among hyena remains as den evidence has already been discussed in the previous section, however, age at death of other taxa also supports this interpretation. The absence of cut marks on bone remains and the use-wear analysis already demonstrated that humans had no role in the accumulation, this is also proven by age at death of prey. Indeed, humans hunted in large groups and preferred prime (e.g. adult) individuals, in order to supply as much meat as possible from each hunt.

The hypothesis of a catastrophic accumulation has not been mentioned so far, because of the obvious traces of carnivore activity, however, it is a rather frequent agent of bone accumulation in underground karstic caves with vertical access. It mainly consists of flooding events which drown and transport animals, together with other items and rubble collected on the surface, and deposit them within cracks, caves and ravines. The mortality pattern when these circumstances occur is age independent, since there is no selective action. These events are likely to happen during rainy winter months and in flood-prone areas (Pandolfi, Petronio and Salari, 2013). The Pontine Plain is a wide karst plateau with high-altitude mountains, geomorphologically and climatically suitable to flooding events and water overflow as its swamp environment indicates. Moreover, flooding has already been demonstrated to have transported lithic implements within the Area 3 (see section 4.2). Although flooding can be excluded with certainty as the main agent of accumulation of bones within SU11, the mortality pattern of CM, with abundant individuals of all ages, would be suitable as a result of catastrophic accumulations. Actually, it is possible some bone remains have been transported within the cave by water. This is particularly probable referring to small vertebrates recovered in SU11 and SU12 (e.g. birds, snakes, rodents and amphibian) too small to feed hyenas (Cruz-Uribe, 1991) and extremely rare faunal items of SU14 with no gnaw marks.

It is necessary to consider, for the correct interpretation of this data, that cave hyena’s feeding was not solely based on hunting but that scavenging also played a role (see section 7.2.2). The mortality pattern of macromammals from CM can be interpreted as follows: small and medium mammals were probably the result of hunting activities. Adult hares, weasels and badges were targets easily overwhelmed by cave hyenas, small cervids (i.e. roe and fallow deer) and wolves were probably hunted as individual animals. Medium-sized prey such as horses, red deer, aurochs and wild boars were chased as a group, although the biggest of these still had to be avoided. Rhinoceros were, in contrast, inaccessible targets for hyenas. It is possible to suppose that isolated young and old individuals were hunted while adult remains are the result of scavenging activities. This interpretation is supported by ethological studies on modern hyenas (Sillero-Zubiri and Gottelli, 1991; Berger and Cunningham, 1994).

7.3.3 Cava Muracci: The last of the Stephanorhinus hemitoechus

The narrow-nosed rhinoceros appeared in southern Europe around 500 ka (Pandolfi, Gaeta and Petronio, 2013) and rapidly spread in the entire continent, Near East and north Africa during the last interglacial (Guérin, 1980). It was a medium-sized herbivore with an adaptable diet based on low-growing vegetation, therefore preferring open environments such as steppes and grasslands (Fortelius, 1982; van Asperen and Kahlke, 2015).

The disappearance of this species is not completely clear in both dynamics and timing but it is included within the megafauna extinction which took place during the Late Pleistocene (Barnowsky *et al.*, 2004; Elias and Schreve, 2007). This is currently estimated to have occurred in most of Europe around 45 ka (Stuart and Lister, 2007, 2012), after a progressive north-to-south retreat during cold oscillations, with a dubious latest attestation in Portugal at 31–30 ka BP (Cardoso, 1996). Scholars ascribed the extinction of *Stephanorhinus hemitoechus* to (i) climate changes, (ii) competition among large herbivores, (iii) predation and, finally, a combination of all of these.

The first cause is mainly ascribed to the frequent cold oscillations of MIS 3 caused by Heinrich Event 4 (i), which would have triggered climate and vegetational changes with subsequent migration towards more temperate southern lands and, finally, extinction (Wroe, Field and Grayson, 2006; Lister and Stuart, 2008). This hypothesis, albeit climate degradation is not called into question, may not have been sufficient alone to cause the extinction since the adaptable diet would have permitted rhinoceros to survive in cool habitats (van Asperen and Kahlke, 2015). (ii) There is no evidence of strong competition among herbivores in the Late Pleistocene, and this theory is mainly based on present day observations in Africa during periods of intense drought. Large mammals such as elephants, mammoths and other species of rhinoceros (e.g.

Coelodonta antiquitatis) inhabited Europe simultaneously with narrow-nosed rhinoceros, but their coexistence is limited to a few regions. Therefore, a possible competition cannot be excluded but it does not seem to have been extreme enough to cause the disappearance of a species. (iii) Predation probably played an important role in this extinction since it was carried out by both carnivores and humans. Actually, the latter are considered the main agent in the abovementioned megafauna extinction (Sandom *et al.*, 2014) and isotope analyses show the Neanderthal diet in central Europe was largely based on mammoth and rhinoceros exploitation (Bocherens *et al.*, 2005; Dusseldorp, 2011). However, such an interpretation is currently debated due to the recent reassessment of several Neanderthal sites, which seem to suggest megafauna only represented and opportunistic food resource, whilst Neanderthal diet would be mainly based on medium-sized ungulates (Smith, 2015). Moreover, large-scale hunting of narrow-nosed rhinoceros is not evident in Italy (Pandolfi *et al.*, 2017). Finally, ethological studies of modern carnivores suggest that cave lions could kill adult rhinoceros while hyenas occasionally attack young individuals (Sillero-Zubiri and Gottelli, 1991; Berger and Cunningham, 1994) and, therefore, carcasses are likely to have been scavenged rather than hunted (Diedrich, 2014, 2015).

Summarising, all of these factors do not seem to be sufficient on their own to induce a rapid extinction of a species. However, if the climatic stress probably led to the maximum contraction and fragmentation of rhinoceros populations in southern *refugia*, concurrent competition and predation may have induced extinction before a new expansion of populations was possible (Pandolfi *et al.*, 2017). The extinction of the narrow-nosed rhinoceros in Italy was estimated around >41 ka cal based on several central and southern localities (see Tab. 1 in Pandolfi et al. 2017). Unfortunately, the dating of many of these sites has been produced a long time ago and would need a revision.

The discovery at CM of a fragmented femur and three lower teeth of at least three individuals provided the opportunity to re-examine this chronological framework. The femur (R. 842) belongs to a young individual and has been discovered in Area 4; two lower molars (R. 363, Fig. 7.3; 365) have been collected close together in Area 5, therefore they probably belong to the same adult individual; the last lower molar (R. 645) originates from SU11 of Area 3 and belongs to a young individual. The latter has been radiocarbon dated to 42,054–40,804 cal BP (Gatta, Sinopoli, *et al.*, 2016) and sets, therefore, a new upper limit for the extinction of this species (Pandolfi *et al.*, 2017) suggesting the Pontine Plain could have been a *refugium* for this species.

Fig. 7.3 R. 363: lower molar tooth of Stephanorhinus hemitoechus from Area 5.

7.3.4 Pupal chambers

A pupal chamber is a small space usually dug in soft material (i.e. soil, wood, rotting meat etc.) by a larva in the pupal stage, within which it undergoes metamorphosis which will lead it to its final insect stage. Insects are extremely sensitive to climate and vegetational changes, therefore their identification would be a valuable environmental indicator. Nevertheless, insects are rarely preserved within these chambers, therefore, the taxonomic assignment of the chambers to a species is not easy and is based on three features: chamber shape (i.e. long axis-to-short axis ratio); structure of the walls; typology of filling (active or passive) (Sacchi and Petti, 2008). However, studies of these fossil remains are very limited. A few discoveries of pupal chambers in sediments from Argentina (Genis 2004 and references therein), Uruguay (Roselli, 1987), Spain (Genise and Edwards, 2003) and Mongolia (Johnston, Eberth and Anderson, 1996) have been documented.

The rare presence of pupal chambers on skeletal remains of dinosaurs (Britt, Scheetz and Dangerfield, 2008; Bader, Hasiotis and Martin, 2009), extinct mammals (Laudet and Antoine, 2004; Fejfar and Kaiser, 2005) and humans (Huchet *et al.*, 2013) have also been recorded and described by Gautier (1993). They appear as circular borings extremely regular and variously distributed on the bone surface (Fig. 7.4), dug by necrophagous insects in rotting cadavers. Actually, these traces have been misinterpreted for a long time as the result of man-made activities, pathologies, bone cancers and post-depositional factors (Huchet *et al.*, 2013).

At present, the discovery of pupal chambers is limited to the sediments of two sites in Italy, curiously both of them in central Italy, and only one of them (e.g. Santo Stefano Island) has been published by Sacchi and Petti (2008). The discovery of fossil pupal chambers at CM site is therefore fascinating and their presence on bones makes this discovery even more exceptional. These have been found on a metacarpus (Fig. 7.5a) and a phalanx I (Fig. 7.5b) of aurochs from SU11 of Area 3, the first also displaying gnaw marks. Unfortunately, because very few scholars have expertise in pupal chambers, it was impossible to perform a study of those from CM. However, their discovery highlighted a lack of knowledge and studies on potentially valuable ecological indicators, which will be, hopefully, be investigated in the future.

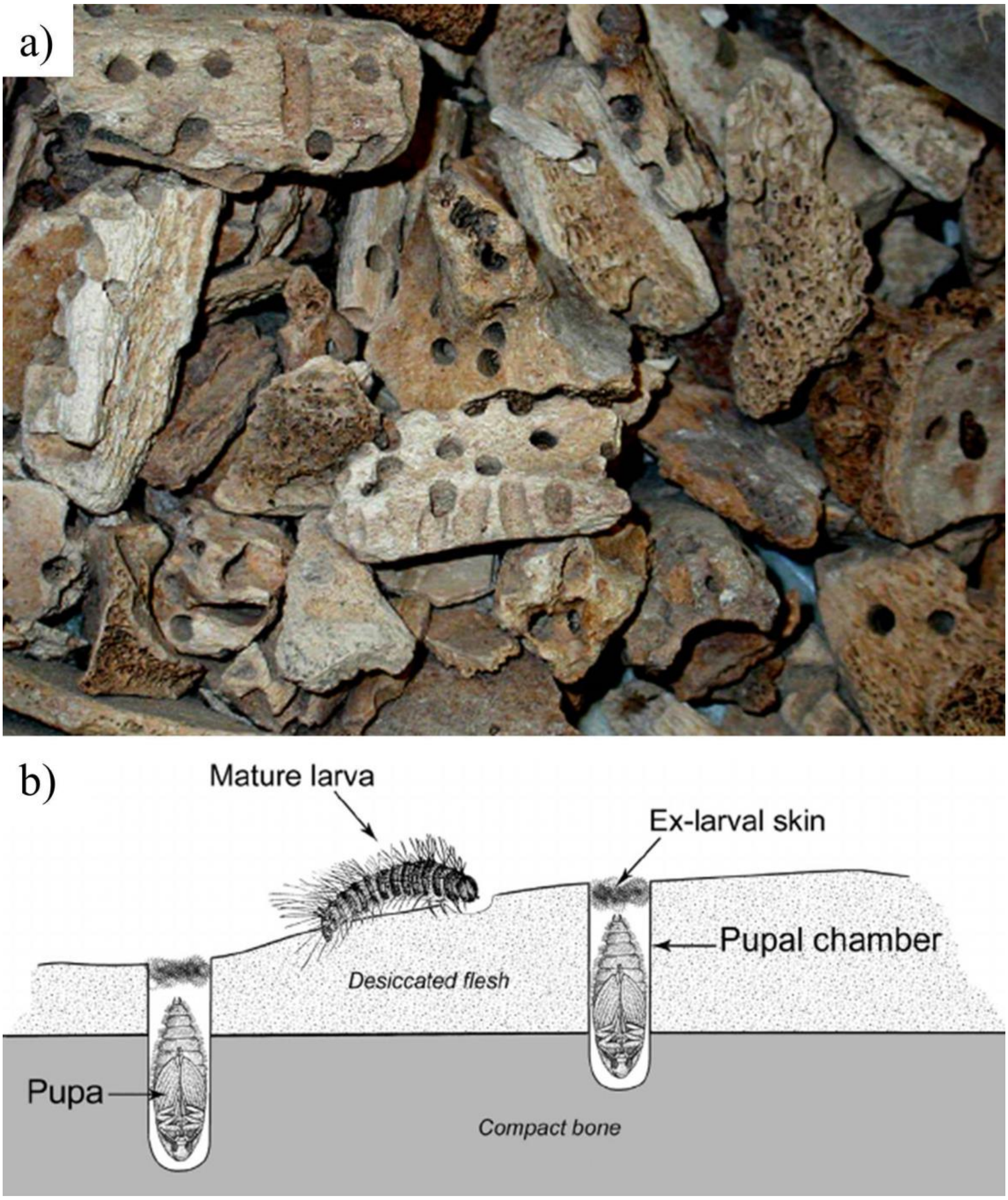


Fig. 7.4 a) Bronze Age human bone remains from Jericho showing pupal chambers. From (Huchet et al. 2013); b) Schematic section of necrophagous insects' pupal chambers.

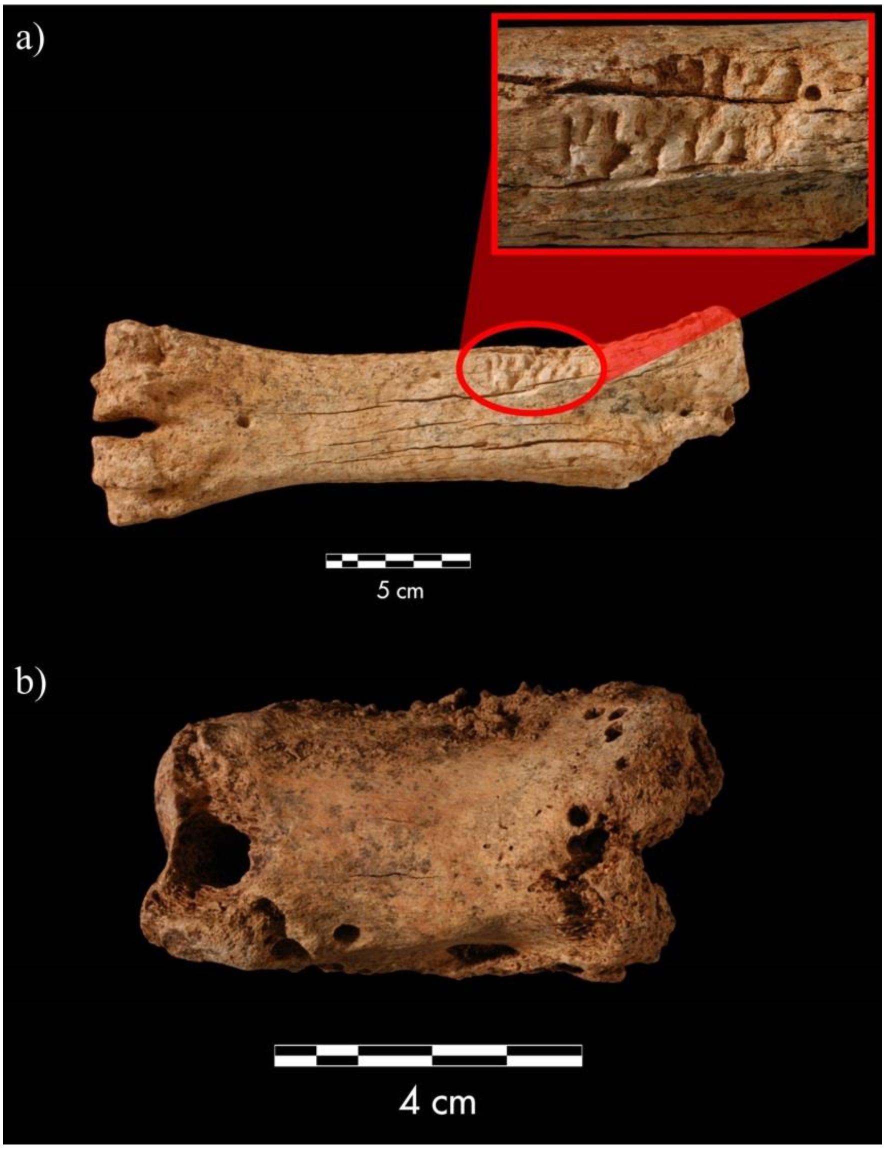


Fig. 7.5 a) Metacarpus and b) I phalanx of *Bos primigenius* from SU11 of Area 3 at Cava Muracci displaying pupal chambers.

7.4 Cava Muracci's fauna within the Pontine Plain context

The Pontine Plain is an extremely important region from a palaeontological point of view. Numerous fossil deposits covering a broad timeline have been discovered, however, the collected data is not as relevant as it might be. The reasons for that, as fully described in Chapter II, are due to a combination of factors: (i) the intensive excavation of most fossil deposits between the 1930s and 1960s with outdated methods, particularly scarce attention to stratigraphic references and focusing on human remains; (ii) the limited number of detailed studies and publications of faunal remains; Moreover, only a few sites contain fossil fauna from MIS 3 or comparable to that of CM, substantially reducing the number of reference datasets for a prehistoric period which underwent many climatic changes.

The layer SU11 of Area 3 at CM is argued here to be a Late Pleistocene hyena den. Diedrich (2010; 2014) proposed a model based on hyena population pattern and comparison with modern den structure through which it would be possible to understand what use was made of Pleistocene dens. This model distinguishes three types of dens in Europe: (i) 'cub raising den', in which the hyena mother is often the only adult together with cubs. This is usually identified by a majority of very young individuals, since the mortality pattern within the first year is rather high. Prey remains and coprolites are also present in good quantity (Diedrich, 2014); (ii) the 'communal den' is a cave intensively exploited by individuals between young (i.e. already weaned) and senile age classes, therefore remains of adults and senile individuals are the most represented. Coprolites to mark the den are also extremely abundant (Diedrich, 2010, 2012a, 2012b, 2014); (iii) 'prey storage' are the last type as well as the most common den in cold regions rich in prey (Tournepiche and Couture, 1999; Diedrich, 2017). These sites are more food deposits than actual dens, prey remains in anatomical connection are abundant, natural mortality of senile hyenas is also found, whilst coprolites are rare. Following Diedrich's model, due to the majority of young individuals (Tab. 7.3) and the large quantity of coprolites and bone remains, it seems Area 3 can be identified as a cub raising den.

How does the fossil record of CM fit into the larger regional framework of the Pontine Plain? The cave deposits of Monte Circeo and Fondi Plain (i.e. Grotta Guattari, Grotta Breuil, Grotta Barbara, Grotta del Fossellone, Grotta di Sant'Agostino and Grotta dei Moscerini) and the open air site Canale delle Acque Alte returned the most important Late Pleistocene faunal assemblages of the region (see Tab. 5.1). Unfortunately, the assemblage from the latter is the result of collection without stratigraphical references from extended flood accumulations and, although efforts to identify the layer provenience of findings have been recently made (Farina, 2006, 2011), its reliability is highly compromised. Comparisons of CM's fauna are therefore limited to the abovementioned cave deposits which, it is necessary to emphasise, are the result of hominin and carnivore activities, and sometimes both mixed together, during different timeframes of the Late Pleistocene (see Tab. 5.1). Despite that, the results highlight the fact that the assemblage from CM does not differ too much from those analysed. The widespread presence of cave hyena and its role in many fossil deposits of the region is the first relevant piece of data. The second is the widespread presence in all of these sites of taxa found at CM, with some variety such as the presence of rhinoceros at CM or cave bear and cave lion at Monte Circeo. Aurochs, cervids and equids are the main species as at CM, although extremely different percentages are noted: Cervids and aurochs alternately are the preferred prey with much less frequent horses at Monte Circeo (Stiner, 1994; Alhaique and Tagliacozzo, 2000). This has been described as the result of selective hunting by hominins (Stiner, 1994; Alhaique and Tagliacozzo, 2000) but the hilly context in which these sites are located had an important role as well, since hyena accumulations returned similar compositions.

In conclusion, the CM assemblage seems to be perfectly comparable to other Late Pleistocene assemblages of the Pontine Plain, despite the different chronological and habitat settings of some of them. Actually, this homogeneity among several sites dating between 120 ka and 30 ka seems to suggest the region preserved during this timeframe an environmental stability and this will be further discussed in Chapter VIII.

7.5 Environmental significance of the fauna

The faunal assemblage recovered from CM provides an opportunity to reconstruct a complex environmental framework for the Pontine Plain during the period 44–34 ka (Gatta *et al.*, in press a). Vegetational and climatic indications of both macromammals and microvertebrates are coherent and, most of all, comparable to previous pollen analysis. The bone accumulation by hyena hunting activity, which we already mentioned is constrained to within a maximum of 50 km from their den (see Argant 2004; Argant & Dimitrijevic 2007; Mills 1989; Scott 1987), is extremely valuable to define the spatial mesoscale of reconstruction based on fauna. It is therefore perfectly compatible with vegetational data provided by pollen and they will both be discussed together in the next chapter. Moreover, the joint hunting and scavenging subsistence of cave hyenas indicates a broad spectrum of fauna available in the region. It is highly probable it will not reflect the entire population of an area but large assemblages, such as in the CM site, are usually good environmental references for reconstructions.

Taxa discovered at CM are widespread in Europe and Italy during the Late Pleistocene, however, during the cold oscillations of MIS 3 (e.g. Heinrich events 4) their populations are more fragmented and isolated, therefore, the discovery of all these species in a single small-scale assemblage is ecologically extremely interesting.

The ecological picture among macromammals is mainly described by herbivores, since carnivores (i.e. *Canis lupus*, *Meles meles* and *Crocuta crocuta*), in the past as at present, were widespread from north-to-south Europe in a large variety of ecosystems and are therefore of little help toward environmental reconstruction (Gatta *et al.*, in press a). Microvertebrates support and strengthen the reconstruction. The abundance of *Equus ferus* and the few *Stephanorhinus hemitoechus* remains and *Bufotes* sp. and *Microtus (Terricola) savii* among microvertebrates indicate wide open lowland-steppes characterised by abundant grass and low vegetation; the presence of wild boar indicates copious water, such as humid woods and swamps, surrounding the CM site. *Bufotes* sp, *Rana* (s.l.), *Anguis veronensis, Natrix natrix*, *Arvicola amphibious* and fish remains strongly support this environmental feature; forested and wooded areas with open spaces and glades rich in grass are suggested by abundant *Bos primigenius*, *Capreolus capreolus*, *Cervus elaphus*, *Dama dama dama* and *Apodemus cf. A. sylvaticus*, *Myodes glareolus* and *Glis glis* (Gatta *et al.*, in press a). Macromammals and microvertebrates both suggest a temperate climate during their accumulation within SU11. A cold oscillation is possibly represented by *M. arvalis* in underlying SU12 which, in opposition to *M. (T.) savii* in SU11, is a rodent typical of cooler temperatures (*ibidem*).

The fauna analysis indicates a mosaic landscape composed of at least three coexistent but different temperate habitats within a short distance (≈ 30 km), these can be summarised from west to east as follows:

- The coastline was most probably characterised by wetlands and lacustrine environments, the latter of which are still present nowadays. Swamps and ponds were also present along the rivers, a feature that disappeared only after the reclamation during the last century. Wild boars recovered at CM lived in this habitat, and several of the microvertebrates particularly amphibians and reptiles.
- The central part of the Pontine Plain was a widespread grassland with steppe, low vegetation and patchy arboreal areas. It was inhabited by some of the large mammals from CM, such as the cave hyena, rhinoceros and wild horses together with pine voles.
- The hills below the Lepino-Ausoni mountains were likely covered with open woods and forests, which constituted the living environment of several taxa hunted by cave hyena, such as aurochs, wolves, cervids but also small rodents.

A possible limit of this reconstruction could be considered to be the chronological resolution of the SU11. As already noted for pollen analysis, the 10 kyr time-span of this layer may reflect a coexistence of different environments but also a sequence of short and rapid climate changes. The latter would mainly refer to the Heinrich Event 4, which took place about 38 ka (Hemming, 2004). Although taphonomy of bones and stratigraphic integrity seems to suggest the entire accumulation is referable to a single episode of hyena activity, i.e., several habitats were present at the same time, further dating of this layer is necessary to resolve the time-span and, possibly, answer this question.

7.6 Conclusions

Faunal remains from CM have been described in this chapter. The study involved 1346 fossil bones of large mammals and hundreds of microvertebrate remains, including small mammals, birds, reptiles, fishes and amphibian. This analysis permitted the identification of 27 different taxa and their careful examination yielded a series of valuable information.

Examination of remains allowed us to identify the SU11 of Area 3 as a hyena den. This interpretation is corroborated by a wide range of evidence, such as coprolites, gnaw marks, age at death of faunal remains and other key fossils which define hyena accumulations. Moreover, the analysis of individual taxa of this assemblage resulted in the unusually late dating of 42,054–40,804 cal BP for at least one of the narrow-nosed rhinoceros recovered, which improves the current knowledge regarding the extinction of this large mammal in Italy. Finally, the unexpected discovery of two bone remains with insect pupal chambers highlights the poor attention towards this type of remains despite its considerable ecological potential. Unfortunately, it was not possible to carry out analysis of these remains during the elaboration of this thesis but their exploitation is one of the future expectations of this research project.

Macrofauna and microvertebrates from CM, despite their widespread presence during the Italian Late Pleistocene, yielded new and coherent ecological data which has allowed us to propose an environmental reconstruction of the Pontine Plain during the chronological interval between 44–34 ka. Regarding the reliability and spatial scale of such a reconstruction, it is necessary to consider a characteristic of the faunal assemblage on which it is based, i.e. the bone accumulation of CM is the result of hyena hunting activity (albeit a small introduction of remains during flooding events cannot be excluded). This agent of accumulation has two implications:

1- The first of them is the range of hunting of the carnivore of about 50 km from the den, which delimits the spatial scale of this reconstruction to a mesoscale. It is the appropriate scale to investigate regional environments (see section 1.4.1) and is perfectly compatible with the spatial scale of pollen analysis produced (see section 6.3). 2- The bone assemblage reflects species selected by the carnivore, these certainly do not represent all the faunal species of the Pontine Plain. However, concerns regarding a somehow distorted ecological picture are unnecessary. The dietary habits of cave hyenas clearly show that, albeit seasonal and local selections are noticed, the set of prey found in a den reflect the wildlife surrounding the den with a good approximation.

The environmental context seems to have been extremely diversified and permitted the coexistence of several taxa with different living habitats in a short range. This was possible due to the morphology of the region which presents coastlines and high mountains within a distance of 30 km. The landscape can be divided into three main habitats: wetlands along the coast and the rivers of the plain; extensive steppes and grasslands in the central lowland; forested and open wooded hills along the east margin of the region.

The faunal analysis presented, besides being valuable to improve our knowledge of the Pontine Plain’s fauna during the Late Pleistocene, offers with its small-scale ecological indications an important contribution to completing in the next chapter the environmental reconstruction of the region.

Chapter VIII

Discussion

This discussion puts forward four discursive sections, drawing these together in the conclusion. The first one summarises the results and provisional observations on the Pontine Plain environment inferred from the data recovered from the analyses of Cava Muracci (hereinafter CM). These are briefly described in order of their significance and originality within this project: pollen data, zooarchaeological inferences and description of the human exploitation of the territory. The second section integrates all the above-mentioned deductions and introduces a holistic environmental reconstruction of the region. The third section refers to the previous debate on the concept of *refugium* (see section 1.3) and attempts to understand whether and to what extent the Pontine Plain can be considered one of them. Finally, the fourth section draws together the outcomes of this thesis. The implications of this work on the local, regional and continental scale are discussed, identifying the key strengths and some aspects in need of future development, further explored in Chapter IX.

8.1 Results summary

This thesis has five aims (see section 1.1). Three of them have been achieved in Chapters V, VI and VII. These were to suggest a pattern of human exploitation and to propose two frameworks of environmental and climatic reconstruction of the Pontine Plain, one based on pollen data from coprolites and the other on faunal remains. All of these will be summarised in this section, so as to develop with ease the following discussion about environmental reconstruction and *refugium* in section 8.2 and 8.3.

8.1.1 Palaeoenvironmental inferences from coprolites

Pollen analysis was carried out on a set of 16 cave hyena coprolites, representative of the whole collection from SU11 (Gatta, Sinopoli, et al. 2016). The high resolution of pollen data from faeces is appropriate to investigate reconstructions of small regions (e.g. mesoscale ($1–10^4$ km^2)) such as the Pontine Plain. The typical intake of pollen occurring through feeding of the carnivores allowed the investigation of the vegetation within the hunting area, which spans over a maximum range of 50 km from the den (Argant 2004; Argant & Dimitrijevic 2007; Scott 1987; Mills 1989).

The modest preservation of grains (650–2200 pollen grains/g) allowed the identification of 27 herbaceous, aquatic and arboreal taxa (Gatta, Sinopoli, et al. 2016). Their coexistence allowed the reconstruction of a varied local environment. The main feature identified is an extended steppe. However, the different percentages of steppe-plants such as Amaranthaceae, Poaceae and *Artemisia* (see Fig. 6.4) seem to suggest that the steppe was varied rather than homogeneous. In particular, except for *Artemisia*, which indicates some very dry patchy areas, Poaceae suggest a low degree of aridity as also testified by the abundance of Amaranthaceae, which indicates a relevant presence of water in the region. It is worth noting that two aquatic taxa (i.e. *Typha* and *Sparganium*) indicate a completely different habitat, with abundant still water in the form of rivers and marshes, within a short distance (Gatta, Sinopoli, et al. 2016). The vegetational framework is completed by rather uniform values of thermophilous and mesophilous tree pollen, with the first probably forming small Mediterranean woodlands on the plain and the latter situated in the cooler hilly areas. In sum, the vegetational composition suggests a temperate climate.

8.1.2 Palaeoenvironmental inferences from fauna

A large collection of almost 2000 large bone remains has been recovered from CM, 1346 of which were found in the SU11 of Area 3 (Gatta *et al.*, in press a; Gatta and Rolfo, 2017a). The excellent preservation of fossils enabled us to taxonomically classify almost 50% of the total remains, despite the high rate of fragmentation, identifying 12 macro-faunal taxa (Gatta *et al.*, in press a; Gatta and Rolfo, 2017a). In addition, hundreds of microvertebrate remains have been found by sieving the soil sediments of the cave, increasing the total number of taxa to 27 (Gatta *et al.*, in press a; Gatta and Rolfo, 2017a). This assemblage returned valuable ecological inferences. Moreover, not only is the local spatial scale perfectly comparable to that of pollen data, due to the same agent of accumulation (e.g. hyena hunting activity), but also the resulting environmental framework shows important similarities which corroborate the reliability of both analyses.

Micro- and macro- remains suggested the contemporaneous presence of three different vegetational patterns, the same as indicated by pollen, but also allowed us to reconstruct the geomorphology of these areas. Extensive steppe/grassland plains habitat is suggested by the large number of *Equus ferus*, the few *Stephanorhinus hemitoechus* and *Microtus (Terricola) savii*. A completely different habitat rich in water is indicated by *Sus scrofa*, *Bufotes* sp, *Rana* (s.l.), *Anguis veronensis*, *Natrix natrix, Arvicola amphibious* and even fish remains. Finally, the very abundant *Bos primigenius*, cervids such as *Capreolus capreolus, Cervus elaphus*, *Dama dama dama* and the microvertebrates *Apodemus cf. A. sylvaticus*, *Myodes glareolus* and *Glis glis* testify to the presence of wooded areas in hills and at higher altitudes.

8.1.3 Spatial analysis of human exploitation of the Pontine Plain

Although this thesis is developed in a strictly ecological perspective, an analysis of the human exploitation of the area was absolutely necessary to investigate its potential as a human *refugium*. In order to succeed in this task, the features which are commonly considered of key importance for prehistoric life have been analysed.

A central role was played by geomorphological features of the region (Henry, Belmaker and Bergin, 2017). The Pontine Plain is a well-delimited territory with two opposite points of access which made it a natural corridor along the Italian peninsula. Such a shape was likely to be preferred by Palaeolithic hunters, who could easily control the large herbivore movements by living from the edges of this area (Bailey, 2005). The confirmation that this strategy could have been applied by Palaeolithic people of central Italy is offered by the spatial distribution of archaeological sites within the studied area, which have a notable concentration along the coastline (Rolfo, 2009). The position of the Pontine Plain along the Mediterranean coastline and the warmth coming from the latter are important natural features, since the proximity to coastlines with their warmer climate is considered to be one of the main elements of potential *refugia* (Bar-Yosef, 2000; Boyle, 2000; Finlayson and Giles Pacheco, 2000; Panagopoulou *et al.*, 2004).

Finally, despite being a relatively small region, the Pontine Plain displays a very varied landscape, with plains, hills and mountains all present within a few kilometres.

The abundance of food resources is another important element. Chapter VII already highlighted a wide diversity of large mammals that hominins could feed on. Among those clear preferences have been deduced from the study of faunal remains from archaeological deposits (Stiner and Kuhn, 1992). Although the regional fauna did not undergo profound changes during the Late Pleistocene, Middle and Upper Palaeolithic hunters had different prey preferences. The Neanderthals, seem to have equally exploited all the large mammals available in the territory, with a preference for red deer just towards the end of the sequence (Stiner and Kuhn, 1992). The AMH, had a strong preference for red and fallow deer (*ibidem*). An early but marginal exploitation of marine resources (i.e. molluscs, marine turtles and seals) is also attested in the cave of Grotta dei Moscerini (Vitagliano, 1984; Kuhn, 1995). The abundant supply of fresh water in the region has been described in detail in Chapter II, adding another potentially inexhaustible resource to their inhabitants.

The last element considered is the availability of lithic raw material, a fundamental resource for the production of cutting and hunting tools in prehistory. The Pontine Plain has no flint or obsidian sources, but marine pebbles are abundant along the coast. The key role of this resource for humans and its abundance are demonstrated by the great quantity and spread of the tools recovered in the entire region (see Chapter III and Figs. 3.3–3.4), by the almost complete absence of exotic raw material, which was unnecessary, and by the focused adaptation to knapping these pebbles, which led to the development of the Pontinian culture (Kuhn 1991b; Kuhn 1995; Stiner & Kuhn 1992).

In conclusion, these elements suggested that the region offered a set of noteworthy opportunities during the Late Pleistocene, which may also indicate that it had an important role for human communities within it.

8.2 The multidisciplinary palaeoenvironmental reconstruction of the Pontine Plain

The fourth aim of this thesis is to combine ecological inferences from pollen and faunal data and present for a detailed environmental reconstruction of the Pontine Plain between 44–34 ka BP. The results of individual studies immediately highlighted common elements to both environmental frameworks which made their combination straightforward and smooth. Moreover, their congruency at spatial and temporal mesoscales, determined by the hunting behaviour of cave hyena, allowed us to combine these two sources of information without problems of resolution or complementarity (Gatta *et al.*, in press a; Gatta, Sinopoli, *et al.*, 2016). The resulting reconstruction is an extremely interesting and complex framework of different habitats and diversified biota. The Pontine Plain during the MIS 3 was most likely characterised by three main landscapes, which developed as linear habitats oriented north-to-south, and can be outlined as follows.

1- The westernmost of these is the coastal plain in front of the Tyrrhenian Sea. During the Late Pleistocene, the onset of cold oscillations at about 80 ka BP produced the expansion of ice sheets. During the LGM at 20 ka BP, a consistent marine regression between 70–100 m is estimated (Antonioli, 2012) which would release from the sea about 7–11 km of extra land on the Pontine Plain (Stiner 1994: 27) (Fig. 2.6c). Presumably, during the 44–34 ka BP interval of this reconstruction, the regression was not at its maximum but it is highly probable that several kilometres were uncovered by receding waters. Therefore, the shoreline at present does not reflect that of the MIS 3 but it was placed at least 3–4 km ahead of the Monte Circeo. The beaches were rich in those marine pebbles of small and medium size exploited in large quantities during the Middle and Upper Palaeolithic (Kuhn, 1995), the same raw material of the lithic implements found at CM (Gatta and Rolfo, 2017a). The geology of the area and a comparison with present day settings suggest that this part of the Pontine Plain was characterised by many rivers and streams flowing into the sea, while fossil dunes forming sand ridges were present along the entire shoreline (Cipollari and Cosentino, 1993). Behind the sand dunes, a swamp basin, perhaps of brackish water, followed the entire coastline. This habitat was certainly the warmest and most humid of the Pontine Plain, it was rich in vegetation as suggested by the percentages of thermophilous trees from pollen data (Gatta, Sinopoli, et al. 2016 and Fig. 6.4). Finally, faunal remains from CM returned a number of taxa which would have lived in this habitat (Gatta *et al.*, in press a). The large wild boar (*Sus scrofa*) was probably the only prey of the hyena living in this area, while small vertebrates recovered at CM were amphibians such as toads (*Bufotes* sp.) and frogs (*Rana* (s.l.)) and the reptiles such as slow worms (*Anguis veronensis*) and grass snakes (*Natrix natrix*), which probably were not hunted due to the small meat intake (Gatta *et al.*, in press a).

2- At the centre of the Pontine Plain, an extensive plain characterised the landscape. It was over 40 km long north-to-south and, due to the above-mentioned sea regression, over 15 km wide east-to-west (Cipollari and Cosentino, 1993) (Fig. 2.6c). The archaeological site of CM (Gatta and Rolfo, 2017a) is located in its northern sector. During the MIS 3, this plain appeared completely different from the present day. The most significant element of this landscape is the underlying limestone platform which runs through the full extent of the plain at a minimum underground depth and had a crucial role in the surface aspect of the territory. This geological feature is the main cause of the limited permeability of the entire region, which was reflected by waterlogging and widespread marshes up to the reclamation of the last century. The distribution of swamps, based on comparisons with historical times and geological data, led us to suppose that during MIS 3 this particular condition was especially localised in two areas: along the north-east border, supplied by the numerous rivers and streams of all size from the surrounding Alban Hills and the Lepini Mountains; in the western part of the plain, following the marine regression, where swampy ground probably persisted (Cipollari and Cosentino, 1993).

Pollen data show that this habitat was characterised by two types of uninterrupted steppe (Gatta, Sinopoli, *et al.*, 2016): an extremely arid one is indicated by the almost constant presence of *Artemisia* (Fig. 6.4). This first type of steppe was probably located in the middle of the plain, distant from the western marshes of the coastline and those at the foothills of the Alban Hills-Lepini Mountains in north-east. The second type was more humid and similar to a prairie, as suggested by Poaceae, with abundant water-demanding Amaranthaceae along the many rivers, streams and pools. The existence of pools is testified by the presence of *Typha* and *Sparganium* pollen grains within the coprolites, probably attributable to water consumption (Gatta, Sinopoli, *et al.*, 2016). The closeness of water to the den of CM is also confirmed by the recovery of freshwater fish remains within SU11 (Gatta *et al.*, in press a). There is no specific evidence to demonstrate that these remains are the result of hyena fishing, a behaviour which has been documented in prehistory on rare occasions and infrequently in modern hyenas. However, the taphonomy of the layer seems to suggest that occurrence, as no other predators or raptors frequented the cave during the deposition of the layer (Gatta and Rolfo, 2017a). These water sources were the only natural feature to break the flatness of the extensive plain, together with small arboreal patches.

The faunal taxa from CM strengthen the reconstructed picture of the landscape. The abundance of *Equus ferus* remains and *Microtus (Terricola) savii* confirm the presence of widespread open environments. The genus *Bufotes* corroborates the interpretation that at least a part of the area was humid, probably close to rivers and ponds, whilst the *Stephanorhinus hemitoechus* suggests that plenty of grasses, shrubs and bushes grew on the plain (Gatta *et al.*, in press a). Faunal and vegetational taxa indicate that the climate was generally temperate, perhaps slightly cold.

It is presumed, based on the location of the den and the quantity of horse remains, that this area was regularly attended by cave hyena. Conversely, the human presence in the area is poorly known. Unfortunately, the extensive reclamation works of the last century and the intensive use of the land for agricultural purposes severely damaged the stratigraphic integrity and possible archaeological evidence of open air sites. This is the reason why the rare cave sites of the area such as CM have a very important role in local prehistoric interpretations. Nevertheless, this does not mean that people did not live in the area. The archaeological sites introduced in Chapter V clearly show a continuous, but with varying intensity, exploitation of fauna typical of clearly local steppe/grassland habitats. This is also confirmed by the richness of lithic tools abandoned on the plain, which are commonly recovered during ploughing activities (Kamermans and Sevink, 2009; Gatta, Achino, *et al.*, 2016).

3- The last habitat of the Pontine Plain was constituted by the hilly areas at the base of the Alban Hills and the foothills beneath the Lepino-Ausoni Ridge. The hills are the result of the intense volcanic activity by the volcano Albano since 561 ka BP (Karner, Marra and Renne, 2001), while the second feature developed due to the same tectonic motions which formed the overlying Lepino-Ausoni Ridge (D’Argenio, Pescatore and Scandone, 1973; Parotto and Praturlon, 1975). This is the landscape that maintains the geomorphology most similar to that of the 44–34 ka BP interval. The many rivers and streams crossing the Pontine Plain flowed here in the valleys among hills, but the significant arboreal cover was probably the main feature of this habitat. The mesophilous trees and other arboreal taxa from pollen data were probably primarily concentrated here, forming broad Mediterranean woodlands, which in some areas assumed the features of proper forests (Gatta, Sinopoli, *et al.*, 2016). This habitat was the least extensive of the three detected. Although it ran along the entire east border of the Pontine Plain, it was only a few kilometres wide before abrupt mountains isolated the region. Despite that, its impact in the archaeological record is relevant. The list of species recovered at CM, typical of arboreal and/or hilly areas, is particularly long. *Bos primigenius*, the most abundant taxon and preferred prey of cave hyena at CM (Gatta *et al.*, in press a), is a marker of hilly woodlands, possibly open or with many glades where plentiful grass was available (van Vuure, 2002; Pandolfi, Petronio and Salari, 2011). The same habitat was common to all the cervids found, i.e. *Capreolus capreolus*, *Cervus elaphus* and *Dama dama dama* (Apollonio, 2003; Mattioli, 2003; Perco, 2003; Marra *et al.*, 2014), which all together make a high percentage of the total fauna. Sporadic carnivores, such as *Canis lupus* and *Meles meles*, which were widespread in a few habitats during the Late Pleistocene of Italy (Gatta *et al.*, in press a), probably inhabited this area as well. Finally, some microvertebrates such as *Apodemus* cf. *A. sylvaticus* and *Glis glis* are particularly common in forested areas (Capizzi and Filippucci, 2008a, 2008b). The biota suggests that the climate was temperate. Due to the altitude and proximity to mountains it is probable that the temperature changed significantly on a seasonal basis, with snow and abundant rain during the winter and warm summers.

The NISP (Tab. 7.1) and a number of remains displaying gnaw marks (Tab. 7.4) from Area 3 clearly indicate that a large part of hyena prey comes from this hilly habitat, which was most probably the preferred hunting area (Gatta *et al.*, in press a). The human presence in this area is extremely difficult to understand (see Chapter V). It has been thought for decades that it was completely absent in the hilly areas in the north, on the slopes of the volcano Albano, and secondarily in the foothills of the Lepino-Ausoni Ridge. Recently it has been noticed that rare open air evidence of Neanderthal presence in the Alban Hills is buried under a deep layer of volcanic deposits dating at 36 ka BP (Rolfo and Giaccio, 2000; Rolfo, Giaccio and Sposato, 2006), which prevented further discoveries. On the other side, AMH seem to prefer the inland Apennine regions of central Italy with a sporadic presence along the coast, and are therefore extremely scarce in the intermediate hilly areas (Barker, 1999).

This reconstruction of the Pontine Plain is elaborate but supported by other evidence. The first of them is the geomorphology of the region, which is of great impact and generates also at present an unusual diversity of habitats within such a short distance (Blasi, 1994; Barbieri *et al.*, 1999; Gatta, Sinopoli, *et al.*, 2016). During the Late Pleistocene, such diversity was certainly even more evident, due to the above-mentioned drop in the sea level and the hydrogeological features of the area (see section 2.1). Moreover, the activity of the Volcano Albano in the Alban Hills district probably strongly affected both climate and biota of the entire region, albeit studies to understand the extent of its influence are currently absent.

The second evidence to enhance the reliability of this study is the comparison with data from other sites. Local reconstructions with MIS 3 sediments are not available or reliable, which is why the research of this thesis is needed. Therefore, an examination of pollen data from sites outside of the region is required but not optimal. Issues of scale and resolution would be inevitable, especially considering that divergences in the vegetational frameworks of Latium are evident even among nearby sites, due to the strong regional geographic and climatic variability (Gatta, Sinopoli, *et al.*, 2016). Nevertheless, a general regional trend of vegetation and climate can be inferred. Pollen records considered are those from lake sediments introduced in Chapters II and III, i.e. Lagaccione, Lago di Vico, Stracciacappa, Valle di Baccano, Valle di Castiglione and Lago Grande di Monticchio (Fig. 3.2 and Allen et al. 2000; Ciuffarella 1996; Follieri et al. 1988; Follieri et al. 1989; Giardini 1993; Giardini 2007; Magri 1999; Magri & Sadori 1999; Watts et al. 1996; Watts et al. 2000). The climate and vegetational frameworks obtained from these sites display affinities with that reconstructed through the study of CM's deposits. In particular, the climate of central Italy seems to have been milder than the rest of Europe, albeit characterised by frequent cold-arid and temperate oscillations (Follieri & Magri 2001). These oscillations caused a recurrent alternation of the dominant vegetational pattern called "Lazio Complex", with steppe-grassland landscapes dominated by *Artemisia*, *Poaceae* and *Amaranthaceae* during cold stages and mesophilous and Mediterranean forests characterised by *Pinus*, *Juniper*, *Quercus* and *Ulmus* during temperate ones (Follieri *et al.*, 1995, 1998). The Pontine Plain reflects this picture very closely. The coexistence of steppe-grassland and forests within the region could be due to the high sensitivity of vegetation to these varied landscapes and/or to a relevant difference of temperature in these areas. The greater presence of steppe-grassland habitats than arboreal coverage suggested by pollen data from CM (Tab. 6.4) may indicate that the hyena occupation is related to a cool-arid climate.

Fauna from CM highlighted that climate during SU11 was warmer than during SU12, when a cold oscillation possibly occurred, therefore climate was probably not harsh between 44–34 cal BP (Gatta *et al.*, in press a). Moreover, it is worth noting that the faunal analysis of CM remains featured species typical of temperate habitats (*ibidem*). Fossil deposits from other areas of the Pontine Plain are of little help in understanding the climate or vegetation of the area during MIS 3. The scarcity of faunal remains from this period is the main restriction on a detailed interpretation of the environment. Nevertheless, an element in support of the reconstruction proposed in this research is the relative consistency of fauna during the entire Late Pleistocene of the region (Stiner, 1994), in particular through most of the time between MIS 4 and MIS 2, with the simultaneous presence of species preferring slightly cool and warm environments. This seems to indicate that only minor environmental changes took place in the Pontine Plain. A relevant climatic change between MIS 4 and MIS 3 is proposed for the region by Farina (2011), but such a reconstruction is based on a small assemblage with uncertain stratigraphic indications and chronologies dug over eighty years ago and, therefore, considered to be unreliable.

