PALAEOLITHIC ITALY

ADVANCED STUDIES ON EARLY HUMAN ADAPTATIONS IN THE APENNINE PENINSULA

edited by
Valentina Borgia &
Emanuela Cristiani

PALAEOLITHIC ITALY

Sidestone Press

PALAEOLITHIC ITALY

ADVANCED STUDIES ON EARLY HUMAN ADAPTATIONS IN THE APENNINE PENINSULA

edited by
Valentina Borgia &
Emanuela Cristiani

Published by Sidestone Press, Leiden
www.sidestone.com

Imprint: Sidestone Press Academics

Lay-out & cover design: Sidestone Press
Photograph cover: image concept: Valentina Borgia and Emanuela Cristiani.

ISBN 978-90-8890-583-4 (softcover)
ISBN 978-90-8890-584-1 (hardcover)
ISBN 978-90-8890-585-8 (PDF e-book)

Contents

Participants in the workshop "Out of Italy, Advanced studies on the Italian Palaeolithic", 22-23 May 2015, Cambridge, McDonald Institute for Archaeological Research.

Foreword

The 2015 conference at Cambridge University's McDonald Institute for Archaeological Research bringing together recent and current work on the Italian Palaeolithic was an enormously stimulating occasion, and has resulted in the exciting set of papers in this volume. It has been fascinating to read these papers, many of them arising from recent PhD research, getting on for half a century after I was researching for my own PhD on the prehistory of central Italy. That started out as a study of the Mesolithic/Neolithic transition as a contribution to a British Academy Major Research Project on the Early History of Agriculture, but I ended up looking at aspects of subsistence from the Middle Palaeolithic to the Bronze Age. This involved spending many weeks in dusty stores analysing collections of animal bones from excavated sites; visiting museums and research institutions to understand the associated material culture; and wandering over the countryside from Tuscany and Marche to Campania and Abruzzo, and from the Tyrrhenian and Adriatic shores to the high Apennines, conducting Site Catchment Analysis to the bemusement of *contadini* and *pastori* – and on several occasions *carabinieri*! It is surprising, though also in some ways reassuring, to see so many of the Middle and Upper Palaeolithic sites that I visited featuring again and again in the present volume as classic stratigraphies and assemblages that the authors needed to consult, albeit with new methodologies and, in the main, new questions. From the pre-Alps to the Salento peninsula, and from the Italian Riviera to the Fucine Basin, we learn in these papers how new work can greatly inform the old, and old work inform the new.

The papers range in time from the earliest traces of archaic humans well over a million years ago (Papers 1,2) to the hunter-gatherer-fisher societies of the Terminal Pleistocene and Early Holocene *c.*18,000-8000 years ago (Papers 11-17). Most of the papers focus on stone tools, the most durable and omnipresent component of Palaeolithic archaeology, with *chaïne opératoire* approaches and raw material analyses in particular yielding new insights into scales of behaviour from the butchery of an individual elephant (Paper 2) and people sleeping huddled round a hearth at Riparo Tagliente (Paper 13), to regional or Italy-wide responses to climate change (*e.g.* Papers 4, 7, 13); into changing scales of mobility and territoriality (*e.g.* Papers 5, 10); and into the mixes of planned, expedient and opportunistic technologies, and multi-purpose and specialised activity *locales*, developed in response to the challenges of seasonal food resources and spatially restricted raw materials in different climatic regimes (*e.g.* Papers 5, 6, 9-12). One of the most interesting arguments, building on the more precise radiocarbon chronologies and tephrachronologies that are a signal achievement of work in the past 10-15 years, is that modern humans came into empty places inhabited by Neanderthals several centuries earlier, rather than encountering them (Papers 7, 8).

There are still enormous 'known unknowns', of course, quite apart from the 'unknown unknowns'. Cultural interactions between Italian Palaeolithic societies and contemporary Palaeolithic people are generally seen as likely to have been to the west or east, but the modern migrations to which Italy is exposed, and my own work at the Haua Fteah cave on the Libyan coast, remind me of how little we understand of Italy's potential maritime connectivities with the southern Mediterranean shores even in the Pleistocene. The comparison of isotope analyses of human skeletal remains with interpretations from studies of food residues such as plant remains, fish/animal bones and molluscs (Paper 17) reminds us how difficult it still is to reconstruct the daily, seasonal and annual diets of Palaeolithic peoples even when we have good data sets. Analysis of organic residues on stone tools can give us insights into how plant as well as animal products were used in the Pleistocene, whilst the parenchyma (tissue) of tuberous plants as well as vestiges of seeded plants now known to survive at many Palaeolithic sites have the potential to reveal opportunistic versus storage systems of plant use in parallel with the *chaîne opératoire* lithic studies. The papers that deal with faunal material (Papers 6, 9, 14) demonstrate how much this material also can tell us about Palaeolithic lives, and not just about the food quest – the new work at Arene Candide (Paper 15), in particular, reminds us of how the technological, economic, social and ritual must all have been inextricably entangled in most Palaeolithic lives, at least in the case of modern humans. Yet the study of the leg bones of some Palaeolithic and Mesolithic individuals (Paper 16) is a healthy contrast to that image, showing that they all lived lives that in terms of daily and enduring physical stress were tougher than the training regimes of modern College athletes, and from an earlier age!

Palaeolithic Italy eloquently confirms the importance of Italy's Palaeolithic archaeology for some of the most important debates about Europe's deep past. And one of the most striking aspects of the volume is the international collaborations that underpin most of this work.

Prof. Graeme Barker
McDonald Institute for Archaeological Research
University of Cambridge

Introduction

Valentina Borgia & Emanuela Cristiani

More than 15 years have passed since the publication of Margherita Mussi's comprehensive *Overview of the Italian Paleolithic and Mesolithic* (2001), the most substantial synthesis in English published to date on the subject of the Italian Palaeolithic. Research on this time period in Italy has not only continued since the book's release, but also thrived, greatly complementing and expanding the wealth of information presented by Mussi. Over the past several years, for example, a number of important Palaeolithic sites, especially in the southern parts of the country, have been re-opened and re-examined: Uluzzo Cave, Romanelli Cave, Serra Cicora A Cave, Bernardini Cave, just to name a few. A range of modern analytical methods and cutting-edge techniques have been applied to the study of the materials found during these latest excavations, as well as to archaeological finds from earlier fieldwork. Significant archaeological data have also emerged from two ERC-funded projects -*Hidden Food* directed by Emanuela Cristiani (University of Cambridge), and *Success* by Stefano Benazzi (University of Bologna). All in all, this latest research has not only contributed new data on Palaeolithic Italy, but also on the earliest peopling of Europe; the Neanderthal extinction and behavioural complexity; and the dispersal of Anatomically Modern Humans, their modern technologies and symbolic behaviour – demonstrating that Italy's Palaeolithic archaeological record has much to offer to our understanding of the evolutionary development of various hominin species that inhabited the continent during the Late Pleistocene.

This edited volume, in which a large portion of this latest research is showcased, represents the most recent synthesis in English on the topic of Palaeolithic Italy. It comprises 16 interdisciplinary contributions using a variety of methodological and interpretative perspectives investigating Late Pleistocene adaptations in Italy.

A number of these chapters were first presented as conference papers during the symposium '*Out of Italy: Advances in Italian Palaeolithic*' organised by ourselves and held at Cambridge University's McDonald Institute for Archaeological Research on 22-23 May 2015. The aim of the symposium was to share our most recent early prehistoric research in Italy and to encourage future inter-institutional collaborations between the many European and North American research centres and universities where the 38 scholars who took part in the symposium, working in the fields of stone and osseous technology, prehistoric symbolism, bioarchaeology, geoarchaeology, environmental archaeology, and archaeozoology, are based. Such was the success of the *'Out of Italy'* symposium, that a research meeting on the Italian Palaeolithic and Mesolithic was organised at the University of Genova (Italy) a few months later.

The studies presented here are arranged chronologically.

The dynamics of the earliest human peopling of Italy in the Lower Palaeolithic are presented by Marta Arzarello in her research at two of Italy's most ancient sites: Monte Poggiolo and Pirro nord, dated to about 1.0 Mya and 1.2 Mya, respectively. Other Lower Palaeolithic sites, La Polledrara di Cecanibbio and La Ficoncella, are the object of a paper by Cristina Lemorini focusing on the use of small chipped stone tools. These are, compared to bifaces, "apparently negligible" tools, but a functional approach shows that these may have been used in the exploitation of *Palaeoloxodon* carcasses.

The volume offers an overview on the subsistence strategies of Neanderthal populations, in particular in relation to their lithic technologies. The southern region of Salento is the geographical focus for the study of Neanderthal mobility patterns in relation to raw material procurement. As the Middle Palaeolithic case study by Enza Spinapolice shows, this area is devoid of high quality flint, which led to intense mobility patterns by Neanderthals, and also to a certain variability in the lithic raw materials gathered by these groups.