8.3 *Refugium* or not *refugium*

Was the Pontine Plain a *refugium* between 44–34 ka BP? To find an answer to this question is the last aim of this research project. The meaning and validity of this concept are still highly debated (Bennett and Provan, 2008; Stewart *et al.*, 2010) and have already been widely discussed in Chapter I, but this thesis does not want to engage in detail in this discussion. The case study of this research project did not return any evidence of late Neanderthals, therefore there is no intention or ambition to feed this archaeological debate. On the other side, this thesis aimed to investigate, through the analysis of some parameters such as regional biota (i.e. flora and fauna), geography and availability of raw material, whether the Pontine Plain offered milder environmental pressures and perhaps favourable living conditions to a wide variety of species during the harsh climate events of Heinrich 5 and 4.

The majority of living species endured contractions of population due to climatic oscillations during the Late Pleistocene (Hofreiter and Stewart, 2009; Marta, Mattoccia and Sbordoni, 2013). The presence of refuge areas with suitable factors made the survival of some species possible. This is obviously an oversimplified description of a complex concept which encloses a much greater number of elements, such as the individual nature of species (Davis and Shaw, 2001; Hewitt, 2004). Nonetheless, based on the new evidence of this research project and previously published data, I believe that it is possible to define the Pontine Plain as a glacial *refugium* in central Italy at least during the timeframe between 44–34 ka BP.

8.3.1 The vegetation says: “refugium!”

Southern Italy is commonly known to have been a glacial *refugium* for temperate plant species during the Late Pleistocene (Hewitt, 2004; Riel-Salvatore and Negrino, 2009), together with southern Iberia and Balkans, whilst little attention has been given to the centre of the Italian peninsula. Despite this, a recent study of temperate tree distribution in Italy from the LGM to present day demonstrated that the picture is more complex (Marta, Mattoccia and Sbordoni, 2013). Contrary to previous reconstructions, the vegetational data proposed by Marta et al show that a proper tree refuge was present along the Tyrrhenian coast of central Italy during the LGM (~ 22 ky BP), whilst only a patchwork of favourable areas has been detected in southern Italy (Marta et al. 2013, Figure 6). Unfortunately, the time span of the study by Marta et al. does not include the period covered by this thesis but the results obtained are still significant, since they demonstrate that central Italy had the conditions to play a crucial role in an extremely harsh climate such as LGM. As a matter of fact, the role of some Tyrrhenian areas of central Italy as a *refugium* for several thermophilous and mesophilous vegetational taxa during the last glacial, therefore including the cold oscillations of MIS 3, has been demonstrated before (Follieri et al. 1995; Follieri et al. 1998). Firstly, these studies by Follieri et al. show that the presence of some warm related plant species within the CM’s record is not unreasonable and our pollen data are reliable. In addition, the correlation of some pollen taxa from CM with those from contemporaneous sites acknowledged as refuge areas (Follieri et al. 1995; Follieri et al. 1998) strongly supports the interpretation of the Pontine Plain as a *refugium* for some vegetational taxa as well.

Discussing of refuge areas, a reference to the landscape surrounding Gorham’s Cave in Gibraltar, probably the most renowned Neanderthal *refugium* in Europe, is necessary. The environment of this region was thermo-Mediterranean and subhumid, the main habitat was a grassland with an open arboreal coverage and areas of proper woods (Finlayson, Finlayson and Recio Espejo, 2008). This biodiversity has been probably an influential factor in ensuring the survival of Neanderthals. The presence in the surrounding area of more or less widespread woodland, grassland, steppe, wetland, riverine and littoral vegetation has been detected by charcoal and pollen analysis (Carrión *et al.*, 2008). Comparisons with the habitats of the Pontine Plain as described above are evident, with all the above habitats also present in the Pontine Plain. Moreover, similarities of the topographic features are also noticeable. Both regions are well defined, with extensive coastline to delimit at least one of their boundaries and coastal areas interacting with plains and rocky mountains within a short distance. This is especially true for Gorham's Cave, as Gibraltar is an exceptionally restricted and short peninsula at present. These common elements, as well as the milder evidence of the Mediterranean Sea, are probably the main reason for these comparable vegetational frameworks.

In addition to the ecological analogies and differences with the above-mentioned records of Latium and southern Iberia, in order to understand to what extent the Pontine Plain could be considered more suitable as a *refugium*, the comparison with the site of Tana delle Iene (Apulia, southern Italy) has been carried out. I chose this site based on a few factors: firstly, I was looking for a context in southern Italy since this area is commonly considered to have held milder environmental conditions than the rest of the peninsula (Hewitt, 2004; Riel-Salvatore and Negrino, 2009). Secondly, a small scale area would be preferable with geographic characteristic similar to those of the Pontine Plain and, in particular, close to the coastline. Lastly, Tana delle Iene has been investigated through a palynological analysis of cave hyena coprolites (Petrucci, Giardini and Sadori, 2005; Gatta, Sinopoli, *et al.*, 2016), exactly as at CM. Therefore, the method of reconstruction is perfectly compatible with that achieved in this thesis.

Juxtaposition of these two contexts returned interesting results. The general framework depicts two regions with very similar environments, with extensive steppe-grassland formation characterised by *Artemisia* and Poaceae formations. However, a slight but potentially significant difference has been noted. Tana delle Iene, despite the southernmost location, seems to reflect a more arid and cold environment than CM. This is particularly evident with regards to the very low percentages of thermophilous and mesophilous arboreal taxa and the abundance of Cichorioideae at Tana delle Iene, a vegetation typical of glacial periods. This is in opposition to the situation at CM, where a discrete percentage of thermophilous and mesophilous trees and a high percentage of Amaranthaceae has been recorded (Gatta, Sinopoli, *et al.*, 2016). This evidence could suggest a milder and more humid environment at CM than in the district of Apulia. These are relevant data considering that the Apulia region is traditionally considered a refuge area. In sum, this comparison seems to suggest that the area surrounding CM can be equally considered a *refugium*. It is necessary to specify that Tana delle Iene is dated between 60 and 40 ka (Giaccio and Coppola, 2000), therefore earlier than CM. Despite that, I believe the comparison and conclusions achieved are sufficiently reliable. Both sites are mostly within the MIS 3 interval (Lisiecki and Raymo, 2005), whilst it is hard to quantify how much these regions have been influenced by Heinrich Events. However, both sites include within their chronologies one of them (i.e. H4 for Cava Muracci and H5 for Tana delle Iene) while another one occurred just before the deposit formation of these sites started, respectively H5 at 45 ka and H6 at ~60 ka (Hemming, 2004).

In conclusion, the reconstruction proposed in this thesis suggests the Pontine Plain was characterised by extremely rich and varied vegetation at least between 44–33 ka BP (Gatta, Sinopoli, *et al.*, 2016). The local environment was not, as far as a comparison between distant regions of different countries can be considered reliable, dissimilar to other contexts considered to have been refuge areas. Moreover, previous studies already highlighted that the region had a key role for the survival of several mesophilous and thermophilous taxa (Follieri *et al.*, 1995, 1998; Follieri and Magri, 2001). New studies of local ecology during the Late Pleistocene are necessary to further improve our understanding of the region and, perhaps, strengthen its interpretation as a glacial *refugium*.

8.3.2 A new Mediterranean glacial refugium for temperate fauna

A second aspect to investigate is whether, and to what extent, the Pontine Plain served as a *refugium* also for small and large vertebrates. The relative stability of the Pontine Plain’s faunal composition, during millennia of rapid climate fluctuations and vegetational evolution throughout Europe as a result of the global Dansgaard–Oeschger events (Geraga *et al.*, 2005; Lister and Stuart, 2008; Barker *et al.*, 2011; Long and Stoy, 2013; Evans, Flatman and Flemming, 2014; Zhang *et al.*, 2014) may support the hypothesis that the local features partially isolated this area and preserved its micro-climate making of it an ecological *refugium*.

It is worth reiterating that Italy is currently indicated, together with the Iberian peninsula and the Balkans, as a main glacial refuge area for several fauna and flora species during the Late Pleistocene (Stewart and Lister, 2001; Sommer and Nadachowski, 2006; Triska, 2009; Stewart *et al.*, 2010). Although such an interpretation is often limited to the southern part of Italy, recent studies revealed that also the central part of the peninsula offered a refuge to various species, some of which repopulated the continent during warmer phases (Salari and Kotsakis, 2011). Moreover, the narrow range of temperature/humidity of some small vertebrates recovered in the cave sites of Monte Circeo (Salari and Kotsakis, 2011) supports the interpretation of climatic stability during MIS 3.

Large scale studies of fossil deposits from all of Europe demonstrate that, albeit the role of the above-mentioned main three *refugia* is not disputed, faunal distribution during the LGM is much more elaborate than previously thought. The discovery of abundant temperate species in several nearby sites in the Dordogne and the Carpathians suggests that these regions also offered a mild climate (Sommer and Nadachowski, 2006). The presence of these glacial refuge areas in central and western Europe, outside of the traditionally acknowledged southern geographic range, indicate that the predictive models used at present to locate *refugia* are not completely reliable. This does not prove the Pontine Plain as a *refugium* but demonstrates that other regions should be taken into account when evidence different from that predicted by general models suggests it.

In the framework of this research project, the narrow-nosed rhinoceros described in detail in Chapter VII and particularly in section 7.3.3 is worth a special mention. The extinction of this species occurred around 45 ka and is considered to be part of the wider event known as “the megafauna extinction” (Stuart and Lister, 2007, 2012). The reasons behind this event are not entirely clear (Stuart and Lister, 2014), but probably consisted of a combination of factors, with climate playing a crucial role (Wroe, Field and Grayson, 2006; Lister and Stuart, 2008; Pandolfi *et al.*, 2017). The narrow-nosed rhinoceros is a good indicator of temperate environments. Its presence in the Pontine Plain dating to 42,054–40,804 cal BP at the onset of Heinrich Event 4, is meaningful, as it suggests that the region was characterised by a temperate climate and vegetation (Gatta *et al.*, in press a). This is also the latest known occurrence of the species in Italy and one of the latest in Europe at present (Pandolfi *et al.*, 2017), which makes the region a strong candidate for the role of *refugium*. The extinction of this species does not necessarily mean that the region ecologically failed as a *refugium*. The survival of animal taxa within a delimited area is linked to several factors, such as the presence of a small population, which made inevitable a persistent inbreeding and subsequent genetic failure (Lande, 1988). An extremely long duration of harsh climate conditions and forced confinement within the refuge area could also lead to an unfavourable inbreeding (Lande, 1988). In both cases, the population would fail to survive but this would not be due to the refuge or its features. The discovery of the latest individual of a species within an area considered to be a *refugium* fuelled some arguments against the validity of the concept of *refugium* itself. Actually, it is quite common to observe this kind of evidence. The reason behind this must be sought in some animals' behaviour to move towards refuge areas only when a contraction phase of the population has already begun and, sometimes, it does not matter how favourable environmental conditions are, the population could be too small or destabilised to survive (Stewart *et al.*, 2010). Therefore, the *refugia* are frequently the last area inhabited by a population (von Koenigswald, 1999; Lister and Stuart, 2008).

The presence of cave hyenas, the main characteristic of the CM site, is also interesting. This carnivore progressively reduced its area of distribution from around 40 ka BP and went completely extinct around 31 ka BP in Italy as part of the megafauna extinction (Stuart and Lister, 2014). The almost ubiquitous distribution of this species in distinct climatic zones of Europe is of little help to support environmental inferences, but severe climate is considered as a main cause in their extinction. The presence of cave hyena in the Pontine Plain up to 34 ka BP, when it had disappeared in most of the continent, is thus noteworthy as it seems to indicate the region had long offered favourable environmental conditions for this species survival.

All in all, the entire assemblage from CM suggests a temperate climate (Gatta *et al.*, in press a). A few species such as *Equus ferus* and *Bos primigenius* are widespread in Europe also in slightly cold regions, but harsh climate in the Pontine Plain has to be excluded as the absence of strictly cold taxa indicates. In particular, it is relevant that at CM the cold adapted species *Capra ibex* is absent, which has instead been found in the many nearby cave sites of Monte Circeo during cold oscillations (Stiner, 1994, 2004). Finally, the discovery of a cold small vertebrate such as *M. arvalis* in SU12 at CM (see Chapter VII) and its absence in the overlying SU11 indicate that the latter stage was warmer (Gatta *et al.,* in press a). It seems then reliable to affirm that the Pontine Plain had milder climate than the surrounding areas during the analysed timeframe between 44–34 ka BP.

The presence of some cold or slightly cold taxa, such as the above-mentioned *Equus ferus* and *Bos primigenius* at CM, would not preclude the identification of a refuge area. Indeed, several sites considered to be refuge areas returned evidence of mixed temperate and cold species, suggesting that the conventional concept of the well-separated *refugium* is probably not valid anymore (Sommer and Nadachowski, 2006). It is reasonable to consider that in some cold areas across the European continent, where local areas with a temperate microclimate were present, species adapted to both these climates lived side by side. These areas were likely closer to the ecological limit of both faunal groups, almost too cold for temperate species which found a *refugium* in them and nearly too warm for cold species (*ibidem*).

In conclusion, the analysis of faunal remains from CM and their ecological preferences seems to suggest that the Pontine Plain held favourable climate conditions to permit the survival of temperate fauna between 44–34 ka BP, when cold oscillations and harsh climate events such as Heinrich 4 took place. However, the implications of faunal analysis for such a complex situation, as before for pollen data, must of course be considered preliminary and exploratory when applied to the broader regional context as further evidence is necessary to strengthen the data obtained.

8.3.3 Was the Pontine Plain a refugium for the last Neanderthals?

CM did not return any human remains and it is not possible to give a final answer to this question at present. However, some assumptions regarding the influence of the region on hominin life are possible. These are the result of indirect evidence, such as the availability of resources needed for survival and the palaeoenvironmental context resulting from pollen and faunal analyses, and therefore the reliance on these considerations is currently hypothetical.

The hypothesis that this region of central Italy served as a *refugium* for hominins has already been suggested in the past. This idea is mainly based on the evidence from Grotta Breuil, one of the many caves of Monte Circeo. A few Neanderthal remains and Pontinian lithic industries were discovered in layers ESR dated between 36,600±2700 BP and 33,000±4000 BP (Schwarcz, Buhay, *et al.*, 1991; Manzi and Passarello, 1995; Alhaique, Bietti, *et al.*, 1998; Grimaldi and Spinapolice, 2010). Section 5.1.2 and in Chapter IV showed the limits of the use of the ESR technique in karstic contexts and of the reliability of Grotta Breuil’s dates. However, this site is still largely considered as one of the latest Neanderthal sites in Italy which would offer *refugium* to this species. A single site with evidence of late Neanderthals is probably not an entirely convincing element to support such an important statement but it is the only available one at present and leads to a comparison with other more striking contexts such as south Iberia.

Personally, I believe that any comparison between contexts situated in different countries should be considered with caution due to the numerous meaningful factors which have a role in the interpretation of these regions. In addition, as already mentioned, the Pontine Plain still suffers the lack of a broad database. Nevertheless, I tried to identify some of the key factors which can describe a glacial refuge area for Neanderthals, i.e. (i) geographic characteristics; (ii) physical features of the terrain; (iii) availability of flint raw material; (iv) abundance and diversity of potential prey; (v) supply of fresh water sources, and tried to determine whether similarities with the Pontine Plain were evident. The Neanderthal extinction in Gorham’s Cave is supposed to have been caused mainly by the loss of these resources (Finlayson and Giles Pacheco, 2000). However, the presence of natural resources in the studied area seems to had been consistent.

(i) Finlayson (1999), listing the factors which define southern Iberia as a glacial *refugium,* such as the southerly location and favourable weather conditions, highlighted the importance of topography and boundaries. In particular, the spatial distribution of several relevant Neanderthal sites in Europe revealed that the so-called *refugia* are usually well-delimited areas in proximity to extensive coastlines (Finlayson, 2008) which would offer the conditions for an isolated survival (Stewart, 2005; Finlayson *et al.*, 2006; Finlayson and Carrión, 2007; Finlayson, Finlayson and Recio Espejo, 2008). The importance of the warmer Mediterranean influence, and therefore of a southern location, to define a glacial *refugium* for temperate species has been proposed also by Riel Salvatore & Negrino (2009). They also highlighted how the necessary features of *refugia* to be well-delimited and in proximity to coastlines is naturally determined by the geography of the peninsula as a restricted area of land oriented north-to-south enclosed by the Mediterranean Sea, which would make it a large-scale refuge (Riel-Salvatore and Negrino, 2009).

(ii) Physical terrain is a major factor in the analyses of the human potential of a region. Recent studies highlighted that Neanderthals had a particular terrain preference and adaptation (Burke, 2006; Finlayson and Carrión, 2007; Churchill, 2014), which highly affected their distribution and survival and it is, therefore, necessary to determine potential *refugia* of this species. In particular, studies of site exploitation, settlement patterns and body morphology highlighted that Neanderthals preferred to exploit small areas (Feblot-Augustins, 1997; Verpoorte, 2006; Uthmeier, Ickler and Kurbjuhn, 2008; Macdonald, Roebroeks and Verpoorte, 2009) with irregular and diversified habitats (Finlayson, 2004; Stewart, 2005; Dusseldorp, 2009) with gradual ecotonal boundaries (Jennings *et al.*, 2011). This choice gave them access to a wide variety of resources within a restricted region, allowing them to overcome some biological insufficiencies of their species, such as difficulty in performing long-distance movements and high energetic costs (Henry, Belmaker and Bergin, 2017). These limits are not present in AMH, enabling them to develop a different land-use and geographic distribution, with a preference for large settings and exploitation of both regular (e.g. lowlands) and irregular (e.g. mountains) habitats (Binford, 2001; Marlowe, 2005; Miller and Barton, 2008).

The physical features of the Pontine Plain and the results of both pollen and faunal analyses provided in previous chapters indicate that this area is a small region with extremely diverse and rich habitats. Moreover, alternation of different habitats is not abrupt but gentle and progressive. The archaeological data seems to reflect the behavioural strategies for both Neanderthal and AMH groups. In particular, it can be argued that the exploitation of the area by Neanderthals was intense and they may have adapted their needs to the natural resources of the surrounding environment, possibly without crossing the boundaries of the Pontine Plain. This interpretation is supported by the development of regional knapping techniques to exploit the local flint (Kuhn, 1995), which allowed them to avoid long-distance movements to access exotic raw material. However, it is also evident from the large number of Middle Palaeolithic sites (Fig. 3.4), which are much higher than the Upper Palaeolithic ones (Fig. 5.3). Indeed, evidence of AMH is sparse but covers a much larger area beyond the Pontine Plain perimetre, including the inland mountains. Exotic raw materials which testify to extensive movements are also common (Rolfo, 2008). In conclusion, the Pontine Plain seems to have had the terrain features required by a *refugium* during the Late Pleistocene.

(iii) The key role of flint availability for the production of everyday tools is well known in archaeology. Sources of this material were as fundamental in prehistory as sources of water and only with the discovery of metals has progressively lost its importance. The abundance and intensive exploitation of lithic raw material in the Pontine Plain has been thoroughly discussed in Chapter V. Here, to emphasize that the regional flint sources were adequate for human requirements, it is sufficient to remark that Neanderthals developed a particular production named "Pontiniano" to knap local pebbles and that exotic raw material was absent during the Middle Palaeolithic (Kuhn, 1995; Alhaique *et al.*, 1996; Riel-Salvatore and Negrino, 2009).

(iv) Faunal richness is a fundamental feature of a glacial refugium, since it would ensure a steady presence of food (Jennings *et al.*, 2011). This is particularly true during the Middle Palaeolithic when subsistence was considerably based on meat consumption, albeit recent studies of dental calculus proved that plants also played a relevant role in Neanderthal diet (Henry, Brooks and Piperno, 2014; Weyrich *et al.,* 2017). Gorham's Cave and its remarkable biodiversity (Finlayson *et al.*, 2006; Carrión *et al.*, 2008; Stringer *et al.*, 2008) seems to confirm this assumption. Chapter VII highlighted how the Pontine Plain as well was inhabited by a wide range of faunal taxa. Twenty seven were recognised in the only archaeological record at CM which, however, is heavily affected by prey selection of cave hyena. The richness of the Pontine Plain is not limited to the terrestrial fauna but to marine as well. Some of the earliest evidence of exploitation of sea resources by Neanderthals in Europe is indeed attested here (Vitagliano, 1984; Stiner, 1994). It may not be a coincidence that other Middle Palaeolithic evidence of marine resource exploitation is located in Portugal and southern Iberia (Antunes, 1992; Cortés and Simòn, 2001; Cortés, 2005), among which once again Gorham's Cave is prominent (Stringer *et al.*, 2008), which are traditionally considered to have been refuge areas. In sum, it seems consistent to affirm that the Pontine Plain during the Late Pleistocene offered abundant food resources, probably adequate to feed large human groups.

(v) The presence of fresh drinking water is fundamental to life. It is not by chance that the development of the first complex societies occurred along important rivers or lakes during the Holocene. This is rather true also at present, despite technological advances that allow us to carry water for thousands of miles. Water has always been a synonym of life. It is not by chance that scientists are looking for its presence on Mars to answer the question whether life on that planet is possible. During prehistory, and particularly during millennia of harsh climatic conditions such as the Last Glacial, the proximity to rivers, lakes or springs would have played a key role in the survival of human groups. The high concentration of Palaeolithic archaeological sites, mainly caves, in valleys, riverside or coastal area confirms this interpretation. I described in Chapter II the complex hydrogeology of the Pontine Plain and mentioned the key role of water several times within this thesis. The entire region was characterised by dozens of rivers fed by karstic springs and rainfall from the nearby Lepino-Ausoni Mountains. The abundance of this resource was such as to cause problematic swamping of a large part of the plain. Overall, albeit previous studies of spatial distribution of water sources within the region during the Middle-Upper Palaeolithic are absent and would need to be investigated, the presence of this indispensable resource in the studied area is not questionable.

In summary, direct evidence of late Neanderthals in the Pontine Plain is extremely scarce. Despite that, waiting for new and more conclusive studies of the human presence in the region, a few preliminary records have been marked. Analysing the presence of some of the key elements identified within other refuge areas, it seems plausible to affirm that the studied region offered during the Late Pleistocene favourable conditions for human survival. Obviously, this is based on only some aspects of the area and therefore strictly hypothetical at present but returns an intriguing prospective to foster further studies.

8.3.4 Concluding remarks

The possible role of the refuge area of the Pontine Plain for flora, fauna and hominins has been investigated. The data analysed shows that the studied area clearly had this important role for a number of vegetational and faunal taxa. More complicated is the argument concerning the impact of the environment on human groups, given the limited and indirect evidence, although it seems possible to hypothesize that the region had the necessary conditions to serve as a *refugium* at least between 44–34 ka BP. The important conclusions achieved will increase their value if they will be supported by further data from new research and excavations, and are useful for a different consideration of the region within the Italian and European prehistoric framework.

8.4 Significance, strengths and weaknesses of this research

The key strength of this research project is the multidisciplinary approach, integrating new ideas and techniques, used to investigate the palaeoenvironmental reconstruction of the Pontine Plain. The holistic method applied to investigate the CM site, with detailed attention to all the archaeological, geological, palaeontological and ecological aspects, is not new in the European perspective, but it is to a certain extent innovative in the prehistoric archaeology of central Italy. In the latter, individual features (e.g. lithic technology, faunal remains, human remains, geological features etc.) have too often been studied indipendently, thus missing key connections within the sites and with the surrounding environment. The predominance of this approach in Italy is documented by the literature review (see Chapter III) and this attitude prevented the full exploitation of archaeological data, the comprehensive understanding of individual sites and regional correlations. With regard to the latter, the study of CM did not focus exclusively on the interpretation of the archaeological site but aimed to place it into the wider regional context, thus improving our understanding of it. The research designed in this thesis was mainly based on the archaeological framework and finds from CM, but its applicability to several other sites in this region is indubitable and already demonstrated elsewhere in Europe.

The pollen analysis from coprolites is also crucial in this work and should be so in others to come. This aspect of palynology is extremely undervalued in Italy and was never performed in central Italy before this project. This study clearly demonstrates that it represents an effective approach for achieving high-resolution reconstructions of local environments, a resource particularly valuable in those contexts in which other ecological indicators such as lake sediments are unavailable.

The major impact of this thesis is the development of an environmental reconstruction based on pollen and faunal data from the past, but the study of the contemporary geomorphology of the area was also a key complementary element to the research. This analysis has resulted in a new ecological perception of the Pontine Plain between 44–34 ka BP with important archaeological consequences for the interpretation of the many sites in it.

Finally, the English language of this thesis is an important factor for the spread of local research. A very large part of the archaeological literature on the Pontine Plain was produced in Italian during the last century and is difficult to access for international scholars. This thesis offered the opportunity to partially fill this gap and provided a review of the most significant publications and excavation reports of the past, highlighting some doubtful information, mainly regarding stratigraphic and chronological data.

The best efforts have been made to achieve this reconstruction. Nevertheless, the work itself has brought to light some points for improvement. Some limitations were already clear when this research project was begun, whilst others became evident afterwards, but all of them offer the motivation to continue the investigation in the future (see section 9.2). Firstly, the main restriction of this research was its self-funded status. Although several small research grants were obtained from different institutions and associations to perform a number of analyses, funding is still limited in quantity; (ii) Secondly, the choice to base a regional reconstruction on the evidence from a single site, albeit multidisciplinary, might seem a dangerous constraint. However, ecological inferences based on single site analysis are rather common in the scientific literature. An exhaustive analysis of restricted samples may return the most accurate results and be fairly representative of small-scale regions (Dincauze, 2000). Moreover, a number of factors justify the use of a single case study. As outlined throughout the thesis, CM represents the most recent investigation of the region, which offered us the opportunity to perform stratigraphic excavations and subsequent analyses with up-to-date methods and technologies. Furthermore, a single site is more affordable in consideration of the budget restriction. Despite that, further data from other sites are desirable in the future for an area particularly poor in environmental information during the 44–34 ka BP interval. Finally, the third point to be improved is the chronology of SU11 and its interval of 10k years spanning a single layer. An interval of this extent is not unusual within a prehistoric context, especially for contexts where taphonomic agents highly affect the efficiency of radiocarbon dating such as CM, but a higher resolution would be a remarkable achievement to narrow down the environmental framework obtained even more. Great efforts have been made to date this site, with several methods attempted for a total of 32 dates (i.e. 3 U-Th attempts; 6 ^{14}C attempts; 4 ^{14}C with UF pretreatment attempts; 19 $^{40}Ar/^{39}Ar$ attempts) since the karstic environment severely affected traditional dating methods. Nevertheless, additional efforts should be considered in the future.

Despite these open working problems, the outcome of this research is extremely positive. A local environmental reconstruction for a relevant archaeological area has been provided, through the use of resources previously overlooked, allowing a new interpretation of the role played by the Pontine Plain region during the Late Pleistocene.

8.5 Conclusions

This discussion has dealt with the multidisciplinary palaeoenvironmental reconstruction of the Pontine Plain and its potential role as a *refugium*. After a summary of results on remains from CM, the conclusive environmental reconstruction of the Pontine Plain based on data from both pollen and fauna has been proposed. This integrated analysis enabled me to outline a complex framework of the area during the second half of MIS 3 defined by (i) a wide coastal area, warm and particularly humid, characterised by abundant thermophilous vegetation and inhabited by many faunal species, especially amphibians and reptiles; (ii) an extensive temperate steppe-prairie characterised by small woods and abundant water sources such as ponds, rivers and marshes (inhabited by both large mammals, among which are the cave hyena which originated the fossil deposit, and small vertebrates); (iii) a narrow but significant Mediterranean forest with glades and rivers that composed the elevated eastern landscape of the region. This area was intensively inhabited by most of the faunal taxa discovered at CM and its climate was temperate, although seasonal variation was probably relevant.

This is the first local reconstruction based on small scale data with high spatial resolution, which made it possible to reliably define the habitats within the region. This ecological structure, partially unknown in the past, seems to have been highly interesting and appealing in the LGM context, and it offered the opportunity to compare the Pontine Plain with a few other European regions investigated in the past, in the attempt to shed light on a possible *refugium* role of the studied area during the 44–34 ka BP timeframe of the Late Pleistocene.

This study suggested that the region served as a glacial *refugium* to a different extent for several temperate floral and faunal species. Pollen and faunal analyses both revealed the presence of species that were unexpected in the area during such a cold timeframe, or even presumed to be extinct (i.e *Stephanorhinus hemitoechus*). The interpretation of data regarding a possible refuge area for human groups is complex. Several of the most influential elements necessary to make a territory hospitable to Neanderthals have been recognised in the Pontine Plain, even during the harshest climatic millennia considered in this PhD. However, straightforward archaeological evidence is absent. Further investigations are necessary to answer this research question with confidence. Overall, examining the data produced it seems evident that the region benefited from milder environmental conditions than most of the continent during the MIS 3 and, therefore, could be considered a glacial *refugium* for temperate species at least during the 44–34 ka BP interval.

Chapter IX

Conclusion and Future Expectations

This concluding chapter summarises the contents of this thesis and a number of topics identified for future work based on the outcomes of this research.

9.1 Summary of work

Research on the Pontine Plain has been lacking a detailed environmental reconstruction for MIS 3. Ecological inferences have been based so far on single fossil collections or pollen data from very distant lakes, resulting in a fragmented and partial framework, with significant difficulties for the interpretation of many sites in the region. This thesis aims to be the first step in solving this issue, offering an environmental reconstruction of the Pontine Plain to understand whether it could be considered a *refugium* during the Late Pleistocene.

The concept of *refugium* is highly debated. This mainly refers to restricted areas in which the last known Neanderthals survived isolated for several thousand years before they became extinct. In this thesis, the word *refugium* takes its meaning from the discipline of ecology and indicates areas where environmental constraints were milder than the surroundings even during severe climate oscillations. This concept, together with the chronological framework of the Middle-Upper Palaeolithic transition and the theoretical background of time and space scales, was introduced in **Chapter I**.

Chapter II had two main goals: the first was to describe the geographical context and climate of the region investigated in this research, the Pontine Plain. It is situated along the Tyrrhenian coast of central Italy and is naturally bounded by the Alban Hills to the north and the Lepino-Ausoni ridge to the south-east. This region has been subject to continuous events, mainly tectonic, geological and hydrological, which shaped an extremely varied territory with coastal areas, extensive plains, frequent hills and abrupt mountain chains within a very short distance. The geomorphological variability causes the presence of several phytoclimatic classes at present (Blasi 1994), while climate during MIS 3 is still poorly understood. During the Last Glacial, climate appeared to be characterised by numerous oscillations of cold-arid and temperate-humid stages. The second part of this chapter outlined the case study of this research: Cava Muracci (hereinafter CM), which is an active travertine quarry where seven fossiliferous cave deposits have been discovered during the quarrying and have yielded abundant faunal remains (=1346), coprolites (=107) and a rare lithic industry (=60). One of them, denominated Area 3, was better preserved than the others and allowed us to carry out accurate stratigraphic investigations. The layer SU11 has been dated between 44–34 ka BP and returned a large quantity of well-preserved remains upon which the environmental reconstruction of this research is founded.

Chapter III presented the literature review of the main studies in the region. This synthesis outlines the scientific background of this research, featuring several gaps in the regional literature. The main gap is the low importance given to environmental investigations within the Pontine Plain, as opposed to the importance given to lithic studies. Increasing interest has been directed to faunal remains in the last decade. Unfortunately, the number of fossil assemblages exhaustively studied, chronologically comparable to that of CM, is rather limited. Finally, a large part of the archaeological literature has been published in the mid-20th century and is not scientifically valid any more. On the one hand, these issues result in a problematic lack of comparable data. On the other hand, they promote the importance of new research projects such as this one.

Materials and methods adopted in this research were described in **Chapter IV**. The first part focused on the dating of CM, which has been attempted with several methods before being successfully achieved. Afterwards, approaches and procedures of analysis applied to lithic, coprolites and faunal remains were defined.

A framework for the human presence in the Pontine Plain during the Middle and Upper Palaeolithic was outlined in **Chapter V**. Techno-typological and use-wear analysis of lithic industries from CM was also discussed. This demonstrated that implements were transported within the cave by external factors, probably flood water, whilst humans did not live in the cave but only in the surrounding areas. Finally, a picture of the territory exploited by humans has been proposed based on topographic features, food resources and raw material availability.

Chapter VI described pollen analysis from coprolites of CM. Palynology of fossil faeces, carried out for the first time in central Italy, proved to be a valid method to make deductions about the local (i.e. small scale) vegetation. Results yielded meaningful palaeoecological inferences and permitted us to elaborate a first environmental reconstruction of the Pontine Plain. The picture obtained is that of an extremely varied temperate landscape, with at least three different habitats: wetland shoreline, steppe plains and wooded hills.

The analysis of faunal remains was given in **Chapter VII**. Taphonomy permitted us to recognise the SU11 as a hyena den and these carnivores as the main agent of bone accumulation, an interpretation also confirmed by the age at death estimates of the prey animals. Taxonomy allowed us to identify 27 different taxa, among these the presence of the late-surviving *Stephanorhinus hemitoechus* is relevant, as it seems to have found a *refugium* in this region. The fauna returned meaningful ecological data highlighting the presence of at least three main different habitats: wetland, steppe/grassland and wooded areas. The similar ecological outcome from both pollen and fauna, and the same spatial mesoscale support the reliability of each research method and encourage a combination of them to be made in order to carry out a multidisciplinary reconstruction.

Chapter VIII made use of the results generated in previous Chapters VI and VII to achieve a multidisciplinary environmental reconstruction of the Pontine Plain between 44–34 ka BP. An attempt to clarify whether this region can be considered a *refugium* for animal and plant species has been carried out. Finally, the pattern of human exploitation elaborated in Chapter V has been analysed to understand if the possibility of a *refugium* also applied to hominins. The discussion suggests the region provided environmental conditions, abundance of resources and terrain features fundamental to survive even during the harshest climate oscillations of the last glacial. Nevertheless, the role of *refugium* of the area is demonstrated only for several plant and faunal species whilst it is only probable for human groups. Future studies can greatly increase our understanding of the region in this direction. In conclusion, strengths and weaknesses of this research project have been considered. The ratio among them it is definitely positive and demonstrates this thesis has added value to the archaeological knowledge of the area, the few minor weaknesses identified can be overcome with studies to come and the next section will explain how some of them have already been scheduled.

9.2 Future expectations

This research indicates that there is a potential for future studies on two levels. The first one consists of a series of systematic investigations of CM which were not available during this research, to improve the results of this thesis. The second one would be to carry out research on new sites and archival collections from old excavations in the Pontine Plain, to improve our knowledge of the entire region.

The CM site has been thoroughly investigated but it is still possible to refine the work done so far. One of the weaknesses mentioned in section 8.4 is the interval of 10k years of the layer SU11 from Area 3, from where the biological remains examined in this thesis come from. A higher resolution could increase the relevance of palaeoecological inferences. A set of 10 bone samples is currently being analysed at the Oxford Radiocarbon Accelerator Unit (ORAU) with ultrafiltration pre-treatment, which significantly increases their reliability, to achieve this aim. The resulting dates are going to be among the most consistent and reliable for the region, and will be a reference for the presence/absence of many faunal and vegetational species during MIS 3.

Referring to finds from CM, some additional investigation is possible. The few fossil remains with pupal chambers from SU11 (see section 7.3.4), which could provide high-resolution ecological information, are finds worth of study. The rarity of fossil bones with pupal chambers and the scarcity of scholars specialized in this field made any attempt to analyse those from CM in time for this research unsuccessful. However, these remains offer the opportunity to develop an aspect of environmental archaeology poorly exploited until now. Therefore, further efforts have been made to examine them. The pupal chambers are currently under the expert investigation of Dr Jean-Bernard Huchet at the Muséum national d'Histoire naturelle of Paris and will return results within the next few months. The second feature to consider among CM bone remains is the high fragmentation which made almost 50% of the total finds taxonomically unrecognisable. It has already been mentioned in section 4.4 that a ZooMS analysis was considered inapplicable due to poor preservation of collagen, but its extensive application to the entire assemblage may still return some results.

Finally, surveys to monitor the discovery of new remains should be performed with consistency in the quarry of CM. Seven caves have been discovered in a few years during this research but quarrying could bring to light new underground caves containing archaeological finds. This is a very likely possibility, considering the karst nature of the area (i.e. rich in natural caves) and the remarkable presence of fauna and human groups in the region. Actually, the number of fossil deposits and sporadic remains continuously increased during the writing up of this thesis and since the last revision of this work. A first step for the future is to use those remains to augment the present study.

In a future and wider perspective, it would be crucial to extend the approach applied to CM to other sites in the Pontine Plain, both new and already investigated. Several sites within the region, especially those of Monte Circeo, returned thousands of archaeological remains (i.e. faunal bones and coprolites) appropriate for ecological investigations which have never been used for this purpose since the 1930s. The study of these sites and remains therein could confirm or strengthen the palaeoecological data already obtained and considerably increase our knowledge of the region during the Late Pleistocene. The focus of interest in these sites is not only in their environmental potential but also concerns the chronology of many of them. The literature review highlighted how most investigations of the Pontine Plain occurred in the last century and a large part of these sites are missing proper dating at present. Therefore, an extensive review would be necessary to produce new dates and revise those produced a long time ago with outdated techniques.

9.3 Conclusion and achievement of aims

Reitz and Shackley (2012), and many before them, argued that archaeological sites are inevitably connected to the surrounding environments. These have to be investigated combining all resources available, and knowledge of them is fundamental for a correct interpretation of the evidence. This thesis aspired to apply this concept to the Pontine Plain, a region rich in Palaeolithic sites but so far missing a detailed reconstruction of the Late Pleistocene environment, and to interpret its role as an ecological *refugium*. In order to fulfil this ambition, a multidisciplinary research project has been developed.

9.3.1 Achievement of aims

The human exploitation of the region with its related opportunities and constraints has been investigated (i.e. **Aim 1**) by considering the natural topographic features and site location; by analysing the subsistence of both Neanderthals and AMH through the bone remains from several sites; and by examining lithic raw material availability. Altogether, these revealed an interesting picture of the Middle and Upper Palaeolithic of the Pontine Plain, which offered a set of characteristics (i.e. abundance and variability of food resources, availability of lithic raw material, well-delimited and diverse topography etc.) which significantly influenced human activity and are often found in other areas thought to be *refugia*.

A first picture of the vegetation and climate of the region was obtained developing palynological analysis of cave hyena coprolites (i.e **Aim 2**). This approach, albeit hardly practised in Italy, demonstrated that pollen within coprolites can be a powerful resource for investigating environments of the past. Its most useful features are the possibility to track back pollen to the habitats frequented by the producer and the short time of pollen accumulation within faeces, which is usually daily. These characteristics are extremely favourable for allowing a small scale reconstruction of local environments. On the other hand, pollen concentration within faeces of carnivores is rather low and a large number of samples are usually necessary to reflect the entire vegetational pattern of the area.

A complete and detailed study of faunal remains from SU11 of CM has also been completed (i.e. **Aim 3**). This study highlighted the presence of at least 27 different taxa in the surrounding area of CM with meaningful environmental implications. As a general rule, faunal deposits from archaeological sites are not considered ideal environmental markers since their accumulation is subject to artificial agents of selection (e.g. humans or predators). However, the analysis of CM’s assemblage and comparisons with other regional fossil accumulations revealed that large deposits made by cave hyenas reflect well the faunal variety of the area. Furthermore, the hunting range of hyena (e.g. about 50 km) also permits us to confidently determine the presence of their prey animals within a restricted area, of great relevance for the overall local environmental reconstruction. It also demonstrated that, combined with indications of small vertebrates, faunal interpretation can yield a fine-detailed landscape interpretation.

A detailed and multidisciplinary environmental reconstruction of the Pontine Plain between 44–34 ka BP was carried out combining both palaeoecological and archaeozoological data, achieving **Aim 4** of this thesis. The landscape was composed of a mosaic of habitats, which allowed us to recognise within the region three different ecological zones oriented north-to-south, i.e. a warm and humid coastal area in the west; a wide temperate steppe-prairie with abundant water sources and small arboreal patches inland; and a temperate Mediterranean open forest along the hilly areas to the east.

The **fifth and last aim** of this thesis demanded an investigation of whether and to what extent the Pontine Plain could be considered a glacial *refugium* for its entire biota. This has been the most delicate and complex purpose of this research project, since the same concept of *refugium* is highly debated. Moreover, differently to the other aims examined, evidence is rather limited to investigate such a complex issue and future studies have an important role to fill this lack of knowledge. At present, it was anyway possible to infer that the region served as a *refugium* for some plant and animal species whilst only assumptions were possible regarding the correlation between the region and human groups.

9.3.2 Conclusion

This research has provided a holistic environmental reconstruction of the Pontine Plain between 44–34 ka BP, previously known only through pollen from very distant lakes. This study also considered the possible role of the region as an ecological *refugium*. Environmental results appear to suggest that the area was characterised by mild conditions and a variety of coexisting habitats during the climatically harshest millennia on the continent. The late appearance and relevant variety of faunal taxa within such a small territory are compatible with the concept of *refugium,* for which comparative examples were provided. However, only a few sites with human evidence - and of uncertain reliability - are present during this period and none of them returned human remains, therefore any specific inferences about human *refugia* are extremely speculative.

From a methodological perspective, this work demonstrated that pollen from coprolites may have particular application in understanding local environments, a scale otherwise not easy to investigate with commonly analysed lake sediments. Moreover, the application of palynology of coprolites in this thesis also proved that the underestimation of, and reluctance towards, this approach in Italy are to some extent scientifically unjustified. This study also established that fauna can return more than a generic indication of the environment, particularly if both macro- and micro- fauna remains are analysed. However, the most noteworthy result is the demonstration that multidisciplinary research is crucial to producing successful environmental reconstructions. This research found that using this approach to understanding the regional setting could fill the lack of information of any specific analysis carried out in a single field. In future work, it would be important to extend this cooperation to as many fields of study as possible, to improve reliability, detail and comprehension of the many processes which act on a landscape.

Overall, this research contributed significantly: (i) to the understanding of palaeoecology in central Italy during a fundamental transitional stage of mankind (Gatta, Sinopoli, *et al.*, 2016) and (ii) to the analytical potential of pollen data from fossil faeces to perform local reconstructions (*ibidem*); to Italian archaeology, (iii) providing an environmental background to put numerous Palaeolithic archaeological sites in context (Gatta and Rolfo, 2017a); to palaeontology in two ways, (iv) firstly on a regional scale, as it considerably improved our knowledge of several aspects of faunal life (Gatta *et al.*, in press a), and (v) on a continental one, returning the discovery of the latest radiometrically dated *Stephanorhinus hemitoechus* currently known in Europe (Pandolfi *et al.*, 2016, 2017); to the geology of central Italy, producing (vi) the first tephrostratigraphic database of activity by the Volcano Albano, a valuable chrono-stratigraphic reference for future studies in this region, whether geological, palaeontological or archaeological (Gatta and Marra, 2017; Gatta *et al.*, 2017); and to the science of chronology, (vii) highlighting the potentiality of tephrochronology (e.g. combining ^{40}Ar/^{39}Ar dating and trace-element composition) as a solid and low-cost alternative to other dating methods in contexts where they may be unavailable (*ibidem*).

Appendices

2.1 In 1956, Ascenzi recorded the finding of: the complete skull of an adult, two incomplete adult skulls, the fragments of a skull of a child, an incomplete jaw, a hemimandible, an axis, an incomplete lumbar vertebra, various fragments of other vertebrae, numerous fragments of ribs, the sternum of a child, a clavicle, a shoulder blade, a complete left humerus and an incomplete right humerus, an incomplete ulna, a left capitate bone, three complete metacarpals and two incomplete metacarpals, four phalanges, three fragments of coxal, a complete left femur and four incomplete right femurs, a complete right tibia and eight incomplete tibias (two right and six left), an incomplete right fibula and an additional fragment of one, an incomplete right kneecap, a complete right heel and two incomplete left heels, one right scaphoid, a left cuboid, two right cuneiform, three complete metatarsals, two incomplete ones and five phalanges.

4.1 Fourier transform infrared spectroscopy (FTIR) results:

Coprolite samples	IR-SR values	C/P values
# 524	4,51996	0,13193
# 504	4,19473	0,16994
# 21	3,62491	0,20493
# 505	4,53631	0,13497
# 508	4,23898	0,18273
# 478	4,70425	0,14617
# 22	4,1125	0,16272
# 11	4,41505	0,15666
# 316	4,47664	0,211615
# 507	3,98026	0,22127

Appendix A. Database of the lithic assemblage from Cava Muracci (Cisterna di Latina, Italy).

# Find	*Area*	*Sector*	*SU*	*Industry*	*Lenght*	*Width*	*Thickness*	*Colour*	*Raw material*	*Butt*	*Retouch*
31	3	B	11	Carenè Point	3,3	1,6	1,4	GLEY1 7/10Y light greenish gray	Fine	Absent	Scalariform
32	3	A	11	Pebble Cap	2,6	1,3	0,4	2.5Y 5/2 grayish brown	Medium		
33	3	A	11	Simple Straight Scraper	3,1	2,8	1,2	5YR 4/1 dark gray	Fine	Absent	Scalariform
34	3	A	11	Core Debris	2,4	3	0,7	GLEY 1 7/10Y light greenish gray	Fine		
35	3	A	12	Debitage	2,3	1,3	0,8	2.5Y 6/3 light yellowish brown	Medium	Corticated	
36	3	A	11	Transverse Scraper	3,9	2,4	1,5	GLEY1 7/N light gray	Coarse	Faceted	Simple Marginal
37	3	A	12	Debitage	1,3	2,1	0,2	10YR 6/2 light brownish gray	Fine	Flat	
38	3	A	11	Carenated Scraper	3,1	2,2	1,2	10R 7/1 light gray	Fine	Absent	Simple
41	3	B	11	Scraper	2,9	1,8	0,7	GLEY1 5N greenish gray	Fine	Flat	Scalariform
42	3	B	11	Core Debris	3,8	4,3	1,6	2.5Y 6/2 light brownish gray	Medium		
50	3	A	12	Core Debris	5,2	3,1	1,3	2.5Y 7/2 light gray	Medium		
106	3	A	11	Simple Convex Scraper	2,6	2,1	0,9	2.5YR 6/1 reddish gray	Medium	Corticated	Simple Marginal
110	3	B	11	Flake	1,9	2	0,9	10YR 7/1 light gray	Fine	Corticated	
114	3	B	11	Carenated Scraper	2,2	1,8	1,2	2.5Y 6/4 light yellowish brown	Medium	Absent	Simple Marginal
115	3	B	11	Trasverse Scraper	1,9	3,3	1,4	10YR 7/2 light gray	Coarse	Corticated	Steep Scalariform
253	3	A	11	Debitage	1,1	2,1	0,3	2.5Y 7/2 light gray	Medium	Absent	Flat Invasive
257	3	A	12	Debitage	1,4	1,1	0,4	5YR 6/4 light reddish brown	Fine	Faceted	
265	3	A	11	Notch	3,1	1,9	1,1	2.5Y 7/4 pale yellow	Fine	Flat	Simple Steep
400	3	B	11	Levallois Point	3,9	1,8	0,7	5Y 6/1 gray	Fine	Flat	Inverse
498	3	A	11	Debitage	2,6	1,8	0,4	10YR 5/2 grayish brown	Medium	Absent	
499	3	A	11	Core Debris	3,5	3,7	2,6	2.5Y 6/1 gray	Coarse		
500	3	A	11	Pebble	4,9	2,9	2,1	2.5Y 5/3 light olive brown	Coarse		
564	3	B	11	Debitage	1,5	2,1	0,5	2.5Y 6/6 olive yellow	Fine		
569	3	B	11	Transverse Convex Scraper	2,4	3,5	1	GLEY1 8/10GY light greenish gray	Medium	Corticated	Simple Scalariform
575	3	B	11	Debitage	1,1	1	0,4	10YR 8/4 very pale brown	Jasper	Flat	

576	3	B	11	Debitage	2,4	1,2	0,5	2.5YR 7/4 light reddish brown	Medium	Flat	
577	3	B	11	Debitage	1,5	1	0,2	10YR 8/3 very pale brown	Medium	Corticated	Scalariform
578	3	B	11	Debitage	1,3	1,3	0,4	2.5YR 7/8 light red	Medium	Corticated	
579	3	B	11	Side Scraper	3,9	2	1,7	5YR 6/1 gray	Fine	Absent	
580	3	–		Side Scraper	1,5	1,9	0,8	2.5Y 6/3 light yellowish brown	Medium	Absent	Simple Right Side
723	3	–		Debitage	3,2	1,6	0,6	10YR 7/6 yellow	Fine	Flat	
724	3	A	11	Trasverse Scraper	2	3,2	1,4	GLEY1 6/N gray	Fine	Corticated	Simple Irregular
729	3	–		Simple Scraper	2,1	2,4	1,1	2.5YR 7/1 light reddish gray	Fine	Corticated	Simple
732	3	A	11	Straight Scraper	3,9	1,8	0,7	GLEY1 8/N white	Fine	Flat	Simple
735	3	–		Debitage	3,3	3	1,3	2.5Y 6/1 gray	Medium	Flat	
736	3	–		Straight Scraper	3,4	5	1,9	2.5Y 5/1 gray	Fine	Absent	Scalariform "La Quina"
737	3	–		Debitage	1,3	1,8	0,6	2.5Y 6/2 light brownish gray	Medium	Flat	
738	3	–		Convex Transverse Scraper	2,8	1,2	0,9	7.5YR 5/6 strong brown	Fine	Flat	Scalariform "La Quina"
739	3	–		Debitage	1,6	2,3	0,5	10YR 7/3 very pale brown	Fine	Absent	
740	3	–		Debitage	1,3	1,2	0,2	5YR 5/6 yellowish red	Fine		
800	3	A	11	Straight Scraper	3,8	2,8	1,2	2.5Y 7/4 pale yellow	Medium	Faceted	Simple Marginal
801	3	A	11	Debitage	2,2	2,1	1	2.5Y 8/2 pale yellow	Medium	Flat	
802	3	A	11	Debitage	1,6	2,6	0,6	2.5YR 6/4 light reddish brown	Medium	Corticated	
803	3	A	11	Side Scraper	2,6	2,8	0,9	2.5Y 6/3 light yellowish brown	Jasper	Absent	Scalariform
804	3	A	11	Debitage	1,1	1,5	0,6	2.5Y 8/3 pale yellow	Jasper	Flat	
805	3	A	11	Core	4,2	4,6	2,5	10YR 8/3 very pale brown	Coarse		
806	3	A	11	Curved Point	1,5	2,2	0,6	5Y 6/2 light olive gray	Medium	Absent	Scalariform Left Side
844	3	B	11	Debitage	2,4	2,1	1,3	2.5Y 6/2 light brownish gray	Medium	Absent	
845	3	B	11	Debitage	1,6	1,7	0,3	10YR 7/2 light gray	Fine	Flat	

Appendix B. Database of the coprolites collection from Cava Muracci (Cisterna di Latina, Italy).

# Find	*Area*	*Sector*	*SU*	*Type*	*Taxon*	*Widest/Shorter diametre (mm)*	*Weight (g)*
9	3	–		Coprolite	*Crocuta crocuta spelaea*	44x27	49g
10	3	–		Coprolite	*Crocuta crocuta spelaea*	36x35	23g
11	3	–		Coprolite	*Crocuta crocuta spelaea*	42x32	41g
12	3	–		Coprolite	*Crocuta crocuta spelaea*	45x29	40g
13	3	A	11	Coprolite	*Crocuta crocuta spelaea*	–	40g
14	3	A	11	Coprolite	*Crocuta crocuta spelaea*	36x35	45g
15	3	A	11	Coprolite	*Crocuta crocuta spelaea*	37x22	28g
16	3	A	11	Coprolite	*Crocuta crocuta spelaea*	–	39g
17	3	–		Coprolite	*Crocuta crocuta spelaea*	49x31	34g
18	3	–		Coprolite	*Crocuta crocuta spelaea*	32x22	21g
19	3	–		Coprolite	*Crocuta crocuta spelaea*	42x26	36g
20	3	–		Coprolite	*Crocuta crocuta spelaea*	29x29	30g
21	3	–		Coprolite	*Crocuta crocuta spelaea*	57x50	108g
22	3	–		Coprolite	*Crocuta crocuta spelaea*	53x47	87g
23	3	–		Coprolite	*Crocuta crocuta spelaea*	67x51	174g
316	4	–		Coprolite	*Crocuta crocuta spelaea*	52x39	52g
317	4	–		Coprolite	*Crocuta crocuta spelaea*	29x20	9g
354	3	B	11	Coprolite	*Crocuta crocuta spelaea*	45x35	69g
386	3	–		Coprolite	*Crocuta crocuta spelaea*	–	6g
423	3	B	11	Coprolite	*Crocuta crocuta spelaea*	48x33	25g
425	3	B	11	Coprolite	*Crocuta crocuta spelaea*	35x25	30g
428	3	B	11	Coprolite	*Crocuta crocuta spelaea*	24x12	8g
474	3	A	11	Coprolite	*Crocuta crocuta spelaea*	–	49g
475	3	A	11	Coprolite	*Crocuta crocuta spelaea*	38x37	31g
476	3	A	11	Coprolite	*Crocuta crocuta spelaea*	54x44	86g

477	3	A	11	Coprolite	*Crocuta crocuta spelaea*	46x41	49g
478	3	A	11	Coprolite	*Crocuta crocuta spelaea*	48x46	69g
479	3	A	11	Coprolite	*Crocuta crocuta spelaea*	–	55g
504	3	B	11	Coprolite	*Crocuta crocuta spelaea*	–	28g
505	3	B	11	Coprolite	*Crocuta crocuta spelaea*	32x30	37g
506	3	B	11	Coprolite	*Crocuta crocuta spelaea*	43x41	40g
507	3	B	11	Coprolite	*Crocuta crocuta spelaea*	47x46	52g
508	3	B	11	Coprolite	*Crocuta crocuta spelaea*	53x50	60g
520	3	B	11	Coprolite	*Crocuta crocuta spelaea*	39x31	47g
522	3	B	11	Coprolite	*Crocuta crocuta spelaea*	45x30	19g
524	3	B	11	Coprolite	*Crocuta crocuta spelaea*	52x47	104g
542	3	A	11	Coprolite	*Crocuta crocuta spelaea*	–	25g
585	3	B	11	Coprolite	*Crocuta crocuta spelaea*	20x15	6g
609	3	–		Coprolite	*Crocuta crocuta spelaea*	–	10g
646	3	A	11	Coprolite	*Crocuta crocuta spelaea*	28x22	21g
653	3	–		Coprolite	*Crocuta crocuta spelaea*	31x15	10g
725	3	B	11	Coprolite	*Crocuta crocuta spelaea*	44x19	23g
726	3	B	11	Coprolite	*Crocuta crocuta spelaea*	–	6g
727	3	B	11	Coprolite	*Crocuta crocuta spelaea*	43x21	20g
728	3	B	11	Coprolite	*Crocuta crocuta spelaea*	–	28g
730	3	B	11	Coprolite	*Crocuta crocuta spelaea*	28x15	11g
731	3	B	11	Coprolite	*Crocuta crocuta spelaea*	38x36	63g
733	3	B	11	Coprolite	*Crocuta crocuta spelaea*	46x31	32g
734	3	B	11	Coprolite	*Crocuta crocuta spelaea*	26x22	11g
741	3	–		Coprolite	*Crocuta crocuta spelaea*	46x14	20g
807	7	–		Coprolite	*Crocuta crocuta spelaea*	85x55	209g
808	3	A	11	Coprolite	*Crocuta crocuta spelaea*	34x19	19g
810	3	A	11	Coprolite	*Crocuta crocuta spelaea*	37x23	18g

811	3	A	11	Coprolite	*Crocuta crocuta spelaea*	42x25	35g
812	3	A	11	Coprolite	*Crocuta crocuta spelaea*	45x29	43g
813	3	A	11	Coprolite	*Crocuta crocuta spelaea*	41x24	22g
814	3	A	11	Coprolite	*Crocuta crocuta spelaea*	41x40	63g
815	3	A	11	Coprolite	*Crocuta crocuta spelaea*	34x32	36g
816	3	A	11	Coprolite	*Crocuta crocuta spelaea*	29x20	7g
817	3	A	11	Coprolite	*Crocuta crocuta spelaea*	45x36	89g
818	3	B	11	Coprolite	*Crocuta crocuta spelaea*	29x25	16g
819	3	B	11	Coprolite	*Crocuta crocuta spelaea*	38x27	37g
820	3	B	11	Coprolite	*Crocuta crocuta spelaea*	36x30	26g
821	3	B	11	Coprolite	*Crocuta crocuta spelaea*	45x41	39g
822	3	B	11	Coprolite	*Crocuta crocuta spelaea*	42x21	35g
823	3	B	11	Coprolite	*Crocuta crocuta spelaea*	35x33	55g
824	7	–		Coprolite	*Crocuta crocuta spelaea*	42x40	62g
825	7	–		Coprolite	*Crocuta crocuta spelaea*	52x35	52g
826	7	–		Coprolite	*Crocuta crocuta spelaea*	55x39	78g
827	7	–		Coprolite	*Crocuta crocuta spelaea*	46x39	67g
828	7	–		Coprolite	*Crocuta crocuta spelaea*	45x34	55g
829	7	–		Coprolite	*Crocuta crocuta spelaea*	34x26	17g
830	7	–		Coprolite	*Crocuta crocuta spelaea*	41x35	68g
831	7	–		Coprolite	*Crocuta crocuta spelaea*	48x38	44g
832	7	–		Coprolite	*Crocuta crocuta spelaea*	40x34	49g
833	7	–		Coprolite	*Crocuta crocuta spelaea*	38x33	42g
834	7	–		Coprolite	*Crocuta crocuta spelaea*	55x40	78g
835	7	–		Coprolite	*Crocuta crocuta spelaea*	49x38	74g
836	7	–		Coprolite	*Crocuta crocuta spelaea*	26x16	4g
837	7	–		Coprolite	*Crocuta crocuta spelaea*	31x30	26g
838	7	–		Coprolite	*Crocuta crocuta spelaea*	34x25	16g

839	7	–	Coprolite	*Crocuta crocuta spelaea*	42x29	49g
840	7	–	Coprolite	*Crocuta crocuta spelaea*	42x29	50g
841	7	–	Coprolite	*Crocuta crocuta spelaea*	50x34	82g
868	3	–	Coprolite	*Crocuta crocuta spelaea*	37x27	36g
1107	7	–	Coprolite	*Crocuta crocuta spelaea*	–	11g
1108	7	–	Coprolite	*Crocuta crocuta spelaea*	–	10g
1158	7	–	Coprolite	*Crocuta crocuta spelaea*	41x30	27g
1165	7	–	Coprolite	*Crocuta crocuta spelaea*	39x33	28g
1166	7	–	Coprolite	*Crocuta crocuta spelaea*	35x33	23g
1169	7	–	Coprolite	*Crocuta crocuta spelaea*	33x28	17g
1171	7	–	Coprolite	*Crocuta crocuta spelaea*	39x34	35g
1173	7	–	Coprolite	*Crocuta crocuta spelaea*	39x38	32g
1203	7	–	Coprolite	*Crocuta crocuta spelaea*	29x22	15g
1205	7	–	Coprolite	*Crocuta crocuta spelaea*	33x27	35g
1206	7	–	Coprolite	*Crocuta crocuta spelaea*	37x31	30g
1207	7	–	Coprolite	*Crocuta crocuta spelaea*	33x22	11g
1208	7	–	Coprolite	*Crocuta crocuta spelaea*	44x25	34g
1209	3	–	Coprolite	*Crocuta crocuta spelaea*	31x29	24g
1210	3	–	Coprolite	*Crocuta crocuta spelaea*	48x41	51g
1211	4	–	Coprolite	*Crocuta crocuta spelaea*	36x21	26g
1212	4	–	Coprolite	*Crocuta crocuta spelaea*	33x15	11g
1213	4	–	Coprolite	*Crocuta crocuta spelaea*	34x26	14g
1214	4	–	Coprolite	*Crocuta crocuta spelaea*	41x28	31g
1215	4	–	Coprolite	*Crocuta crocuta spelaea*	–	4g
1216	4	–	Coprolite	*Crocuta crocuta spelaea*	–	14g
1217	4	–	Coprolite	*Crocuta crocuta spelaea*	–	9g

Appendix C. Database of the large fauna assemblage from Cava Muracci (Cisterna di Latina, Italy).

# Find	*Area*	*Sector*	*SU*	*Type*	*Taxon*	*Body Part*	*Age*	*Side*	*Gnawing*
1	3	A	11	Fauna	*Bos primigenius*	Antler			
2	3	A	11	Fauna	*Crocuta crocuta spelaea*	Incisor tooth	a		
3	3	A	11	Fauna	*Crocuta crocuta spelaea*	Molar tooth	y\a	Lower\Left	
4	3	A	11	Fauna	*Equus ferus*	Molar tooth	a		
5	3	A	11	Fauna	*Crocuta crocuta spelaea*	Jaw	a\s	Lower\Left	
6	3	A	11	Fauna	*Crocuta crocuta spelaea*	Jaw	yy	Lower\Right	
24	1	–		Fauna	*Bos primigenius*	Humerus	a	Right	
25	1	–		Fauna	*Bos primigenius*	Metacarpus	a		X
26	2	–		Fauna	*Bos primigenius*	Scapula	a	Left	X
27	2	–		Fauna	*Equus ferus*	Molar tooth	s	Upper Left	
28	2	–		Fauna	*Equus ferus*	Premolar tooth	s	Upper Left	
29	2	–		Fauna	*Equus ferus*	Jaw	s	Upper Right	
30	2	–		Fauna	*Equus ferus*	Molar tooth	s	Upper Left	
43	3	A	11	Fauna	*Equus ferus*	Molar tooth	a\s	Upper Left	
44	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Lower Right	
45	3	A	11	Fauna	*Bos primigenius*	Molar tooth	a\s	Upper Right	
46	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Upper Right	
47	3	A	11	Fauna	*Equus ferus*	Molar tooth	a\s		
48	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Lower Left	
49	3	A	11	Fauna	*Equus ferus*	Molar tooth	a	Lower Left	
51	3	A	11	Fauna	*Indet.*	Fragment bone			
52	3	A	11	Fauna	*Equus ferus*	Metatarsus II	a	Left	
53	3	A	11	Fauna	*Equus ferus*	Metacarpus	a	Left	X
54	3	A	11	Fauna	*Bos primigenius*	Deciduous premolar tooth	yy	Upper Left	

55	3	A	11	Fauna	*Bos primigenius*	Humerus		Right	X
56	3	A	11	Fauna	*Bos primigenius*	Vertebrae		Lumbar	
57	3	A	11	Fauna	*Bos primigenius*	Central tarsal bone	a	Right	
58	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Lower Left	
59	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Lower Right	
60	3	A	11	Fauna	*Cervus elaphus*	Jaw	s	Upper Left	
61	3	A	11	Fauna	*Bos primigenius*	Deciduous Incisor tooth	a	Upper Right	
62	3	A	11	Fauna	*Indet.*	Molar tooth			
63	3	A	11	Fauna	*Equus ferus*	Premolar tooth	s	Upper Left	
64	3	A	11	Fauna	*Equus ferus*	Molar tooth	a	Upper Left	
65	3	A	11	Fauna	*Indet.*	Molar tooth			
66	3	A	11	Fauna	*Bos primigenius*	Tibia	a	Left	X
67	3	A	11	Fauna	*Bos primigenius*	Metatarsus	a	Right	
68	3	A	11	Fauna	*Bos primigenius*	Metacarpus	a	Left	X
69	3	A	11	Fauna	*Equus ferus*	Tibia	a	Right	X
70	3	A	11	Fauna	*Equus ferus*	Metatarsus	a	Right	X
71	3	A	11	Fauna	*Bos primigenius*	Metacarpus	a	Right	X
72	3	A	11	Fauna	*Equus ferus*	Metatarsus	a	Right	X
73	3	A	11	Fauna	*Cervus elaphus*	Antler			X
74	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Upper Left	
75	3	A	11	Fauna	*Equus ferus*	Deciduous molar tooth	yy	Upper Left	
76	3	A	11	Fauna	*Bos primigenius*	Metapodial	a		X
77	3	–		Fauna	*Equus ferus*	Deciduous molar tooth	yy	Lower Right	
78	3	A	11	Fauna	*Equus ferus*	Metapodial	a	Left	X
79	3	A	11	Fauna	*Equus ferus*	Metacarpus	a	Left	X
80	3	A	11	Fauna	*Bos primigenius*	Molar tooth	a	Upper Left	

81	3	A	11	Fauna	*Cervus elaphus*	Jaw	a	Upper Left	
82	3	A	11	Fauna	*Bos primigenius*	Deciduous molar tooth	yy	Upper Right	
83	3	A	11	Fauna	*Equus ferus*	Metapodial	a		X
84	3	–		Fauna	*Cervus elaphus*	Jaw	s	Lower Right	
85	3	–		Fauna	*Equus ferus*	Molar tooth	s	Lower Right	
86	3	–		Fauna	*Bos primigenius*	Molar tooth	s	Lower	
87	3	–		Fauna	*Equus ferus*	Jaw			
88	3	–		Fauna	*Equus ferus*	Molar tooth	s	Lower Left	
89	3	–		Fauna	*Bos primigenius*	Deciduous Incisor tooth	yy	Upper Left	
90	3	–		Fauna	*Equus ferus*	Molar tooth	s	Lower Right	
91	3	B	11	Fauna	*Cervus elaphus*	Molar tooth	a	Upper Left	
92	3	B	11	Fauna	*Equus ferus*	Premolar tooth	s	Upper Right	
93	3	B	11	Fauna	*Bos primigenius*	Astragalus	y\a	Left	X
94	3	B	11	Fauna	*Bos primigenius*	Astragalus	y\a	Left	X
95	3	B	11	Fauna	*Bos primigenius*	Tibia	a	Left	X
96	3	B	11	Fauna	*Bos primigenius*	Humerus	a	Left	
97	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Upper Left	
98	3	A	11	Fauna	*Bos primigenius*	Deciduous molar tooth	yy	Lower	
99	3	A	11	Fauna	*Equus ferus*	Incisor tooth	s	Lower	
100	3	A	11	Fauna	*Bos primigenius*	Coxal	a		X
101	3	A	11	Fauna	*Lepus sp.*	II metatarsus		Left	
102	3	A	11	Fauna	*Equus ferus*	Canine tooth			
103	3	A	11	Fauna	*Cervus elaphus*	Premolar tooth	a	Lower Left	
104	3	A	11	Fauna	*Bos primigenius*	Premolar tooth	a\s	Upper Left	
105	3	A	11	Fauna	*Cervus elaphus*	Molar tooth	s	Lower	
107	3	A	11	Fauna	*Bos primigenius*	Premolar tooth	a	Lower Left	

108	3	A	11	Fauna	*Equus ferus*	Jaw	s	Upper Left	
109	3	A	11	Fauna	*Cervus elaphus*	Molar tooth	s	Upper Right	
111	3	A	11	Fauna	*Crocuta crocuta spelaea*	Canine tooth	a	Lower Right	
112	3	A	11	Fauna	*Equus ferus*	Deciduous Incisor tooth	yy	Upper	
113	3	A	11	Fauna	*Bos primigenius*	Premolar tooth	s	Upper	
116	3	B	11	Fauna	*Bos primigenius*	Deciduous molar tooth	yy		
117	3	B	11	Fauna	*Dama dama*	Antler			X
118	3	A	11	Fauna	*Bos primigenius*	Skull			
119	3	A	11	Fauna	*Cervus elaphus*	Metacarpus II			X
120	3	A	11	Fauna	*Cervus elaphus*	Radius	a	Left	X
121	3	A	11	Fauna	*Bos primigenius*	Humerus	a	Right	X
122	3	A	11	Fauna	*Cervus elaphus*	Metatarsus	a	Right	X
123	3	A	11	Fauna	*Cervus elaphus*	Tibia	a	Right	X
124	3	A	11	Fauna	*Equus ferus*	Premolar tooth	y\a	Upper Left	
125	3	A	11	Fauna	*Bos primigenius*	Metacarpus	a		
126	3	A	11	Fauna	*Bos primigenius*	Tibia		Right	X
127	4	–		Fauna	*Cervus elaphus*	Tibia	y	Left	
128	4	–		Fauna	*Equus ferus*	Radius+ulna	a	Left	X
129	3	A	11	Fauna	*Bos primigenius*	Astragalus	a	Right	
130	3	A	11	Fauna	*Bos primigenius*	Astragalus	a	Left	
131	3	A	11	Fauna	*Cervus elaphus*	Radius	a	Left	X
132	3	A	11	Fauna	*Bos primigenius*	Coxal	a	Left	X
133	3	A	11	Fauna	*Bos primigenius*	Metatarsus	a	Left	X
134	3	A	11	Fauna	*Cervus elaphus*	Antler	a		X
135	3	A	11	Fauna	*Bos primigenius*	Deciduous molar tooth	y	Upper Right	
136	3	A	11	Fauna	*Bos primigenius*	Premolar tooth	s	Lower Right	

137	3	A	11	Fauna	*Bos primigenius*	Molar tooth	y	Lower Left	
138	3	A	11	Fauna	*Equus ferus*	Molar tooth	a\s	Upper Right	
139	3	A	11	Fauna	*Equus ferus*	Molar tooth	a	Upper Right	
140	3	A	11	Fauna	*Crocuta crocuta spelaea*	Molar tooth	y	Upper Right	
141	3	A	11	Fauna	*Equus ferus*	Premolar tooth	s	Upper Right	
142	3	A	11	Fauna	*Equus ferus*	Premolar tooth	s	Upper Left	
143	3	A	11	Fauna	*Equus ferus*	Molar tooth	a\s	Upper Right	
144	3	–		Fauna	*Equus ferus*	Molar tooth	a	Upper Right	
146	3	–		Fauna	*Equus ferus*	Incisor tooth	a	Upper	
147	3	–		Fauna	*Bos primigenius*	Deciduous molar tooth	y	Upper Left	
148	3	–		Fauna	*Equus ferus*	Premolar tooth	a	Upper Left	
149	3	–		Fauna	*Equus ferus*	Molar tooth	s	Lower Right	
150	3	–		Fauna	*Equus ferus*	Molar tooth	s	Lower Right	
151	3	–		Fauna	*Cervus elaphus*	Molar tooth	s	Upper Right	
152	3	–		Fauna	*Equus ferus*	Molar tooth	a	Lower Right	
153	3	–		Fauna	*Bos primigenius*	Molar tooth	a\s	Upper Right	
154	3	–		Fauna	*Bos primigenius*	Incisor tooth	a	Lower	
155	3	–		Fauna	*Equus ferus*	Premolar tooth	s	Lower Left	
156	3	–		Fauna	*Equus ferus*	Premolar tooth	s	Lower Left	
157	3	–		Fauna	*Bos primigenius*	Premolar tooth	a	Lower Left	
158	3	–		Fauna	*Cervus elaphus*	Premolar tooth	y\a	Lower Left	
159	3	–		Fauna	*Bos primigenius*	Molar tooth	y\a	Upper Left	
160	3	–		Fauna	*Equus ferus*	Jaw	s	Lower Right	
161	3	–		Fauna	*Cervus elaphus*	Metatarsus	a	Left	
162	3	–		Fauna	*Cervus elaphus*	Antler	a		X
163	3	–		Fauna	*Bos primigenius*	Calcaneus	a	Left	X

164	3	–		Fauna	*Bos primigenius*	Calcaneus	a	Left	X
165	3	–		Fauna	*Equus ferus*	Tibia	a	Left	
166	3	–		Fauna	*Bos primigenius*	Tibia	y\a	Right	X
167	3	–		Fauna	*Bos primigenius*	Tibia	a	Left	X
168	3	–		Fauna	*Bos primigenius*	Vertebrae	a	Toracic	
169	3	–		Fauna	*Equus ferus*	Coxal	a	Right	X
170	3	A	11	Fauna	*Cervus elaphus*	Antler			X
171	3	A	11	Fauna	*Cervus elaphus*	Antler			X
172	3	A	11	Fauna	*Cervus elaphus*	Antler	a		X
173	3	A	11	Fauna	*Cervus elaphus*	Antler			X
174	3	A	11	Fauna	*Cervidae*	Antler			X
175	3	A	11	Fauna	*Bos primigenius*	Coxal	a	Left	X
176	3	A	11	Fauna	*Bos primigenius*	Astragalus	a	Left	X
177	3	A	11	Fauna	*Equus ferus*	Metatarsus IV	a		
178	3	A	11	Fauna	*Equus ferus*	Metatarsus II	a	Left	
179	3	A	11	Fauna	*Bos primigenius*	Metatarsus	a	Right	X
180	3	A		Fauna	*Bos primigenius*	Molar tooth	s	Lower Right	
181	3	A	11	Fauna	*Equus ferus*	Premolar tooth	s	Upper Left	
182	3	A		Fauna	*Bos primigenius*	Molar tooth	a	Upper Left	
183	3	A		Fauna	*Cervus elaphus*	Jaw		Lower	
184	3	A	11	Fauna	*Cervus elaphus*	Jaw	a	Lower Left	
185	3	A	11	Fauna	*Bos primigenius*	Premolar tooth	a	Upper Right	
186	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Upper Right	
187	3	A		Fauna	*Bos primigenius*	Jaw	yy	Lower Left	
188	3	A	11	Fauna	*Cervus elaphus*	Molar tooth	a	Upper Right	
189	3	A		Fauna	*Cervus elaphus*	Molar tooth	a	Lower Left	

190	3	A	11	Fauna	*Equus ferus*	Premolar tooth	a\s	Upper Left	
191	3	A	11	Fauna	*Cervus elaphus*	Jaw	s	Lower Left	
192	3	A	11	Fauna	*Bos primigenius*	Molar tooth	s	Lower Right	
193	3	A	11	Fauna	*Bos primigenius*	Molar tooth	s	Lower Right	
194	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Upper Right	
195	3	A	11	Fauna	*Bos primigenius*	Molar tooth	s	Lower Right	
196	3	–		Fauna	*Equus ferus*	Metatarsus	a	Right	X
197	3	–		Fauna	*Bos primigenius*	Metatarsus	a	Right	X
198	3	–		Fauna	*Equus ferus*	Metatarsus	a	Left	X
199	3	–		Fauna	*Equus ferus*	Tibia	a	Right	X
200	3	–		Fauna	*Bos primigenius*	Femur	a	Left	X
201	3	–		Fauna	*Equus ferus*	Metatarsus	a	Right	X
202	3	–		Fauna	*Bos primigenius*	Metapodial	a		X
203	3	–		Fauna	*Equus ferus*	Metacarpus	a	Left	X
204	3	–		Fauna	*Bos primigenius*	Calcaneus	a	Left	X
205	3	–		Fauna	*Equus ferus*	Calcaneus	a	Right	X
206	3	–		Fauna	*Cervus elaphus*	Antler			X
207	3	–		Fauna	*Cervus elaphus*	Antler			X
208	3	–		Fauna	*Bos primigenius*	Femur	a	Left	X
209	3	–		Fauna	*Bos primigenius*	Calcaneus	a	Right	X
210	3	–		Fauna	*Equus ferus*	Coxal	a	Left	X
212	3	–		Fauna	*Bos primigenius*	Metacarpus	a	Left	X
213	3	–		Fauna	*Bos primigenius*	Humerus	a	Right	X
214	3	–		Fauna	*Bos primigenius*	Femur		Left	X
215	3	A	11	Fauna	*Bos primigenius*	Metatarsus	a	Right	X
216	3	A	11	Fauna	*Cervus elaphus*	Humerus	a	Left	X

217	3	A	11	Fauna	*Bos primigenius*	Humerus	a	Right	X
218	3	A	11	Fauna	*Bos primigenius*	Metacarpus	a	Left	X
219	3	A	11	Fauna	*Bos primigenius*	Metacarpus	a	Right	X
220	3	A	11	Fauna	*Bos primigenius*	Astragalus	y\a	Left	
221	3	A	11	Fauna	*Bos primigenius*	Metatarsus	a	Left	X
222	3	A	11	Fauna	*Bos primigenius*	Tibia	a	Right	X
223	3	A	11	Fauna	*Equus ferus*	Jaw	s	Upper Left	
224	3	A	11	Fauna	*Bos primigenius*	Calcaneus	a	Left	X
225	3	A	11	Fauna	*Bos primigenius*	Calcaneus	a	Right	X
226	3	A	11	Fauna	*Equus ferus*	Astragalus	y\a	Right	
227	3	A	11	Fauna	*Cervus elaphus*	Tibia	a	Right	X
228	3	–		Fauna	*Bos primigenius*	Metatarsus	a	Right	X
229	3	A	11	Fauna	*Equus ferus*	Astragalus	y\a	Right	
230	3	A	11	Fauna	*Cervus elaphus*	Antler			X
231	3	A	11	Fauna	*Equus ferus*	Humerus	a	Left	X
232	3	A	11	Fauna	*Equus ferus*	Jaw	s	Upper	
233	3	A	11	Fauna	*Equus ferus*	Jaw	a	Upper Left	
234	3	A	11	Fauna	*Equus ferus*	Molar tooth	a\s	Upper Right	
235	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Upper Left	
236	3	A	11	Fauna	*Bos primigenius*	Molar tooth	s	Lower Right	
237	3	A	11	Fauna	*Equus ferus*	Premolar tooth	a\s	Upper Right	
238	3	–		Fauna	*Bos primigenius*	Metacarpus	a	Right	X
239	3	A	11	Fauna	*Bos primigenius*	Premolar tooth	a	Upper Right	
240	3	A	11	Fauna	*Cervus elaphus*	Deciduous molar tooth	yy	Upper Left	
241	3	A	11	Fauna	*Equus ferus*	Incisor tooth	s	Lower	
242	3	A	11	Fauna	*Bos primigenius*	Deciduous molar tooth	yy	Upper Right	

243	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Upper Right	
244	3	A	11	Fauna	*Equus ferus*	Deciduous molar tooth	yy	Upper Right	
245	3	A	11	Fauna	*Bos primigenius*	Deciduous molar tooth	a	Upper Right	
246	3	–		Fauna	*Bos primigenius*	Calcaneus	a	Left	X
247	3	–		Fauna	*Equus ferus*	Metatarsus IV	a		
250	3	A	11	Fauna	*Bos primigenius*	Premolar tooth	s	Upper Left	
251	3	A		Fauna	*Cervus elaphus*	Jaw	yy	Lower	
252	3	A	11	Fauna	*Cervus elaphus*	Antler			X
254	2	–	20	Fauna	*Bos primigenius/Bison*	Metacarpus	a	Right	X
255	3	A	11	Fauna	*Bos primigenius*	Premolar tooth	a	Lower Left	
256	3	A	11	Fauna	*Bos primigenius*	Deciduous molar tooth	yy	Upper Left	
258	3	A	11	Fauna	*Bos primigenius*	Deciduous molar tooth	yy	Upper Left	
259	3	A	11	Fauna	*Equus ferus*	Incisor tooth	s	Lower	
260	3	A	11	Fauna	*Equus ferus*	Molar tooth	s		
261	3	A	11	Fauna	*Crocuta crocuta spelaea*	Ulna	y	Left	X
262	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Lower Right	
263	3	A	11	Fauna	*Bos primigenius*	Molar tooth	a		
264	3	A	11	Fauna	*Bos primigenius*	molar erupting	y	Lower Right	
266	1	–		Fauna	*Bos primigenius*	Metacarpus	a	Left	X
267	1	–		Fauna	*Bos primigenius*	Astragalus			X
268	1	–		Fauna	*Bos primigenius*	Astragalus			
269	1	–		Fauna	*Cervus elaphus*	Ulna	a	Left	X
270	1	–		Fauna	*Cervus elaphus*	Antler	a		X
271	1	–		Fauna	*Cervus elaphus*	Radius+ulna	a	Left	
272	3	A	11	Fauna	*Bos primigenius*	Metacarpus	a		X
273	3	–		Fauna	*Bos primigenius*	Tibia		Right	X

274	3	–	Fauna	*Indet.*	Fragment bone			X
275	3	–	Fauna	*Bos primigenius*	Astragalus	y	Left	
276	3	–	Fauna	*Bos primigenius*	Astragalus	a	Right	X
277	3	–	Fauna	*Bos primigenius*	Astragalus	a	Right	
278	3	–	Fauna	*Bos primigenius*	Astragalus	y	Right	X
279	3	–	Fauna	*Bos primigenius*	Astragalus	a	Left	
280	3	–	Fauna	*Bos primigenius*	Astragalus	a	Right	X
281	3	–	Fauna	*Cervus elaphus*	Antler	a		X
282	3	–	Fauna	*Bos primigenius*	Central tarsal bone	a	Right	X
283	3	–	Fauna	*Bos primigenius*	Large cuneiform bone	a	Right	
284	3	–	Fauna	*Bos primigenius*	Calcaneus	a	Left	X
285	3	–	Fauna	*Bos primigenius*	Calcaneus	a	Left	X
286	4	–	Fauna	*Dama dama*	Molar tooth	a	Lower Left	
287	4	–	Fauna	*Cervus elaphus*	Molar tooth	a	Lower Right	
288	4	–	Fauna	*Dama dama*	Molar tooth	y\a	Lower	
289	4	–	Fauna	*Bos primigenius*	Deciduous molar tooth	yy	Upper	
290	4	–	Fauna	*Crocuta crocuta spelaea*	Canine tooth	a		
291	4	–	Fauna	*Indet.*	Tooth			
292	4	–	Fauna	*Cervus elaphus*	Molar tooth	y	Lower Left	
293	4	–	Fauna	*Bos primigenius*	molar tooth	a	Upper	
294	4	–	Fauna	*Bos primigenius*	Premolar tooth	a	Upper Right	
295	4	–	Fauna	*Dama dama*	I Phalanx	a		
296	4	–	Fauna	*Dama dama*	I Phalanx	a		
297	4	–	Fauna	*Dama dama*	I Phalanx	a		
298	4	–	Fauna	*Dama dama*	I Phalanx	a		
299	4	–	Fauna	*Capreolus capreolus*	I Phalanx	a		

300	4	–		Fauna	*Cervus elaphus*	II Phalanx	yy		
301	4	–		Fauna	*Bos primigenius*	I Phalanx	y	Right	
302	4	–		Fauna	*Dama dama*	Metapodial	yy		
303	4	–		Fauna	*Equus ferus*	Astragalus	a	Right	
304	4	–		Fauna	*Dama dama*	Astragalus	yy	Right	
305	4	–		Fauna	*Dama dama*	Calcaneus	y\a	Right	
306	4	–		Fauna	*Indet.*	I Phalanx	y		
307	4	–		Fauna	*Equus ferus*	Incisor tooth			
308	4	–		Fauna	*Cervus elaphus*	Tibia	a	Right	X
309	4	–		Fauna	*Dama dama*	Humerus	a	Right	X
310	4	–		Fauna	*Dama dama*	Radius	a	Left	
311	4	–		Fauna	*Dama dama*	Metatarsus	a	Left	
312	4	–		Fauna	*Lepus sp.*	Tibia	a	Right	
313	4	–		Fauna	*Crocuta crocuta spelaea*	Ulna	yy	Right	
314	4	–		Fauna	*Cervidae*	Antler	yy		
315	4	–		Fauna	*Cervidae*	Antler	yy		
318	4	–		Fauna	*Dama dama*	Large cuneiform bone	yy	Right	
322	3	A	11	Fauna	*Equus ferus*	Radius+ulna		Left	X
323	3	A	11	Fauna	*Equus ferus*	Tibia		Left	X
324	3	A	11	Fauna	*Bos primigenius*	Tibia		Right	X
325	3	C		Fauna	*Indet.*	Fragment bone			
326	3	A	11	Fauna	*Indet.*	Fragment bone			
327	4	–		Fauna	*Lepus sp.*	II metatarsus	a\s	Right	
328	3	C		Fauna	*Bos primigenius*	Molar tooth			
329	3	C		Fauna	*Equus ferus*	Molar tooth		Upper	
330	3	C		Fauna	*Sus scrofa*	Canine tooth	a	Lower Left	

331a	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Upper Left	
331b	3	A	11	Fauna	*Indet.*	Fragment bone			
332a	3	A	11	Fauna	*Indet.*	Fragment bone			
332b	3	A	11	Fauna	*Bos primigenius*	Scapula		Left	
333	3	A	11	Fauna	*Cervus elaphus*	Antler	a		X
334	3	B	11	Fauna	*Equus ferus*	Molar tooth	a	Lower	
336	3	B	11	Fauna	*Canis lupus*	II metatarsus	a\s	Left	
337	3	B	11	Fauna	*Indet.*	Antler			
338	3	B	11	Fauna	*Equus ferus*	Molar tooth	a	Upper Left	
339	3	B	11	Fauna	*Equus ferus*	Molar tooth	a\s	Upper Right	
340	3	A	11	Fauna	*Cervus elaphus*	Antler			X
345	3	A	11	Fauna	*Crocuta crocuta spelaea*	Molar tooth	y	Upper Left	
346	3	A	11	Fauna	*Crocuta crocuta spelaea*	Molar tooth	a	Upper	
347	3	A	11	Fauna	*Crocuta crocuta spelaea*	Jaw	s	Lower Right	
348	5	–		Fauna	*Cervidae*	Antler			X
349	3	A	11	Fauna	*Cervus elaphus*	I Phalanx	a		
350	3	A	11	Fauna	*Cervus elaphus*	Antler			X
351	3	A	11	Fauna	*Equus ferus*	Molar tooth		Upper	
352	3	A	11	Fauna	*Equus ferus*	III Phalanx			
353	3	B	11	Fauna	*Indet.*	Fragment bone			X
355	2	–	20	Fauna	*Crocuta crocuta spelaea*	Jaw	yy	Lower Right	
356	3	A	11	Fauna	*Equus ferus*	Metatarsus	a	Right	X
357	3	A	11	Fauna	*Cervus elaphus*	Humerus	a	Left	
358	3	A	11	Fauna	*Cervus elaphus*	Antler	a		X
359	3	A	11	Fauna	*Bos primigenius*	Radius+Ulna	a	Right	
360	3	A	11	Fauna	*Indet.*	Fragment bone			

361	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Lower Left	
362	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Lower Right	
363	5	–		Fauna	*Stephanorhinus hemitoechus*	Molar tooth	a	Lower Left	
364	3	A	11	Fauna	*Bos primigenius*	Metacarpus	a	Left	X
365	5	–		Fauna	*Stephanorhinus hemitoechus*	Molar tooth	a	Lower Right	
366	3	A	11	Fauna	*Indet.*	Vertebrae	yy	Dorsal	
367	2	–	20	Fauna	*Dama dama*	Antler	y		X
368	3	B	11	Fauna	*Bos primigenius*	Atlas	a		X
369	3	B	11	Fauna	*Bos primigenius*	Femur		Left	X
370	3	B	11	Fauna	*Cervus elaphus*	Antler			X
371	3	B	11	Fauna	*Bos primigenius*	Metatarsus	a	Right	X
372	3	B	11	Fauna	*Equus ferus*	Astragalus			
373	3	B	11	Fauna	*Bos primigenius*	Tibia	a	Right	X
374	3	B	11	Fauna	*Bos primigenius*	metacarpus	a	Right	X
375	3	B	11	Fauna	*Cervus elaphus*	Antler			X
376	3	B	11	Fauna	*Cervus elaphus*	Antler			X
377	3	B	11	Fauna	*Bos primigenius*	Calcaneus	a	Right	X
378	3	B	11	Fauna	*Indet.*	Fragment bone			
379	3	B	11	Fauna	*Cervus elaphus*	Tibia	a	Left	
380	3	B	11	Fauna	*Cervus elaphus*	Antler			X
381	3	B	11	Fauna	*Indet.*	Fragment bone			
382	3	B	11	Fauna	*Cervus elaphus*	Antler			X
383	3	B	11	Fauna	*Equus ferus*	Molar tooth	s	Upper Right	
384	3	B	11	Fauna	*Bos primigenius*	Metatarsus	a	Right	X
385	3	B	11	Fauna	*Bos primigenius*	Calcaneus	a	Left	X
386	3	B	11	Fauna	*Bos primigenius*	Metacarpus	a		X

387	3	B	11	Fauna	*Bos primigenius*	Astragalus	a	Right	X
388	3	A	11	Fauna	*Equus ferus*	Molar tooth	a\s	Lower Left	
389	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Lower Left	
390	3	A	11	Fauna	*Equus ferus*	Molar tooth	a	Upper Left	
391	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Upper Right	
392	3	A	11	Fauna	*Equus ferus*	Molar tooth	a	Upper Left	
393	3	A	11	Fauna	*Equus ferus*	Molar tooth	a\s	Upper Right	
394	3	A	11	Fauna	*Bos primigenius*	Molar tooth	a	Lower Right	
395	3	A	11	Fauna	*Cervus elaphus*	Molar tooth	s	Upper Left	
396	3	A	11	Fauna	*Bos primigenius*	Molar tooth			
397	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Lower Left	
398	3	A	11	Fauna	*Equus ferus*	Incisor tooth	s	Lower	
399	3	A	11	Fauna	*Equus ferus*	Canine tooth	a\s		
401	3	A	11	Fauna	*Indet.*	Fragment bone			
402	3	A	11	Fauna	*Bos primigenius*	Radius+Ulna		Left	X
403	3	A	11	Fauna	*Cervus elaphus*	Metacarpus		Left	
404	3	A	11	Fauna	*Indet.*	Fragment bone			
405a	3	A	11	Fauna	*Indet.*	Fragment bone			
405b	3	A	11	Fauna	*Indet.*	Fragment bone			
405c	3	A	11	Fauna	*Bos primigenius*	Calcaneus	a	Right	X
406	3	A	11	Fauna	*Bos primigenius*	Humerus	a	Left	X
407	3	A	11	Fauna	*Bos primigenius*	Tibia	a	Left	X
408	3	A	11	Fauna	*Cervus elaphus*	Antler			
409	3	A	11	Fauna	*Bos primigenius*	Vertebrae	a	Toracic	
410	3	A	11	Fauna	*Equus ferus*	Astragalus			
411	3	A	11	Fauna	*Cervus elaphus*	Antler			X

412	3	A	11	Fauna	*Equus ferus*	Metacarpus	a	Left	X
413	3	A	11	Fauna	*Cervus elaphus*	Antler			X
414	3	A	11	Fauna	*Equus ferus*	Jaw	a	Upper Right	
415	3	A	11	Fauna	*Bos primigenius*	Humerus	a	Right	X
416	3	A	11	Fauna	*Bos primigenius*	Tibia	a	Right	X
417	3	A	11	Fauna	*Bos primigenius*	Molar tooth	s	Lower Right	
418	3	A	11	Fauna	*Bos primigenius*	Femur		Right	X
419	3	A	11	Fauna	*Equus ferus*	Premolar tooth	a	Upper Left	
420	3	A	11	Fauna	*Equus ferus*	Metatarsus	a	Left	X
421	3	A	11	Fauna	*Bos primigenius*	Deciduous Canine tooth	yy	Upper Right	
422a	3	A	11	Fauna	*Equus ferus*	Jaw	s	Lower Right	
422b	3	A	11	Fauna	*Equus ferus*	Jaw	a\s	Lower Left	
424	3	B	11	Fauna	*Crocuta crocuta spelaea*	Canine tooth	y	Upper Left	
426	3	B	11	Fauna	*Bos primigenius*	Molar tooth	a\s		
427	3	B	11	Fauna	*Cervus elaphus*	Premolar tooth	a\s	Upper Right	
429	3	A	11	Fauna	*Cervus elaphus*	Antler	a		X
430	3	A	11	Fauna	*Cervus elaphus*	Antler			X
431	2	–	20	Fauna	*Equus ferus*	Jaw	a	Lower	
432	3	A	11	Fauna	*Bos primigenius*	Humerus	a	Right	X
433	3	A	11	Fauna	*Bos primigenius*	Vertebrae	a	Toracic	
434	5	–		Fauna	*Dama dama*	Humerus	y	Right	
435	5	–		Fauna	*Indet.*	Femur	yy		
436	5	–		Fauna	*Indet.*	Vertebrae	yy		
437	5	–		Fauna	*Indet.*	Phalanges	yy		
438	3	A	11	Fauna	*Cervus elaphus*	Deciduous molar tooth	yy	Lower Left	
439	3	A	11	Fauna	*Bos primigenius*	Deciduous molar tooth	yy	Upper	