A more general overview of the Italian Middle Palaeolithic, comprising an in-depth look at the site of Riparo del Molare, is offered by Aureli and Ronchitelli. Their study presents a good synthesis, from a technological point of view and through interpretative models, of the evolution of this period's lithic industries. A more focused topic, the appearance of blade technology, is covered in the chapter by Carmignani and Sarti, with a detailed comparison between the sequence at Grotta del Cavallo and other contemporary sites in Europe.

Grotta del Cavallo is also the focus of the research presented by Francesca Romagnoli on the role of shell technology in Neanderthal coastal settlements. The study presents both an overview of the use of *Callista chione* by Neanderthals and how this informs us about their approaches to available resources, and an analytical approach to these types of finds based on experimental data obtained by the author.

The hottest topic of debate from the past few years – Neanderthals *versus* anatomically modern humans (AMH) – is discussed from a variety of points of view. Negrino *et al.* report on the Middle-to-Upper-Palaeolithic Transition in the northern region of Liguria, where, however, no such Transition has been documented and there has been no evidence of contact between Mousterian and Proto-Aurignacian people, although their respective datings almost overlap. In fact, around 45,000 years ago both Neanderthals and AMH were present in Italy and the decisive study of the human remains found in the Uluzzian layers of Grotta del Cavallo (by Stefano Benazzi) allowed to attribute to AMH this "transitional" culture.

An interesting point of view, the exploitation of avifauna as a food source by the two different populations, is illustrated in the chapter by Gala *et al.*, which studies the bird remains found in 10 Middle and Upper Palaeolithic sites across the peninsula.

Moving to a clear modern human context, the contribution of Bertola *et al.* provides an overview on raw material procurement and circulation in relation to climatic changes throughout the Upper Palaeolithic in northeastern Italy. This is an area extremely rich both in well-documented prehistoric sites and good quality flint sources.

The following contribution, by Emanuele Cancellieri, focuses on lithic technology and cultural exchanges between the Epigravettian settlements found in an area now partly eroded and submerged: the Great Adriatic Plain. Further Upper Palaeolithic lithic industry studies include the research carried out in the Late Epigravettian layers of Grotta Continenza, in Abruzzo, where 60 scrapers on blade with a sinuous profile were found. The possibility that these particular tools may be linked to the processing of lake fish (given the abundance of *Salmo truta* remains also found at the site) is discussed by Marco Serradimigni.

The use of space by Late Palaeolithic groups, in particular those living at the rock shelter site of Riparo Tagliente (Veneto) at the end of LGM, is debated by Fontana *et al.* Several phases of occupation have been identified, allowing Fontana and colleagues to note when changes in the organisation of domestic space took place at Riparo Tagliente during the Late Palaeolithic.

Not only lithic in our volume: the osseous assemblage of the Epigravettian site of Riparo Dalmeri is discussed by Emanuela Cristiani.

The re-excavation and latest study of the cave of Arene Candide in Liguria by Riel-Salvatore *et al.* presented the perfect occasion for a re-appraisal of the chronological succession of funerary rituals throughout the Palaeolithic, entailing both the presentation of new findings and an in-depth consideration of the symbolic thought noted to have taken place at this key Palaeolithic site.

The paper of Sparacello examines the habit of mobility of Middle/ Upper Palaeolithic (virtually used to long distances) and Mesolithic (virtually more sedentary) individuals is valued, considering biomechanical patterns of limbs and comparing it with modern athletes.

The chapter of Mannino *et al.* closes the volume. In this paper the role of aquatic resources in the diet of Palaeolithic and Mesolithic hunters (or better fishers) is examined through carbon and nitrogen isotope analyses on bone collagen.

There is no pretension of exhaustiveness in this volume; the papers presented here constitute more a glimpse on the new directions of the research on Palaeolithic Italy than a complete panorama. In particular, we regret the lack of contributions on Palaeolithic art, of which Italy is very rich, demonstrating a strong centrality of the studies on lithic industries in our Country.

Hopefully, other meetings and other collections of articles will follow this volume and complement all the new data presented here.

Research is in progress, though… to be continued.

Acknowledgements

We wish to thank all the authors for having contributed to this project. Special thanks to Prof. Graeme Barker and Prof. Carlo Peretto for agreeing to write the foreword and the afterword to this volume. Thanks also to the 34 reviewers who took the time to comment on and improve the research papers presented here.