440	5	–		Fauna	*Indet.*	Vertebrae	yy	Dorsal	
441	5	–		Fauna	*Indet.*	Vertebrae	yy	Dorsal	
442	5	–		Fauna	*Indet.*	Vertebrae	yy	Dorsal	
443	5	–		Fauna	*Indet.*	Vertebrae	yy	Dorsal	
444	5	–		Fauna	*Indet.*	Vertebrae	yy	Dorsal	
445	5	–		Fauna	*Indet.*	Vertebrae	yy	Lumbar	
446	5	–		Fauna	*Indet.*	Vertebrae	yy	Lumbar	
447	3	A	11	Fauna	*Indet.*	Vertebrae	a	Dorsal	
448	5	–		Fauna	*Dama dama*	Scapula	a	Left	
449	6	–		Fauna	*Cervidae*	Antler			
450	5	–		Fauna	*Indet.*	Vertebrae	yy	Lumbar	
451	5	–		Fauna	*Indet.*	Vertebrae	yy	Cervical	
452	5	–		Fauna	*Indet.*	Vertebrae	yy	Cervical	
453	5	–		Fauna	*Dama dama*	Astragalus	yy	Right	
454	5	–		Fauna	*Indet.*	Costa	yy		
455	5	–		Fauna	*Indet.*	Costa	yy		
456	3	A	11	Fauna	*Dama dama*	Jaw	yy	Lower Left	
457	5	–		Fauna	*Dama dama*	Jaw	yy	Lower	
458	3	A	11	Fauna	*Bos primigenius*	Jaw	s	Lower Right	
459	3	A	11	Fauna	*Bos primigenius*	Humerus	a	Left	X
460	3	A	11	Fauna	*Equus ferus*	Metapodial	a		X
461	3	A	11	Fauna	*Bos primigenius*	Metacarpus	a		X
462	3	A	11	Fauna	*Equus ferus*	Tibia	a	Left	X
463	3	A	11	Fauna	*Equus ferus*	Coxal	a	Left	X
464	3	A	11	Fauna	*Bos primigenius*	Vertebrae	a	Toracic	
465	3	A	11	Fauna	*Equus ferus*	Metatarsus	a	Right	

466	3	A	11	Fauna	*Equus ferus*	Molar tooth			
467	3	A	11	Fauna	*Equus ferus*	Metacarpus	a	Left	X
468	3	A	11	Fauna	*Equus ferus*	Molar tooth	s		
469	3	A	11	Fauna	*Dama dama*	Molar tooth	a	Upper Left	
470	3	A	11	Fauna	*Dama dama*	Molar tooth	a	Upper Left	
471	3	A	11	Fauna	*Bos primigenius*	Deciduous molar tooth	y	Lower Right	
472	3	A	11	Fauna	*Equus ferus*	Incisor tooth	a	Lower	
473	3	A	11	Fauna	*Equus ferus*	Incisor tooth	a	Lower Left	
480	3	A	11	Fauna	*Dama dama*	Antler			X
481	3	A	11	Fauna	*Cervus elaphus*	Antler			X
482	3	A	11	Fauna	*Dama dama*	Humerus	a	Right	X
483	3	A	11	Fauna	*Indet.*	Femur	yy	Right	
484	3	A	11	Fauna	*Lepus sp.*	Coxal		Right	
485	3	A	11	Fauna	*Cervus elaphus*	Jaw	y	Upper Right	
486	3	A	11	Fauna	*Crocuta crocuta spelaea*	Jaw	yy	Upper Left	
487	3	A	11	Fauna	*Bos primigenius*	Astragalus		Right	X
488	3	A	11	Fauna	*Bos primigenius*	Astragalus			X
489	3	A	11	Fauna	*Equus ferus*	Navicolare	a	Left	
490	3	A	11	Fauna	*Bos Primigenius*	Scapula	a	Left	X
491	3	A	11	Fauna	*Cervus elaphus*	Radius	a	Left	X
492	3	A	11	Fauna	*Equus ferus*	Calcaneus	a	Right	X
493	3	A	11	Fauna	*Cervus elaphus*	Antler	a		
494	3	B	11	Fauna	*Bos primigenius*	Jaw	a\s	Lower Right	
495	1	–		Fauna	*Dama dama*	Jaw	y	Lower Left	
496	3	A	11	Fauna	*Equus ferus*	Radius+ulna	a	Left	X
501	3	A	11	Fauna	*Cervus elaphus*	Premolar tooth	s	Upper Right	

502	3	A	11	Fauna	*Equus ferus*	Molar tooth	a	Lower Right	
503	3	A	11	Fauna	*Equus ferus*	Molar tooth	a	Upper Left	
509	3	A	11	Fauna	*Bos primigenius*	Astragalus	a	Right	X
510	3	B	11	Fauna	*Bos primigenius*	Deciduous molar tooth	y	Upper Left	
511	3	A	11	Fauna	*Equus ferus*	I Phalanx	a	Left	
512	3	A	11	Fauna	*Equus ferus*	Molar tooth	a	Upper Left	
513	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Lower Left	
514	3	A	11	Fauna	*Indet.*	Fragment bone			
515	3	A	11	Fauna	*Indet.*	Fragment bone			
516	3	A	11	Fauna	*Indet.*	Fragment bone			
517	3	A	11	Fauna	*Indet.*	Fragment bone			
518	3	A	11	Fauna	*Indet.*	Fragment bone			
519	3	A	11	Fauna	*Bos primigenius*	Radius+Ulna	a		
521	3	B	11	Fauna	*Bos primigenius*	Molar tooth	y\a	Lower Right	
523	3	A	11	Fauna	*Crocuta crocuta spelaea*	Deciduous canine tooth	yy		
525	3	A	11	Fauna	*Dama dama*	Metacarpus			
526	3	A	11	Fauna	*Indet.*	Phalanges			
527	3	A	11	Fauna	*Indet.*	Fragment bone			
528	3	A	11	Fauna	*Equus ferus*	II Phalanx	a		X
529	3	A	11	Fauna	*Indet.*	Fragment bone			
530	3	B	11	Fauna	*Equus ferus*	Molar tooth	s	Upper Right	
531	3	B	11	Fauna	*Equus ferus*	Metapodial	a		X
532	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Upper Left	
533	3	A	11	Fauna	*Equus ferus*	Metapodial	a		X
534	3	A	11	Fauna	*Cervus elaphus*	Jaw	s	Lower Right	
535	3	A	11	Fauna	*Cervus elaphus*	Metacarpus			X

536	3	A	11	Fauna	*Equus ferus*	Metapodial	a		X
537	3	A	11	Fauna	*Cervus elaphus*	Antler			X
538	3	A	11	Fauna	*Cervus elaphus*	Antler			X
539	3	A	11	Fauna	*Equus ferus*	Molar tooth	s	Upper	
540	3	A	11	Fauna	*Cervus elaphus*	Molar tooth	a	Lower Right	
541	3	A	11	Fauna	*Equus ferus*	Jaw	s	Upper Left	
543	3	–		Fauna	*Cervus elaphus*	Antler	a		
544	3	A	11	Fauna	*Bos primigenius*	Metacarpus	a	Right	X
545	3	A	11	Fauna	*Equus ferus*	Pelvis	a		
546	3	A	11	Fauna	*Equus ferus*	Pelvis	a		
547	3	A	11	Fauna	*Equus ferus*	Pelvis	a		
548	3	A	11	Fauna	*Dama dama*	Metacarpus			X
549	3	B	11	Fauna	*Equus ferus*	Molar tooth	a	Lower Right	
550	3	B	11	Fauna	*Bos primigenius*	Tibia			X
551	3	B	11	Fauna	*Equus ferus*	Molar tooth	s	Upper Left	
552	3	B	11	Fauna	*Bos primigenius*	Incisor tooth	yy	Lower	
553	3	B	11	Fauna	*Cervus elaphus*	Antler			X
554	3	B	11	Fauna	*Bos primigenius*	Tibia	a	Right	X
555	3	A	11	Fauna	*Cervidae*	Antler			X
556	3	A	11	Fauna	*Bos primigenius*	Calcaneus	a	Left	X
557	3	B	11	Fauna	*Crocuta crocuta spelaea*	Canine tooth	a	Upper Left	
558	3	B	11	Fauna	*Equus ferus*	Incisor tooth	a\s	Lower	
559	3	B	11	Fauna	*Equus ferus*	Premolar tooth	s	Upper Right	
560	3	B	11	Fauna	*Cervus elaphus*	Antler			X
561	3	A	11	Fauna	*Bos primigenius*	Coxal	a	Left	
562	3	B	11	Fauna	*Indet.*	Fragment bone			

563	3	B	11	Fauna	*Indet.*	Fragment bone			
565	3	B	11	Fauna	*Indet.*	Fragment bone			
566	3	B	11	Fauna	*Equus ferus*	Molar tooth	a	Lower Left	
567	3	A	11	Fauna	*Equus ferus*	Molar tooth	a\s	Upper Left	
568	3	A	11	Fauna	*Indet.*	Vertebrae			
570	3	A	11	Fauna	*Bos primigenius*	Jaw	y	Lower Right	
571	3	A	11	Fauna	*Bos primigenius*	Astragalus	a	Right	
572	3	A	11	Fauna	*Bos primigenius*	Radius+Ulna	a	Right	
581	3	B	11	Fauna	*Equus ferus*	Deciduous Molar tooth	yy		
582	3	B	11	Fauna	*Meles meles*	Tibia	y	Left	
583	3	B	11	Fauna	*Cervus elaphus*	P4	s	Upper Right	
584	3	B	11	Fauna	*Bos primigenius*	Deciduous Molar tooth	yy	Upper Left	
586	3	A	11	Fauna	*Bos primigenius*	Metatarsus	a		X
587	3	A	11	Fauna	*Bos primigenius*	Femur	a	Left	X
588	3	A	11	Fauna	*Indet.*	Vertebrae	a		
589	3	A	11	Fauna	*Indet.*	Vertebrae	a		
590	3	A	11	Fauna	*Indet.*	Vertebrae	a		
591	3	A		Fauna	*Bos primigenius*	metatarsus	a		
592	3	A	11	Fauna	*Bos primigenius*	Radius+Ulna	a		X
593	3	A	11	Fauna	*Cervus elaphus*	Metapodial			X
594	3	A	11	Fauna	*Indet.*	Radius+Ulna	a		
595	3	A	11	Fauna	*Bos primigenius*	Metatarsus	a		
596	3	A	11	Fauna	*Bos primigenius*	Tibia	a	Right	
597	3	A	11	Fauna	*Bos primigenius*	Tibia	y\a	Right	
598	3	A	11	Fauna	*Bos primigenius*	Metacarpus			
599	3	A	11	Fauna	*Cervus elaphus*	Metatarsus			

600	3	A	11	Fauna	*Cervidae*	Metatarsus			
601	3	A	11	Fauna	*Indet.*	Metapodial			X
602	3	A	11	Fauna	*Cervus elaphus*	Antler			
603	3	A	11	Fauna	*Bos primigenius*	Calcaneus	a		
604	3	A	11	Fauna	*Bos primigenius*	Radius	a	Left	
605	3	A	11	Fauna	*Bos primigenius*	Humerus	a	Left	
606	3	A	11	Fauna	*Equus ferus*	Coxal	a	Left	
607	3	A	11	Fauna	*Equus ferus*	Coxal	a		
608	3	B	11	Fauna	*Bos primigenius*	Humerus	a	Left	
609	3	A	11	Fauna	*Equus ferus*	Calcaneus	a	Left	
610	3	B	11	Fauna	*Bos primigenius*	Ulna	a		
611	3	A	11	Fauna	*Bos primigenius*	Metatarsus	a	Right	X
612	3	A	11	Fauna	*Cervus elaphus*	Humerus	a	Left	
613	3	A	11	Fauna	*Equus ferus*	Metapodial	a		X
614	3	A	11	Fauna	*Bos primigenius*	Coxal	a	Right	
615	3	B	11	Fauna	*Dama dama*	Radius			
616	3	A	11	Fauna	*Equus ferus*	Astragalus		Right	X
617	3	A	11	Fauna	*Indet.*	Coxal			
618	3	B	11	Fauna	*Equus ferus*	Femur		Right	
619	3	A	11	Fauna	*Bos primigenius*	Humerus			
620	3	A	11	Fauna	*Cervus elaphus*	Metapodial			
621	3	B	11	Fauna	*Bos primigenius*	Metatarsus			
622	3	A	11	Fauna	*Cervidae*	Antler			X
623	3	B	11	Fauna	*Bos primigenius*	Molar tooth			
624	3	B	11	Fauna	*Crocuta crocuta spelaea*	Metapodial			
625	3	B	11	Fauna	*Canis lupus*	Metacarpus			

626	3	A	11	Fauna	*Bos primigenius*	Tibia	a	Right	
627	3	A	11	Fauna	*Equus ferus*	Coxal		Left	X
628	3	A	11	Fauna	*Bos primigenius*	Radius		Left	
629	3	A	11	Fauna	*Equus ferus*	Astragalus		Left	
630	3	A	11	Fauna	*Bos primigenius*	Metapodial			
631	3	B	11	Fauna	*Bos primigenius*	Metatarsus			X
632	3	B	11	Fauna	*Crocuta crocuta spelaea*	Humerus		Left	
633	3	A	11	Fauna	*Equus ferus*	Coxal		Right	X
634	3	–		Fauna	*Bos primigenius*	Femur			X
635	3	–		Fauna	*Dama dama*	Metatarsus			
636	3	–		Fauna	*Bos primigenius*	Radius+Ulna			X
637	3	–		Fauna	*Bos primigenius*	Radius+Ulna			X
638	3	–		Fauna	*Bos primigenius*	Humerus			X
639	3	–		Fauna	*Bos primigenius*	Vertebrae	y\a		
640	3	–		Fauna	*Dama dama*	Metatarsus			
641	3	A	11	Fauna	*Crocuta crocuta spelaea*	Skull			
642	3	–		Fauna	*Bos primigenius*	Metacarpus		Left	
643	3	A	11	Fauna	*Indet.*	Fragment bone			X
644	3	A	11	Fauna	*Bos primigenius*	Ulna			
645	3	A	11	Fauna	*Stephanorhinus hemitoechus*	Molar tooth	y	Lower	
647	3	–		Fauna	*Bos primigenius*	Tibia		Right	
648	3	–		Fauna	*Bos primigenius*	Femur		Left	
649	3	C		Fauna	*Bos primigenius*	Calcaneus		Right	
650	3	–		Fauna	*Bos primigenius*	Humerus		Left	X
651	3	C		Fauna	*Bos primigenius*	Humerus		Right	X
652	3	–		Fauna	*Bos primigenius*	Femur		Left	X

654	3	C		Fauna	*Bos primigenius*	Metatarsus			X
655	3	–		Fauna	*Equus ferus*	Radius		Right	
656	3	C		Fauna	*Bos primigenius*	Metatarsus		Right	
657	3	C		Fauna	*Bos primigenius*	Radius		Right	X
658	3	A	11	Fauna	*Bos primigenius*	Radius		Left	X
659	3	A	11	Fauna	*Cervus elaphus*	Metacarpus			
660	3	A	11	Fauna	*Cervidae*	Metapodial			
661	3	A	11	Fauna	*Equus ferus*	Calcaneus			X
662	3	A	11	Fauna	*Bos primigenius*	Femur		Right	X
663	3	A	11	Fauna	*Bos primigenius*	Metatarsus		Left	X
664	3	A	11	Fauna	*Bos primigenius*	Metacarpus		Left	X
665	3	A	11	Fauna	*Cervus elaphus*	Femur	y	Left	X
666	3	A	11	Fauna	*Bos primigenius*	Coxal		Right	X
667	3	A	11	Fauna	*Cervus elaphus*	Metatarsus		Right	X
668	3	A	11	Fauna	*Lepus sp.*	Femur		Right	
669	3	A	11	Fauna	*Bos primigenius*	Femur		Left	X
670	3	A	11	Fauna	*Bos primigenius*	Metacarpus			
671	3	A	11	Fauna	*Bos primigenius*	Tibia		Left	
672	3	–		Fauna	*Dama dama*	Antler			X
673	3	A	11	Fauna	*Bos primigenius*	I Phalanx	s		X
674	3	A	11	Fauna	*Bos primigenius*	Metapodial			X
675	3	A	11	Fauna	*Bos primigenius*	Tibia		Right	X
676	3	A	11	Fauna	*Bos primigenius*	Metatarsus		Right	X
677	3	A	11	Fauna	*Equus ferus*	Metatarsus			X
678	3	A	11	Fauna	*Cervus elaphus*	Radius		Right	X
679	4			Fauna	*Dama dama*	Femur		Right	X

680	4	–		Fauna	*Bos primigenius*	Humerus	Left	X
681	3	A	11	Fauna	*Bos primigenius*	Scapula		
682	4	–		Fauna	*Bos primigenius*	Radius	Left	X
683	4	–		Fauna	*Cervus elaphus*	Metatarsus	Right	X
684	3	A	11	Fauna	*Bos primigenius*	Humerus	Left	X
685	4	–		Fauna	*Dama dama*	Tibia	Right	X
686	3	A	11	Fauna	*Bos primigenius*	Humerus	Right	X
687	4	–		Fauna	*Bos primigenius*	Metacarpus	Left	
688	3	A	11	Fauna	*Bos primigenius*	Vertebrae		
689	3	A	11	Fauna	*Bos primigenius*	Jaw	Lower Left	X
690	3	A	11	Fauna	*Bos primigenius*	Humerus	Left	X
691	3	A	11	Fauna	*Cervus elaphus*	Skull	Right	
692	3	A	11	Fauna	*Bos primigenius*	Humerus	Left	X
693	3	A	11	Fauna	*Bos primigenius*	Calcaneus	Left	X
694	3	–		Fauna	*Bos primigenius*	Metatarsus	Right	X
695	3	–		Fauna	*Equus ferus*	Metatarsus	Right	X
696	4	–		Fauna	*Cervus elaphus*	Metacarpus		
697	3	–		Fauna	*Equus ferus*	Jaw	Lower	
698	3	–		Fauna	*Bos primigenius*	Metatarsus		X
699	3	A	11	Fauna	*Bos primigenius*	Humerus	Right	X
700	3	–		Fauna	*Bos primigenius*	Tibia	Left	X
701	3	A	11	Fauna	*Bos primigenius*	jaw	Lower Right	
702	3	A	11	Fauna	*Dama dama*	Tibia	Left	X
703	3	A	11	Fauna	*Bos primigenius*	Metatarsus	Left	X
704	3	A	11	Fauna	*Bos primigenius*	Metatarsus	Right	X
705	3	A	11	Fauna	*Bos primigenius*	Metatarsus		X

706	3	A	11	Fauna	*Equus ferus*	Coxal		Left	X
707	3	A	11	Fauna	*Bos primigenius*	Metapodial			X
708	3	A	11	Fauna	*Bos primigenius*	Metapodial			X
709	2	–		Fauna	*Bos primigenius*	Humerus			X
710	3	A	11	Fauna	*Equus ferus*	Humerus		Right	X
711	3	A	11	Fauna	*Cervus elaphus*	Radius		Left	X
712	3	A	11	Fauna	*Bos primigenius*	Metacarpus		Left	X
713	2	–		Fauna	*Bos primigenius*	Petrous bone			
714	2	–		Fauna	*Bos primigenius*	Metacarpus		Right	X
715	3	A	11	Fauna	*Equus ferus*	Calcaneus		Right	X
716	3	A	11	Fauna	*Bos primigenius*	Metapodial			X
717	3	A	11	Fauna	*Bos primigenius*	Femur		Left	X
718	2	–		Fauna	*Bos primigenius*	Radius		Left	X
719	2	–		Fauna	*Bos primigenius*	Vertebrae			X
720	2	–		Fauna	*Bos primigenius*	Metapodial			X
721	3	A	11	Fauna	*Bos primigenius*	Radius		Left	X
722	3	A	11	Fauna	*Bos primigenius*	Coxal		Right	X
842	4	–		Fauna	*Stephanorhinus hemitoechus*	Femur	y		
863	3	–		Fauna	*Bos primigenius*	M2	a	Upper	
864	3	–		Fauna	*Cervus elaphus*	Premolar tooth	a	Upper	
865	3	–		Fauna	*Equus ferus*	P3/4	a	Lower Right	
866	3	–		Fauna	*Equus ferus*	M1/2	a	Upper Left	
867	3	–		Fauna	*Dama dama*	M2	a	Upper	
869	3	–		Fauna	*Dama dama*	M1	a	Lower	
870	3	–		Fauna	*Equus ferus*	Incisor tooth	a	Upper Left	
871	3	–		Fauna	*Bos primigenius*	Premolar tooth	a	Upper	
872	3	–		Fauna	*Bos primigenius*	Premolar tooth	a	Upper	

873	3	–		Fauna	*Dama dama*	M1/2	a	Lower	
908	3	A	11	Fauna	*Equus ferus*	I incisor	a		
910	3	A	11	Fauna	*Cervus elaphus*	Molar tooth	y\a	Upper Right	
911	3	A	11	Fauna	*Cervus elaphus*	jaw	a	Right	
912	3	A	11	Fauna	*Bos primigenius*	Molar tooth	a	Upper Left	
913	3	A	11	Fauna	*Cervus elaphus*	Molar tooth	a	Upper Right	
914	3	A	11	Fauna	*Cervus elaphus*	Jaw	a	Right	
915	3	A	11	Fauna	*Dama dama*	Molar tooth	a	Lower Right	
916	3	A	11	Fauna	*Equus ferus*	Molar tooth	a	Lower Right	
918	3	A	11	Fauna	*Equus ferus*	Molar tooth	y\a	Upper Right	
919	3	A	11	Fauna	*Equus ferus*	Molar tooth	y\a	Upper Right	
920	3	A	11	Fauna	*Equus ferus*	Molar tooth	a	Lower Left	
921	3	A	11	Fauna	*Bos primigenius*	Molar tooth	a	Upper Left	
922	3	A	11	Fauna	*Equus ferus*	Molar tooth	a	Upper Left	
923	3	A	11	Fauna	*Cervus elaphus*	jaw	a	Right	
924	3	–		Fauna	*Bos primigenius*	Tibia	a	Left	X
925	3	–		Fauna	*Cervus elaphus*	Metatarsus	a	Left	
926	3	–		Fauna	*Cervus elaphus*	Antler	a	Left	X
927	3	–		Fauna	*Cervus elaphus*	Metatarsus	a		
928	3	–		Fauna	*Equus ferus*	M3	a	Lower Left	
929	3	–		Fauna	*Cervus elaphus*	M1	a	Upper	
930	3	–		Fauna	*Equus ferus*	Metapodial	a		X
931	3	–		Fauna	*Bos primigenius*	Coxal	y	Right	
932	3	–		Fauna	*Equus ferus*	Metapodial	a		X
933	3	–		Fauna	*Equus ferus*	P3	a	Upper Right	
934	3	–		Fauna	*Cervus elaphus*	M1	y	Upper	
935	3	–		Fauna	*Dama dama*	P2	y	Lower	
936	3	–		Fauna	*Cervidae*	Premolar tooth	a		

937	3	–	Fauna	*Equus ferus*	M1/2	a	Upper Right	
938	3	–	Fauna	*Equus ferus*	P3/4	a	Upper Left	
939	3	–	Fauna	*Equus ferus*	II Phalanx	a		X
940	3	–	Fauna	*Bos primigenius*	M1/2	a	Lower	
941	3	–	Fauna	*Equus ferus*	P3/4	a	Upper Right	
942	3	–	Fauna	*Bos primigenius*	Femur	a		
943	3	–	Fauna	*Cervus elaphus*	Metatarsus	a	Right	X
944	3	–	Fauna	*Bos primigenius*	Third molar tooth	a	Lower Left	
946	3	–	Fauna	*Sus scrofa*	Mandible	y	Lower Left	X
947	3	–	Fauna	*Cervus elaphus*	Antler	a	Right	
948	3	–	Fauna	*Bos primigenius*	Skull	a		
949	3	–	Fauna	*Cervus elaphus*	Premolar tooth	a	Lower Left	
950	3	–	Fauna	*Bos primigenius*	Molar tooth	y	Upper Left	
952	3	–	Fauna	*Dama dama*	Molar tooth	a	Upper Right	
953	3	–	Fauna	*Dama dama*	M2	a	Upper	
954	3	–	Fauna	*Cervus elaphus*	Premolar tooth	a	Lower	
955	3	–	Fauna	*Equus ferus*	P4	yy	Lower	
956	3	–	Fauna	*Cervus elaphus*	M2	y	Upper	
957	3	–	Fauna	*Bos primigenius*	Jaw	a	Left	
959	3	–	Fauna	*Equus ferus*	Incisor tooth	a		
960	3	–	Fauna	*Cervidae*	Atlas	a		
961	3	–	Fauna	*Equus ferus*	Metapodial	a		
962	3	–	Fauna	*Bos primigenius*	Molar tooth	a	Upper Right	
963	3	–	Fauna	*Cervus elaphus*	Premolar tooth	a	Upper	
964	3	–	Fauna	*Equus ferus*	M1/2	a	Lower Left	
965	3	–	Fauna	*Dama dama*	Premolar tooth	a	Upper	
966	3	–	Fauna	*Equus ferus*	Incisor tooth	a\s	Lower Right	
970	4	–	fauna	*Cervus elaphus*	tibia	y	Right	

971	4	–	Fauna		Vertebrae			
972	4	–	Fauna		Vertebrae			
973	4	–	Fauna	*Sus scrofa*	Calcaneus		Right	
974	4	–	Fauna	*Sus scrofa*	Calcaneus		Right	
975	4	–	Fauna	*Cervus elaphus*	II Phalanx		Left	
976	4	–	Fauna	*Cervus elaphus*	I Phalanx		Left	
977	4	–	Fauna	*Cervus elaphus*	I Phalanx		Left	
978	4	–	Fauna	*Cervus elaphus*	III Phalanx	y	Left	
979	4	–	Fauna	*Sus scrofa*	Ulna		Left	
980	4	–	Fauna	*Cervus elaphus*	Radius		Left	
981	4	–	Fauna	*Cervus elaphus*	radius	y	Right	
982	4	–	Fauna	*Lepus sp.*	radius		Right	
983	4	–	fauna	*Bos primigenius*	Patella		Right	
984	4	–	Fauna	*Cervus elaphus*	Metatarsus			
985	4	–	Fauna	*Cervus elaphus*	Metatarsus	y		
986	4	–	fauna	*Cervus elaphus*	Metatarsus	y		
987	4	–	Fauna	*Dama Dama*	Metacarpus		Left	
988	4	–	Fauna	*Cervus elaphus*	Metacarpus	y	Left	
989	4	–	Fauna	*Cervus elaphus*	Metatarsus	y	Right	
990	4	–	Fauna	*Cervus elaphus*	I Phalanx	y	Left	
991	4	–	Fauna	*Cervus elaphus*	Incisor tooth			
992	4	–	Fauna	*Dama Dama*	Molar tooth	y		
993	4	–	Fauna	*Dama Dama*	I molar			
994	4	–	Fauna	*Dama Dama*	Molar tooth			
995	3	–	Fauna	*Bos primigenius*	Horn			X
996	3	–	Fauna	*Bos primigenius*	Metatarsus	a	Left	X
997	3	–	Fauna	*Bos primigenius*	Metatarsus	a	Left	
998	3	–	Fauna	*Bos primigenius*	III Cervical Vertebrae	a		

999	3	–	Fauna	*Bos primigenius*	Metatarsus	a	Right	X
1000	3	–	Fauna	*Indet.*	Vertebrae			
1001	3	–	Fauna	*Indet.*	Costa			
1002	3	–	Fauna	*Equus ferus*	Radius	a	Left	X
1003	3	–	Fauna	*Equus ferus*	Tibia	a	Left	X
1004	3	–	Fauna	*Bos primigenius*	Tibia	a	Right	X
1005	3	–	Fauna	*Cervus elaphus*	Antler			X
1006	3	–	Fauna	*Cervus elaphus*	Metatarsus	a	Left	
1007	3	–	Fauna	*Cervus elaphus*	Metatarsus	a	Left	X
1008	3	–	Fauna	*Cervus elaphus*	Radius	a	Right	
1009	3	–	Fauna	*Equus ferus*	Incisor tooth	y\a	Lower Left	
1010	3	–	Fauna	*Cervus elaphus*	Antler	a	Right	
1011	3	–	Fauna	*Bos primigenius*	Astragalus	a	Right	X
1012	3	–	Fauna	*Cervidae*	Antler	a	Left	
1013	3	–	Fauna	*Cervus elaphus*	Antler	a	Right	
1014	3	–	Fauna	*Bos primigenius*	Pelvis			
1015	3	–	Fauna	*Bos primigenius*	Coxal	a		X
1016	3	–	Fauna	*Bos primigenius*	Calcaneus	a	Right	X
1017	3	–	Fauna	*Cervidae*	Frontal and pedicle antler	a	Right	
1018	3	–	Fauna	*Cervus elaphus*	Frontal and pedicle antler	a	Left	X
1019	3	–	Fauna	*Bos primigenius*	Humerus	a	Right	
1020	3	–	Fauna	*Bos primigenius*	Humerus	a	Left	
1021	3	–	Fauna	*Dama Dama*	Antler	a		X
1022	3	–	Fauna	*Bos primigenius*	Metacarpus	a	Right	X
1022 (BIS)	3	–	Fauna	*Dama Dama*	Metatarsus	a	Left	
1023	3	–	Fauna	*Equus ferus*	Coxal	a	Right	
1024	3	–	Fauna	*Bos primigenius*	Epistropheus	y\a		
1024 (BIS)	3	–	Fauna	*Bos primigenius*	Tibia	a	Right	

1025	3	–		Fauna	*Bos primigenius*	Tibia	a	Left	X
1025 (BIS)	3	–		Fauna	*Cervus elaphus*	Tibia	a	Left	
1026	3	–		Fauna	*Cervus elaphus*	Tibia		Left	
1027	3	–		Fauna	*Bos primigenius*	Metacarpus	a	Left	
1028	3	–		Fauna	*Bos primigenius*	Coxal			X
1029	3	–		Fauna	*Bos primigenius*	Tibia		Right	
1030	3	–		Fauna	*Bos primigenius*	Metatarsus	a	Left	
1031	3	–		Fauna	*Cervus elaphus*	Metatarsus			X
1032	3	–		Fauna	*Equus ferus*	Femur	a	Right	X
1033	3	A	11	Fauna	*Equus ferus*	Jaw	a	Upper Left	
1034	3	A	11	Fauna	*Bos primigenius*	Tibia	y	Right	
1035	3	A	11	Fauna	*Cervus elaphus*	jaw	a	Right	X
1035 bis	3	A	11	Fauna	*Bos primigenius*	Central tarsal bone	a	Left	
1036	3	A	11	Fauna	*Equus ferus*	Third molar tooth	a	Upper Left	
1037	3	A	11	Fauna	*Cervus elaphus*	Jaw	a	Right	
1038	3	A	11	Fauna	*Cervus elaphus*	Jaw	a	Left	
1039	3	A	11	Fauna	*Capreolus Capreolus*	Molar tooth		Lower	X
1040	3	A	11	Fauna	*Cervus elaphus*	jaw	a	Left	
1041	3	A	11	Fauna	*Bos primigenius*	Molar tooth	a	Upper Right	
1042	3	A	11	Fauna	*Bos primigenius*	Molar tooth		Upper	
1043	3	A	11	Fauna	*Bos primigenius*	Molar tooth		Upper	
1044	3	A	11	Fauna	*Bos primigenius*	Third molar tooth	a	Lower Left	
1045	3	A	11	Fauna	*Cervus elaphus*	Third molar tooth	a	Lower Left	
1046	3	A	11	Fauna	*Equus ferus*	Molar tooth	a		
1047	3	A	11	Fauna	*Bos primigenius*	Molar tooth	a	Upper Right	
1048	3	A	11	Fauna	*Equus ferus*	Molar tooth	a	Lower Left	
1049	3	A	11	Fauna	*Equus ferus*	Molar tooth	a	Upper	
1050	7	A		Fauna	*Cervus elaphus*	Radius		Left	X

1051	7	–	Fauna	*Cervus elaphus*	Metatarsus		Left
1052	7	–	Fauna	*Lepus sp.*	Tibia		Right
1053	7	–	Fauna	*Cervus elaphus*	Metatarsus	y	Left
1054	7	–	Fauna	*Cervus elaphus*	III Phalanx		
1055	7	–	Fauna	*Cervus elaphus*	I Phalanx		
1056	7	–	Fauna	*Cervus elaphus*	I Phalanx		
1057	7	–	Fauna	*Cervus elaphus*	II Phalanx		
1058	7	–	Fauna	*Cervus elaphus*	II Phalanx		
1059	7	–	Fauna	*Cervus elaphus*	II Phalanx		
1060	7	–	Fauna	*Cervus elaphus*	II Phalanx		
1061	7	–	Fauna	*Dama Dama*	II Phalanx		
1062	7	–	Fauna	*Dama Dama*	II Phalanx		
1063	7	–	Fauna	*Dama Dama*	II Phalanx		
1064	7	–	Fauna	*Dama Dama*	II Phalanx		
1065	7	–	Fauna	*Lepus sp.*	I Phalanx		
1066	7	–	Fauna	*Cervus elaphus*	Metapodial	y	
1067	7	–	Fauna	*Cervus elaphus*	Metapodial	y	
1068	7	–	Fauna	*Cervus elaphus*	Metapodial	y	
1069	7	–	Fauna	*Cervus elaphus*	Metapodial	y	
1070	7	–	Fauna	*Cervus elaphus*	Metapodial	y	
1071	7	–	Fauna	*Cervus elaphus*	Metapodial		
1072	7	–	Fauna	*Dama Dama*	Metatarsus		
1073	7	–	Fauna	*Indet.*	Costa		
1074	7	–	Fauna	*Indet.*	Tibia		
1075	7	–	Fauna	*Indet.*	Humerus		
1076	7	–	Fauna	*Lepus sp.*	Metacarpus		Right
1077	7	–	Fauna	*Lepus sp.*	Tibia		Right
1078	7	–	Fauna	*Lepus sp.*	I Phalanx		

1079	7	–	Fauna	*Cervus elaphus*	Femur	y	Left	
1080	7	–	Fauna	*Cervus elaphus*	Humerus		Left	
1081	7	–	Fauna	*Cervus elaphus*	I Phalanx			
1082	7	–	Fauna	*Cervus elaphus*	radius		Left	
1083	7	–	Fauna	*Cervus elaphus*	Calcaneus		Left	
1084	7	–	Fauna	*Equus ferus*	Patella			
1085	7	–	Fauna	*Cervus elaphus*	Humerus	y		
1086	7	–	Fauna	*Indet.*	Indet.	y		
1087	7	–	Fauna	*Dama dama*	M3			
1088	7	–	Fauna	*Dama dama*	M2			
1089	7	–	Fauna	*Dama dama*	M1+P3 inferior + frag mand			
1090	7	–	Fauna	*Cervus elaphus*	M3 Inferior + frag mand			
1091	7	–	Fauna	*Cervus elaphus*	Molar tooth			
1092	7	–	Fauna	*Cervus elaphus*	Premolar tooth			
1093	7	–	Fauna	*Cervus elaphus*	Premolar tooth			
1094	7	–	Fauna	*Cervus elaphus*	Premolar tooth			
1095	7	–	Fauna	*Cervus elaphus*	Molar tooth			
1096	7	–	Fauna	*Equus ferus*	Premolar tooth			
1097	7	–	Fauna	*Cervus elaphus*	Ulna			X
1098	7	–	Fauna	*Cervus elaphus*	Metapodial	y		
1099	7	–	Fauna	*Indet.*	Costa			
1100	7	–	Fauna	*Equus ferus*	Molar tooth			
1101	7	–	Fauna	*Crocuta crocuta spelaea*	M3		Right	
1102	7	–	Fauna	*Crocuta crocuta spelaea*	Premolar tooth			
1103	7	–	Fauna	*Capreolus Capreolus*	M3			
1104	7	–	Fauna	*Capreolus Capreolus*	Premolar tooth			
1105	7	–	Fauna	*Dama Dama*	Metatarsus	y		
1106	7	–	Fauna	*Capreolus Capreolus*	Premolar tooth			

1601	3	–		Fauna	*Equus ferus*	Calcaneus	a	Left	X
1931	3	–		Fauna	*Bos primigenius*	Metatarsus	a	Left	
1510a	3	A	11	Fauna	*Bos primigenius*	Molar tooth	a	Lower Right	
1510b	3	A	11	Fauna	*Bos primigenius*	Central tarsal bone	a	Left	
1530	3	A	11	Fauna	*Equus ferus*	Molar tooth	a	Lower Left	
1531	3	A	11	Fauna	*Bos primigenius*	Metatarsus		Right	X
1532	3	A	11	Fauna	*Bos primigenius*	Metatarsus		Left	X

Appendix D. Database of the small vertebrates from Cava Muracci (Cisterna di Latina, Italy).

# Find	*Area*	*Sector*	*SU*	*Type*	*Taxon*	*Body Part*
CIS16/1110	3	B	11	Small vertebrates	Osteichthyes indet.	Vertebrae
CIS16/1111	3	B	11	Small vertebrates	*Bufo bufo*	Vertebrae
CIS16/1112	3	B	11	Small vertebrates	*Bufotes* gr. *B. viridis*	Urostyle
CIS16/1113	3	B	11	Small vertebrates	*Rana* (*s.l.*) sp.1	Maxilla
CIS16/1114	3	B	11	Small vertebrates	*Rana* (*s.l.*) sp.1	Humerus
CIS16/1115	3	B	11	Small vertebrates	*Rana* (*s.l.*) sp.1	Urostyle
CIS16/1116	3	B	11	Small vertebrates	*Rana* (*s.l.*) sp.2	Humerus
CIS16/1117	3	B	11	Small vertebrates	*Podarci*s sp.	Mandible
CIS16/1118	3	B	11	Small vertebrates	*Podarci*s sp.	Vertebrae
CIS16/1119	3	B	11	Small vertebrates	*Podarci*s sp.	Vertebrae
CIS16/1120	3	B	11	Small vertebrates	*Podarci*s sp.	Vertebrae
CIS16/1121	3	B	11	Small vertebrates	*Podarci*s sp.	Vertebrae
CIS16/1122	3	B	12	Small vertebrates	*Podarci*s sp.	Vertebrae
CIS16/1123	3	B	11	Small vertebrates	*Anguis veronensis*	Vertebrae
CIS16/1124	3	B	11	Small vertebrates	*Anguis veronensis*	Vertebrae
CIS16/1125	3	B	11	Small vertebrates	*Anguis veronensis*	Vertebrae
CIS16/1126	3	B	11	Small vertebrates	*Anguis veronensis*	Vertebrae
CIS16/1127	3	B	11	Small vertebrates	*Anguis veronensis*	Vertebrae
CIS16/1128	3	B	11	Small vertebrates	*Anguis veronensis*	Vertebrae
CIS16/1129	3	B	11	Small vertebrates	*Natrix natrix*	Vertebrae
CIS16/1130	3	B	11	Small vertebrates	*Natrix natrix*	Vertebrae
CIS16/1131	3	B	11	Small vertebrates	*Natrix natrix*	Vertebrae
CIS16/1132	3	B	11	Small vertebrates	*Natrix natrix*	Vertebrae
CIS16/1133	3	B	11	Small vertebrates	*Natrix natrix*	Vertebrae
CIS16/1134	3	B	11	Small vertebrates	*Hierophis viridiflavus*	Vertebrae

CIS16/1135	3	B	11	Small vertebrates	*Arvicola amphibius*	Mandible
CIS16/1136	3	B	11	Small vertebrates	*Arvicola amphibius*	Mandible
CIS16/1137	3	B	11	Small vertebrates	*Arvicola amphibius*	Mandible
CIS16/1138	3	B	12	Small vertebrates	*Arvicola amphibius*	Mandible
CIS16/1139	3	B	12	Small vertebrates	*Arvicola amphibius*	Mandible
CIS16/1140	3	B	12	Small vertebrates	*Arvicola amphibius*	Mandible
CIS16/1141	3	B	12	Small vertebrates	*Arvicola amphibius*	Mandible
CIS16/1142	3	B	12	Small vertebrates	*Arvicola amphibius*	m1
CIS16/1143	3	B	12	Small vertebrates	*Arvicola amphibius*	m1
CIS16/1144	3	B	12	Small vertebrates	*Arvicola amphibius*	m1
CIS16/1145	3	B	12	Small vertebrates	*Arvicola amphibius*	m1
CIS16/1146	3	B	12	Small vertebrates	*Arvicola amphibius*	m1
CIS16/1147	3	B	12	Small vertebrates	*Arvicola amphibius*	m1
CIS16/1148	3	B	12	Small vertebrates	*Arvicola amphibius*	m1
CIS16/1149	3	B	12	Small vertebrates	*Arvicola amphibius*	m1
CIS16/1150	3	B	11	Small vertebrates	*Microtus (Terricola) savii*	Mandible
CIS16/1151	3	B	11	Small vertebrates	*Microtus (Terricola) savii*	Mandible
CIS16/1152	3	B	11	Small vertebrates	*Microtus (Terricola) savii*	m1
CIS16/1153	3	B	11	Small vertebrates	*Microtus (Terricola) savii*	m1
CIS16/1154	3	B	11	Small vertebrates	*Microtus (Terricola) savii*	Maxilla
CIS16/1155	3	B	12	Small vertebrates	*Microtus (Microtus) arvalis*	m1
CIS16/1156	3	B	12	Small vertebrates	*Microtus (Microtus) arvalis*	m1
CIS16/1157	3	B	12	Small vertebrates	*Microtus (Microtus) arvalis*	m1
CIS16/1158	3	B	12	Small vertebrates	*Microtus (Microtus) arvalis*	m1
CIS16/1159	3	B	12	Small vertebrates	*Microtus (Microtus) arvalis*	m1
CIS16/1160	3	B	11	Small vertebrates	*Myodes glareolus*	Mandible
CIS16/1161	3	B	11	Small vertebrates	*Myodes glareolus*	m1
CIS16/1162	3	B	11	Small vertebrates	*Apodemus cf. A. sylvaticus*	m1

CIS16/1163	3	B	11	Small vertebrates	*Apodemus cf. A. sylvaticus*	m1
CIS16/1164	3	B	11	Small vertebrates	*Apodemus cf. A. sylvaticus*	m2
CIS16/1165	3	B	11	Small vertebrates	*Glis glis*	M3

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29	Figure	Fig. 2.1 The natural boundaries of Pontine Plain…				Yes	Author's own work
32	Figure	Fig. 2.2 Reconstruction of the structure of the Vulcano Laziale lithosome….	G. Giordano, 2013 - AIV International Summer School in Volcanology - Explosive Volcanism of Alkaline-Mafic Magmas. Frascati 25-29 Sept. 2013	© Giordano, G.	15.08.17	Yes	Written permission
32	Figure	Fig. 2.3 Reconstruction of the structure of the Tuscolano-Artemisio lithosome…	G. Giordano, 2013 - AIV International Summer School in Volcanology - Explosive Volcanism of Alkaline-Mafic Magmas. Frascati 25-29 Sept. 2013	© Giordano, G.	15.08.17	Yes	Written permission

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33	Figure	Fig. 2.5 Reconstruction of the structure of the Via dei Laghi lithosome…	G. Giordano, 2013 - AIV International Summer School in Volcanology - Explosive Volcanism of Alkaline-Mafic Magmas. Frascati 25-29 Sept. 2013	© Giordano, G.	15.08.17	Yes	Written permission
38	Figure	Fig. 2.6 Geomorphological evolution of the Pontine Plain…				Yes	Author’s own work
42	Figure	Fig. 2.7 Location of Pleistocene pollen records of Latium…				Yes	Author’s own work
47	Figure	Fig. 2.8 Stratigraphic sequence of the excavation area named Point 3…	Gatta, M., Kotsakis, T., et al. submitted to Research in Paleontology and Stratigraphy	© 2017 RIPS	15.08.17	Yes	Licensed with a CC BY-NC-ND 4.0
51	Figure	Fig. 2.9 Location of collection and excavation areas within the quarry…	Gatta, M., Sinopoli, G., et al., 2016. Review of Palaeobotany and Palynology, 233, pp.56–66	© 2016 Elsevier	15.08.17	Not yet	
69	Figure	Fig. 3.1 Location of the cores in the Pontine region…				Yes	Author’s own work

69	Figure	Fig. 3.2 Location of previously published cores in Central Italy…				Yes	Author’s own work
76	Figure	Fig. 3.3 Timeline of the Pontinian archaeological discoveries in coastal Latium…	Rolfo, M.F. & Aureli, D., 2012. Roma	© 2012 M.F. Rolfo	15.08.17	Yes	Written permission
77	Figure	Fig. 3.4 Geographical distribution of the Middle Palaeolithic Pontinian sites…	Rolfo, M.F. & Aureli, D., 2012. Roma	© 2012 M.F. Rolfo	15.08.17	Yes	Written permission
94	Figure	Fig. 4.1 A dissected coprolite. It is possible to note the penetration of external contamination…	Gatta, M., Sinopoli, G., et al., 2016. Review of Palaeobotany and Palynology, 233, pp.56–66	© 2016 Elsevier	15.08.17	Not yet	
96	Figure	Fig. 4.2 a-b) The resulting matrix after the first treatment with HCl…					Author’s own work
107	Figure	Fig. 5.1 Six areas of Italy with the highest concentrations of Middle Palaeolithic sites	Fiore, I., Gala, M. & Tagliacozzo, A., 2004. International Journal of Osteoarchaeology, (14), pp.273–286	© 2004 John Wiley & Sons, Ltd.	15.08.17	Not yet	
108	Figure	Fig. 5.2 Most important Lower Palaeolithic sites of Latium…	Rolfo, M.F., 2008. Museo e Territorio VI. pp. 79–115	© 2008 M.F. Rolfo	15.08.17	Yes	Written permission
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119	Figure	Fig. 5.5 a) Centripetal core technique; b) and c). Platform core technique…				Yes	Author’s own work
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124	Figure	Fig. 5.7 Transverse polish from hard contact material on R. 498…				Yes	Author’s own work
126	Figure	Fig. 5.8 The bad preservation of the implements impeded a proper analysis of the traces…				Yes	Author’s own work
127	Figure	Fig. 5.9 Several macro and micro-alterations…				Yes	Author’s own work
151	Figure	Fig. 6.1 Cave hyena coprolites with digested bone…	Gatta, M. & Rolfo, M.F., 2017a. Mediterranean Archaeology and Archaeometry, 17(2), pp.105–116	© 2017 MAA	15.08.17	Yes	Written permission
151	Figure	Fig. 6.2 Pollen taxa from CM’s coprolites, showing modest preservation of grains…				Yes	Author’s own work
152	Figure	Fig. 6.3 a) Morphological types of Pleistocene *Crocuta crocuta spelaea* coprolites…	Gatta, M. & Rolfo, M.F., 2017a. Mediterranean Archaeology and Archaeometry, 17(2), pp.105–116	© 2017 MAA	15.08.17	Yes	Written permission
154	Figure	Fig. 6.4 Percentage pollen	Gatta, M., Sinopoli, G., et al.,	© 2016 Elsevier	15.08.17	Not yet	

		diagram of coprolites…	2016. Review of Palaeobotany and Palynology, 233, pp.56–66				
177	Figure	Fig. 7.1 a) Radii of Cervus elaphus displaying systematic bone exploitation…	Gatta, M., Kotsakis, T., et al. submitted to Research in Paleontology and Stratigraphy	© 2017 RIPS	15.08.17	Yes	Licensed with a CC BY-NC-ND 4.0
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181	Figure	Fig. 7.3 R. 363: lower molar tooth of Stephanorhinus hemitoechus from Area 5…				Yes	Author's own work
183	Figure	Fig. 7.4 a) Bronze Age human bone remains from Jericho showing pupal chambers…	Huchet, J.-B. et al., 2013. Journal of Archaeological Science, 40, pp.3793–3803	© 2013 Elsevier	15.08.17	Not yet	
184	Figure	Fig. 7.5 a) Metacarpus and b) I phalanx of Bos primigenius from SU11 of Area 3 at Cava Muracci displaying pupal chambers…				Yes	Author's own work

Bibliography

Accordi, B. (1966) ‘La componente traslativa nella tettonica dell’Appennino laziale-abruzzese’, *Geologica Romana*, V, pp. 355–406.

Accordi, G. and Carbone, F. (1988) *Carta delle litofacies del Lazio-Abruzzo ed aree limitrofe*. Rome: Consiglio Nazionale delle Ricerche.

Alhaique, F. and Bietti, A. (2007) ‘Strategie di insediamento e di sussistenza nel Lazio centro-meridionale fra Paleolitico medio e Mesolitico.’, in *Atti XL Riunione Scientifica IIPP*. Istituto Italiano di Preistoria e Protostoria, pp. 55–78.

Alhaique, F., Bietti, A., Capasso Barbato, L., Grimaldi, S., Kotsakis, T., Kuhn, S. L., Lemorini, C., Manzi, G., Recchi, A., Schwarcz, H. P. and Stiner, M. C. (1996) ‘Nuovi risultati sul musteriano finale di Grotta Breuil (S. Felice Circeo, Latina)’, in Peretto, C. and Milliken, S. (eds) *L’adattamento umano all’ambiente*. Forlì, pp. 177–188.

Alhaique, F., Bietti, A., Capasso Barbato, L., Grimaldi, S., Kotsakis, T., Kuhn, S. L., Lemorini, C., Manzi, G., Recchi, A., Schwarcz, H. P. and Stiner, M. C. (1998) ‘Settlement patterns and subsistence strategies in the late Mousterian site of Grotta Breuil’, in *Atti del XIII Congresso dell’Unione Internazionale di Scienze Preistoriche e Protostoriche 6*, pp. 221–228.

Alhaique, F., Bietti, A., Del Lucchese, A., Grimaldi, S., Manzi, G., Martini, S., Negrino, F., Recchi, A., Schwarcz, H. P. and Stiner, M. C. (2000) ‘Biological and cultural variability at the Neandertal/Modern Human transition in Italian archeological sites’, *Rivista di Antropologia*, 78, pp. 105–116.

Alhaique, F., Biondi, S. V., Cassoli, P. F., Recchi, A. and Tagliacozzo, A. (1998) ‘Modification in the exploitation of animal resources between the Middle Paleolithic and the Aurignacian at Grotta del Fossellone (Monte Circeo, Italy)’, in *Atti del XIII Congresso dell’Unione Internazionale di Scienze Preistoriche e Protostoriche 2*, pp. 571–576.

Alhaique, F. and Lemorini, C. (1996) ‘Butchering with stone tools: an experimental approach to use wear analysis and taphonomic studies of the archaeological material from Grotta Breuil', *Quaternaria Nova*, VI, pp. 393–411.

Alhaique, F. and Tagliacozzo, A. (2000) 'L'interpretazione dei dati faunistici nella ricostruzione delle strategie di sussistenza nel Paleolitico Medio: L'esempio del Lazio', in *Atti del 2° Convegno Nazionale di Archeozoologia*. Forlì: Abaco Edizioni, pp. 111–124.

Allen, J. R. M., Brandt, U., Brauer, A., Hubbertens, A. W., Huntley, B., Keller, J., Kraml, M., Mackensen, A., Mingram, J., Negendank, J. F. W., Nowaczyk, N. R., Oberhansli, H., Watts, W. A., Wulf, S. and Zolitschka, B. (1999) 'Rapid environmental changes in southern Europe during the last glacial period', *Nature*, 400, pp. 740–743.

Allen, J. R. M., Watts, W. A. and Huntley, B. (2000) 'Weichselian palynostratigraphy, palaeovegetation and palaeoenvironment; the record from Lago Grande di Monticchio, southern Italy', *Quaternary International*, 73–74, pp. 91–110.

Altuna, J. (1971) 'Fauna de mamíferos de los yacimientos prehistóricos de Guipúzcoa', *Munibe*, 22, pp. 3–41.

Amaldi, G., Segre, A. G. and Tribalto, G. (1965) 'Alcune considerazioni sulla gravimetria e sulla geologia del F. 158 Latina della Carta Geologica d'Italia', *Assoc. Geofisica Italiana*.

Amick, D. S. (2007) 'Investigating the behavioral causes and archaeological effect of lithic recycling', in McPherron, S. (ed.) *Tools Versus Cores: Alternative Approaches to Stone Tool Analysis*. Newcastle: Cambridge Scholars Publications, pp. 223–252.

Amodio, M. and Bovina, G. (2006) 'Settori di analisi ambientale di supporto alla progettazione delle sistemazioni idrauliche con tecniche di ingegneria naturalistica', in *Manuale di ingegneria naturalistica - sistemazione dei versanti*.

Amori, G. (2008) 'Myodes glareolus (Schreber, 1780)', in Amori, G., Contoli, L., and Nappi, A. (eds) *Fauna d'Italia, Mammalia II, Erinaceomorpha, Soricomorpha, Lagomorpha, Rodentia*. Milano: Calderini, pp. 541–550.

van Andel, T. H., Davies, W. and Weninger, B. (2003) 'The human presence in Europe during the Late Glacial period I: human migrations and changing climate', in Van Andel, T. H. and Davies, W. (eds) *Neanderthals and Modern Humans in the European Landscape during the Last Glaciation*. Cambridge: McDonald Institute of Archaeological Research, pp. 31–56.

Anderson, P. C. (1980a) 'A Microwear Analysis of Selected Flint Artefacts from the

Mousterian of Southwest France', *Lithic Technology*, 9, pp. 1–33.

Anderson, P. C. (1980b) 'A Testimony of Prehistoric Tasks: Diagnostic Residues on Tool Working Edges', *World Archaeology*, 12(1), pp. 181–194.

Anderson, P. C. (1981) *Contribution methodologique a l'analyse des microtraces d'utilisation sur les outils prehistoriques*. University of Bordeaux.

Angelici, F. M. (2003) 'Mustela nivalis (Linnaeus, 1766)', in Boitani, L., Lovari, S., and Vigna Talianti, A. (eds) *Fauna d'Italia, Mammalia III, Carnivora-Artiodactyla*. Bologna: Calderini, pp. 142–152.

Angle, M. and Germano, A. (2003) 'Museo e Territorio', in Rubini, M. (ed.) *Museo e Territorio. Atti della I e II Giornata degli Studi 'Il territorio veliterno nell'antichità'*. Velletri, pp. 23–30.

Antonioli, F. (2012) 'Sea level change in Western-Central Mediterranean since 300 kyr: comparing global sea level curves with observed data', *Alpine and Mediterranean Quaternary*, 25, pp. 15–23.

Antunes, M. (1992) 'The Man of Figueira Brava cave (ca. 30000 BP)', *Memoria Acad. Cienc. Lisboa*, 31, pp. 487–536.

Anzidei, A. P., Angelelli, A., Arnoldus-Huyzendveld, A., Caloi, L., Palombo, M. R. and Segre, A. (1989) 'Le gisement Pléistocène de la Polledrara di Cecanibbio (Rome, Italie)', *L'Anthropologie*, 93, pp. 749–82.

Apollonio, M. (2003) 'Dama dama (Linnaeus, 1758)', in Boitani, L., Lovari, S., and Vigna Taglianti, A. (eds) *Fauna d'Italia, Mammalia III, Carnivora-Artiodactyla*. Bologna: Calderini, pp. 295–304.

Arduini, P. and Teruzzi, G. (1993) *The MacDonald encyclopedia of fossils*. London: Little, Brown and Company.

Argant, J. (1990) 'Climat et environment au Quaternaire dans le Bassin de Rhone d'aprés les données palynologiques', *Documents du Laboratoire de Géologie de Lyon*, 111, pp. 1–199.

Argant, J. (2004) 'Le gisement pliocène final de Saint-Vallier (Dròme, France): palynologie The late pliocene site of Saint-Vallier (Dròme, France): pollen analysis', *Geobios*, 37, pp. 81–90.

Argant, J. and Dimitrijevic, V. (2007) 'Pollen analyses of Pleistocene hyaena coprolites from Montenegro and Serbia', *Geoloski anali Balkanskog poluostrva*, 68, pp. 73–80.

doi: 10.2298/GABP0701073A.

van Asperen, E. N. and Kahlke, R.-D. (2015) ‘Dietary variation and overlap in Central and Northwest European Stephanorhinus kirchbergensis and S. hemitoechus (Rhinocerotidae, Mammalia) influenced by habitat diversity.’, *Quaternary Science Reviews*, 107, pp. 47–61.

Avellino, E., Bietti, A., Giacopini, L., Lo Pinto, A. and Vicari, M. (1989) ‘A new Dryas II site in southern Lazio - Riparo Salvini: Thoughts on the late Epigravettian in middle and southern Tyrrhenian Italy’, in Bonsall, C. (ed.) *The Mesolithic in Europe*. Edinburgh: John Donald, pp. 516–537.

Bader, K. S., Hasiotis, S. T. and Martin, L. D. (2009) ‘Application of forensic science techniques to trace fossils on dinosaur bones from a quarry in the Upper Jurassic Morrison Formation, Northeastern Wyoming’, *Palaios*, 24, pp. 140–158.

Bailey, G. (1981) ‘Concepts, timescales and explanations in economic prehistory’, in *Economic Archaeology*, pp. 97–117.

Bailey, G. (1983) ‘Concepts of Time in Quaternary Prehistory’, *Annual Review of Anthropology*. Annual Reviews 4139 El Camino Way, P.O. Box 10139, Palo Alto, CA 94303-0139, USA, 12(1), pp. 165–192. doi: 10.1146/annurev.an.12.100183.001121.

Bailey, G. (2004) *The wider significance of submerged archaeological sites and their relevance to world prehistory*, *Submarine Prehistoric Archaeology of the North Sea: Research Priorities and Collaboration with Industry*. York.

Bailey, G. (2005) ‘Site catchment analysis’, in Renfrew, C. and Bahn, P. (eds) *Archaeology: the Key Concepts*. London: Routledge, pp. 230–235.

Bailey, G., Carrion, J., Fa, D., Finlayson, C., Finlayson, G. and Rodriguez-Vidal, J. (2008) ‘The coastal shelf of the Mediterranean and beyond: Corridor and refugium for human populations in the Pleistocene’, *Quaternary Science Reviews*, 27(23–24), pp. 2095–2099. doi: 10.1016/j.quascirev.2008.08.005.

Balletto, E., Bologna, M. A. and Corti, C. (2007) ‘Bufo viridis Laurenti, 1768 complex’, in Lnaza, B., Andreone, F., Bologna, M. A., Corti, C., and Razzetti, E. (eds) *Fauna d’Italia, Amphibia*. Bologna: Calderini, pp. 296–305.

Banks, W. E., D’Errico, F. and Zilhão, J. (2013) ‘Humane climate interaction during the Early Upper Paleolithic: testing the hypothesis of an adaptive shift between the Proto-Aurignacian and the Early Aurignacian’, *Journal of Human Evolution*, 64, pp. 39–55.

Bar-Yosef, O. (2000) ‘The Middle and early Upper Paleolithic in Southwest Asia and neighboring regions’, in Bar-Yosef, O. and Pilbeam, D. (eds) *The Geography of Neandertals and Modern Humans in Europe and the Greater Mediterranean*. Peabody Museum Bulletin 8, pp. 107–156.

Bar-Yosef, O. (2002) ‘The upper Paleolithic revolution’, *Annual Review of Anthropology*, 31, pp. 363–393.

Bar-Yosef, O. (2003) ‘Reflections on selected issued of the Upper Paleolithic’, in Goring, A. N. and Belfer-Cohen, A. (eds) *Mora than Meets the Eye: Studies on Upper Palaeolithic Diversity in the Near East*. Oxford: Oxbow Books, pp. 265–273.

Barberi, F., Buonasorte, G., Cioni, R., Fiordelisi, A., Foresi, L., Laccarino, S., Laurenzi, M. A., Sbrana, A., Vernia, L. and Villa, I. M. (1994) ‘Plio–Pleistocene geological evolution of the geothermal area of Tuscany and Latium’, *Mem. Descr. Carta Geol. Ital.*, 49, pp. 77–134.

Barbieri, M., Castorina, F., Dai Pra, G., Esu, D., Gliozzi, E., Paganin, G. and Sadori, L. (1999) ‘Multidisciplinary study of Middle-Upper Pleistocene deposits in a core from the Piana Pontina (Central Italy)’, *Giornale di Geologia*, 61, pp. 47–73.

Bard, E., Hamelin, B. and Fairbanks, R. G. (1990) ‘U-Th ages obtained by mass spectrometry in corals from Barbados: sea level during the past 130,000 years’, *Nature*, 346(6283), pp. 456–458. doi: 10.1038/346456a0.

Barker, G. (1981) *Landscape and society : prehistoric central Italy*. London: Academic Press.

Barker, G. (1999) ‘Hunting and farming in prehistoric Italy: changing perspectives on landscape and society’, *Papers of the British School at Rome*, 67, pp. 1–36.

Barker, S., Knorr, G., Edwards, R. L., Parrenin, F., Putnam, A. E., Skinner, L. C., Wolff, E. and Ziegler, M. (2011) ‘800,000 Years of Abrupt Climate Variability’, *Science*, 334(6054), pp. 347–351. doi: 10.1126/science.1203580.

Barnowsky, A. D., Koch, P. L., Feranec, R. S., Wing, S. L. and Shabel, A. B. (2004) ‘Assessing the causes of Late Pleistocene extinctions on the continents’, *Science*, 306, pp. 70–75.

Bartolini, S., Cioppi, E., Rook, L. and Delfino, M. (2014) ‘Late Pleistocene fossils and the future distribution of Rana temporaria (Amphibia, Anura) along the Apennine Peninsula (Italy)’, *Zoological Studies*, 53(76), pp. 1–10.

Bearder, S. K. (1977) ‘Feeding habits of spotted hyenas in a woodland habitat’, *East African Wildlife Journal*, 15, pp. 163–280.

Bell, M. and Walker, M. J. (2005) *Late Quaternary Environmental Change: Physical and Human Perspectives*. 2nd edn. Harlow: Pearson Education Limited.

Benazzi, S., Douka, K., Fornai, C., Bauer, C. C., Kullmer, O., Svoboda, J., Pap, I., Mallegni, F., Bayle, P., Coquerelle, M., Condemi, S., Ronchitelli, A., Harvati, K. and Weber, G. W. (2011) ‘Early dispersal of modern humans in Europe and implications for Neanderthal behaviour’, *Nature*, 479(7374), pp. 525–528. doi: 10.1038/nature10617.

Benazzi, S., Slon, V., Talamo, S., Negrino, F., Peresani, M., Bailey, S. E., Sawyer, S., Panetta, D., Vicino, G., Starnini, E., Mannino, M. A., Salvadori, P. A., Meyer, M., Pääbo, S. and Hublin, J.-J. (2015) ‘The makers of the Protoaurignacian and implications for Neandertal extinction’, *Science,* 348(6236), pp. 793–796.

Benini, A., Boscato, P. and Gambassini, P. (1997) ‘Grotta della Cala (Salerno): industrie litiche e faune uluzziane ed aurignaziane’, *Rivista di Scienze Preistoriche*, XLVIII, pp. 37–96.

Bennett, K. D. and Provan, J. (2008) ‘What do we mean by “refugia”?’, *Quaternary Science Reviews*, 27(27), pp. 2449–2455. doi: 10.1016/j.quascirev.2008.08.019.

Bennett, K. D., Tzedakis, P. C. and Willis, K. J. (1991) ‘Quaternary Refugia of north European trees’, *Journal of Biogeography*, 18, pp. 103–115.

Berger, J. and Cunningham, C. (1994) ‘Active intervention and conservation: Africa’s pachyderm problem.’, *Science*, 263, pp. 1241–1242.

Berna, F., Matthews, A. and Weiner, S. (2004) ‘Solubilities of bone mineral from archaeological sites: the recrystallization window’, *Journal of Archaeological Science*, 31(7), pp. 867–882. doi: 10.1016/j.jas.2003.12.003.

Bertè, D. F. and Pandolfi, L. (2014) ‘Canis lupus (Mammalia, Canidae) from the Late Pleistocene deposit of Avetrana (Taranto, Southern Italy)’, *Rivista Italiana di Paleontologia e Stratigrafia*, 120, pp. 367–379.

Bertini, A., Minissale, A. and Ricci, M. (2014) ‘Palynological approach in upper Quaternary terrestrial carbonates of central Italy: Anything but a “mission impossible”’, *Sedimentology*, 61, pp. 200–220.

Berto, C., Berte, D., Luzi, E., López-García, J. M. P., Ereswiet-Soltan, A. and Arzarello, M. (2016) ‘Small and large mammals from the Ciota Ciara cave (Borgosesia, Vercelli, Italy): An Isotope Stage 5 assemblage', *Comptes Rendus Palevol*, 15, pp. 669–680.

Bertran, P., Klaric, L., Lenoble, A., Masson, B. and Vallin, L. (2010) 'The impact of periglacial processes on Palaeolithic sites: The case of sorted patterned grounds', *Quaternary International*, 214(1–2), pp. 17–29. doi: 10.1016/j.quaint.2009.10.021.

Bertran, P., Lenoble, A., Todisco, D., Desrosiers, P. M. and Sorensen, M. (2012) 'Particle size distribution of lithic assemblages and taphonomy of Palaeolithic sites', *Journal of Archaeological Science*, 39(10), pp. 3148–3166.

Biddittu, I. (1971) 'Il Paleolitico Inferiore di Arce e Fontana Liri, Frosinone', *Archeologia, antropologia, etnologia*, 101, pp. 251–52.

Biddittu, I., Cassoli, P. F. and Malpieri, L. (1967) 'Stazione musteriana di Valle Radice nel comune di Sora (Frosinone)', *Quaternaria*, IX, pp. 321–348.

Biddittu, I., Cassoli, P. F., Radicati di Brozolo, F., Segre, A., Segre Naldini, E. and Villa, I. M. (1979) 'Anagni, a K-ar dated lower and Middle Pleistocene site, central Italy: a preliminary report.', *Quaternaria*, 21, pp. 53–71.

Biddittu, I. and Segre, A. G. (1977) 'Giacimenti preistorici e quaternario della provincia di Frosinone', *Bollettino dell'Istituto di Storia e di Arte del Lazio Meridionale*, 9, pp. 21–44.

Bietti, A. (1969) 'Due stazioni di superficie del Paleolitico Superiore nella Pianura Pontina', *Bull. Paletnologia Italiana*, 78, pp. 7–39.

Bietti, A. (1977) 'Analysis and illustration of the Epigravettian industry collected during the 1955 excavations at Palidore (Rome, Italy)', *Quaternaria*, 19, pp. 197–387.

Bietti, A. (1980) 'Un tentativo di classificazione quantitativa del "Pontiniano" Laziale nel quadro delle industrie Musteriane in Italia', *Rivista di Antropologia*, 61, pp. 161–202.

Bietti, A. (1981) 'Un tentativo di classificazione quantitativa del "Pontiniano" laziale nel quadro delle industrie musteriane in Italia. Problemi di derivazione e di interpretazione culturale', *Rivista di Antropologia*, 61, pp. 161–202.

Bietti, A. (1982) 'The Mousterian Complexes of Italy: A Search for Cultural Understanding of the Industrial Assemblages', *Anthropos*, 27, pp. 231–251.

Bietti, A. (1984) 'Primi risultati dello scavo nel giacimento epigravettiano finale di Riparo Salvini (Terracina, Latina)', in *Atti della XXIV riunione scientifica dell'Istituto Italiano di Preistoria e Protostoria*, pp. 195–205.

Bietti, A. (1989) ‘Cultural adaptations and environment: two test cases from the southern-central Tyrrhenian Italy’, *Rivista di Antropologia*, 67, pp. 239–264.

Bietti, A. (1991) ‘Is there a pontinian culture?’, *Quaternaria Nova*, 1, pp. 673–678.

Bietti, A. and Grimaldi, S. (1993) ‘Mousterian assemblages in central Italy: “cultural facies” or behavioral adaptations?’, *Quaternaria Nova*, 3, pp. 21–38.

Bietti, A. and Grimaldi, S. (1995) ‘Levallois debitage in central Italy: technical achievements and raw material procurement’, in *The Definition and Interpretation of Levallois Technology*, pp. 125–142.

Bietti, A. and Kuhn, S. L. (1991) ‘Techno-typological studies on the Mousterian industry of Grotta Guattari’, *Quaternaria Nova*, 1, pp. 193–211.

Bietti, A., Kuhn, S. L., Segre, A. G. and Stiner, M. C. (1991) ‘Grotta Breuil: Introduction and stratigraphy’, *Quaternaria Nova*, I, pp. 305–324.

Bietti, A., Manzi, G., Passarello, P., Segre, A. G. and Stiner, M. C. (1988) ‘The 1986 excavation campaign at Grotta Breuil (Monte Circeo, Latina)’, *Archeologia Laziale*, IX, pp. 372–388.

Bietti, A., Manzi, G. and Zei, M. (1988) *Il territorio Pontino nella preistoria: l’uomo di Neanderthal*, *Quaderni del CEPIG*.

Bietti, A. and Stiner, M. C. (1992) ‘Les Modèles de subsistance et de habitat de l’epigravettien italien: l’exemple de Riparo Salvini (Terracina, Latium)’, in Laville, H., Rigaud, J. P., and Vandermeersch, B. (eds) *Colloque international: Le peuplement magdalénien*. Paris, pp. 137–52.

Binford, L. . (1965) ‘Archaeological systematics and the study of cultural process’, *American Antiquity*, 31, pp. 203–210.

Binford, L. . (1981) ‘Behavioural Archaeology and the “Pompeii Premise”’, *Journal of Anthropological Research*, 37, pp. 195–208.

Binford, L. . (1990) ‘Mobility, Housing, and Environment: A Comparative Study’, *Journal of Anthropological Research*, 46(2), pp. 119–152.

Binford, L. R. (1977) ‘Forty-seven trips: a case-study in the character of archaeological formation process’, in Wright, R. S. V. (ed.) *Stone Tools as Cultural Markers*. Canberra: Australian Institute for Aboriginal Studies, pp. 24–36.

Binford, L. R. (1979) ‘Organization and formation processes: looking at curated technologies', *Journal of Anthropological Research*, 35, pp. 255–273.

Binford, L. R. (2001) *Constructing Frames of Reference*. Berkeley: University of California Press.

Blanc, A. C. (1930) 'Grotta Romanelli, II: dati ecologici e paletnologici', *Archivio per l'Antropologia e l'Etnologia*, 58, pp. 1–4.

Blanc, A. C. (1935a) 'La stratigrafia del Canale Mussolini nell'Agro Pontino', *Atti Società Toscana di Scienze Naturali*, XLIV(44), pp. 52–57.

Blanc, A. C. (1935b) 'Lo studio stratigrafico di pianure costiere', *Bollettino della Società Geologica Italiana*, 54, pp. 277–288.

Blanc, A. C. (1935c) 'Sulla fauna quaternaria dell'Agro Pontino', *Atti della Società Toscana di Scienze Naturali*, 44, pp. 108–110.

Blanc, A. C. (1936) 'Sulla stratigrafia quaternaria dell'Agro Pontino e della bassa Versilia', *Bollettino della Società Geologica Italiana*, 60, pp. 375–396.

Blanc, A. C. (1937a) 'Fauna a Ippopotamo ed industrie paleolitiche nel riempimento delle grotte litoranee del Monte Circeo - I. La Grotta delle Capre - II. La Grotta del Fossellone', *Rendiconti dell'Accademia Nazionale dei Lincei*, XXV, pp. 88–93.

Blanc, A. C. (1937b) 'Nuovi giacimenti paleolitici del Lazio e della Toscana', *Studi Etruschi*, XI, pp. 273–304.

Blanc, A. C. (1938) 'Una serie di nuovi giacimenti pleistocenici e paleolitici in grotte litoranee del Monte Circeo', *Rendiconti dell'Accademia Nazionale dei Lincei*, 17, pp. 201–209.

Blanc, A. C. (1939a) 'Il Monte Circeo: le sue grotte paleolitiche ed il suo uomo fossile', *Boll. Reale Società Geografica Italiana*, 17, pp. 485–493.

Blanc, A. C. (1939b) 'L'homme fossile du Mont Circé', *L'Anthropologie*, 49, pp. 253–264.

Blanc, A. C. (1939c) 'L'uomo fossile del Monte Circeo: un cranio neandertaliano nella Grotta Guattari a S. Felice Circeo', *Rivista di Antropologia*, XXXII, pp. 287–308.

Blanc, A. C. (1939d) 'Un giacimento aurignaziano medio nella Grotta del Fossellone al Monte Circeo', in *Atti XXVII Riunione della Società Italiana per il Progresso delle Scienze*. Roma, pp. 1–7.

Blanc, A. C. (1940) 'The fossil man of Circe's Mountain', *Natural History*, May, pp.

280–287.

Blanc, A. C. (1954) ‘Reperti fossili Neandertaliani della Grotta del Fossellone al Monte Circeo: Circeo IV’, *Quaternaria*, 1, pp. 171–175.

Blanc, A. C. (1955) ‘Ricerche sul Quaternario Laziale’, *Quaternaria*, 2, pp. 187–200.

Blanc, A. C. (1957) ‘On the Pleistocene sequence of Rome’, *Quaternaria*, 4.

Blanc, A. C. (1958) ‘Torre in Pietra, Saccopastore, Monte Circeo, on the position of the Mousterian in the Pleistocene sequence of the Rome area’, in *Hundert Jahre Neanderthaler*. Utrecht, pp. 167–174.

Blanc, A. C. (1961) ‘Some evidence for the ideologies of early man’, in *The social life of early man*. Chicago, pp. 119–136.

Blanc, A. C. and Segre, A. G. (1947) ‘Nuovi giacimenti tirreniani e paleolitici sulla costiera tra Sperlonga e Gaeta’, *Historia Naturalis*, 2, pp. 1–2.

Blanc, A. C. and Segre, A. G. (1953) ‘Excursion au Mont Circé’, in *INQUA, IVe Congress*. Rome: INQUA, p. 112.

Blanc, A. C., Segre, A. G. and Tongiorgi, E. (1953) ‘Le quaternaire de l’Agro Pontino. Supplément au livret guide Excursion au Mont Circé’, in *INQUA, IVe Congress*. Rome: INQUA, p. 15.

Blasco, M. F. (1995) *Hombres, fieras y presas. Estudio arqueozoológico y tafonómico del yacimiento del Paleolítico Medio de la cueva de Gabasa I (Huesca)*. Zaragoza: Monografías Arqueológicas 38.

Blasco, R. and Fernandez Peris, J. (2012) ‘A uniquely broad spectrum diet during the Middle Pleistocene at Bolomor Cave (Valencia, Spain)’, *Quaternary International*, 252, pp. 16–31.

Blasco, R., Rosell, J., Fernandez Peris, J., Arsuaga, J. L., Bermudez de Castro, J. M. and Carbonell, E. (2013) ‘Environmental availability, behavioural diversity and diet: a zooarchaeological approach from the TD10-1 sublevel of Gran Dolina (Sierra de Atapuerca, Burgos, Spain) and Bolomor Cave (Valencia, Spain)’, *Quaternary Science Reviews*, 70, pp. 124–144.

Blasi, C. (1994) *Fitoclimatologia del Lazio*. Roma.

Bleed, P. and Meier, M. (1980) ‘An objective test of the effects of heat treatment on flakeable stone’, *American Antiquity*, 45, pp. 502–507.

Bleicher, G. M. (1866) ‘Sur la geologie des environs de Rome, formés de terrains diluviens et tertiaires’, *Bulletin de la Société Géologique de France*, pp. 645–654.

Bocherens, H., Drucker, D. G., Billiou, D., Geneste, J. M. and Kervazo, B. (2008) ‘Grotte Chauvet (Ardèche, France): A “natural experiment” for bone diagenesis in karstic context’, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 266, pp. 220–226.

Bocherens, H., Drucker, D. G., Billiou, D., Patou-Mathis, M. and Vandermeersch, B. (2005) ‘Isotopic evidence for diet and subsistence pattern of the Saint-Césaire I Neanderthal: review and use of a multi-source mixing model’, *Journal of Human Evolution*, 49, pp. 71–87.

Böhme, M., Paggetti, E., Razzetti, E. and Vanni, S. (2007) ‘Bufo bufo (Linnaeus, 1758)’, in Lanza, B., Andreone, F., Bologna, M. A., Corti, C., and Razzetti, E. (eds) *Fauna d’Italia, Amphibia*. Bologna: Calderini, pp. 289–296.

Bon, C., Berthonaud, V., Maksud, F., Labadie, K., Poulain, J., Artiguenave, F., Wincker, P., Aury, J.-M. and Elalouf, J.-M. (2012) ‘Coprolites as a source of information on the genome and diet of the cave hyena’, *Proceedings of the Royal Society B*, 279, pp. 2825–2830.

Bona, F., Laurenti, B. and Delfino, M. (2009) ‘Climatic fluctuations during the last glacial in the North-Western Lombardian Prealps: The Upper Pleistocene faunal assemblages of the Caverna Generosa (Como, Italy)’, *Rivista Italiana di Paleontologia e Stratigrafia*, 115, pp. 253–267.

Bonatti, E. (1970) ‘Pollen sequence in the lake sediments’, in Hutchinson, G. E., Monatti, E., Margaritora, F., Patrick, R., Racek, A., Roback, S. A., Stella, E., Ward-Perkins, J. B., and Wellman, T. R. (eds) *Ianula: An account of the history and development of the Lago di Monterosi, Latium, Italy.*, pp. 26–31.

Bond, G., Wallace, B., Johnsen, S., McManus, J., Labeyrie, L., Jouzel, J. and Bonani, G. (1993) ‘Correlations between climate records from North Atlantic sediments and Greenland ice’, *Nature*, 365, pp. 143–147.

Boni, C., Bono, P., Calderoni, G., Lombardi, S. and Turi, B. (1980) ‘Indagine idrogeologica e geochimica sui rapporti tra ciclo carsico e circuito idrotermale nella pianura pontina (Lazio meridionale)’, *Geologia applicata e idrogeologia*, 15, pp. 203–247.

Bordes, F. (1961) *Typologie du Paléolithique Ancien et Moyen*. 2nd editio. Bordeaux: Publication de l'Institut de Préhistoire de l'Université de Bordeaux, Imprimeries Delmas.

Bottema, S. (1999) 'Landscape archaeology and reconstruction of the Mediterranean environment based on palynology', in *Environmental Reconstruction in Mediterranean Landscape Archaeology*, pp. 9–24.

Bottema, S. and Woldring, H. (1994) 'Bronze age and Byzantine pollen of the Kestel tin-mine (Turkey) and its possible origin: practical and experimental pollen analysis in archaeological context', in Davis, O. K. (ed.) *Aspects of archaeological palynology: methodology and applications*. AASP Contribution Series no. 29, pp. 7–15.

Bourdon, B., Henderson, G. M., Lundostrom, C. C. and Turner, S. P. (2003) *Uranium-series geochemistry, Reviews in Mineralogy and Geochemistry*. Washington, D.C.: Mineralogical Society of America.

Boyle, K. V. (2000) 'Reconstructing Middle Palaeolithic subsistence strategies in the South of France', *International Journal of Osteoarchaeology*, 10, pp. 336–356.

Brabazon, T. (2010) *How not to write a PhD thesis*. Available at: https://www.timeshighereducation.co.uk/news/how-not-to-write-a-phd-thesis/410208.article.

Branch, N., Canti, M., Clark, P. and Turney, C. (2005) *Environmental Archaeology: Theoretical and Practical Approaches*. London: Hodder Education.

Britt, B. B., Scheetz, R. D. and Dangerfield, A. (2008) 'A Suite of Dermestid Beetle Traces on Dinosaur Bone from the Upper Jurassic Morrison Formation, Wyoming, USA', *Ichnos*, 15(2), pp. 59–71.

Brock, F., Bronk Ramsey, C. and Higham, T. (2007) 'Quality assurance of ultrafiltred bone dating', *Radiocarbon*, 49(2), pp. 187–192.

Broglio, A. (1994) 'II Paleolitico Superiore del FriulieVenezia Giulia', in *Atti della XXIX Riunione Scientifica del Istituto Italiano do Preistoria e Protostoria*. Florence, pp. 36–56.

Broglio, A. (1995) 'Discontinuity tra Musteriano e Protoaurignaziano mediterraneo nella Grotta di Fumane (Monti Lessini, Prealpi Venete)', *Veleia*, 12, pp. 49–65.

Bronk Ramsey, C., Higham, T. F. G., Bowles, A. and Hedges, R. (2004) 'Improvements to the pretreatment of bone at Oxford', *Radiocarbon*, 46(1), pp. 155–163.

Brown, K., Fa, D., Finlayson, G. and Finalyson, C. (2011) ‘Small game and marine resource exploitation by Neanderthals: the evidence from Gibraltar’, in Bicho, N. F., Haws, J. A., and Davis, L. G. (eds) *Trekking the shore*. New York: Springer, pp. 247–272.

Brown, T. A., Nelson, D. E., Vogel, J. S. and Southon, J. R. (1988) ‘Improved collagen extraction by modified Longin method’, *Radiocarbon*, 30(2), pp. 171–177.

Bryant Jr., V. M. and Holloway, R. G. (1983) ‘The role of palynology in archaeology’, *Advances in Archaeological Method and Theory*, 6, pp. 191–224.

Bryant Jr., V. M. and Reinhard, K. J. (2012) ‘Coprolites and archaeology: The missing links in understanding human health’, in Hunt, A. P., Milàn, J., Lucas, G., and Spielmann, J. A. (eds) *Vertebrate Coprolites*. Albuquerque: New Mexico Museum of Natural History and Science, pp. 379–387.

Buckland, W. (1822) ‘Account of an assemblage of fossil teeth and bones of elephant, rhinoceros, hippopotamus, bear, tiger and hyaenam and sixteen other animals; discovered in a cave at Kirkdale, Yorkshire, in the year 1821; with a comparative view of five similar caverns in ’, *Philosophical Transactions of the Royal Society of London*, 112, pp. 171–236.

Buckland, W. (1824) *Reliquiae diluvianae: or, observations on the organic remains contained in caves, fissures, and diluvial gravel, and on other geological phenomena, attesting the action of an universal deluge*. London: John Murray.

Buckland, W. (1829) ‘On the discovery of coprolites, or fossil faeces, in the lias at Lyme Regis, and in other formations’, *Transactions of Geological Society of London*, II(3), pp. 223–236.

Burke, A. (2006) ‘Neanderthal settlement patterns in Crimea: A landscape approach’, *Journal of Anthropological Archaeology*, 25(4), pp. 510–523. doi: 10.1016/j.jaa.2006.03.003.

Burke, A., Levavasseur, G., James, P. M. A., Guiducci, D., Izquierdo, M. A., Bourgeon, L., Kageyama, M., Ramstein, G. and Vrac, M. (2014) ‘Exploring the impact of climate variability during the Last Glacial Maximum on the pattern of human occupation of Iberia’, *Journal of Human Evolution*, 73, pp. 35–46. doi: 10.1016/j.jhevol.2014.06.003.

Burroni, D., Donahue, R. E., Pollard, A. M. and Mussi, M. (2002) ‘The Surface Alteration Features of Flint Artefacts as a Record of Environmental Processes’, *Journal* *of Archaeological Science*, 29(11), pp. 1277–1287. doi: 10.1006/jasc.2001.0771.

Burroughs, W. J. (2005) *Climate change in prehistory: the end of the reign of chaos*. Cambridge University Press.

Cagnin, M. (2008) ‘Arvicola amphibius (Linnaeus, 1758)’, in Amori, G., Contoli, L., and Nappi, A. (eds) *Fauna d’Italia, Mammalia II, Erinaceomorpha, Soricomorpha, Lagomorpha, Rodentia*. Milano: Calderini, pp. 445–458.

Caloi, L. and Palombo, M. R. (1989a) ‘I grandi mammiferi del Pleistocene superiore di Grotta Barbara (Monte Circeo), Lazio meridionale’, *Bollettino del Servizio Geologico d’Italia*, 106, pp. 3–58.

Caloi, L. and Palombo, M. R. (1989b) ‘The Wurmian mammalian fauna of Grotta Barbara (Monte Circeo): Palaeoeconomical and environment conditions data’, *Hystrix*, 1, pp. 85–94.

Caloi, L. and Palombo, M. R. (1991) ‘Les grands mammiféres du Pleistocène Superiéur de Grotta Barbara (Monte Circeo, Latium Méridional): encadrement biostratigraphique et implications paléoécologiques’, *Quaternaria Nova*, I, pp. 267–276.

Caloi, L. and Palombo, M. R. (1992) ‘Le faune a grandi mammiferi del Pleistocene superiore dell’Italia Centrale: biostratigrafia e paleoambiente’, *Bollettino del Servizio Geologico d’Italia*, CXI, pp. 77–104.

Camarós, E., Cueto, M., Teira, L. C., Tapia, J., Cubas, M., Blasco, R., Rosell, J. and Rivals, F. (2013) ‘Large carnivores as taphonomic agents of space modification: an experimental approach with archaeological implications’, *Journal of Archaeological Science*, 40(2), pp. 1361–1368. doi: 10.1016/j.jas.2012.09.037.

Camilli, E. L. and Ebert, J. I. (1992) ‘Artifact reuse and recycling in continuous surface distributions and implications for interpreting land use patterns’, in Rossignol, J. and Wandsnider, L. (eds) *Space, Time, and Archaeological Landscapes*. New York: Plenum Press, pp. 113–136.

Camponeschi, B. and Nolasco, F. (1983) ‘Le risorse naturali della Regione Lazio: Monti Lepini e Pianura Pontina’, *Regione Lazio*, (8).

Camps, M. (2009) ‘Where there is a will there is a way? 30 years of debate on the Mid-Upper Paleolithic transition in western Europe’, in Camps, M. and Szmidt, C. (eds) *The Mediterranean from 50,000 to 25,000 BP: Turning Points and New Directions*. Oxford: Oxbow Books, pp. 1–10.

Camps, M. and Higham, T. (2012) ‘Chronology of the Middle to Upper Palaeolithic transition at Abric Romaní, Catalunya’, *Journal of Human Evolution*, 62, pp. 89–103.

Caparròs, M., Ruìz, C. B., Moigne, A. M. and Bohorquez, A. M. (2012) ‘Did Neanderthals and Carnivores Compete for Animal Nutritional Resources in the Surroundings of the Cave of Zafarraya?’, *Journal of Taphonomy*, 10(3–4), pp. 395–415.

Capelli, G., Delitala, M. C., Primavera, P., Salvati, R., Taddeucci, A. and Tuccimei, P. (2004) ‘Atti del 1° Seminario APAT sullo Stato dell’arte sullo studio dei fenomeni di sinkholes e ruolo delle amministrazioni statali e locali nel governo del territorio. Roma 20-21 Maggio 2004’, in *Lo studio degli spring-sinkhole del gruppo dei Laghi del Vescovo (pianura Pontina) attraverso l’uso del radon badget*, pp. 189–199.

Capelli, G. and Salvati, R. (2002) *Il Progetto Sinkhole del Lazio*.

Capizzi, D. and Filippucci, M. G. (2008a) ‘Apodemus sylvaticus (Linnaeus, 1758)’, in Amori, G., Contoli, L., and Nappi, A. (eds) *Fauna d’Italia, Mammalia II, Erinaceomorpha, Soricomorpha, Lagomorpha, Rodentia*. Milano: Calderini, pp. 604–616.

Capizzi, D. and Filippucci, M. G. (2008b) ‘Glis glis (Linnaeus, 1766)’, in Amori, G., Contoli, L., and Nappi, A. (eds) *Fauna d’Italia, Mammalia II, Erinaceomorpha, Soricomorpha, Lagomorpha, Rodentia*. Milano: Calderini, pp. 381–394.

Caputo, C., Ciccacci, S., De Rita, D., Fredi, P., Palmieri, E. L. and Salvini, F. (1993) ‘Drainage pattern and tectonics in some volcano areas of Latium (Italy)’, *Geologica Romana*, 29, pp. 1–13.

Cardini, L. and Biddittu, I. (1967) ‘L’attività scientifica dell’Istituto Italiano di Paleontologia Umana dalla sua fondazione’, *Quaternaria*, 9, pp. 353–383.

Cardoso, J. L. (1996) ‘Les grands mammifères du Pléistocène supérieur du Portugal. Essai de synthèse.’, *Geobios*, 29(2), pp. 235–250.

Carrión, J. S. (1999) ‘The palaeoecological potential of pollen records in caves: the case of Mediterranean Spain’, *Quaternary Science Reviews*, 18, pp. 1061–1073.

Carrión, J. S. (2002) ‘A taphonomic study of modern pollen assemblages from dung and surface sediments in arid environments of Spain’, *Review of Palaeobotany and Palynology*, 120, pp. 217–232.

Carrión, J. S., Finlayson, C., Fernandez, S., Finlayson, G., Allue, E., Lopezsaez, J., Lopezgarcia, P., Gilromera, G., Bailey, G. and Gonzalezsamperiz, P. (2008) ‘A coastal reservoir of biodiversity for Upper Pleistocene human populations: palaeoecological investigations in Gorham’s Cave (Gibraltar) in the context of the Iberian Peninsula’, *Quaternary Science Reviews*, 27(23–24), pp. 2118–2135. doi: 10.1016/j.quascirev.2008.08.016.

Carrión, J. S. and Leroy, S. (2010) ‘Iberian floras through time: land of diversity and survival’, *Review of Palaeobotany and Palynology*, 162, pp. 227–230.

Carrión, J. S., Riquelme, J. A., Navarro, C. and Munuera, M. (2001) ‘Pollen in hyaena coprolites reflects late glacial landscape in southern Spain’, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 176, pp. 193–205.

Carrión, J. S., Scott, L., Huffman, T. and Dreyer, C. (2000) ‘Pollen analysis of Iron Age cow dung in southern Africa’, *Veget. Hist. Archaeobot.*, 9, pp. 239–249.

Carrión, J. S., Scott, L. and Vogel, J. S. (1999) ‘Twentieth-century changes in montane vegetation in the eastern Free State, South Africa, derived from palynology of hyrax dung middens’, *Journal of Quaternary Science*, 14, pp. 1–16.

Cassoli, P. F., di Stefano, G. and Tagliacozzo, A. (1999) ‘I vertebrati dei livelli superiori (A e Alfa) della serie stratigrafica di Notarchirico’, in Piperno, M. (ed.) *Notarchirico. Un sito del Pleistocene medio iniziale nel Bacino di Venosa (Basilicata)*. Osanna, Venosa, pp. 361–438.

Casto, L. (2005) *I Beni culturali a caraterre geologico del Lazio: I Monti Lepini, Ausoni ed Aurunci*. Regione Lazio.

Casto, L. and Zarlenga, F. (1997) *I beni culturali a caraterre geologico del Lazio: La Pianura Pontina, Fondana e i Monti Ausoni meridionale*. ENEA and Regione Lazio.

Ceselli, L. (1866) *Strumenti in silice della prima epoca della pietra della Campagna Romana*.

Chase, P. (1988) ‘Scavenging and hunting in the Middle Paleolithic: the evidence from Europe’, in Dibble, H. and Montet-White, A. (eds) *Upper Pleistocene Prehistory of Western Eurasia*. Philadelphia: University of Pennsylvania Press, pp. 225–232.

Cherry, J. (2003) ‘Archaeology beyond the site: regional survey and its future’, in Leventhal, R. and Papadopoulos, J. (eds) *Theory and Practice in Mediterranean Archaeology: Old World and New World Perspectives*. Los Angeles, pp. 137–160.

Chiarini, E., Giardini, M., La Posta, E., Papasodaro, F. and Sadori, L. (2007) ‘Sedimentology, palynology and new geochronological constraints on quaternary deposits of the Corvaro intermontane basin (central Italy)’, *Revue de Micropaléontologie*, 50, pp. 309–314.

Chilardi, S., Frayer, D., Gioia, P., Macchiarelli, R. and Mussi, M. (1996) ‘Fontana Nuova di Ragusa (Sicily, Italy): Southernmost Aurignacian Site in Europe’, *Antiquity*, 79(269), pp. 553–564.

Chu, W., Thompson, C. and Hosfield, R. (2015) ‘Micro-abrasion of flint artifacts by mobile sediments: a taphonomic approach’, *Archaeol. Anthropol. Sci*, 7, pp. 3–11.

Churchill, S. E. (2014) *Thin on the ground: Neandertal, biology, archeology and ecology*. Ames-Chichester-Oxford.

Cipollari, P. and Cosentino, D. (1993) ‘Le “Arenarie di Torrice”: un deposito di bacino di piggy back del Messiniano nell’Appennino centrale’, *Boll. Soc. Geol. It.*, 112(2), pp. 497–505.

Ciuffarella, L. (1996) *Studio palinologico di una lunga sequenza di Valle di Baccano (complesso vulcanico Sabatino, Italia centrale)*. Università degli studi di Roma La Sapienza.

Clark, G. A. (2002) ‘Neandertal archaeology - implications for our origins’, *American Anthropologist*, 104, pp. 50–68.

Collins, M. J., Nielsen-Marsh, C. M., Hiller, J., Smith, C. I., Roberts, J. P., Prigodich, R. V., Wess, T. J., Csapò, J., Millard, A. R. and Turner-Walker, G. (2002) ‘The survival of organic matter in bone: a review’, *Archaeometry*, 44, pp. 383–394.

Collins, M. J., Walton, D. and King, A. (1998) ‘The geochemical fate of proteins’, *Nitrogen-Containing Macromolecules in the Bio- and Geosphere*, 707, pp. 74–87.

Colonese, A. C., Mannino, M. A., Bar-Yosef Mayer, D. E., Fa, D. A., Finalyson, J. C., Lubell, D. and Stiner, M. C. (2011) ‘Marine mollusc exploitation in Mediterranean prehistory: an overview’, *Quaternary International*, 239, pp. 86–103.

Conard, N. J. and Bolus, M. (2003) ‘Radiocarbon dating the appearance of modern humans and timing of cultural innovations in Europe: new results and new challenges’, *Journal of Human Evolution*, 44(3), pp. 331–371.

Conard, N. J., Bolus, M. and Munzel, S. C. (2012) ‘Middle Paleolithic land use, spatial organization and settlement intensity in the Swabian Jura, southwestern Germany’, *Quaternary International*, 247, pp. 236–245.

Condemi, S., Mounier, A., Giunti, P., Lari, M., Caramelli, D. and Longo, L. (2013)

‘Possible Interbreeding in Late Italian Neanderthals? New Data from the Mezzena Jaw (Monti Lessini, Verona, Italy)’, *PLoS ONE*. Edited by D. Frayer. Public Library of Science, 8(3), p. e59781. doi: 10.1371/journal.pone.0059781.

Conti, N., Coppola, D., Petronio, C., Petrucci, M., Sardella, R. and Salari, L. (2012) ‘La fauna del Pleistocene superiore di Tana delle Iene (Ceglie Messapica, Brindisi, Italia meridionale)’, *Bollettino del Museo Civico di Storia Naturale di Verona*, 36, pp. 63–76.

Conti, N., Petronio, C. and Salari, L. (2010) ‘The Late Pleistocene equids from “Tana delle Iene” (Ceglie Messapica, Brindisi, Southern Italy)’, *Bollettino della Società Paleontologica Italiana*, 49, pp. 227–236.

Conticelli, S. and Peccerillo, A. (1992) ‘Petrology and geochemistry of potassic and ultrapotassic volcanism in central Italy: petrogenesis and inferences on the evolution of the mantle sources’, *Lithos*, 28(3–6), pp. 221–240. doi: 10.1016/0024-4937(92)90008-M.

Contoli, L., Nappi, A. and Castiglia, R. (2008) ‘Caratteri generali dei Microtus (Terricola) del “gruppo savii”’, in Amori, G., Contoli, L., and Nappi, A. (eds) *Fauna d’Italia, Mammalia II, Erinaceomorpha, Soricomorpha, Lagomorpha, Rodentia*. Milano: Calderini, pp. 525–535.

Corbino, C. A. (2015) ‘Deposizioni rituali di rospi in una sepoltura enotria della prima età del Ferro’, *Annali dell’Università degli studi di Ferrara, Museologia Scientifica e Naturalistica*, 11, pp. 81–84.

Cortés, M. (2005) ‘The Neandertal far west: The Middle Paleolithic at the South of the Iberian Peninsula’, *Museo Altamira Monografias*, 20, pp. 55–74.

Cortés, M. and Simòn, M. D. (2001) ‘Cave Bajondillo (Torremolinos, Malaga, Andalucia): News of the transition between the Middle and Upper Paleolithic in the South of Iberian Peninsula’, in *Trabalhos de Arqueologia. 17. Les Premiers hommes modernes de la Péninsule Ibérique.* Lisboa: Actes du Colloque de la Commission VIII de l’UISPP Vila Nova de Foz Coa.

Costamagno, S., Liliane, M., Cédric, B., Bernard, V. and Bruno, M. (2006) ‘Les Pradelles (Marillac-le Franc, France): a mousterian reindeer hunting camp?’, *Journal of Anthropological Archaeology*, 25, pp. 466–484.

Crezzini, J., Boscato, P., Ricci, S., Ronchitelli, A., Spagnolo, V. and Boschin, F. (2016) ‘A spotted hyaena den in the Middle Palaeolithic of Grotta Paglicci (Gargano promontory, Apulia, Southern Italy)', *Archaeological and Anthropological Sciences*, 8(2), pp. 227–240. doi: 10.1007/s12520-015-0273-0.

Cristiani, E., Lemorini, C., Martini, F. and Sarti, L. (2005) 'Scrapers of Callista chione from Grotta del Cavallo (Middle Palaeolithic cave in Apulia): evaluating the use-wear potential', in Luik, H., Choyke, A. M., Batey, C. E., and Lougas, L. (eds) *From hooves to horns, from mollusc to mammoth. Manufacture and use of bone artefact from prehistoric times to the present.* Tallinn, pp. 319–325.

Cruz-Uribe, K. (1991) 'Distinguishing Hyena from Hominid Bone Accumulations', *Journal of Field Archaeology*, 18(4), pp. 467–486.

Cupillard, C. and Welte, A.-C. (2006) 'Le Magdalénien de la grotte « Grappin » à Arlay (Jura, France) : nouveaux regards', *L'Anthropologie*, 110(4), pp. 624–683. doi: 10.1016/j.anthro.2006.07.011.

D'Ambrosio, E., Giaccio, B., Lombardi, L., Marra, F., Rolfo, M. F. and Sposato, A. (2010) 'L'attività recente del centro eruttivo di Albano tra scienza e mito: un'analisi critica del rapporto tra il vulcano laziale e la storia dell'area albana', in *Lazio e Sabina 6. Atti del Convegno*, pp. 211–222.

D'Argenio, B., Pescatore, T. and Scandone, P. (1973) 'Schema geologico dell'Appennino Meridionale (Campania e Lucania). Moderne vedute sulla Geologia dell'Appennino, Convegno Roma 1972.', *Quad. Accad. Naz. Lincei*, 183.

d'Errico, F. and Sánchez Goñi, M. F. (2003) 'Neandertal extinction and the millennial scale climatic variability of OIS 3', *Quaternary Science Reviews*, 22(8), pp. 769–788. doi: 10.1016/S0277-3791(03)00009-X.

Dansgaard, W., Johnsen, S., Clausen, H. B., Dahl-Jensen, D., Gundestrup, N. S., Hammer, C. U., Hvidberg, C. S., Steffensen, J. P., Jouzel, J. and Bond, G. (1993) 'Evidence for general instability of past climate from 250-Kyr ice-core record', *Nature*, 364, pp. 218–220.

Davies, W. and Gollop, P. (2003) 'The Human Presence in Europe during the Last Glacial Period II: Climate Tolerance and Climate Preferences of Mid- and Late Glacial Hominids', in *Neanderthals and modern humans in the European landscape during the last glaciation: archaeological results of the Stage 3 Project*. Cambridge: The McDonald Institute for Archaeological Research, pp. 131–146.

Davis, M. B. and Shaw, R. G. (2001) 'Range Shifts and Adaptive Responses to

Quaternary Climate Change', *Science*, 292(5517), pp. 673–679. doi: 10.1126/science.292.5517.673.

Delfino, M. (2002) *Erpetofaune italiane del Neogene e del Quaternario*. University of Modena and Reggio Emilia.

Delfino, M. (2004) 'The Middle Pleistocene herpetofauna of Valdemino Cave (Liguria, north-western Italy)', *Herpetological Journal*, 14, pp. 113–128.

Delfino, M. and Atzori, M. (2013) 'An update on the Early Pleistocene herpetofauna from Pirro Nord', *Palaeontographica*, A(298), pp. 19–29.

Delfino, M. and Sala, B. (2007) 'Late Pliocene albanerpetontid (Lissamphibia) from Italy', *Journal of Vertebrate Paleontology*, 27, pp. 716–719.

Delpech, F. (1983) 'Les faunes du Paléolithique supérieur dans le Sud-Ouest de la France', *Cahiers du Quaternaire*, 6(6), pp. 1–453.

Dibble, H., Chase, P., McPherron, S. and Tuffreau, A. (1997) 'Testing the reality of a "living floor" with archaeological data', *American Antiquity*, 62, pp. 629–651.

Diedrich, C. G. (2010) 'Specialized horse killers in Europe: Foetal horse remains in the Late Pleistocene Srbsko Chlum-Komín Cave hyaena den in the Bohemian Karst (Czech Republic) and actualistic comparisons to modern African spotted hyaenas as zebra hunters', *Quaternary International*, 220, pp. 174–187.

Diedrich, C. G. (2012a) 'An Ice Age spotted hyena Crocuta crocuta spelaea (Goldfuss 1823) population, their excrements and prey from the Late Pleistocene hyena den of the Sloup Cave in the Moravian Karst, Czech Republic', *Historical Biology*, 24(2), pp. 161–185. doi: 10.1080/08912963.2011.591491.

Diedrich, C. G. (2012b) 'Late Pleistocene Crocuta crocuta spelaea (Goldfuss, 1823) clans as prezewalski horse hunters and woolly rhinoceros scavengers at the open air commuting den and contemporary Neanderthal camp site Westeregeln (central Germany)', *Journal of Archaeological Science*, 39(6), pp. 1749–1767. doi: 10.1016/j.jas.2012.01.013.

Diedrich, C. G. (2012c) 'Typology of ice age spotted hyena Crocuta crocuta spelaea (Goldfuss, 1823) coprolite aggrefate pellets from the european Late Pleistocene and their significance at dens and scavenging sites', in Hunt, A. P., Milàn, J., Lucas, S. G., and Spielmann, J. A. (eds) *Vertebrate Coprolites*. Alburquerque: New Mexico Museum of Natural History and Science, pp. 369–377.

Diedrich, C. G. (2014) ‘Palaeopopulations of Late Pleistocene Top Predators in Europe: Ice Age Spotted Hyenas and Steppe Lions in Battle and Competition about Prey’, *Paleontology Journal*, pp. 1–34. doi: 10.1155/2014/106203.

Diedrich, C. G. (2015) ‘Late Pleistocene spotted hyena den sites and specialized rhinoceros scavengers in the karstified Zechstein areas of the Thuringian Mountains (Central Germany).’, *Quaternary Science Journal*, 64(1), pp. 29–45.

Diedrich, C. G. (2017) ‘Late Pleistocene hyena skeleton remains of a communal/prey depot cave den in the Bohemian Mountains (Czech Republic) - its osteology, taphonomy and palaeoecology’, *Acta Zoologica*, 98(1), pp. 66–93. doi: 10.1111/azo.12152.

Dietrich, W. O. (1951) ‘Koprolithen aus dem Pleistozan Ostafrikanas’, *Neues Jahrbuch für Geologie und Paläontologie*, pp. 310–314.

Dincauze, D. F. (1987) ‘Strategies for Paleoenvironmental Reconstruction in Archaeology’, *Advances in Archaeological Method and Theory*, 11, pp. 255–336.

Dincauze, D. F. (2000) *Environmental Archaeology: Principles and Practice*. Cambridge University Press.

Djamali, M., Biglari, F., Abdi, K., Andrieu-Ponel, V., de Beaulieu, J.-L., Mashkour, M. and Ponel, P. (2011) ‘Pollen analysis of coprolites from a late Pleistocene-Holocene cave deposit (Wezmeh Cave, west Iran): insights into the late Pleistocene and Late Holocene vegetation and flora of the central Zagros Mountains’, *Journal of Archaeological Science*, 38, pp. 3394–3401.

Djindjian, F. . (2012) ‘Is the MP-EUP transition also and economic and social revolution?’, *Quaternary International*, 259, pp. 72–77.

Dobberstein, R. C., Collins, M. J., Craig, O. E., Taylor, G., Penkman, K. E. H. and Ritz-Timme, S. (2009) ‘Archaeological collagen: Why worry about collagen diagenesis?’, *Archaeological and Anthropological Sciences*, 1, pp. 31–42.

Douka, K., Grimaldi, S., Boschian, G., del Lucchese, A. and Higham, T. F. G. (2012) ‘A new chronostratigraphic framework for the Upper Palaeolithic of Riparo Mochi (Italy)’, *Journal of Human Evolution*, 62(2), pp. 286–299. doi: 10.1016/j.jhevol.2011.11.009.

Duarte, C., Maurício, J., Pettitt, P. B., Souto, P., Trinkaus, E., van der Plicht, H. and Zilhão, J. (1999) ‘The early Upper Paleolithic human skeleton from the Abrigo do

Lagar Velho (Portugal) and modern human emergence in Iberia.’, *Proceedings of the National Academy of Sciences of the United States of America*. National Academy of Sciences, 96(13), pp. 7604–7609. doi: 10.1073/PNAS.96.13.7604.

Duffin, C. J. (2012) ‘The earliest published records of coprolites’, in Hunt, A. P., Milàn, J., Lucas, G., and Spielmann, J. A. (eds) *Vertebrate Coprolites*. Albuquerque: New Mexico Museum of Natural History and Science, pp. 25–28.

Dujardin, V. (2003) ‘Sondages à La Quina aval (Gardes-le-Pontaroux, Charente)’, *Antiq. Natl.*, 33, pp. 21–26.

Dunnell, R. C. (1982) ‘Science, social science and common sense: the agonizing dilemma of modern archaeology’, *Journal of Anthropological Research*, 38, pp. 1–25.

Durante, S. and Settepassi, F. (1976) ‘La malacofauna della Grotta Guattari’, *Quaternaria*, 19, pp. 35–69.

Dusseldorp, G. L. (2009) *View to Kill. Investigating Middle Palaeolithic Subsistence Using an Optimal Foraging Strategy*. Sidestone Press.

Dusseldorp, G. L. (2011) ‘Studying Pleistocene Neanderthal and cave hyena dietary habits: combining isotopic and archaeozoological evidence.’, *Journal of Archaeological Method and Theory*, 18, pp. 224–255.

Ebert, J. I. (1992) *Distributional Archaeology*. University of Utah Press.

Eisner, W. and Kamermans, H. (2004) ‘Late Quaternary Vegetation History of Latina, Italy: a Final Report on the Mezzaluna Core’, in Holstrom, S., Voorrips, A., and Kamermans, H. (eds) *The Agro Pontino Archaeological Survey*. Leiden: Leiden University.

Eisner, W., Kamermans, H. and Loving, S. H. (1984) ‘Risultati preliminari di una ricerca palinologica nell’Agro Pontino’, in *Atti della XXIV riunione scientifica dell’Istituto Italiano di preistoria e protostoria nel Lazio*. Firenze, pp. 207–211.

Eisner, W., Kamermans, H. and Wymstra, T. J. (1986) ‘The Agro Pontino survey: results from a first pollen core’, *Dialoghi di Archeologia*, 2, pp. 145–153.

Elias, S. A. and Schreve, D. (2007) ‘Late Pleistocene Megafaunal Extinctions’, in Elias, S. A. (ed.) *Encyclopedia of Quaternary Science, 4*. Amsterdam: Elsevier Science Publishers B.V., pp. 3202–3217.

Enloe, J. (2006) ‘Geological processes and site structure: assessing integrity at a Late Paleolithic open-air site in northern France’, *Geoarchaeology*, 21, pp. 523–540.

Eren, M. I., Boehm, A. R., Morgan, B. M., Anderson, R. and Andrews, B. (2011) ‘Flaked Stone Taphonomy: a Controlled Experimental Study of the Effects of Sediment Consolidation on Flake Edge Morphology’, *Journal of Taphonomy*, 9(3), pp. 201–217.

Eren, M. I., Durant, A., Neudorf, C., Haslam, M., Shipton, C., Bora, J., Korisettar, R. and Petraglia, M. (2010) ‘Experimental examination of animal trampling effects on artifact movement in dry and water saturated substrates: a test case from South India’, *Journal of Archaeological Science*, 37(12), pp. 3010–3021. doi: 10.1016/j.jas.2010.06.024.

Erlandson, J. M. (2001) ‘The archaeology of aquatic adaptations: paradigms for a new millennium’, *Journal of Archaeological Research*, 9, pp. 287–350.

Erlandson, J. M. and Fitzpatrick, S. M. (2006) ‘Oceans, islands, and coasts: current perspectives on the role of the sea in human prehistory’, *Journal of Island and Coastal Archaeology*, 1, pp. 5–33.

Esper, J. F. (1774) *Ausführliche Nachricht von neuentdeckten Zoolithen unbekannter vierfüssiger Thiere und denen sie enthaltenden, so wie verschiedenen anderen, denkwürdigen Grüften der Oberbürgischen Lande des Marggrafthums Bayreuth.* Nürnberg.

Evans, A., Flatman, J. and Flemming, N. (2014) *Prehistoric Archaeology on the Continental Shelf: A Global Review*. Springer.

Evans, J. G. (2003) *Environmental archaeology and the social order*. London: Routledge.

Fabbri, P. F., Panetta, D., Sarti, L., Martini, F., Salvadori, P. A., Caramella, D., Fedi, M. and Benazzi, S. (2016) ‘Middle paleolithic human deciduous incisor from Grotta del Cavallo, Italy’, *American Journal of Physical Anthropology*, 161(3), pp. 506–512.

Facchini, F. and Belcastro, M. G. (eds) (2009) *La lunga storia di Neandertal: biologia e comportamento*. Editoriale Jaca Book.

Faegri, K. and Iversen, J. (1989) *Textbook of Pollen Analysis*. Fourth edi. Edited by K. Faegri, P. E. Kaland, and K. Krzywinski. New York: John Wiley & Sons.

Fairbanks, R. G. (1989) ‘A 17,000-year glacio-eustatic sea level record: influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation’, *Nature*. Nature Publishing Group, 342(6250), pp. 637–642. doi: 10.1038/342637a0.

Farina, S. (2006) *Revisione dei mammiferi del tardo Pleistocene-Olocene antico di*

'Canale Mussolini' (Agro Pontino, Lazio): analisi sistematica, distribuzione stratigrafica e considerazioni climatico-ambientali.

Farina, S. (2011) 'Late Pleistocene-Holocene mammals from "Canale delle Acque Alte (Canale Mussolini)" (Agro Pontino, Latium)', *Bollettino della Società Paleontologica Italiana*, 50(1), pp. 11–22.

Feblot-Augustins, J. (1997) 'Middle and Upper Paleolithic raw material transfers in Western and Central Europe', *Journal of Middle Atlantic Archaeology*, 13, pp. 57–90.

Féblot-Augustins, J. (2009) 'Revisiting European Upper Paleolithic raw material transfers: the demise of the cultural ecological paradigm?', in Adams, B. and Blades, B. (eds) *Lithic Materials and Paleolithic Societies*. John Wiley & Sons, pp. 25–46.

Fejfar, O. and Kaiser, T. M. (2005) 'Insect bone-modification and palaeoecology of Oligocene mammal-bearing sites in the Doupov Mountains,northwestern Bohemia. Dvérce, Detan, Valec (NW Bohemia)', *Palaeontologia Electronica*, 8(1), pp. 1–11.

Fernandes, P., Le Bourdonnec, F.-X., Raynal, J.-P., Poupeau, G., Piboule, M. and Moncel, M.-H. (2007) 'Origins of prehistoric flints: The neocortex memory revealed by scanning electron microscopy', *Comptes Rendus Palevol*, 6(8), pp. 557–568. doi: 10.1016/j.crpv.2007.09.015.

Fernandes, P., Raynal, J.-P. and Moncel, M.-H. (2008) 'Middle Palaeolithic raw material gathering territories and human mobility in the southern Massif Central, France: first results from a petro-archaeological study on flint', *Journal of Archaeological Science*, 35(8), pp. 2357–2370.

di Filippo, M. and Toro, B. (1980) 'Analisi gravimetrica delle strutturee geologiche del Lazio meridionale', *Geologica Romana*, 19, pp. 285–294.

Finlayson, C. (2004) *Neanderthals and Modern Humans: An Ecological and Evolutionary Perspective*. Cambridge: Cambridge University Press.

Finlayson, C. (2008) 'On the importance of coastal areas in the survival of Neanderthal populations during the Late Pleistocene', *Quaternary Science Reviews*, 27(27), pp. 2246–2252. doi: 10.1016/j.quascirev.2008.08.033.

Finlayson, C. and Carrión, J. S. (2007) 'Rapid ecological turnover and its impact on Neanderthal and other human populations', *Trends in Ecology & Evolution*, 22(4), pp. 213–222. doi: 10.1016/j.tree.2007.02.001.

Finlayson, C. and Giles Pacheco, F. (2000) 'The Southern Iberian Peninsula in the Late

Pleistocene: Geography, Ecology and Human Occupation', in Stringer, C. B., Barton, R. N. E., and Finlayson, C. (eds) *Neanderthals on the Edge*. Oxford: Oxbow Books, pp. 139–154.

Finlayson, C., Giles Pacheco, F., Rodriguez-Vidal, J., Fa, D. A. D. A., Gutierrez Lopez, J. M., Santiago Perez, A., Finlayson, G., Allueé, E., Baena Preysler, J., Caceres, I., Carrion, J. S., Fernandez Jalvo, Y., Gleed-Owen, C. P. C. P., Jimenez Espejo, F. J., Lopez, P., Lopez Saez, J. A., Riquelme Cantal, J. A., Sanchez Marco, A., Giles Guzman, F., Brown, K., Fuentes, N., Valarino, C. A., Villalpando, A., Stringer, C. B. C. B., Martinez Ruiz, F., Sakamoto, T., Rodríguez-Vidal, J., Fa, D. A. D. A., María Gutierrez López, J., Santiago Pérez, A., Finlayson, G., Allue, E., Baena Preysler, J., Cáceres, I., Carrión, J. S., Fernández Jalvo, Y., Gleed-Owen, C. P. C. P., Jimenez Espejo, F. J., López, P., Antonio López Sáez, J., Antonio Riquelme Cantal, J., Sánchez Marco, A., Giles Guzman, F., Brown, K., Fuentes, N., Valarino, C. A., Villalpando, A., Stringer, C. B. C. B., Martinez Ruiz, F. and Sakamoto, T. (2006) 'Late survival of Neanderthals at the southernmost extreme of Europe', *Nature*. Nature Publishing Group, 443(7113), pp. 850–853. doi: 10.1038/nature05195.

Finlayson, G., Finlayson, C., Pacheco, F. G., Vidal, J. R., Carrion, J. S. and Espejo, J. R. (2008) 'Caves as archives of ecological and climatic changes in the Pleistocene', *Quaternary International*, 181, pp. 55–63.

Finlayson, G., Finlayson, C. and Recio Espejo, J. M. (2008) 'Dynamics of a thermo-Mediterranean coastal environment – the Coto Doñana National Park', *Quaternary Science Reviews*, 27(23–24), pp. 2145–2152. doi: 10.1016/j.quascirev.2008.08.031.

Finlayson, J. C. (1999) 'Late Pleistocene human occupation of the Iberian Peninsula', *Journal of Iberian Archaeology*, 1, pp. 59–68.

Fiore, I., Gala, M. and Tagliacozzo, A. (2004) 'Ecology and Subsistence Strategies in the Eastern Italian Alps during the Middle Palaeolithic', *International Journal of Osteoarchaeology*, 14, pp. 273–286.

Fiorenza, L., Benazzi, S., Henry, A. G., Salazar-Garcia, D. C., Blasco, R., Picin, A., Wroe, S. and Kullmer, O. (2015) 'To Meat or Not to Meat? New Perspectives on Neanderthal Ecology', *Yearbook of Physical Anthropology*, 156, pp. 43–71.

Flannery, K. V. (1969) 'Origins and ecological effects of early domestication in Iran and the Near East', in Ucko, P. J. and Dimbleby, G. W. (eds) *The domestication and exploitation of plants and animals*. Chicago: Aldine, pp. 73–100.

Fletcher, R. (1992) ‘Time perspectivism, Annales, and the potential of archaeology’, in Knapp, B. (ed.) *archaeology, Annales and Ethnohistory*. Cambridge. Cambridge, pp. 35–49.

Foley, R. A. (1981a) ‘A Model of Regional Archaeological Structure’, *Proceedings of the Prehistoric Society*, 47, pp. 1–17.

Foley, R. A. (1981b) ‘Off-Sites Archaeology: An Alternative Approach for the Short-Sited’, in Hodder, I., Isaac, G., and Hammond, N. (eds) *Pattern of the Past: Essays in Honour of David Clarke*. Cambridge: Cambridge University Press, pp. 157–183.

Follieri, M., Giardini, M., Magri, D. and Sadori, L. (1995) ‘Fluttuazioni vegetazionali nel Lazio durante l’ultimo glaciale’, *Giornale Botanico Italiano*, 129(1), pp. 255–259.

Follieri, M., Giardini, M., Magri, D. and Sadori, L. (1998) ‘Palynostratigraphy of the last glacial period in the volcanic region of central Italy’, *Quaternary International*, 47–48, pp. 3–20.

Follieri, M. and Magri, D. (2001) ‘Middle and upper Pleistocene natural environment in the Roman area: climate, vegetation and landscape’, in Cavarretta, G., Gioia, P., Mussi, M., and Palombo, M. R. (eds) *1st International Congress ‘The World of Elephants’*. Roma: Consiglio Nazionale delle Ricerche - Roma, pp. 43–47.

Follieri, M., Magri, D. and Sadori, L. (1988) ‘250,000-year pollen record from Valle di Castiglione (Roma)’, *Pollen et Spores*, 30, pp. 329–356.

Follieri, M., Magri, D. and Sadori, L. (1989) ‘Pollen stratigraphical synthesis from Valle di Castiglione (Roma)’, *Quaternary International*, 3–4, pp. 81–84.

Ford, T. D. and O’Connor, B. (2009) ‘A vanished industry: Coprolite mining’, *Mercian Geologists*, 17, pp. 93–100.

Fornaseri, M. (1963) *La regione vulcanica dei Colli Albani: Vulcano Laziale*. Consiglio nazionale delle ricerche.

Fortelius, M. (1982) ‘Ecological aspects of dental functional morphology in the Plio-Pleistocene rhinoceroses of Europe’, in Kurten, B. (ed.) *Teeth: Form, Function, and Evolution*. New York: Columbia University Press, pp. 163–181.

Frank, A. H. E. (1969) ‘Pollen stratigraphy of the Lake of Vico (Central Italy)’, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 6, pp. 67–85.

Frayer, D., Jelinek, A., Olivia, M. and Wolpoff, M. H. (2006) ‘Aurignacia males from the Mladec Caves, Moravia, Czech Republic’, in *Early modern humans at the Moravian*

Gate: The Mladec Caves and their remains. Wien: Springer, pp. 185–272.

Freda, C., Gaeta, M., Karner, D. B., Marra, F., Renne, P., Taddeucci, J., Scarlato, P., Christensen, J. and Dallai, L. (2006) ‘Eruptive history and petrologic evolution of the Albano multiple maar (Alban Hills, Central Italy)’, *Belletin of Volcanology*, 68, pp. 567–591.

Fu, Q., Li, H., Moorjani, P., Jay, F., Slepchenko, S. M., Bondarev, A. A., Johnson, P. L. F., Aximu-Petri, A., Prüfer, K., de Filippo, C., Meyer, M., Zwyns, N., Salazar-García, D. C., Kuzmin, Y. V., Keates, S. G., Kosintsev, P. A., Razhev, D. I., Richards, M. P., Peristov, N. V., Lachmann, M., Douka, K., Higham, T. F. G., Slatkin, M., Hublin, J.-J., Reich, D., Kelso, J., Viola, T. B. and Pääbo, S. (2014) ‘Genome sequence of a 45,000-year-old modern human from western Siberia’, *Nature*. Nature Research, 514(7523), pp. 445–449. doi: 10.1038/nature13810.

Fulop, R.-H., Heinze, S., John, S. and Rethemeyer, J. (2013) ‘Ultrafiltration of bone samples is neither the problem nor the solution’, *Radiocarbon*, 2–3, pp. 491–500.

Funiciello, R., Giordano, G. and De Rita, D. (2003) ‘The Albano maar lake (Colli Albani Volcano, Italy): recent volcanic activity and evidence of pre-Roman Age catastrophic lahar events’, *Journal of Volcanology and Geothermal Research*, 123(1–2), pp. 43–61. doi: 10.1016/S0377-0273(03)00027-1.

Funiciello, R. and Parotto, M. (1978) ‘Il substrato sedimentario nell’area dei Colli Albani: considerazioni geodinamiche e paleogeografiche sul margine tirrenico dellAppennino centrale’, *Geologica Romana*, 17, pp. 233–287.

Gallant, T. (1986) ‘Background noise and site definition: a contribution to site methodology’, *Journal of Field Archaeology*, 13(4), pp. 403–418.

Gamble, C. (1986) *The Palaeolithic Settlement of Europe*. Cambridge University Press.

Gamble, C., Davies, W., Pettitt, P. and Richards, M. (2004) ‘Climate change and evolving human diversity in Europe during the last glacial.’, *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*. The Royal Society, 359(1442), pp. 243-53–4. doi: 10.1098/rstb.2003.1396.

García, N. and Arsuaga, J. L. (2001) ‘Les carnivores (Mammalia) des sites du Pléistocène ancien et moyen d’Atapuerca (Espagne)’, *L’Anthropologie*, 105, pp. 83–93.

Gatta, M., Achino, K. F., La Rosa, M., Ceruleo, P., Silvestri, L. and Rolfo, M. F. (2016) ‘PONT-AIR: Pontinian open-air project’, *Antiquity Project Gallery*, 351, p. 3.

Gatta, M., Giaccio, B., Marra, F., Rolfo, M. F. and Jicha, B. (2017) ‘Trace-element fingerprinting of the 69–36 ka Colli Albani eruptive units: a preliminary dataset for archaeological and tephra studies in central-southern Italy’, *Journal of Archaeological Science: Reports*, 16, pp. 330–340. doi: 10.1016/j.jasrep.2017.10.007.

Gatta, M., Kotsakis, T., Pandolfi, L., Petronio, C., Salari, L., Achino, K. F., Silvestri, L. and Rolfo, M. F. (in press a) ‘The Late Pleistocene faunal assemblage from Cava Muracci (Latium, Italy): Palaeoecological implications for coastal central Italy during MIS 3’, *Comptes Rendus Palevol*.

Gatta, M. and Marra, F. (2017) ‘Tephrostratigraphic database of Late Pleistocene landscapes of Central Italy’, *Quaternary Newsletter*, 141, pp. 40–42.

Gatta, M. and Rolfo, M. F. (2015) ‘New Pleistocene Evidence from the Western Coast of Italy: A Landscape Approach’, *Antiquity Project Gallery*, 346, p. 3.

Gatta, M. and Rolfo, M. F. (2017a) ‘Cava Muracci: A new Middle-Upper Palaeolithic site in west-central Italy’, *Mediterranean Archaeology and Archaeometry*, 17(2), pp. 105–116. doi: 10.5281/zenodo.581729.

Gatta, M. and Rolfo, M. F. (2017b) ‘Rinvenimenti preistorici nei travertini di Cisterna di Latina’, in Garofalo, P. (ed.) *Proceedings of the conference ‘De Agro Pomptino’, Cisterna di Latina, 15 March 2014*. Cisterna di Latina.

Gatta, M. and Rolfo, M. F. (no date) ‘Prehistoric and palaeontological finds from Cisterna di Latina (loc. Muracci)’, in *Proceedings of the conference Lazio e Sabina 12, Rome 8-9 June 2015*. Rome.

Gatta, M., Sinopoli, G., Giardini, M., Giaccio, B., Hajdas, I., Pandolfi, L., Bailey, G., Spikins, P., Rolfo, M. F. and Sadori, L. (2016) ‘Pollen from Late Pleistocene hyena (Crocuta crocuta spelaea) coprolites: An interdisciplinary approach from two Italian sites’, *Review of Palaeobotany and Palynology*, 233, pp. 56–66. doi: 10.1016/j.revpalbo.2016.07.005.

Gaudzinski, S. (2006) ‘Monospecific or species-dominated faunal assemblages during the Middle Palaeolithic in Europe’, in Hovers, E. and Kuhn, S. (eds) *Transitions before the transition*. New York: Springer, pp. 137–148.

Gautier, A. (1993) ‘Trace Fossils in Archaeozoology’, *Journal of Archaeological Science*, 20(5), pp. 511–523.

Genise, J. F. (2004) ‘Ichnotaxonomy and ichnostratigraphy of chambered trace fossils in paleosols attributed to coleopterans, ants and termites’, *Geological Society of London*, 228, pp. 419–453.

Genise, J. F. and Edwards, N. (2003) ‘Ichnotaxonomy, Origin, and Paleoenvironment of Quaternary Insect Cells from Fuerteventura, Canary Islands, Spain.’, *Journal of the Kansas Entomological Society*, 76(2), pp. 320–327.

Geraga, M., Tsaila-Monopolis, S., Ioakim, C., Papatheodorou, G. and Ferentinos, G. (2005) ‘Short-term climate changes in the southern Aegean Sea over the last 48,000 years’, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 220(3–4), pp. 311–332. doi: 10.1016/j.palaeo.2005.01.010.

Giaccio, B. and Coppola, D. (2000) ‘Note preliminari sul contesto stratigrafico e paleoecologico del sito “Tana delle iene” (Ceglie Messapica, Brindisi, SE Italia)’, *Il Quaternario*, 13(1), pp. 5–20.

Giaccio, B., Isaia, R., Fedele, F. F., Di Canzio, E., Hoffecker, J. F., Ronchitelli, A., Sinitsyn, A. A., Anikovich, M. A., Lisitsyn, S. N. and Popov, V. V. (2008) ‘The Campanian Ignimbrite and Codola tephra layers: two temporal/stratigraphic markers for the Early Upper Palaeolithic in southern Italy and eastern Europe’, *Journal of Volcanology and Geothermal Research*, 177, pp. 208–226.

Giacobini, G. (1991) ‘Hyaenas or cannibals: Fifty years of debate on the Guattari Cave Neandertal Cranium’, *Quaternaria Nova*, I, pp. 593–604.

Giardini, M. (1993) ‘Late Pleistocene and Holocene history of vegetation at Stracciacappa, Monti Sabatini volcanic district (central Italy)’, in *INQUA SEQS Symp. Quaternary Stratigraphy in Volcanic Areas*. Rome, p. 34.

Giardini, M. (2007) ‘Late Quaternary vegetation history at Stracciacappa’, *Veget. Hist. Archaeobot.*, 16, pp. 301–316.

van Gijn, A. (1990) *The Wear and Tear of Flint. Principles of Functional Analysis Applied to Dutch Neolithic Assemblages*, *Analecta Praehistorica Leidensia*.

Gilbert, M. T., Jenkins, D. L., Gotherstrom, A., Naveran, N., Sanchez, J. J., Hofreiter, M., Thomsen, P. F., Binladen, J., Higham, T. F. G., Yohe II, R. M., Parr, R., Cummings, L. S. and Willerslev, E. (2008) ‘DNA from pre-Clovis human coprolites in Oregon, North America’, *Science*, 320, pp. 786–789.

Gill, F. and Bull, I. D. (2012) ‘Lipid analysis of vertebrate coprolites’, in Hunt, A. P., Milàn, J., Lucas, G., and Spielmann, J. A. (eds) *Vertebrate Coprolites*. Albuquerque:

New Mexico Museum of Natural History and Science, pp. 93–98.

Gilligan, I. (2007) ‘Neanderthal extinction and modern human behaviour: the role of climate change and clothing’, *World Archaeology*. Routledge, 39(4), pp. 499–514. doi: 10.1080/00438240701680492.

Giordano, G., De Benedetti, A. A., Diana, A., Diano, G., Esposito, A., Fabbri, M., Gaudioso, F., Marasco, F., Mazzini, I., Miceli, M., Mincione, V., Porreca, M., Rodani, S., Rosa, C., Vinkler, A. P., Caprilli, E., Taviani, S., Trigari, A., Bilardello, D., Malinconico, S., Sabato Ceraldi, T., Funiciello, R., Mattei, M., De Rita, D., Parotto, M. and Cas, R. A. F. (2010) ‘Stratigraphy, volcano-tectonics and evolution of the Colli Albani volcanic field’, in Funiciello, R. and Giordano, G. (eds) *The Colli Albani Volcano*. London: Geological Society, pp. 43–97.

Giordano, G., De Benedetti, A. A., Diana, A., Diano, G., Gaudioso, F., Marasco, F., Miceli, M., Mollo, S., Cas, R. A. F. and Funiciello, R. (2006) ‘The Colli Albani mafic caldera (Roma, Italy): Stratigraphy, structure and petrology’, *Journal of Volcanology and Geothermal Research*, 155(1–2), pp. 49–80. doi: 10.1016/j.jvolgeores.2006.02.009.

Given, M. (2003) ‘Mapping and Manuring: Can we compare sherd density figures?’, in Alcock, S. and Cherry, J. (eds) *Side by Side survey: Comparative Regional Studies in the Mediterranean World*. Oxford, pp. 13–21.

Goldfuss, G. A. (1823) ‘Osteologische Beiträge zur Kenntnis verschiedener Säugethiere der Vorwelt. VI. Ueber die Hölen-Hyäne (Hyaena spelaea).’, *Nova Acta Physico-Medica Academiea Caesarae Leopoldino-Carolinae Naturae Curiosorum*, 3, pp. 456–490.

González-Sampériz, P., Leroy, S., Carrion, J. S., Garcìa-Antòn, M., Gil-Garcìa, M. J. and Figueiral, I. (2010) ‘Steppes, savannahs and botanic gardens during the Pleistocene’, *Review of Palaeobotany and Palynology*, 162, pp. 427–457.

González-Sampériz, P., Montes, L. and Utrilla, P. (2003) ‘Pollen in hyena coprolites from Gabasa Cave (northern Spain)’, *Review of Palaeobotany and Palynology*, 126(1–2), pp. 7–15. doi: 10.1016/S0034-6667(03)00033-2.

Gordon, C. C. and Buikstra, J. E. (1981) ‘Soil pH, Bone Preservation, and Sampling Bias at Mortuary Sites’, *American Antiquity*, 46(3), pp. 566–571.

Gosden, C. (1994) *Social Being and Time*. Blackwell. Oxford.

Gray, J. and Boucot, A. J. (1975) ‘Color changes in pollen and spores: a review’, *Geological Society of America Bulletin*, 86, pp. 1019–1033.

Green, R. E., Krause, J., Briggs, A. W. and Maricic, T. (2010) ‘A Draft Sequence of the Neandertal Genome’, *Science*, 328(5979), pp. 710–722.

Grimaldi, S. (1995) *Variabilità comportamentale e concetto Levallois. Ipotesi di modelli comportamentali neandertaliani in Italia centrale attraverso lo studio tecnologico di alcune industrie litiche*. Università degli Studi di Roma ‘La Sapienza’.

Grimaldi, S. and Santaniello, F. (2014) ‘New insights into Final Mousterian lithic production in western Italy’, *Quaternary International*, 350, pp. 116–129.

Grimaldi, S. and Spinapolice, E. E. (2010) ‘The late Mousterian of Grotta Breuil (Monte Circeo, Lazio, Italy): interpreting new and ancient data’, in *Middle Palaeolithic Human Activity and Paleoecology: New Discoveries and Ideas*. Wrozlaw: ACTA UNIVERSITATIS WRATISLAVIENSIS, pp. 411–421.

Grun, R. (2006) ‘Direct Dating of Human Fossils’, *Yearbook of Physical Anthropology*, 49, pp. 2–48.

Grun, R., Aubert, M., Hellstrom, J. and Duval, M. (2010) ‘The challenge of direct dating old human fossils’, *Quaternary International*, 223–224, pp. 87–93.

Grun, R., Aubert, M., Joannes-Boyau, R. and Moncel, M.-H. (2008) ‘High resolution analysis of uranium and thorium concentration as well as U-series isotope distributions in a Neanderthal tooth from Payre (Ardèche, France) using laser ablation ICP-MS’, *Geochimica et Cosmochimica Acta*, 72, pp. 5278–5290.

Guérin, C. (1980) ‘Les rhinocéros (Mammalia, Perissodactyla) du Miocène terminal au Pléistocène supérieur en Europe occidentale. Comparaison avec les espèces actuelles.’, *Documents des Laboratoires de Géologie de Lyon*, 79(1,2,3), pp. 1–1185.

Guest, G. (2003) ‘Fishing Behavior and Decision-Making in an Ecuadorian Community: A Scaled Approach’, *Human Ecology*, 31(4), pp. 611–644.

Gumerman, G. J. and Dean, J. S. (1989) ‘Prehistoric Cooperation and Competition in the Western Anasazi Area’, in Cordell, L. S. and Gumerman, G. J. (eds) *Dynamics of Southwest Prehistory*. Washington, D.C.: Smithsonian Institution Press, pp. 99–148.

Gvoždík, V., Benkovský, N., Crottini, A., Bellati, A., Moravec, J. and Romano, A. (2013) ‘An ancient lineage of slow worms, genus Anguis (Squamata: Anguidae), survived in the Italian Peninsula’, *Molecular Phylogenetics and Evolution*, 69, pp. 1077–1092.

Haagsma, B. J. (1993) ‘A pollen core from Monticchio in the Agro Pontino (South Lazio), a study on human impact in the Agro Pontino during the first millennium BC’, in Attema, P. (ed.) *An archaeological survey in the Pontine Region Vol. I text. A contribution to the early settlement history of South Lazio. 900-100 BC.*, pp. 249–255.

Hajdas, I., Michczynski, A., Bonani, G., Wacker, L. and Furrer, H. (2009) ‘Dating bones near the limit of the radiocarbon dating method: study case mammoth from Niederweningen, Zh Switzerland’, *Radiocarbon*, 51(2), pp. 675–680.

Hansen, J. (2001) ‘Macroscopic plant remains from Mediterranean Caves and Rockshelters: Avenues of interpretation’, *Geoarchaeology*, 16, pp. 401–432.

Hawks, J., Hunley, K., Lee, S.-H. and Wolpoff, M. (2000) ‘Population bottlenecks and Pleistocene human evolution’, *Molecular Biology and Evolution*, 17, pp. 2–22.

Hedges, R. and Law, I. A. (1989) ‘The radicoarbon dating of bone’, *Applied Geochemistry*, 4(3), pp. 249–253.

Heilen, M. P. (2005) *An archaeological theory of landscapes*. University of Arizona.

Hemming, S. R. (2004) ‘Heinrich events: Massive late Pleistocene detritus layers of the North Atlantic and their global climate imprint’, *Reviews of Geophysics*, 42(1), p. RG1005. doi: 10.1029/2003RG000128.

Henry-Gambier, D., Maureille, B. and White, R. (2004) ‘Vestiges humains des niveaux de l’Aurignacien ancin du site de Brassempouy (Landes)’, *Bulletins et mémoires de la Société d’Anthropologie de Paris*, 16, pp. 49–87.

Henry, A. G., Brooks, A. S. and Piperno, D. R. (2011) ‘Microfossils in calculus demonstrate consumption of plants and cooked foods in Neanderthal diets (Shanidar III, Iraq: Spy I and II, Belgium)’, *Proceedings of the National Academy of Sciences of the United States of America*, 108, pp. 468–491.

Henry, A. G., Brooks, A. S. and Piperno, D. R. (2014) ‘Plant foods and the dietary ecology of Neanderthals and early modern humans’, *Journal of Human Evolution*, 69, pp. 44–54. doi: 10.1016/j.jhevol.2013.12.014.

Henry, D. O., Belmaker, M. and Bergin, S. M. (2017) ‘The effect of terrain on Neanderthal ecology in the Levant’, *Quaternary International*, 435, pp. 94–105. doi: 10.1016/j.quaint.2015.10.023.

Henshilwood, C. S. and Marean, C. (2003) ‘The origins of modern human behavior’, *Current Anthropology*, 44, pp. 627–652.

Hercman, H. (2014) ‘U-series dating of collage - A step toward direct U-series dating of fossil bone?’, *Quaternary International*, 339–340, pp. 4–10.

Heusser, C. J. (1955) ‘Pollen profiles from the Queen Charlotte Islands, British Columbia’, *Canadian Journal of Botany*, 33, pp. 429–449.

Hewitt, G. M. (1996) ‘Some genetic consequences of ice ages, and their role in divergence and speciation’, *Biological Journal of the Linnean Society*, 58, pp. 247–276.

Hewitt, G. M. (1999) ‘Post-glacial recolonisation of European biota’, *Biological Journal of the Linnean Society*, 68, pp. 87–112.

Hewitt, G. M. (2000) ‘The genetic legacy of the Quaternary ice ages’, *Nature*, 405, pp. 907–913.

Hewitt, G. M. (2004) ‘Genetic consequences of climatic oscillations in the Quaternary’, *Philosophical Transactions of the Royal Society B: Biological Sciences*, 359(1442), pp. 183–195. doi: 10.1098/rstb.2003.1388.

Higgs, E. S. (1972) *Papers in Economic Prehistory*. Cambridge: Cambridge University Press.

Higham, T., Brock, F., Peresani, M., Broglio, A., Wood, R. and Douka, K. (2009) ‘Problems with radiocarbon dating the Middle to Upper Palaeolithic transition in Italy’, *Quaternary Science Reviews*, 28(13), pp. 1257–1267. doi: 10.1016/j.quascirev.2008.12.018.

Higham, T., Compton, T., Stringer, C., Jacobi, R., Shapiro, B., Trinkaus, E., Chandler, B., Gröning, F., Collins, C., Hillson, S., O’Higgins, P., FitzGerald, C. and Fagan, M. (2011) ‘The earliest evidence for anatomically modern humans in northwestern Europe’, *Nature*. Nature Research, 479(7374), pp. 521–524. doi: 10.1038/nature10484.

Higham, T., Douka, K., Wood, R., Ramsey, C. B., Brock, F., Basell, L., Camps, M., Arrizabalaga, A., Baena, J., Barroso-Ruíz, C., Bergman, C., Boitard, C., Boscato, P., Caparrós, M., Conard, N. J., Draily, C., Froment, A., Galván, B., Gambassini, P., Garcia-Moreno, A., Grimaldi, S., Haesaerts, P., Holt, B., Iriarte-Chiapusso, M.-J., Jelinek, A., Jordá Pardo, J. F., Maíllo-Fernández, J.-M., Marom, A., Maroto, J., Menéndez, M., Metz, L., Morin, E., Moroni, A., Negrino, F., Panagopoulou, E., Peresani, M., Pirson, S., de la Rasilla, M., Riel-Salvatore, J., Ronchitelli, A., Santamaria, D., Semal, P., Slimak, L., Soler, J., Soler, N., Villaluenga, A., Pinhasi, R. and Jacobi, R. (2014) ‘The timing and spatiotemporal patterning of Neanderthal disappearance’, *Nature*. Nature Research, 512(7514), pp. 306–309. doi: 10.1038/nature13621.

Higham, T. F. G., Ramsey, C. B., Karavanić, I., Smith, F. H. and Trinkaus, E. (2006) ‘Revised direct radiocarbon dating of the Vindija G1 Upper Paleolithic Neandertals’, *Proceedings of the National Academy of Sciences of the United States of America*, 103(3), pp. 553–557. doi: 10.1073/pnas.0510005103.

Higham, T., Jacobi, R. M., Basell, L., Bronk Ramsey, C., Chiotti, L. and Nespoulet, R. (2011) ‘Precision dating of the Palaeolithic: A new radiocarbon chronology for the Abri Pataud (France), a key Aurignacian sequence’, *Journal of Human Evolution*, 61, pp. 549–563.

Higham, T., Jacobi, R. M. and Bronk Ramsey, C. (2006) ‘AMS radiocarbon dating of ancient bone using ultrafiltration’, *Radiocarbon*, 48(2), pp. 179–195.

Hockett, B. and Haws, J. A. (2005) ‘Nutritional ecology and the human demography of Neadertal extionction’, *Quaternary International*, 137, pp. 21–34.

Hodder, I. (1991) *Reading the Past*. Cambridge. Cambridge: Cambridge University Press.

Hoffecker, J. F., Elias, S. A. and O’Rourke, D. H. (2014) ‘Out of Beringia?’, *Science*, 343(6174), pp. 979–980.

Hofreiter, M. and Stewart, J. (2009) ‘Ecological Change, Range Fluctuations and Population Dynamics during the Pleistocene’, *Current Biology*, 19(14), pp. 584–594. doi: 10.1016/j.cub.2009.06.030.

Holdaway, S. and Douglass, M. (2011) ‘A Twenty-First Century Archaeology of Stone Artifacts’, *Journal of Archaeological Method and Theory*, 19(1), pp. 101–131. doi: 10.1007/s10816-011-9103-6.

Hollocher, K. and Hollocher, T. C. (2012) ‘Early process in the fossilization of terrestrial feces to coprolites, and microstructure preservation’, *Bulletin - New Mexico Museum of Natural History and Science*. Edited by A. P. Hunt, J. Milàn, G. Lucas, and J. A. Spielmann. Albuquerque: New Mexico Museum of Natural History and Science, 57, pp. 79–91.

Holstrom, S., Voorrips, A. and Kamermans, H. (2004) *The Agro Pontino archaeological survey*. Leiden.

Horwitz, L. K. and Goldberg, P. (1989) ‘A Study of Pleistocene and Holocene Hyena

Coprolites’, *Journal of Archaeological Science*, 16, pp. 71–94.

Horwitz, L. K. and Smith, P. (1988) ‘The effect of striped hyaena activity on human remains’, *Journal of Archaeological Science*, 15(5), pp. 471–488.

Hosfield, R. and Chambers, J. (2005a) ‘Flake modifications during fluvial transportation: three cautionary tales’, *Lithics: Newslet Lithic Stud Soc*, 24, pp. 56–65.

Hosfield, R. and Chambers, J. (2005b) *River gravels and flakes: new experiments in site formation, stone tool transportation and transformation*. Oldenburg: Bilanz.

Howard, C. D. (2002) ‘The gloss patination of flint artifact’, *The Plains Anthrpolo*, 47, pp. 283–287.

Hublin, J.-J. (1984) *The Hamlyn encyclopedia of prehistoric animals*. London: Hamlyn.

Hublin, J.-J. (2015) ‘The modern human colonization of western Eurasia: when and where?’, *Quaternary Science Reviews*, 118, pp. 194–210. doi: 10.1016/j.quascirev.2014.08.011.

Hublin, J.-J., Barroso-Ruíz, C., Medina Lara, P., Fontugne, M. and Reyss, J. L. (1995) ‘The Mousterian site of Zafarraya (Andalucia, Spain): dating and implications on the Palaeolithic peopling processes of Western Europe’, *Comptes Rendus de l’Académie des Sciences - Series IIA*, 321, pp. 931–937.

Huchet, J.-B., Le Mort, F., Rabinovich, R., Blau, S., Coqueugniot, H. and Arensburg, B. (2013) ‘Identification of dermestid pupal chambers on Southern Levant human bones: inference for reconstruction of Middle Bronze Age mortuary practices’, *Journal of Archaeological Science*, 40, pp. 3793–3803.

Hull, K. L. (2005) ‘Process, perception, and practice: Time perspectivism in Yosemite native demography’, *Journal of Anthropological Archaeology*, 24(4), pp. 354–377. doi: 10.1016/j.jaa.2005.06.003.

Huls, C. M., Grootes, P. M. and Nadeau, M.-J. (2007) ‘How clean is ultrafiltration cleaning of bone collagen?’, *Radiocarbon*, 49(2), pp. 193–200.

Huls, C. M., Grootes, P. M. and Nadeau, M.-J. (2009) ‘Ultrafiltration: Boon or Bane?’, *Radiocarbon*, pp. 613–625. doi: 10.2458/azu_js_rc.51.3520.

Hunt, A. P., Lucas, G., Milàn, J. and Spielmann, J. A. (2012) ‘Vertebrate coprolite studies: Status and prospectus’, in Hunt, A. P., Milàn, J., Lucas, G., and Spielmann, J. A. (eds) *Vetebrate Coprolites*. Albuquerque: New Mexico Museum of Natural History and Science, pp. 5–24.

Hunt, C. and Eisner, W. (1991) ‘Palynology of the Mezzaluna Core’, in Voorips, A., Loving, S., and Kamermans, H. (eds) *The Agro Pontino Survey Project: Methods and Preliminary Results*, pp. 49–59.

Hunt, C. O. and Fiacconi, M. (2017) ‘Pollen taphonomy of cave sediments: What does the pollen record in caves tell us about external environments and how do we assess its reliability?’, *Quaternary International*, pp. 1–8. doi: 10.1016/j.quaint.2017.05.016.

Huntley, B. and Birks, H. J. B. (1983) *An Atlas of Past and Present Pollen Maps of Europe, 0-13,000 Years Ago*. Cambridge: Cambridge University Press.

Indes, F. (1875) ‘Lettres sur la formation des tufs dans la campagne romaine, ecc.’, *Bulletin de la Société Géologique de France*, 26, pp. 1868–1869.

Inizan, M. L., Reduron-Ballinger, M., Roche, H. and Tixier, J. (1995) *Technologie de la pierre taillée*. Meudon: CREP.

Ippolito, F. and Sgrosso, I. (1972) ‘Sulle ricerche di idrocarburi nell’area litorale del Lazio e sulla loro interpretazione’, *Rivista Mineraria Siciliana*, 133–135, pp. 1–16.

Jackes, M., Lubell, D. and Crann, C. (2015) ‘Dating and redating Capsian skeletons 3A-4 and 3A-7, Aïn Berriche (Algeria)’, *Journal of Archaeological Science: Reports*, 4, pp. 78–85.

Jacobi, R. M., Higham, T. F. G. and Bronk Ramsey, C. (2006) ‘AMS radiocarbon dating of middle and upper Palaeolithic bone in the British Isles: improved reliability using ultrafiltration’, *Journal of Quaternary Science*, 21, pp. 557–573.

Jennings, R., Finlayson, C., Fa, D. and Finlayson, G. (2011) ‘Southern Iberia as a refuge for the last Neanderthal populations’, *Journal of Biogeography*, 38, pp. 1873–1885.

Jimenez Espejo, F., Martinez Ruiz, F., Finlayson, C., Paytan, A., Sakamoto, T., Ortega-Huertas, M., Finlayson, G., Iijima, K., Gallego-Torres, D. and Fa, D. (2007) ‘Climate forcing and Neanderthal extincion in Southern Iberia: insights from a multiproxy marine record’, *Quaternary Science Reviews*, 26, pp. 836–852.

Johnston, P. A., Eberth, D. A. and Anderson, P. K. (1996) ‘Alleged vertebrate eggs from Upper Cretaceous redbeds, Gobi Desert, are fossil insect (Coleoptera) pupal chambers: Fictovichnus new ichnogenus.’, *Canadian Journal of Earth Sciences*, 33, pp. 511–525.

Jones, A. M., O’Connell, T. C., Young, E. D., Scott, K., Buckingham, C. M., Iacumin, P. and Brasier, M. D. (2001) ‘Biogeochemical data from well preserved 200 ka collagen and skeletal remains’, *Earth and Planetary Science Letters*, 193, pp. 143–149.

van Joolen, E. (2003) *Archaeological Land Evaluation. A Reconstruction of the Suitability of Ancient Landscapes for Various Land Uses in Italy Focused on the First Millennium BC.* Groningen University.

Jouy-Avantin, F., Debenath, A., Moigne, A. and Moné, H. (2003) ‘A Standardised Method for the Description and the Study of Coprolites’, *Journal of Archaeological Science*, 30, pp. 367–372.

Kamermans, H. (1984) *Artefacten onderzoek Agro Pontino Project*. Roma.

Kamermans, H. (1991) ‘Faulted land: The geology of the Agro Pontino’, in Voorrips, A., Loving, S. H., and Kamermans, H. (eds) *The Agro Pontino Survey Project*. Universiteit van Amsterdam, p. 131.

Kamermans, H. and Sevink, J. (2009) ‘Patterns of Middle and Upper Paleolithic land use in Central Lazio (Italy)’, in *Analecta Praehistorica Leidensia*, pp. 41–55.

Karavanić, I. and Smith, F. H. (2013) ‘Alternative Interpretations of the Middle/Upper Paleolithic Interface at Vindija Cave (Northwestern Croatia) in the Context of Central Europe and the Adriatic’, *Archaeology, Ethnology and Anthropology of Eurasia*. No longer published by Elsevier, 41(4), pp. 11–20. doi: 10.1016/j.aeae.2014.07.003.

Karkanas, P., Bar-Yosef, O., Goldberg, P. and Weiner, S. (2000) ‘Diagenesis in Prehistoric Caves: the Use of Minerals that Form In Situ to Access the Completeness of the Archaeological Record’, *Journal of Archaeological Science*, 27, pp. 915–929.

Karkanas, P., Kyparissi-Apostolika, N., Bar-Yosef, O. and Weiner, S. (1999) ‘Mineral Assemblages in Theopetra, Greece: A Framework for Understanding Diagenesis in a Prehistoric Cave’, *Journal of Archaeological Science*, 26, pp. 1171–1180.

Karner, D. B., Marra, F. and Renne, P. (2001) ‘The history of the Monti Sabatini and Alban Hilss volcanoes: groundwork for assessing volcanic-tectonic hazards for Rome.’, *Journal of Volcanology and Geothermal Research*, 107, pp. 185–219.

Keeley, L. (1974) ‘Technique and Methodology in Microwear Review’, *World Archaeology*, 5(3), pp. 323–336.

Keeley, L. (1980) *Experimental Determination of Stone Tool Uses. A Microwear Analysis*. Chicago: University of Chicago Press.

Keeley, L. and Newcomer, M. H. (1977) ‘Microwear Analysis of Experimental Flint Tools, a Test Case’, *Journal of Anthropological Science*, 4, pp. 29–62.

Kelly, M. G. and Huntley, B. (1991) ‘An 11000-year record of vegetation and environment from Lago di Martignano, Latium, Italy’, *J. Quat. Sci.*, 6, pp. 209–224.

Klein, R. (1987) ‘Reconstructing how early people exploited animals’, in Nitecki, M. and Nitecki, D. (eds) *The Evolution of Human Hunting*. New York: Plenum Press, pp. 11–46.

Knapp, B. (1992) *Archaeology Annales, And Ethnohistory*. Sydney: Cambridge University Press.

Koch, P. L. and Barnosky, A. D. (2006) ‘Late Quaternary Extinctions: State of the Debate’, *Annual Review of Ecology, Evolution, and Systematics*. Annual Reviews, 37(1), pp. 215–250. doi: 10.1146/annurev.ecolsys.34.011802.132415.

von Koenigswald, W. (1999) ‘Hat der Mensch das Aussterben der grossen pleistozanen Pflanzenfresser verursacht?’, *Kaupia*, 9, pp. 193–201.

Kolska Horwitz, L. R. (1990) ‘The Origin of Partially Digested Bones Recovered from Archaeological Contexts in Israel’, *Paléorient*, 16(1), pp. 97–106. doi: 10.3406/paleo.1990.4522.

Kotsakis, T. (1991) ‘Late Pleistocene fossil microvertebrates of Grotta Breuil (Monte Circeo, Central Italy)’, *Quaternaria Nova*, I, pp. 325–332.

Kotsakis, T. (2008) ‘Storia paleontologica di erinaceomorfi, soricomorfi, lagomorfi e roditori attuali d’Italia’, in Amori, G., Contoli, L., and Nappi, A. (eds) *Fauna d’Italia, Mammalia II, Erinaceomorpha, Soricomorpha, Lagomorpha, Rodentia*. Milano: Calderini, pp. 1–32.

Kotsakis, T., Abbazzi, L., Angelone, C., Argenti, P., Barisone, G., Fanfani, F., Marcolini, F. and Masini, F. (2003) ‘Plio-Pleistocene biogeography of Italian mainland micromammals’, *Deinsea*, 10, pp. 313–342.

Kotsakis, T., Marcolini, F., De Rita, D., Conti, M. and Esu, D. (2011) ‘Three Late Pleistocene small mammal faunas from the Baccano maar (Rome, central Italy)’, *Paleontologica Italiana*, 50, pp. 103–110.

Krebs, C. J. (1994) *Ecology: the experimental analysis of distribution and abundance*. New York: Harper Collins.

Krings, M., Capelli, C., Tschentscher, F., Geisert, H., Meyer, S., von Haeseler, A., Grossschmidt, K., Possnert, G., Paunovic, M. and Pääbo, S. (2000) ‘A view of Neandertal genetic diversity’, *Nature Genetics*. Nature Publishing Group, 26(2), pp.

144–146. doi: 10.1038/79855.

Kruuk, H. (1972) *The Spotted Hyena. A Story of Predation and Social Behavior*. Chicago: University of Chicago Press.

Kuhn, S. L. (1990) *Diversity within Uniformity. Tool Manifacture and Use in the Pontinian Mousterian of Latium*. New Mexico.

Kuhn, S. L. (1991a) ‘Preliminary observation on tool manufacture and use histories’, *Quaternaria Nova*, I, pp. 367–378.

Kuhn, S. L. (1991b) ‘“Unpacking” reduction: Lithic raw material economy in the mousterian of west-central Italy’, *Journal of Anthropological Archaeology*, 10(1), pp. 76–106. doi: 10.1016/0278-4165(91)90022-P.

Kuhn, S. L. (1995) *Mousterian Lithic Technology: An Ecological Perspective*. Princeton University Press.

Kuhn, S. L. and Bietti, A. (2000) ‘The Late Middle and Early Upper Paleolithic in Italy’, in *The Geography of Neandertals and Modern Humans in Europe and the Greater Mediterranean*. Cambridge, Massachusetts: Harvard University, pp. 49–76.

Kurtén, B. (1968) *Pleistocene mammals of Europe*. London: Weidenfeld & Nicholson.

Laj-Pannocchia (1950) ‘L’industria pontiniana della Grotta di S. Agostino (Gaeta)’, *Rivista di Scienze Preistoriche*, 5, pp. 67–86.

Lande, R. (1988) ‘Genetics and demography in biological conservation’, *Science*, 241(4872), pp. 1455–1460. doi: 10.1126/science.3420403.

Lansing, S. W., Copper, S. M., Boydston, E. E. and Holekamp, K. E. (2009) ‘Taphonomic and Zooarchaeological Implications of Spotted Hyena (Crocuta crocuta) Bone Accumulations in Kenya: A Modern Behavioral Ecological Approach’, *Paleobiology*, 35(2), pp. 289–309.

Lanza, B., Nistri, A. and Vanni, S. (2007) ‘Generi Lithobates Fitzinger, 1843, Pelophylax Fitzinger, 1843, Rana Linnaeus, 1758’, in Lanza, B., Andreone, F., Bologna, M. A., Corti, C., and Razzetti, E. (eds) *Fauna d’Italia, Amphibia*. Bologna: Calderini, pp. 375–376.

Laplace, G. (1964) *Essai de typologie systématique*. Ferrara: Università degli studi di Ferrara.

Larkin, N. R., Alexander, J. and Lewis, M. D. (2000) ‘Using Experimental Studies of

Recent Faecal Material to Examine Hyaena Coprolites from the West Runton Freshwater Bed, Norfolk, U.K.', *Journal of Archaeological Science*, 27(1), pp. 19–31. doi: 10.1006/jasc.1999.0437.

Laudet, F. and Antoine, P.-O. (2004) 'Des chambres de pupation de Dermestidae (Insecta : Coleoptera) sur un os de mammifère tertiaire (phosphorites du Quercy). Implications taphonomiques et paléoenvironnementales', *Geobios*, 37(3), pp. 376–381.

Lee-Thorp, J. and Sealy, J. (2008) 'Beyond documenting diagenesis: The fifth international bone diagenesis workshop', *Palaeogeography, Palaeoclimatology, Palaeoecology*, 266, pp. 129–133.

Lefèvre, D., Raynal, J.-P., Vernet, G., Kieffer, G. and Piperno, M. (2010) 'Tephro-stratigraphy and the age of ancient Southern Italian Acheulean settlements: The sites of Loreto and Notarchirico (Venosa, Basilicata, Italy)', *Quaternary International*, 223/224, pp. 360–368.

Lemorini, C. and Alhaique, F. (1998) 'L'analyse fonctionelle rencontre l'anayse zooarcheologique: l'exemple de Grotta Breuil (Mont Circé, Italie)', in *Atti del XIII Congresso dell'Unione Internazionale di Scienze Preistoriche e Protostoriche 6 (II)*, pp. 1143–1149.

Leroi-Gourhan, A. (1966) 'L'analyse pollinique des coprolithes', *Bulletin de la Société préhistorique francaise*, 63(5), pp. 163–164.

van Leusen, M. (2002) *Pattern to Process: methodological investigations into the formation and interpretation of large-scale patterns in archaeological landscapes*. Groningen.

Lev, E., Kislev, M. E. and Bar-Yosef, O. (2005) 'Mousterian vegetal food in Kebara Cave, Mt. Carmel', *Journal of Archaeological Science*, 32, pp. 475–484.

Levin, S. A. (1992) 'The Problem of Pattern and Scale in Ecology', *Ecology,* 73(6), pp. 1943–1967.

Li, Y. and Lei, C. (1980) 'Fossil mammals from Lishui, Jiangsu', *Vertebrata PalAsiatica*, 18(1), pp. 59–64.

Lisiecki, L. E. and Raymo, M. E. (2005) 'A Pliocene-Pleistocene stack of 57 globally distributed benthic δ 18 O records', *Paleoceanography*, 20(2), pp. 1–17. doi: 10.1029/2004PA001071.

Lister, A. M. and Stuart, A. J. (2008) 'The impact of climate change on large mammal distribution and extinction: Evidence from the last glacial/interglacial transition.', *Comptes Rendus Geoscience*, 340, pp. 615–620.

le Loeuff, J. L. (2012) 'Ferdinand Panescore and his classification of coprolites', in Hunt, A. P., Milàn, J., Lucas, G., and Spielmann, J. A. (eds) *Vertebrate Coprolites*. Albuquerque: New Mexico Museum of Natural History and Science, pp. 147–152.

Long, J. A. and Stoy, P. C. (2013) 'Quantifying the periodicity of Heinrich and Dansgaard–Oeschger events during Marine Oxygen Isotope Stage 3', *Quaternary Research*, 79(3), pp. 413–423. doi: 10.1016/j.yqres.2013.02.003.

Longin, R. (1971) 'New method of collagen extraction for radiocarbon dating', *Nature*, 230(5291), pp. 241–242.

Longo, E., Malegni, F., Mariani, R., Radmilli, A. and Segre, A. (1981) 'Giacimento ad amigdale e resti umani da Castel di Guido a Roma', in *Atti della XXIII Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria*, p. 560.

Longo, E. and Radmilli, A. (1972) 'Nuovo giacimento con amigdale a Roma', *Rivista di Scienze Preistoriche*, 27(2), pp. 403–9.

López-García, J. M., Dalla Valle, C., Cremaschi, M. and Peresani, M. (2015) 'Reconstruction of the Neanderthal and Modern Human landscape and climate from the Fumane cave sequence (Verona, Italy) using small mammal assemblages', *Quaternary Science Reviews*, 128, pp. 1–13.

Loud, L. L. and Harrington, M. R. (1929) 'Lovelock Cave', *University of California Publications in American Archaeology and Ethnology*, 25, p. 183.

Loving, S. H., Voorrips, A., Koot, C. W. and Kamermans, H. (1991) 'The pontinian on the Plain: some results from the Agro Pontino survey', *Quaternaria Nova*, 1, pp. 453–477.

Lowe, J. J., Accorsi, C. A., Bandini Mazzanti, M., Bishop, A., van der Kaars, S., Forlani, L., Mercuri, A. M., Rivalenti, C., Torri, P. and Watson, C. (1996) 'Pollen stratigraphy of sediment sequences from lakes Albano and Nemi (near Rome) and from the central Adriatic, spanning the interval from oxygen isotope Stage 2 to the present day', *Mem. ISt. Ital. Idrobiol.*, 55, pp. 171–208.

Lucas, G. (2005) *The Archaology of Time*. Routledge. London.

Luiselli, L., Anibaldi, C. and Capula, M. (2011) 'Anguis fragilis', in Corti, C., Capula, M., Luiselli, L., Razzetti, E., and Sindaco, R. (eds) *Fauna d'Italia, Reptilia*. Milano:

Calderini, pp. 460–464.

Lyman, R. L. (1994) *Vertebrate taphonomy*. Cambridge University Press.

Ma, A. and Tang, H. (1992) ‘On discovery and significance of a Holocene Ailuropoda-Stegodon fauna from Jinhua, Zhejiang’, *Vertebrata PalAsiatica*, 30, pp. 295–312.

Macdonald, K., Roebroeks, W. and Verpoorte, A. (2009) ‘An energetics perspective on the Neandertal record’, in Hublin, J.-J. and Richards, M. (eds) *The Evolution of Hominin Diets*. New York: Springer, pp. 211–220.

Madella, M., Jones, M. K., Goldberg, P., Goren, Y. and Hovers, E. (2002) ‘The exploitation of plant resources by Neanderthals in Amud Cave (Israel): the evidence from phytolith studies’, *Journal of Archaeological Science*, 29, pp. 703–719.

Magri, D. (1999) ‘Late Quaternary vegetation history at Lagaccione near Lago di Bolsena (Central Italy)’, *Rev. Palaeobot. Palynol.*, 106, pp. 171–208.

Magri, D. (2007) ‘Advances in Italian palynological studies: late Pleistocene and Holocene records’, *GFF - Journal of the Geological Society of Sweden*, 129, pp. 337–344.

Magri, D. and Sadori, L. (1999) ‘Late Pleistocene and Holocene pollen stratigraphy at Lago di Vico, central Italy’, *Veget. Hist. Archaeobot.*, 8, pp. 247–260.

Mainland, I. L. (2008) ‘The uses of archaeological faunal remains in landscape archaeology’, in David, B. and Thomas, J. (eds) *Handbook of Lanscape Archaeology*. Left Coast Press, pp. 544–550.

Malatesta, A. (1978) ‘Torre in Pietra, Roma’, *Quaternaria*, 20, pp. 203–577.

Malpieri, L., Patriarchi, G. and Zei, M. (1981) ‘La stazione preistorica a ossidiana di Selva Piana (Sabaudia)’, *Studi per l’Ecologia del Quaternario*, 3, pp. 111–126.

Manfredini, M. (1977) ‘L’acqua per la Pianura Pontina: situazione e prospettive’, in *Orientamenti per l’analisi idrogeologica dell’Agro Pontino.*

Mansur-Franchomme, M. (1986) ‘Microscopie du matériel lithique: traces d’utilisation, altérations naturelles, accidentelles et technologiques. Exemples de Patagonie’, *Cahiers du Quaternaire*, 9.

Manten, A. A. (1967) ‘Lennart Von Post and the foundation of modern palynology’, *Review of Palaeobotany and Palynology*, 1(1–4), pp. 11–22. doi: 10.1016/0034-6667(67)90105-4.

Manzi, G. and Passarello, P. (1989) *From Casal de' Pazzi to Grotta Breuil: Fossil evidence from Latium before the appearance of modern humans*. Roma.

Manzi, G. and Passarello, P. (1991) 'The human remains from Grotta Breuil (M. Circeo, Italy)', *Quaternaria Nova*, I, pp. 429–439.

Manzi, G. and Passarello, P. (1995) 'At the archaic/modern boundary of the genus Homo: the Neandertals from Grotta Breuil', *Current Anthropology*, 36, pp. 355–366.

Marchetti, M., Parolin, K. and Sala, B. (2000) 'The Biharian fauna from Monte La Mesa (Verona, northeastern Italy)', *Acta Zoologica Cracoviensia*, 443, pp. 79–105.

Marcolini, F., Masini, F. and Argenti, P. (2013) 'The rodents of the Pirro Nord fauna (Foggia, Southern Italy)', *Palaeontographica, Abt. A*, 298, pp. 73–85.

Marean, C. (1998) 'A critique of the evidence for scavenging by Neandertals and early modern humans: new data from Kobeh Cave (Zagros Mountains, Iran) and Die Kelders Cave I layer 10 (South Africa)', *Journal of Human Evolution*, 35, pp. 111–136.

Marinucci, E., Alimonti, C. and Gazzetti, C. (2006) 'Studio sul possibile recupero di pozzi per acqua nella Pianura Pontina', *Acque Sotterranee*, 99, pp. 9–28.

Markova, A., Simakova, A. N., Puzachenko, A. Y. and Kitaev, L. M. (2002) 'Environments of the Russian Plain during the Middle Valdai Briansk Interstade (33,000-24,000 yr B.P.) indicated by fossil mammals and plants', *Quaternary Research*, 57, pp. 391–400.

Marlowe, F. W. (2005) 'Hunter-gatherers and human evolution', *Evolutionary Anthrpology*, 14(2), pp. 54–67.

Marra, F., Ceruleo, P., Jicha, B., Pandolfi, L., Petronio, C. and Salari, L. (2015) 'A new age within MIS 7 for the Homo neanderthalensis of Saccopastore in the glacio-eustatically forced sedimentary successions of the Aniene River Valley, Rome', *Quaternary Science Reviews*, 129, pp. 260–274. doi: 10.1016/j.quascirev.2015.10.027.

Marra, F., Ceruleo, P., Jicha, B., Pandolfi, L., Petronio, C., Salari, L., Sottili, G. and Giaccio, B. (2016) 'Geological-morphological evolution of the Cretone peri-Tyrrhenian basin within the framework of Middle Pleistocene glacio-eustatisms, Latium volcanism and Italian faunal assemblages', *Journal of Quaternary Science*, 31(7), pp. 641–658.

Marra, F., Freda, C., Scarlato, P., Taddeucci, J., Karner, D. B., Renne, P., Gaeta, M., Palladino, D. M., Trigila, R. and Cavarretta, G. (2003) 'Post-caldera activity in the Alban hills volcanic district (Italy): 40Ar/39Ar geochronology and insights into magma evolution', *Bullettin of Volcanology*, 65, pp. 227–247.

Marra, F., Petronio, C., di Stefano, G., Gaeta, M. and Salari, L. (2014) 'Reassessing the sedimentary deposits and vertebrate assemblages from Ponte Galeria area (Rome, central Italy): An archive for the Middle Pleistocene faunas of Europe', *Earth-Science Reviews*, 139, pp. 104–122.

Marshack, M. (1989) 'Evolution of the human capacity: The symbolic evidence', *Yearbook of Physical Anthropology*, 10, pp. 1–34.

Marta, S., Mattoccia, M. and Sbordoni, V. (2013) 'Modelling landscape dynamics in a glacial refugium - or the spatial and temporal fluctuations of tree line altitudes', *Journal of Biogeography*. Edited by M. Bush, 40(9), pp. 1767–1779. doi: 10.1111/jbi.12120.

Martin, P. S., Sabels, B. E. and Shutler Jr., D. (1961) 'Rmpart cave coprolite and ecology of the Shasta ground sloth', *American Journal of Science*, 259, pp. 102–127.

Martinez-Navarro, B., Belmaker, M. and Bar-Yosef, O. (2009) 'The large carnivores from "Ubeidiya" (early Pleistocene, Israel): biochronological and biogeographical implications', *Journal of Human Evolution*, 56, pp. 514–524.

Martini, J. and Kavalieris, I. (1978) 'Mineralogy of the Transvaal caves', *Transactions of Geological Society of Africa*, 81, pp. 47–54.

Martone, M. (2012) *Segni e disegni dell'Agro Pontino: architettura, città, territorio*. ARACNE editrice S.r.l.

Marwick, B. (2003) 'Pleistocene Exchange Networks as Evidence for the Evolution of Language', *Cambridge Archaeological Journal*, 13(1), pp. 67–81.

Mattioli, S. (2003) 'Cervus elaphus (Linnaeus, 1758)', in Boitani, L., Lovari, S., and Vigna taglianti, A. (eds) *Fauna d'Italia, Mammalia III, Carnivora-Artiodactyla*. Bologna: Calderini, pp. 276–294.

Maul, L., Masini, F., Abbazzi, L. and Turner, A. (1998) 'The use of different morphometric data for absolute age calibration of some South- and Middle European arvicolid populations', *Palaeontographia Italica*, 85, pp. 111–151.

McPherron, S. (2005) 'Artifact orientations and site formation processes from total station proveniences', *Journal of Archaeological Science*, 32, pp. 1003–1014.

Mead, J. I. and Swift, S. L. (2012) 'Late Pleistocene (Rancholabrean) dung deposits of the Colorado Plateau, western North America', in Hunt, A. P., Milàn, J., Lucas, G., and Spielmann, J. A. (eds) *Vertebrate Coprolites*. Albuquerque: New Mexico Museum of

Natural History and Science, pp. 337–342.

Meignen, L., Delagnes, A. and Bourguignon, L. (2009) ‘Patterns of Lithic Material Procurement and Transformation During the Middle Paleolithic in Western Europe’, in Adams, B. and Blades, S. (eds) *Lithic Materials and Paleolithic Societies*. Oxford: Wiley-Blackwell, pp. 15–24.

Mellars, P. (1989) ‘Major issues in the emergence of modern humans’, *Current Anthropology*, 30, pp. 349–385.

Mellars, P. (2004) ‘Neanderthals and the modern human colonization of Europe’, *Nature*, 432, pp. 461–465.

Mellars, P. (2005) ‘The impossible coincidence. A single-species model for the origins of modern human behavior in Europe’, *Evolutionary Anthrpology*, 12, pp. 12–27.

Mercier, N., Valladas, H., Joron, J. L., Schiegl, S., Bar-Yosef, O. and Weiner, S. (1995) ‘Thermoluminescence dating and the problem of geochemical evolution of sediments. A case study: the Mousterian levels ad Hayonim’, *Israel Journal of Chemistry*, 35, pp. 137–141.

Milàn, J., Rasmussen, B. W. and Lynnerup, N. (2012) ‘A coprolite in the MDCT-scanner – internal architecture and bone contents revealed’, in Hunt, A. P., Milàn, J., Lucas, G., and Spielmann, J. A. (eds) *Vertebrate Coprolites*. Albuquerque: New Mexico Museum of Natural History and Science, pp. 99–104.

Miller, A. and Barton, C. M. (2008) ‘Exploring the land: a comparison of land-use patterns in the Middle and Upper Paleolithic of the western Mediterranean’, *Journal of Archaeological Science*, 35(5), pp. 1427–1437. doi: 10.1016/j.jas.2007.10.007.

Miller, C. E., Conard, N. J., Goldberg, P. and Berna, F. (2009) ‘Dumping, sweeping and trampling: experimental micromorphological analysis of anthropogenically modified combustion features’, in *The taphonomy of burned organic residues and combustion features in archaeological contexts*. Valbonne.

Milliken, S. (2007) ‘Neanderthals, Anatomically Modern Humans and “modern human behaviour” in Italy’, *Oxford Journal of Archaeology*, 26, pp. 331–358.

Milliman, J. D. and Emery, K. O. (1968) ‘Sea Levels during the past 35,000 years’, *Science*, 162, pp. 1121–1123.

Mills, M. G. L. (1989) ‘The comparative behavioural ecology of hyenas: the importance of diet and food dispersion’, in Gittleman, J. L. (ed.) *Carnivore, Behavior, Ecology and*

Evolution. London: Chapman and Hall, pp. 125–142.

Minami, M., Muto, H. and Nakamura, T. (2004) ‘Chemical techniques to extract organic fractions from fossil bones for accurate 14C dating’, *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, 223–224, pp. 302–307. doi: 10.1016/j.nimb.2004.04.060.

Minami, M., Yamazaki, K., Omori, T. and Nakamura, T. (2013) ‘Radiocarbon dating of VIRI bone samples using ultrafiltration’, *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms2*, 294, pp. 240–245.

Moe, D. (1983) ‘Palynology of sheep’s faeces: relationships between pollen content, diet and local pollen rain’, *Grana*, 22, pp. 105–113.

Moore, P. D., Webb, J. A. and Collinson, M. E. (1991) *Pollen analysis*. Oxford: Blackwell Scientific.

Moss, E. H. (1983a) ‘Some Comments on Edge-Damage as a Factor in a Functional Analysis of Stone Artefacts’, *Journal of Archaeological Science*, 10, pp. 231–242.

Moss, E. H. (1983b) *The Functional Analysis of Flint Implements. Pincevint and Pont d’Ambon, Two Case Studies from the French Final Palaeolithic*. Oxford: BAR International Series.

Mouton, J. (1973) ‘Contributo allo studio delle acque sotterranee dell’Agro romano e pontino’, in *L’acqua per la Pianura Pontina. Situazioni e prospettive*.

Müller, U. C., Pross, J., Tzedakis, P. C., Gamble, C., Kotthoff, U., Schmiedl, G., Wulf, S. and Christianis, K. (2011) ‘The role of climate in the spread of modern humans into Europe’, *Quaternary Science Reviews*, 30(3–4), pp. 273–279.

Murray, T. (1999) *Time and Archaeology*. London: Routledge.

Mussi, M. (1982) ‘Musteriano a denticolati su ciottolo in località S. Andrea di Sabaudia (Prov. di Latina)’, *Origini*, (11), pp. 45–70.

Mussi, M. (1999) ‘The Neandertals in Italy: A Tale of Many Caves’, in Gamble, C. and Roebroeks, W. (eds) *The Middle Palaeolithic occupation of Europe*. Leiden: Leiden University Press, pp. 49–79.

Mussi, M. (2001a) *Earliest Italy: an overview of the Italian Paleolithic and Mesolithic*. New York: Kluwer Academic-Plenum Publishers.

Mussi, M. (2001b) ‘Humans, Carnivores and Caves in the Italian Middle Paleolithic

Record', in Conard, N. J. (ed.) *Settlement Dynamics of the Middle Paleolithic and Middle Stone Age*. Tubingen: Kerns Verlag, pp. 507–517.

Mussi, M., Gioia, P. and Negrino, F. (2002) 'Ten small sites: the diversity of the Italian Aurignacian', in Bar-Yosef, O. and Zilhao, J. (eds) *Towards a definition of the Aurignacian*. Lisbon, pp. 189–209.

Mussi, M. and Zampetti, D. (1978) 'Siti preistorici di superficie nel territorio di S. Felice Circeo (Prov. di Latina)', *Quaternaria*, XX, pp. 41–48.

Mussi, M. and Zampetti, D. (1990) 'Nuovi modelli di ricerca archeologica: il caso di Grotta Barbara al Monte Circeo', in *La valle Pontina nell'antichità*. Roma, pp. 17–21.

Mussi, M. and Zampetti, D. (1991) 'Le site Mousterien de Grotta Barbara', *Quaternaria Nova*, I, pp. 277–287.

Nardin, W. (2010) *Progetto per la realizzazione di opere di pubblica illuminazione e tombinamento del fosso laterale di Via Torrenuova a Latina*.

Navarro, C., Carrión, J. S., Navarro, J., Munuera, M. and Prieto, A. R. (2000) 'An experimental approach to the palynology of cave deposits', *Journal of Quaternary Science*, 15(6), pp. 603–619.

Newcomer, M. H. (1974) 'Study and Replication of Bone Tools from Ksar Akil (Lebanon)', *World Archaeology*, 6(2), pp. 138–153.

Newcomer, M. H. and Keeley, L. (1979) 'Testing a Method of Microwear Analysis with Experimental Flint Tools', in *Lithic Use-Wear Analysis*. New York: Academic Press, pp. 195–206.

Nicholson, R. A. (1996) 'Bone Degradation, Burial Medium and Species Representation: Debunking the Myths, an Experiment-based Approach', *Journal of Archaeological Science*, 23(4), pp. 513–533. doi: 10.1006/jasc.1996.0049.

O'Connor, B. and Ford, T. D. (2001) 'The origins and development of the British coprolite industry: Mining History', *The Bulletin of the Peak District Mines Historical Society*, 14, pp. 46–57.

O'Connor, T. and Evans, J. G. (1999) *Environmental Archaeology*. 2nd edn. The History Press.

O'Neill, R. V., Johnson, A. R. and King, A. W. (1989) 'A hierarchical framework for the analysis of scale', *Landscape Ecology*, 3, pp. 193–205.

O’Regan, H. J. (2008) ‘The Iberian Peninsula – corridor or cul-de-sac? Mammalian faunal change and possible routes of dispersal in the last 2 million years’, *Quaternary Science Reviews*, 27(23), pp. 2136–2144. doi: 10.1016/j.quascirev.2008.08.007.

O’Regan, H. J., Turner, A., Bishop, L. C., Elton, S. and Lamb, A. L. (2011) ‘Hominins without fellow travellers? First appearances and inferred dispersals of Afro-Eurasian large-mammals in the Plio-Pleistocene’, *Quaternary Science Reviews*, 30(11–12), pp. 1343–1352. doi: 10.1016/j.quascirev.2009.11.028.

Odell, G. H. (1977) *The application of Micro-wear Analysis to the Lithic Component of an Entire Prehistoric Settlement: Methods, Problems, and Functional Reconstructions*. Harvard University.

Odell, G. H. (1979) ‘A New and Improved System for the Retrieval of Functional Information from Microscopic Observations of Chipped Stone Tools’, in Hayden, B. (ed.) *Lithic Use-Wear Analysis*. New York: Academic Press, pp. 239–244.

Odell, G. H. (1980) ‘Butchering with Stone Tools: some Experimental Results’, *Lithic Technology*, 9, pp. 38–48.

Oppenheimer, S. (2003) *Out of Eden: the Peopling of the World*. London: Constable.

Pacher, M. (2010) ‘Raw material analysis of Upper Paleolithic bone points and the invention of the Olschewian’, in Neugebauer-Maresch, C. and Owen, L. R. (eds) *New aspects of the Central and Eastern European Upper Palaeolithic – Methods, Chronology, Technology and Subsistence*. Wien: Verlag der Österreichischen Akademie der Wissenschaften, pp. 319–325.

Palma di Cesnola, A. (1993) *Il Paleolitico superiore in Italia: Introduzione allo studio*. Florence: Garlatti e Razzai.

Palma di Cesnola, A. (2001) *Le Paléolithique supérior en Italie*. Grenoble: Jérome Millon.

Palombo, M. R. (2004) ‘Guilds of large mammals from the Pliocene to the Late Pleistocene in Italian peninsula’, in Baquedano, E. and Rubio, S. (eds) *‘Homenaje a Emiliano Aguirre’, Zona Arqueologica 4 (2 Paleontologia). Museo Arqueológico Regional*. Madrid, pp. 372–391.

Panagopoulou, E., Karkanas, P., Tsartsidou, G., Kotjabopoulou, E., Harvati, K. and Ntinou, M. (2004) ‘Late Pleistocene Archaeological and fossil human evidence from Lakonis Cave, Southern Greece’, *Journal of Field Archaeology*, 29, pp. 323–349.

Pandolfi, L., Boscato, P., Crezzini, J., Gatta, M., Moroni, A. and Rolfo, M. F. (2017) ‘Late Pleistocene last occurrences of the narrow-nosed rhinoceros Stephanorhinus hemitoechus (Mammalia, Perissodactyla) in Italy’, *Research in Paleontology and Stratigraphy*, 123(2), pp. 177–190.

Pandolfi, L., Boscato, P., Gatta, M., Rolfo, M. F. and Tagliacozzo, A. (2016) ‘Late Quaternary extinction of the narrow-nosed rhinoceros Stephanorhinus hemitoechus (Mammalia, Perissodactyla) in Italy’, in *XVI Edizione delle Giornate di Palentologia*. Faenza.

Pandolfi, L., Gaeta, M. and Petronio, C. (2013) ‘The skull of Stephanorhinus hemitoechus (Mammalia, Rhinocerotidae) from the Middle Pleistocene of Campagna Romana (Rome, Central Italy): biochronological and paleobiogeographic implications.’, *Bulletin of Geosciences*, 88(1), pp. 51–62.

Pandolfi, L., Petronio, C. and Salari, L. (2011) ‘Bos primigenius Bojanus, 1827 from the Early Late Pleistocene Deposit of Avetrana (Southern Italy) and the Variation in Size of the Species in Southern Europe: Preliminary Report’, *Journal of Geological Research*, 2011, pp. 1–11.

Pandolfi, L., Petronio, C. and Salari, L. (2013) ‘Catastrophic death assemblages from the Late Pleistocene of Italy: the case of Avetrana karst filling (Taranto, Southern Italy)’, *Rivista italiana di Paleontologia e Stratigrafia*, 119(1), pp. 109–124.

Paolucci, P. and Amori, G. (2008) ‘Microtus arvalis (Pallas, 1778)’, in Amori, G., Contoli, L., and Nappi, A. (eds) *Fauna d’Italia, Mammalia II, Erinaceomorpha, Soricomorpha, Lagomorpha, Rodentia*. Milano: Calderini, pp. 494–503.

Parotto, M. and Praturlon, A. (1975) ‘Geological summary of the Central Appennines’, *Quad. Ric. Sci.*, 90, pp. 257–311.

Perco, F. (2003) ‘Capreolus capreolus (Linnaeus, 1758)’, in Boitani, L., Lovari, S., and Vigna Taglianti, A. (eds) *Fauna d’Italia, Mammalia III, Carnivora-Artiodactyla*. Bologna: Calderini, pp. 305–326.

Pereira, L., Richards, M., Goios, A., Alonso, A., Albarràn, C., Garcia, O., Behar, D. M., Golge, M., Hatina, J., Al-Gazali, L., Bradley, D. G., Macaulay, V. and Amorim, A. (2004) ‘High-resolution mtDNA evidence for the late-glacial resettlement of Europe from an Iberian refugium’, *Genome Research*, 15, pp. 19–24.

Perissoratis, C. and Conispoliatis, N. (2003) ‘The impacts of sea-level changes during latest Pleistocene and Holocene times on the morphology of the Ionian and Aegean seas (SE Alpine Europe)’, *Marine Geology*, 196(3–4), pp. 145–156. doi: 10.1016/S0025-3227(03)00047-1.

Pesquero, M. D., Souza-Egipsy, V., Alcalá, L., Ascaso, C. and Fernández-Jalvo, Y. (2014) ‘Calcium phosphate preservation of faecal bacterial negative moulds in hyaena coprolites’, *Acta Palaeontologica Polonica*, 59(4), pp. 997–1005.

Petronio, C., Bellucci, L., Martinetto, E., Pandolfi, L. and Salari, L. (2011) ‘Biochronology and Palaeoenvironmental Changes from the Middle Pliocene to the Late Pleistocene in Central Italy’, *Geodiversitas*, 33, pp. 485–517.

Petronio, C., di Canzio, E. and Salari, L. (2007) ‘The Late Pleistocene and Holocene Mammals in Italy: new biochronological and paleoenvironmental data’, *Palaeontographica*, 279(4), pp. 147–157.

Petronio, C. and Marcolini, F. (2013) ‘Mammal biochronology at the end of Late Villafranchian (Early Pleistocene) – Pirro Faunal Unit’, *Palaeontographica*, A(298), pp. 183–191.

Petronio, C. and Pandolfi, L. (2008) ‘Stephanorhinus Hemitoechus (Falconer, 1868) del Pleistocene Superiore dell’area di Melpignano-Cursi e S. Sidero (Lecce, Italia)’, *Geologica Romana*, 41, pp. 1–12.

Petrucci, M., Giardini, M. and Sadori, L. (2005) ‘Analisi pollinica di coproliti di iena macchiata (Crocuta crocuta Erxleben) dell’ultimo glaciale della Puglia’, *Informatore Botanico Italiano*, 37(1), pp. 932–933.

Petruso, D., Locatelli, E., Surdi, G., Dalla Valle, C., Masini, F. and Sala, B. (2011) ‘Phylogeny and biogeography of fossil and extant Microtus (Terricola) (Mammalia, Rodentia) of Sicily and the southern Italian peninsula based on current dental morphological data’, *Quaternary International*, 243, pp. 192–203.

Pettitt, P. and Bailey, R. M. (2000) ‘AMS radiocarbon and luminescence dating of Gorham’s and Vanguard caves, Gibraltar and implications for the Middle to Upper Palaeolithic transition in Iberia’, in Stringer, C. B., Barton, R. N. ., and Finlayson, J. C. (eds) *Neanderthals on the Edge*. Oxford: Oxbow Books, pp. 155–162.

Pevny, C. D. (2012) ‘Distinguishing taphonomic Processes from Stone Tool use at The Gault Site, Texas’, in Carr, P. J., Bradbury, A. P., and Price, S. E. (eds) *Contemporary Lithic Analysis in the Southeast. Problems, Solutions and Interpretations*. Alabama: The

University of Alabama Press, pp. 55–77.

di Pietro, R. and Blasi, C. (2002) ‘A phytosociological analysis of abandoned olive-grove grasslands of Ausoni mountains (Tyrrhenian district of Central Italy)’, *Lazaroa*, 23, pp. 73–93.

Piggott, S. (1959) *Approach to Archaeology*. Cambridge: Harvard University Press.

Pignatti, S., Pedrotti, F. and Lorenzoni, G. (1961) ‘Ricerche fitosociologiche sulla vegetazione ad Ampelodesmos tenax presso Tivoli e Sezze nel Lazio’, *Delpinoa*, 3, pp. 337–372.

Pigozzi, G. and De Marinis, A. M. (2003) ‘Meles meles (Linnaeus, 1758)’, in Boitani, L., Lovari, S., and Vigna Taglianti, A. (eds) *Fauna d’Italia, Mammalia III, Carnivora-Artiodactyla*. Bologna: Calderini, pp. 158–167.

Pike, A. W. G., Hedges, R. E. M. and van Calsteren, P. (2002) ‘U-series dating of bone using the diffusion-absorption model’, *Geochimica et Cosmochimica Acta*, 66, pp. 4273–4286.

Pike, A. W. G. and Pettitt, P. B. (2003) ‘U-series dating and human evolution’, *Reviews in Mineralogy and Geochemistry*, 52, pp. 607–630.

Pinza, G. (1905) ‘Monumenti primitivi di Roma e del Lazio antico’, *MonAL*, 15.

Piperno, M. (1977) ‘Analyse du sol mustérien de la Grotte Guattari au Mont Circé’, *Quaternaria*, XIX, pp. 71–92.

Piperno, M. and Biddittu, I. (1978) ‘Studio tipologico ed interpretazione dell’industria acheulana e premusteriana dei livelli m e d di Torre in Pietra (Roma)’, *Quaternaria*, 20, pp. 441–563.

Piperno, M. and Giacobini, G. (1991) ‘A taphonomic study of the paleosurface of Guattari Cave (Monte Circeo, Latina, Italy)’, *Quaternaria Nova*, I, pp. 143–161.

Pitti, C. and Tozzi, C. (1971) ‘La grotta del Capriolo e la Buca della Iena presso Mommio (Camaiore, Lucca)’, *Rivista di Scienze Preistoriche*, 26, pp. 213–258.

Poinar, H. N., Hofreiter, M., Spaulding, W. G., Martin, P. S., Stankiewicz, B. A., Bland, H., Evershed, R. P., Possnert, G. and Pääbo, S. (1998) ‘Molecular coproscopy: dung and diet of the extinct ground sloth Nothrotheriops shastensis’, *Nothrotheriops shastensis*, 281, pp. 402–406.

Pokines, J. T. and Kerbis Peterhans, J. C. (2007) ‘Spotted hyena (Crocuta crocuta) den use and taphonomy in the Masai Mara National Reserve, Kenya’, *Journal of Archaeological Science*, 34(11), pp. 1914–1931. doi: 10.1016/j.jas.2007.01.012.

Ponzi, G. (1866a) ‘Sui manufatti di focaia rinvenuti all’Inviolatella nella Campagna Romana e sull’Uomo dell’epoca della pietra’, *Atti della Accademia Pontificia de’ Nuovi Lincei*, 19, pp. 41–52.

Ponzi, G. (1866b) ‘Sull’istromenti in pietra focaia rinvenuti nelle cave di breccia presso Roma riferibili all’industria primitiva’, *Atti della Accademia Pontificia de’ Nuovi Lincei*, 19, pp. 187–189.

Ponzi, G. (1870) ‘Sulle selci scagliate rinvenute in Roma ad Acquatraversa e al Gianicolo nell’Aprile 1870’, *Corrispondenza Scientifica di Roma*, 22, p. 43.

Potts, R. (1998) ‘Variability selection in hominid evolution’, *Evolutionary Anthropology: Issues, News, and Reviews*. John Wiley & Sons, Inc., 7(3), pp. 81–96. doi: 10.1002/(SICI)1520-6505(1998)7:3<81::AID-EVAN3>3.0.CO;2-A.

Potts, R. (2012) ‘Evolution and Environmental Change in Early Human Prehistory’, *Annual Review of Anthropology*. Annual Reviews, 41(1), pp. 151–167. doi: 10.1146/annurev-anthro-092611-145754.

Prüfer, K., Racimo, F., Patterson, N., Jay, F., Sankararaman, S., Sawyer, S., Heinze, A., Renaud, G., Sudmant, P. H., de Filippo, C., Li, H., Mallick, S., Dannemann, M., Fu, Q., Kircher, M., Kuhlwilm, M., Lachmann, M., Meyer, M., Ongyerth, M., Siebauer, M., Theunert, C., Tandon, A., Moorjani, P., Pickrell, J., Mullikin, J. C., Vohr, S. H., Green, R. E., Hellmann, I., Johnson, P. L. F., Blanche, H., Cann, H., Kitzman, J. O., Shendure, J., Eichler, E. E., Lein, E. S., Bakken, T. E., Golovanova, L. V., Doronichev, V. B., Shunkov, M. V., Derevianko, A. P., Viola, B., Slatkin, M., Reich, D., Kelso, J. and Paabo, S. (2014) ‘The complete genome sequence of a Neanderthal from the Altai Mountains’, *Nature*, 505(7481), pp. 43–49.

Ramrath, A., Nowaczyk, N. R. and Negendank, J. F. W. (1999) ‘Sedimentological evidence for environmental changes since 34,000 years BP from Lago di Mezzano, central Italy.’, *Journal of Paleolimnology*, (21), pp. 423–435.

Ready, E. (2010) ‘Neandertal man the hunter: a history of Neandertal subsistence’, *Explorations in Anthropology*, 10, pp. 58–80.

Reinhard, K. J. (2006) ‘A coprological view of Ancestral Pueblo cannibalism’, *American Scientist*, 94, pp. 254–262.

Reitz, E. J. and Shackley, M. L. (2012) *Environmental archaeology*. Springer.

Renfrew, C. (1984) ‘Trade as action at distance’, in *Approaches to Social Archaeology*. Cambridge: Harvard University Press, pp. 3–60.

Richards, M. P. and Trinkaus, E. (2009) ‘Isotopic evidence for diets of European Neanderthals and early modern humans’, *Proceedings of the National Academy of Sciences of the United States of America*, 106, pp. 16034–16039.

Riel-Salvatore, J. and Negrino, F. (2009) ‘Early Upper Paleolithic Population Dynamics and Raw Material Procurement Patterns in Italy’, in Camps i Calbet, M. and Szmidt, C. (eds) *The Mediterranean Between 50-25,000 BP: Turning Points and New Directions*. Oxford: Oxbow Books, pp. 205–224.

Rigaud, J. P. and Simek, J. (1987) ‘“Arms too short to box with God”: Problems and prospects for Paleolithic prehistory in Dordogne, France’, in Soffer, O. (ed.) *The Pleistocene Old World: Regional Perspectives*. New York: Plenum Press, pp. 47–61.

De Rita, D., Faccenna, C., Funiciello, R. and Rosa, C. (1995) ‘Stratigraphy and volcano-tectonics’, in *The Volcano of the Alban Hills*, pp. 33–71.

Rodrìguez-Sànchez, F., Hampe, A., Jordano, P. and Arroyo, J. (2010) ‘Past tree range dynamics in the Iberian Peninsula inferred through phylogeography and palaeodistribution modelling: a review’, *Review of Palaeobotany and Palynology*, 162, pp. 507–521.

Roebroeks, W. (1988) *From Find Scatters to Early Hominid Behaviour. A Study of Middle Palaeolithic Riverside Settlements at Maastricht-Belvédère (The Netherlands)*. Leiden: Leiden University Press.

Rolfo, M. F. (2008) ‘Sezione di Preistoria, Catalogo del Museo Civico di Velletri’, in *Museo e Territorio VI*, pp. 79–115.

Rolfo, M. F. (2009) ‘Il Paleolitico dei Colli Albani’, in Drago Troccoli, L. (ed.) *Il Lazio dai Colli Albani ai Monti Lepini tra preistoria ed età moderna*. Edizioni Quasar, pp. 69–87.

Rolfo, M. F. and Aureli, D. (2012) *Il Pontiniano di plen air: studio e revisione delle industrie litiche dei siti di superficie nell’ambito del fenomeno Pontiniano*. Roma.

Rolfo, M. F., Aureli, D., Giaccio, B. and La Rosa, M. (2013) ‘Il Pontiniano a settant’anni dalla sua definizione. Prospettive passate e future’, in Calandra, E., Ghini, G., and Mari, Z. (eds) *Lazio a Sabina 10 (Atti del Convegno ‘Decimo Incontro di Studi* *sul Lazio e la Sabina', Roma, 4-6 giugno 2013)*. Roma: Lavori e Studi della Soprintendenza per i Beni Archeologici del Lazio, pp. 113–118.

Rolfo, M. F. and Giaccio, B. (2000) 'Nuovi rinvenimenti e osservazioni geoarcheologiche in area albana', *Documenta Albana*, 22, pp. 9–36.

Rolfo, M. F., Giaccio, B. and Sposato, A. (2006) 'Siti del Paleolitico medio nell ' area dei Colli Albani e loro contesto morfologico e pedo-tefrostratigrafico', in *40 Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria: Strategie di Insediamento fra Lazio e Campania in età Preistorica e Protostorica*. Roma, Napoli, Pompei, pp. 273–284.

Rolland, N. and Dibble, H. (1990) 'Anew synthesis of Mousterian variability', *American Antiquity*, 55(3), pp. 480–499.

Ronchitelli, A., Benazzi, S., Boscato, P., Douka, K. and Moroni, A. (2014) 'Comments on "Human-climate interaction during the Early Upper Paleolithic: Testing the hypothesis of an adaptive shift between the Proto-Aurignacian and the Early Aurignacian" by William E. Banks, Francesco d'Errico, João Zilhão', *Journal of Human Evolution*, 73, pp. 107–111.

Rosa, C. (1995) *Evoluzione geologica quaternaria delle aree vulcaniche laziali: confronto tra il settore dei Monti Sabatini e quello dei Colli Albani*.

Roselli, F. L. (1987) 'Paleoicnología: nidos de insectos fósiles de la cubertura Mesozoica del Uruguay', *Publicaciones del Museo Municipal de Nueva Palmira*, 1, pp. 1–56.

De Rossi, M. S. (1867) 'Rapporto sugli studi e sulle scoperte paleo-etnologiche nel bacino della Campagna Romana, con appendice osteologica di Giuseppe Ponzi', *AnnInst*, 39, pp. 5–72.

Ruedi, M., Walter, S., Fischer, M. C., Scaravelli, D., Excoffier, L. and Heckel, G. (2008) 'Italy as a major Ice Age refuge area for the bat Myotis myotis (Chiroptera: Vespertilionidae) in Europe', *Molecular Ecology*, 17, pp. 1801–1814.

Rustioni, M., Ferretti, M. P., Mazza, P., Pavia, M. and Varola, A. (2003) 'The vertebrate fauna from Cardamone (Apulia, southern Italy): an example of Mediterranean Mammoth fauna', in Reumer, J. W. F., de Vos, J., and Mol, D. (eds) *Advances in Mammoth Research (Proceedings of the Second International Mammoth Conference, Rotterdam, May 16-20 1999)*. Rotterdam: Deinsea, pp. 395–403.

Sacchi, E. and Petti, F. M. (2008) ‘Insect pupation chambers from the Pleistocene paleosols of Santo Stefano Island (Pontine Archipelago, Central Italy)’, *Studi trentini di scienze naturali - Acta biologia*, 83, pp. 205–210.

Sadori, L., Giraudi, C., Petitti, P. and Ramrath, A. (2004) ‘Human impact at Lago di Mezzano (central Italy) during the Bronze Age: a multidisciplinary approach’, *Qauternary International*, 113, pp. 5–17.

Sala, B. and Masini, F. (2007) ‘Late Pliocene and Pleistocene small mammal chronology in the Italian peninsula’, *Quaternary International*, 160, pp. 4–16.

Salari, L. (2014) ‘Holocene micromammals (Soricomorpha and Rodentia) from some caves of Central Italy’, *Revue de Paléobiologie*, 33(1), pp. 79–96.

Salari, L., Achino, K. F., Gatta, M., Petronio, C., Rolfo, M. F., Silvestri, L. and Pandolfi, L. (2017) ‘The wolf from Grotta Mora Cavorso (Simbruini Mountains, Latium) within the evolution of Canis lupus L., 1758 in the Quaternary of Italy’, *Palaeogeography Palaeoclimatology Palaeoecology*, 476, pp. 90–105.

Salari, L. and Kotsakis, T. (2011) ‘Late Pleistocene and Holocene bats of Latium (central Italy)’, *Il Quaternario*, 24(1), pp. 121–129.

Salazar-Garcia, D. C., Power, R. C., Sanchis Serra, A., Villaverde, V., Walker, M. J. and Henry, A. G. (2013) ‘Neanderthal diets in central and southeastern Mediterranean Iberia’, *Quaternary International*, 318, pp. 3–18.

Salnicki, J., Teichmann, M., Wilson, V. J. and Murindagomo, F. (2001) ‘Spotted hyaenas Crocuta crocuta prey on new-born elephant calves in Hwange National Park, Zimbabwe’, *Koedoe*, 44(2), pp. 79–83.

Sambridge, M., Grun, R. and Eggins, S. (2012) ‘U-series dating of bone in an open system: the diffusion-adsorption-decay model’, *Quaternary Geochrolnoogy*, 9, pp. 42–53.

Sanchez-Quinto, F. and Lalueza-Fox, C. (2015) ‘Almost 20 years of Neanderthal palaeogenetics: adaptation, admixture, diversity, demography and extinction’, *Philosophical Transactions of the Royal Society of London*, 370(1660). doi: 10.1098/rstb.2013.0374.

Sanchez Goñi, M. F. (1991) ‘On the last glaciation and the interstadials during the Solutrean. A contradiction?’, *Current Anthropology*, 35, pp. 145–214.

Sanchez Goñi, M. F. (1994) ‘The identifcation of European upper palaeolithic interstadials from cave sequences', in Davis, O. K. (ed.) *Aspects of archaeological palynology: methodology and applications*. AASP Contribution Series no. 29, pp. 161–182.

Sánchez Goñi, M. F., Cacho, I., Turon, J. L., Guiot, J., Sierro, F. J., Peypouquet, J. P., Grimalt, J. O. and Shackleton, N. (2002) 'Synchronicity between marine and terrestrial responses to millennial scale climatic variability during the last glacial period in the Mediterranean region', *Climate Dynamics*, 19, pp. 95–105.

Sánchez Goñi, M. F., Turon, J. L., Eynaud, F. and Gendreau, S. (2000) 'European Climatic Response to Millennial-Scale Changes in the Atmosphere-Ocean System during the Last Glacial Period', *Quaternary Research*, 54, pp. 394–403.

Sandom, C., Faurby, S., Sandel, B. and Svenning, J.-C. (2014) 'Global late Quaternary megafauna extinctions linked to humans, not climate change', *Proceedings of the Royal Society B: Biological Sciences*, 281(1787), p. 20133254. doi: 10.1098/rspb.2013.3254.

Sansalone, G., Bertè, D. F., Maiorino, L. and Pandolfi, L. (2015) 'Evolutionary trends and stasis in carnassial teeth of European Pleistocene wolf Canis lupus (Mammalia, Canidae)', *Quaternary Science Reviews*, 110, pp. 36–48.

Santos, G. M., Southon, J. R., Drenzek, N. J., Ziolkowski, L. A., Druffel, E., Xu, X., Zhang, D., Trumbore, S., Eglinton, T. I. and Hughen, K. A. (2010) 'Blank assessment for ultra-small radiocarbon samples: chemical extraction and separation versus AMS', *Radiocarbon*, 52(2), pp. 1322–1335.

Sardella, R. and Petrucci, M. (2012) 'The earliest Middle Pleistocene Crocuta crocuta (Erxleben, 1777) at Casal Selce (Rome, Italy)', *Quaternary International*, 267, pp. 103–110.

Scali, S., Gentili, A. and Lanza, B. (2011) 'Natrix natrix (Linnaeus, 1758)', in Corti, C., Capula, M., Luiselli, L., Razzetti, E., and Sindaco, R. (eds) *Fauna d'Italia, Reptilia*. Milano: Calderini, pp. 552–562.

Schwarcz, H. P., Bietti, A., Buhay, W. M., Stiner, M. C., Grun, R. and Segre, A. G. (1991) 'On the re-examination of Grotta Guattari: Uranium Series and Electron Spin Resonance dates', *Current Anthropology*, 32, pp. 313–316.

Schwarcz, H. P., Buhay, W. M., Grun, R., Stiner, M. C., Kuhn, S. L. and Miller, G. H. (1991) 'Absolute dating in coastal Lazio', *Quaternaria Nova*, I, pp. 51–67.

Scott, L. (1987) 'Pollen analysis of Hyena coprolites and sediments from Equus Cave, Taung, Southern Kalahari (South Africa)’, *Quaternary Research*, 28, pp. 144–156.

Scott, L. (2000) ‘Pollen’, in Partridge, T. C. and Maud, R. . (eds) *The Cainozoic of Southern Africa*. New York: Oxford University Press, pp. 339–350.

Scott, L., Fernández-jalvo, Y., Carrión, J. and Brink, J. (2003) ‘Preservation and interpretation of pollen in hyaena coprolites : taphonomic observations from Spain and southern Africa’, (December), pp. 83–91.

Segre, A. and Ascenzi, A. (1956) ‘Giacimenti del Paleolitico Superiore e del Bronzo nei travertini di Cisterna di Latina (Latina)’, *Rivista di Antropologia*, 43, pp. 367–382.

Segre, A. G. (1983) ‘Geologia quaternaria e Paleolitico nella bassa valle dell’Aniene’, *Riv. Antropol.*, 62, pp. 87–98.

Segre, A. G., Biddittu, I. and Cassoli, P. F. (1984) ‘Il bacino paleolacustre di Sora (Frosinone) e i suoi giacimenti musteriani’, in *Atti XXIV Riunione Scientifica IIPP*, pp. 177–206.

Semenov, S. A. (1981) *Tecnología prehistórica: estudio de las herramientas y objetos antiguos a través de las huellas de uso*. Ediciones Akal.

Sergi, S. (1954) ‘La mandibola neandertaliana Circeo II’, *Rivista di Antropologia*, XLI, pp. 305–344.

Sergi, S. (1974) *Il cranio neandertaliano del Monte Circeo (Circeo I), Rendiconti dell’Accademia Nazionale dei Lincei*. Accademia nazionale dei Lincei.

Sergi, S. and Ascenzi, A. (1955) ‘La mandibola neandertaliana Circeo III’, *Rivista di Antropologia*, XLII, pp. 337–403.

Serre, D., Langaney, A., Chech, M., Teschler-Nicola, M., Paunovic, M., Mennecier, P., Hofreiter, M., Possnert, G. and Pääbo, S. (2004) ‘No Evidence of Neandertal mtDNA Contribution to Early Modern Humans’, *PLoS Biology*. Edited by David Penny. Public Library of Science, 2(3), pp. 313–317. doi: 10.1371/journal.pbio.0020057.

Sevink, J., Duivenvoorden, J. and Kamermans, H. (1991) ‘The soils of the Agro Pontino’, in *The Agro Pontino Survey Project*. Universiteit van Amsterdam, pp. 31–47.

Sevink, J., van der Plicht, J., Feiken, H., van Leusen, P. M. and Bakels, C. C. (2013) ‘The Holocene of the Agro Pontino graben: Recent advances in its palaeogeography, palaeoecology, and tephrostratigraphy’, *Quaternary International*, 303, pp. 153–162.

Sevink, J., Remmelzwaal, A. and Spaargaren, O. C. (1984) *The Soils of Southern Lazio* *and Adjacent Campania*. Amsterdam: Universiteit van Amsterdam.

Sevink, J., Vos, P., Westerhoff, W. E., Stierman, A. and Kamermans, H. (1982) ‘A sequence of marine terraces near Latina (Agro Pontino, Central Italy)’, *Catena*, 9(3–4), pp. 361–378. doi: 10.1016/0341-8162(82)90010-8.

Shackleton, N. J. (1987) ‘Oxygen isotopes, ice volume and sea level’, *Quaternary Science Reviews*, 6(3–4), pp. 183–190. doi: 10.1016/0277-3791(87)90003-5.

Shafer, H. J. and Holloway, R. G. (1979) ‘Organic Residue Analysis in Determining Stone Tool Function’, in Hayden, J. D. (ed.) *Lithic Use-Wear Analysis*. New York: Academic Press, pp. 385–399.

Shanks, M. and Tilley, C. (1987) *Social Theory and Archaeology*. University. Albuquerque.

Shea, J. (1998) ‘Neanderthal and early modern human behavioural variability’, *Current Anthropology*, 39s, pp. 45–78.

Sillero-Zubiri, C. and Gottelli, P. (1991) ‘Threats to Aberdare rhinos: predation versus poaching.’, *Pachyderm*, 14, pp. 37–38.

Sirakov, N., Guadelli, J.-L., Ivanova, S., Sirakova, S., Boudadi-Maligne, M., Dimitrova, I., Ph, F., Ferrier, C., Guadelli, A., Iordanova, D., Iordanova, N., Kovatcheva, M., Krumov, I., Leblanc, J.-C., Miteva, V., Popov, V., Spassov, R., Taneva, S. and Tsanova, T. (2010) ‘An ancient continuous human presence in the Balkans and the beginnings of human settlement in western Eurasia: A Lower Pleistocene example of the Lower Palaeolithic levels in Kozarnika cave (North-western Bulgaria)’, *Quaternary International*, 223, pp. 94–106. doi: 10.1016/j.quaint.2010.02.023.

Sistiaga, A., Mallol, C., Galvan, B. and Summons, R. E. (2014) ‘The Neanderthal meal: a new perspective using faecal biomarkers’, *PLoS ONE*, 9(6), p. e101045. doi: 10.1371/journal.pone.0101045.

Sitzia, L., Bertran, P., Boulogne, S., Brenet, M., Crassard, R., Delagnes, A., Frouin, M., Hatté, C., Jaubert, J., Khalidi, L., Messager, E., Mercier, N., Meunier, A., Peigné, S., Queffelec, A., Tribolo, C. and Macchiarelli, R. (2012) ‘The Paleoenvironment and Lithic Taphonomy of Shi’Bat Dihya 1, a Middle Paleolithic Site in Wadi Surdud, Yemen’, *Geoarchaeology*, 27(6), pp. 471–491.

Skinner, J. D. (1976) ‘Ecology of the brown hyena Hyaena brunnea in the Transcaal with a distribution map for Southern Africa’, *South Africa Journal of Science*, 72, pp.

262–269.

Skinner, J. D., Davis, S. and Llani, G. (1980) ‘Bone collection by striped hyaenas, Hyaena hyaena, in Istrael’, *Paleontology in Africa*, 23, pp. 99–104.

Slimak, L. and Giraud, Y. (2007) ‘Circulations sur plusieurs centaines de kilomètres durant le Paléolithique moyen. Contribution à la connaissance des sociétés néandertaliennes’, *Comptes Rendus Palevol*, 6(5), pp. 359–368.

Smith, F. H., Trinkaus, E., Pettitt, P. B., Karavanić, I. and Paunovic, M. (1999) ‘Direct radiocarbon dates for Vindija G1 and Velika Pecina Late Pleistocene hominid remains’, *Proceedings of the National Academy of Sciences of the United States of America*, 96(22), pp. 12281–12286.

Sommer, R. and Nadachowski, A. (2006) ‘Glacial refugia of mammals in Europe: evidence from fossil records’, *Mammal Review*, 36, pp. 251–266.

Sonneville-Bordes, D. and Perrot, J. (1956) ‘Lexique typologique du Paléolithique supérieur’, *Bulletin Société Préhistorique Francaise*, (51;52;53).

Spaulding, A. (1960) ‘The Dimensions of Archaeology’, in Dole, G. E. and Carneiro, R. L. (eds) *Essays in the Science of Culture*. New York: Cromwell, pp. 437–456.

Spinapolice, E. E. (2012) ‘Raw material economy in Salento (Apulia, Italy): new perspectives on Neanderthal mobility patterns’, *Journal of Archaeological Science*, 39, pp. 680–689.

di Stefano, G., Pandolfi, L., Petronio, C. and Salari, L. (2015) ‘Considerations on the morphometry and the occurrence of Cervus elaphus (Mammalia, Cervidae) from the Late Pleistocene of the Italian Peninsula’, *Rivista italiana di Paleontologia e Stratigrafia*, 121(1), pp. 1–18.

di Stefano, G. and Petronio, C. (1993) ‘A new Cervus elaphus subspecies of Middle Pleistocene age’, *Neues Jahrbuch für Geologie und Paläontologie Abhandlungen*, 190, pp. 1–18.

di Stefano, G. and Petronio, C. (1997) ‘Origin and evolution of the European fallow deer (Dama, Pleistocene)’, *Neues Jahrbuch für Geologie und Paläontologie Abhandlungen*, 203, pp. 57–75.

di Stefano, G. and Petronio, C. (2002) ‘Systematics and evolution of the Eurasian Plio-Pleistocene Cervini (Artiodactyla, Mammalia)’, *Geologica Romana*, 36, pp. 311–334.

Stewart, J. R. (2003) ‘Comment on “Buffered tree population changes in a Quaternary refugium: Evolutionary implications"', *Science*, 299(5608), p. 825a.

Stewart, J. R. (2004) 'Neanderthal-modern human competition? A comparison between the mammals associated with middle and upper Palaeolithic industries in Europe during OIS 3', *International Journal of Osteoarchaeology*, 14, pp. 178–189.

Stewart, J. R. (2005) 'The ecology and adaptation of Neanderthals during the non-analogue environment of Oxygen Isotope Stage 3: armageddon or entente? The demise of the European Neanderthals in Isotope Stage 3', *Quaternary International*, 137, pp. 35–46.

Stewart, J. R. and Dalén, L. (2008) 'Is the glacial refugium concept relevant for northern species? A comment on Pruett and Winker 2005', *Climate Change*, 86, pp. 19–22.

Stewart, J. R., van Kolfschoten, M., Markova, A. and Musil, R. (2003a) 'Neanderthals as part of the broader Late Pleistocene megafaunal extincions?', in Van Andel, T. H. and Davies, W. (eds) *Neanderthals and Modern Humans in the European Landscape during the Last Glaciation 60,000 to 20,000 Years Ago: Archaeological Results of the Stage Three Project*. McDonald Institute Monograph Series, pp. 221–231.

Stewart, J. R., van Kolfschoten, M., Markova, A. and Musil, R. (2003b) 'The mammalian faunas of Europe during Oxygen Isotope Stage three', in van Andel, T. H. and Davies, W. (eds) *Neanderthals and Modern Humans in the European Landscape during the Last Glaciation 60,000 to 20,000 Years Ago: Archaeological Results of the Stage Three Project*. McDonald Institute Monograph Series, pp. 103–129.

Stewart, J. R. and Lister, A. M. (2001) 'Cryptic northern refugia and the origins of modern biota', *Trends in Ecology and Evolution*, 16, pp. 608–613.

Stewart, J. R., Lister, A. M., Barnes, I. and Dalen, L. (2010) 'Refugia revisited: individualistic responses of species in space and time', *Proceedings of the Royal Society B*, 277, pp. 661–671.

Stewart, J. R. and Stringer, C. B. (2012) 'Human Evolution Out of Africa: The Role of Refugia and Climate Change', *Science*, 335(6074), pp. 1317–1321.

Stiner, M. C. (1990) *The ecology of choice: procurement and transport of animal resources by Upper Pleistocene hominids in west-central Italy*. University of New Mexico.

Stiner, M. C. (1991a) 'A taphonomic perspective on the origins of the faunal remains of

Grotta Guattari (Latium, Italy)’, *Current Anthropology*, 32, pp. 103–117.

Stiner, M. C. (1991b) ‘An Interspecific Perspective on the Emergence of the Modern Human Predatory Niche’, in *Human Predators and Prey Mortality*. Pp. Boulder: Westview Press, pp. 149–185.

Stiner, M. C. (1991c) ‘Food Procurement and Transport by Human and Non-Human Predators’, *Journal of Archaeological Science*, 18, pp. 455–482.

Stiner, M. C. (1991d) ‘The cultural significance of Grotta Guattari reconsidered. 1. The faunal remains from Grotta Guattari: a taphonomic perspective’, *Current Anthropology*, 32, pp. 103–117.

Stiner, M. C. (1991e) ‘The Guattari faunas then and now’, *Quaternaria Nova*, I, pp. 163–192.

Stiner, M. C. (1994) *Honor among thieves: A zooarchaeological study of Neandertal ecology*. Princeton New Jersey: Princeton University Press. doi: 10.1002/ajpa.1330990204.

Stiner, M. C. (2004) ‘Comparative ecology and taphonomy of spotted hyaenas, humans, and wolves in Pleistocene Italy’, *Revue de Paléobiologie*, 23, pp. 771–785.

Stiner, M. C. and Kuhn, S. L. (1992) ‘Subsistence , Technology , and Adaptive Variation in Middle Paleolithic Italy’, *American Anthropologist*, 94(2), pp. 306–339.

Stiner, M. C., Kuhn, S. L., Surovell, T. A., Goldberg, P., Meignen, L., Weiner, S. and Bar-Yosef, O. (2001) ‘Bone Preservation in Hayonim Cave (Israel): a Macroscopic and Mineralogical Study’, *Journal of Archaeological Science*, 28(6), pp. 643–659. doi: 10.1006/jasc.2000.0634.

Stockmarr, J. (1971) ‘Tablets with spores used in absolute pollen analysis’, *Pollen et Spores*, 13, pp. 615–621.

Straus, L. G. (1999) ‘Iberia: bridge or cul-de-sac? implications of the Iberian record for the debate on the middle to upper palaeolithic transition’, *Human Evolution*, 14(1–2), pp. 139–149. doi: 10.1007/BF02436201.

Straus, L. G., Bicho, N. and Winegardner, A. C. (2000) ‘The Upper Palaeolithic settlement of Iberia: First-generation maps’, *Antiquity*, 74, pp. 553–566.

Stringer, C. (2000) ‘Coasting out of Africa’, *Nature*, 405, pp. 53–55.

Stringer, C. B., Finlayson, J. C., Barton, R. N. ., Fernández-Jalvo, Y., Cáceres, I., Sabin,

R. ., Rhodes, E. ., Currant, A. ., Rodríguez-Vidal, J., Giles-Pacheco, F. and Riquelme-Cantal, J. . (2008) ‘Neanderthal exploitation of marine mammals in Gibraltar’, *Proceedings of the National Academy of Sciences of the United States of America*. National Academy of Sciences, 105(38), pp. 14319–24. doi: 10.1073/pnas.0805474105.

Stringer, C. and Gamble, C. (1993) *In Search of the Neanderthals*. Thames and. London.

Stuart, A. J. (1982) *Pleistocene vertebrated in the British isles*. London: Longman Higher Education.

Stuart, A. J. and Lister, A. M. (2007) ‘Patterns of Late Quaternary megafaunal extinctions in Europe and northern Asia’, *Courier Forschungsinstitut Senckenberg*, 259, pp. 287–297.

Stuart, A. J. and Lister, A. M. (2012) ‘Extinction chronology of the woolly rhinoceros Coelodonta antiquitatis in the context of late Quaternary megafaunal extinctions in northern Eurasia’, *Quaternary Science Reviews*, 51, pp. 1–17. doi: 10.1016/j.quascirev.2012.06.007.

Stuart, A. J. and Lister, A. M. (2014) ‘New radiocarbon evidence on the extirpation of the spotted hyaena (Crocuta crocuta Erxl.) in northern Eurasia.’, *Quaternary Science Reviews*, 96, pp. 108–116.

Suitcliffe, A. J. (1970) ‘Spotted hyaena: crusher, gnawer, digester and collector of bones’, *Nature*, 227, pp. 1110–1113.

Sykes, R. M. W. (2012) ‘Neanderthals 2.0? Evidence for expanded social networks, ethnic diversity and encultured landscapes in the Late Middle Palaeolithic’, in *Unravelling the Palaeolithic 2012*, pp. 73–83.

Taberlet, P., Fumagalli, L., Wust-Saucy, A.-G. and Cosson, J.-F. (1998) ‘Comparative phylogeography and postglacial colonization routes in Europe’, *Molecular Ecology*, 7, pp. 453–464.

Talamo, S., Hajdinjak, M., Mannino, M. A., Fasani, L., Welker, F., Martini, F., Romagnoli, F., Zorzin, R., Meyer, M., Hublin, J.-J., Higham, T. and Hublin, J.-J. (2016) ‘Direct radiocarbon dating and genetic analyses on the purported Neanderthal mandible from the Monti Lessini (Italy)’, *Scientific Reports*. Nature Publishing Group, 6, p. 29144. doi: 10.1038/srep29144.

Talamo, S. and Richards, M. (2011) ‘A comparison of bone pretreatment methods for

AMS dating of samples >30,000 BP', *Radiocarbon*, 53(3), pp. 443–449.

Taschini, M. (1970) 'La Grotta Breuil al Monte Circeo. Per una impostazione dello studio del Pontiniano', *Origini*, IV, pp. 45–78.

Taschini, M. (1972) 'Sur le Paléoliothique de la Plaine Pontine (Latium)', *Qyaternaria*, XVI, pp. 203–223.

Taschini, M. (1979) 'L'industrie lithique de Grotta Guattari au Mont Circé (Latium): definition culturelle, typologique et chronologique du Pontinien.', *Quaternaria*, XXI, pp. 179–247.

Terrenato, N. (2000) 'The visibility of sites and the interpretation of survey results: towards an analysis of incomplete distributionsTitle', in Francovich, R., Patterson, H., and Barker, G. (eds) *The Archaeology of Mediterranean Landscapes 5: Extracting Meaning from Ploughsoil Assemblages*. Oxford, pp. 60–71.

Thorson, R. M. (1990) 'Archaeological geology', *Geotimes*, February, pp. 32–33.

Tomescu, A. M. F. (2006) 'Probing the seasonality signal in pollen spectra of Eneolithic coprolites (Harsova-Tell, Constanta County, Southeast Romania)', *Muzeul Dunarii de Jos, Calarasi, Cultura si Civilizatie la Dunarea de Jos*, 22, pp. 207–221.

Toth, N. and White, T. D. (1991) 'Assessing the ritual cannibalism hypothesis at Grotta Guattari', *Quaternaria Nova*, I, pp. 213–222.

Tournepiche, J. F. and Couture, C. (1999) 'The hyena den of Rochelot Cave (Charente, France)', *Monographien des Romisch-Germanischen Zentralmuseums*, 42, pp. 89–101.

Tozzi, C. (1970) 'La Grotta di S. Agostino (Gaeta)', *Rivista di Scienze Preistoriche*, XXV, pp. 3–87.

Trigger, B. G. (1989) *A History of Archaeological Thought*. Cambridge. Cambridge.

Tringham, R., Cooper, G., Odell, G. H., Voytec, B. and Whitman, A. (1974) 'Experimentation in the Formation of Edge Damage: A New Approach to Lithic Analysis', *Journal of Field Archaeology*, 1, pp. 171–196.

Triska, P. (2009) *Mammalian Glacial Refugia in Europe*. Masaryk University, Brno.

Turner, M. G. and Gardner, R. H. (1991) 'Quantitative methods in landscape ecology: An introduction', in *Quantitative methods in Landscape Ecology*, pp. 3–14.

Turner, M. G., Gardner, R. H. and O'Neill, R. V. (2001) *Landscape Ecology in Theory and Practice: Pattern and Process*. Springer Science & Business Media.

Tzedakis, P. C. (2005) ‘Towards an understanding of the response of southern European vegetation to orbital and suborbital climate variability’, *Quaternary Science Reviews*, 24, pp. 1585–1599.

Uthmeier, T., Ickler, S. and Kurbjuhn, M. (2008) ‘Site catchment analysis in the Late Crimean Middle Palaeolithic: a GIS based approach’, in Chabai, V., Richter, J., and Uthmeier, T. (eds) *Kabazi V: Interstratification of Micoquian and Levallois-Mousterian Camp Sites, Paleolithic Sites of Crimea, Part 2*. Simferopol- Cologne, pp. 481–508.

Vanni, S. and Zuffi, M. A. L. (2011) ‘Hierophis viridiflavus (Lacépède, 1789)’, in Corti, C., Capula, M., Luiselli, L., Razzetti, E., and Sindaco, R. (eds) *Fauna d’Italia, Reptilia*. Milano: Calderini, pp. 509–516.

Vaquero, M. (2011) ‘New perspectives on recycling of lithic resources using refitting and spatial data’, *Quartar,* 58, pp. 113–130.

Vaquero, M., Esteban, M., Allué, E., Vallverdù, J. and Carbonell, E. (2002) ‘Middle Palaeolithic Refugium, or Archaeological Misconception? A New U-series and Radiocarbon Chronology of Abric Agut (Capellades, Spain)’, *Journal of Archaeological Science*, 29, pp. 953–958.

Veenman, F. (1996) ‘Landevaluatie in de Pontijnse regio (Zuid-Latium, Italië), dateringspro-blemen rond een bronstijdakkerbouwfase.’, *Paleoaktueel*, 8, pp. 59–62.

Vega, R., Amori, G., Aloise, G., Cellini, S., Loy, A. and Searle, J. B. (2010) ‘Genetic and morphological variation in a Mediterranean glacial refugium: evidence from Italian pygmy shrews, Sorex minutus (Mammalia: Soricomorpha)’, *Biological Journal of the Linnean Society*, 100, pp. 774–787.

Vernot, B. and Akey, J. M. (2014) ‘Resurrecting Surviving Neandertal Lineages from Modern Human Genomes’, *Science*, 343(6174), pp. 1017–1021.

Verpoorte, A. (2006) ‘Neanderthal energetics and spatial behaviour’, *Before Farming*, 3, pp. 1–6.

Verpoorte, A. (2009) ‘Limiting factors on early modern human dispersals: The human biogeography of late Pleniglacial Europe’, *Quaternary International*, 201(1), pp. 77–85. doi: 10.1016/j.quaint.2008.05.021.

Villa, I. M., Calanchi, N., Dinelli, E. and Lucchini, F. (1999) ‘Age and evolution of the Albano Crater Lake (Roman Volcanic Province)’, *Acta Vulcanica*, 11(2), pp. 305–310.

Villa, P. and Soriano, S. (2013) *Stability and Innovation in Neandertal technology from MIS 9 to MIS 3 in Central Italy*.

Vita-Finzi, C. and Higgs, E. S. (1970) ‘Prehistoric economy in the Mount Carmel of Palestine: site catchment analysis’, in *Proceedings of the Prehistoric Society*, pp. 1–37.

Vitagliano, S. (1984) ‘Nota sul Pontiniano di Grotta dei Moscerini, Gaeta (Latina)’, in *Atti della XXIV Riunione Scientifica dell’Istituto Italiano di Preistoria e Protostoria nel Lazio*, pp. 155–164.

Vitagliano, S. and Piperno, M. (1991) ‘Lithic industry of Level 27 beta of the Fossellone Cave (S. Felice Circeo, Latina)’, *Quaternaria Nova*, 1, pp. 289–304.

De Vito, L. (1977) ‘Atti «L’acqua per la Pianura Pontina: situazione e prospettive», Consorzio Bonifica Latina.’, in *Risorse e fabbisogni idrici attuali e futuri della Piana Pontina*.

Voelker, A. (2002) ‘Global distribution of centennial-scale records for Marine Isotope Stage (MIS) 3: a database’, *Quaternary Science Reviews*, 21, pp. 1185–1212.

Voorrips, A., Loving, S. H. and Kamermans, H. (1991) *The Agro Pontino survey project: methods and preliminary results*.

van Vuure, T. (2002) ‘History, morphology and ecology of the Aurochs (Bos primigenius)’, *Lutra*, 45, pp. 1–16.

Wakefield, E. F. and Dellinger, S. C. (1936) ‘Diet of the Bluff Dwellers of the Ozark Mountains, and its skeletal effects’, *Annals of Internal Medicine*, 9, pp. 1412–1418.

Walker, M. J. (2001) ‘Excavations at Cueva Negra del Estrecho del Rio Quipar and Sima de las Palomas del Cabezo Gordo: Two sites in Murcia (south-east Spain) with Neanderthal skeletal remains, Mousterian assemblages and late Middle to early Upper Pleistocene fauna’, in Milliken, S. and Cook, J. (eds) *A Very Remote Period Indeed: Papers on the Paleolithic Presented to Derek Roe*. Oxford: Oxbow Books, pp. 153–159.

Walsh, K. (1999) ‘Mediterranean Landscape Archaeology and Environmental Reconstruction’, in Leveau, P., Trémont, F., Walsh, K., and Barker, G. (eds) *Environmental Reconstruction in Mediterranean Landscape Archaeology*, pp. 1–5.

Walter, R. C., Buffler, R. T., Bruggemann, J. J., Guillaume, M. M. M., Berhe, S. M., Negassi, B., Libsekal, Y., Cheng, H., Edwards, R. L., Von Gosel, R., Neraudeau, D. and Gagnon, M. (2000) ‘Early human occupation of the Red Sea coast of Eritrea during the Last Interglacial’, *Nature*, 405, pp. 65–69.

Watts, W. A., Allen, J. R. M. and Huntley, B. (1996) ‘Vegetational history and palaeoclimate of the last glacial period at Laghi di Monticchio, Southern Italy’, *Quaternary Science Reviews*, 15, pp. 113–132.

Watts, W. A., Allen, J. R. M. and Huntley, B. (2000) ‘Palaeoecology of three interstadial events during oxygen-isotope stages 3 and 4: a lacustrine record from Lago Grande di Monticchio, southern Italy’, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 155, pp. 83–93.

Welker, F., Soressi, M., Rendu, W., Hublin, J.-J. and Collins, M. J. (2015) ‘Using ZooMS to identify fragmentary bone from the Late Middle/Early Upper Palaeolithic sequence of Les Cottés, France’, *Journal of Archaeological Science*, 54, pp. 279–286.

Weyrich, L. S., Duchene, S., Soubrier, J., Arriola, L., Llamas, B., Breen, J., Morris, A. G., Alt, K. W., Caramelli, D., Dresely, V., Farrell, M., Farrer, A. G., Francken, M., Gully, N., Haak, W., Hardy, K., Harvati, K., Held, P., Holmes, E. C., Kaidonis, J., Lalueza-Fox, C., de la Rasilla, M., Rosas, A., Semal, P., Soltysiak, A., Townsend, G., Usai, D., Wahl, J., Huson, D. H., Dobney, K. and Cooper, A. (2017) ‘Neanderthal behaviour, diet, and disease inferred from ancient DNA in dental calculus’, *Nature*, 544(7650), pp. 357–361. doi: 10.1038/nature21674.

White, M. and Pettitt, P. (2012) ‘Ancient Digs and Modern Myths: The Age and Context of the Kent’s Cavern 4 Maxilla and the Earliest Homo sapiens Specimens in Europe’, *European Journal of Archaeology*, 15(3), pp. 392–420.

White, T. D. and Toth, N. (1991) ‘The cultural significance of Grotta Guattari reconsidered. 2. The question of the ritual cannibalism at Grotta Guattari’, *Current Anthropology*, 32, pp. 118–124.

Wilkinson, K. and Stevens, C. (2003) *Environmental archaeology: approaches, techniques & applications*. Tempus.

Wood, J. R., Rawlence, N. J., Rogers, G. M., Austin, J. J., Worthy, T. H. and Cooper, A. (2008) ‘Coprolite deposits reveal the diet and ecology of the extinct New Zealand megaherbivore moa (Aves, Dinornithiformes)’, *Quaternary Science Reviews*, 27, pp. 2593–2602.

Wood, J. R. and Wilmshurst, J. M. (2016) ‘A protocol for subsampling Late Quaternary coprolites for multi-proxy analysis’, *Quaternary Science Reviews*, 138, pp. 1–5.

Wood, R. ., Barroso-Ruíz, C., Caparrós, M., Jordá Pardo, J. ., Galván Santos, B. and

Higham, T. F. G. (2012) ‘Radiocarbon dating casts doubt on the late chronology of the Middle to Upper Palaeolithic transition in southern Iberia.’, *Proceedings of the National Academy of Sciences of the United States of America*, 110(8), pp. 2781–2786. doi: 10.1073/pnas.1207656110.

Wroe, S., Field, J. and Grayson, D. K. (2006) ‘Megafaunal extinction: climate, humans and assumptions’, *Trends in Ecology & Evolution*, 21, pp. 61–62.

Wu, J. (2004) ‘Effects of changing scale on landscape pattern analysis: Scaling relations’, *Landscape Ecology*, 19, pp. 125–138.

Wu, J. and Qi, Y. (2000) ‘Dealing with scale in landscape analysis: An overview’, *Geographic Information Sciences*, 6(1), pp. 1–5.

Yalden, D. W. (1999) *The history of the British mammals (Poyser Natural History)*. London: Academic Press Inc.

Yll, R., Carrión, J. S., Marra, a. C. and Bonfiglio, L. (2006) ‘Vegetation reconstruction on the basis of pollen in Late Pleistocene hyena coprolites from San Teodoro Cave (Sicily, Italy)’, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 237(1), pp. 32–39. doi: 10.1016/j.palaeo.2005.11.027.

Yll Aguirre, E., Pantaleòn-Cano, J. and Roure, J. (2001) ‘Anàlisis polìnico de coprolitos de Myotragus balearicus. La extinciòn de especies animales y vegetales durante el Holoceno en Mallorca (Islas Baleares)’, in Fombella Blanco, M. A., Fernàndez Gonzàlez, D., and Valencia Barrera, R. (eds) *Palinologìa: Diversidad y Aplicaciones*. Leòn: Acta XII Simposio de APLE, pp. 205–212.

el Zaatari, S., Grine, F. E., Ungar, P. S. and Hublin, J.-J. (2011) ‘Ecogeographic variation in Neadertal dietary habits: evidenze from occlusal microwear texture analysis’, *Journal of Human Evolution*, 61, pp. 411–424.

Zei, M. (1970) ‘Ricerche nel Lazio meridionale’, *Rivista di Scienze Preistoriche,* 25, pp. 323–325.

Zhang, X., Lohmann, G., Knorr, G. and Purcell, C. (2014) ‘Abrupt glacial climate shifts controlled by ice sheet changes’, *Nature,* 512(7514), pp. 290–294. doi: 10.1038/nature13592.

Zilhão, J. (2000) ‘The Ebro Frontier: a model for the late extincion of Iberian Neanderthals’, in Stringer, C. B., Barton, R. N. E., and Finlayson, J. C. (eds) *Neanderthals on the Edge*. Oxford: Oxbow Books, pp. 111–121.

Zilhão, J. (2006) ‘Chronostratigraphy of the Middle-to-Upper Paleolithic transition in the Iberian Peninsula’, *Pyrenae*, 37(1), pp. 7–84.

Zilhão, J. (2009) ‘Szeletian, not Aurignacian: A review of the chronology and cultural associations of the Vindija G1 Neandertals’, in Camps, M. and Chauhan, P. (eds) *Sourcebook of Paleolithic Transitions*. New York: Springer, pp. 407–426.

Zilhão, J. and D’Errico, F. (1999) ‘The chronology and taphonomy of the earliest Aurignacian and its implications for the understanding of Neanderthal extincion’, *Journal of World Prehistory*, 13, pp. 1–68.

Zilhão, J. and D’Errico, F. (2003) ‘The chronology of the Aurignacian and Transitional technocomplexes. Where do we stand?’, in Zilhao, J. and D’Errico, F. (eds) *The Chronology of the Aurignacian and of the Transitional Technocomplexes. Dating, Stratigraphies, Cultural Implications*. Trabalhos. Lisboa: Instituto Português de Arqueologia, pp. 313–348.

Zilhão, J., Davis, S. J. M., Duarte, C., Soares, A. M. M., Steier, P. and Wild, E. (2010) ‘Pego do Diabo (Loures, Portugal): dating the emergence of anatomical modernity in westernmost Eurasia’, *PLoS ONE*, 5, pp. 1–22.

Zilhão, J. and Pettitt, P. (2006) ‘On the new dates for Gorham’s Cave and the late survival of Iberian Neanderthals’, *Before Farming*, 3, pp. 1–9.