The publication of this volume was made possible through a Marie Skłodowska-Curie Project FP7 – People-2012-IEF (V. Borgia: REA grant agreement n. 328502).

The Italian case in the context of the first European peopling

Marta Arzarello[1]

Abstract

The Italian Peninsula attests to an early human peopling through the presence of several sites, such as Monte Poggiolo and Pirro Nord, the former dated to about 1.0 My (by paleomagnetism and ESR) and the latter dated to 1.2-1.5 My (on a biochronological basis and especially due to the presence of *Allophaiomys ruffoi*). Concerning the site of Pirro Nord, the techno-economical approach to the lithic industries has been used to highlight the technical behaviours and the choices related to raw materials, as well as to make comparisons with other European sites with the same chronology.

In this site, the lithic production is generally characterized by short reduction sequences strongly adapted to the initial morphology of raw material (always flint cobbles or pebbles). The lithic production is mainly facilitated by unipolar/orthogonal/multidirectional débitage; however, centripetal exploitation is also attested to and seems to have an important place inside the debitage economy.

From a general point of view, the other contemporary European sites and the African Mode 1 share these features. However, some peculiarities can be underlined. These indicate an extraordinary *savoir-faire* and capacity for adaptation to the raw material.

Keywords: Italy, Lower Pleistocene, technological behaviour.

1. Introduction

The first European peopling is a controversial concept, as we are giving the word "first" a small and restrictive meaning. From a chronological point of view, the European peopling (considering Europe as a function of the current political boundaries) was

1 Università degli Studi di Ferrara, Dipartimento Studi Umanistici, Sezione di Scienze Preistoriche e Protostoriche, C.so Ercole I d'Este 32 – 44121 Ferrara (Italy). E-mail: marta.arzarello@unife.it.

in: Borgia, V. and E. Cristiani (eds.) 2018: *Palaeolithic Italy. Advanced studies on early human adaptations in the Apennine peninsula*, Sidestone Press Academics (Leiden), pp. 15-26.

subsequent to the peopling of the Near East and Asia. In Dmanisi (Georgia), the human presence is well-attested to at 1.8 Ma (Gabunia 2000; Gabunia *et al.* 2001; Baena *et al.* 2010; Mgeladze *et al.* 2011); in other Asian sites, it seems to be very old, though without clear and unconditionally accepted dates. On the basis of biochronology and palaeomagnetism, several sites have been published with dates around 1.8-1.6 Ma: Longuppo in China (Gao *et al.* 2005; Weiwen and Pu 2007), Riwat in Pakistan (Hemingway, Stapert and Dennel 1989; Gaillard 2006; Ao *et al.* 2010), Yuanmou in China (Gao *et al.* 2005; Weiwen and Pu 2007) and Sangiran in Indonesia (Choi and Driwantoro 2007; Bettis III *et al.* 2009). Most recently, the Ubeidiya site has shown a human presence at 1.4 Ma (Repenning and Fejraf 1982; Tchernnov 1987; Bar-Yosef and Goren-Inbar 1993; Belmaker 2006).

If we compare the European evidence to that of Africa, the picture, of course, becomes even more incomplete, as the first evidence of "human behaviour", understood as technical production, is very well-attested to before 2.5 Ma (Semaw 2000; Harmand *et al.* 2015).Returning to the European context, we must stress that, in Europe, all sites dated around 1 Ma or older are characterized by a relatively low number of lithic remains. This fact undoubtedly affects comparisons between the different sites and should not be forgotten when we try to establish a general picture of the first Europeans' technology (Tab. 1). The fact that technological considerations and comparisons are made based on a sample that is not always reliable, even though it is the only one available, likely greatly affects the estimation of convergences and divergences between lithic assemblages. From another point of view, the fact that the lithic assemblages are generally composed of few pieces (especially compared to those that are chronologically successive) may reflect a less intensive lithic production than that of taphonomic problems. Finally, in seeking to understand human behaviour, we must remember that our interpretation of human technology for the Lower Paleolithic sites is based on just one raw material: stone. However, it is very likely that multiple raw materials were used and that more or fewer differences/similarities/convergences existed between the artefacts.

Site	**N° of published lithic pieces**	**Debitage Methods**	**Bibliography**
Pirro Nord (Apricena, Italy)	349	Unipolar, multifacial, centripetal	(Arzarello, De Weyer and Peretto 2016)
Sima del Elefante (Atapuerca, Spain)	86	Unipolar, centripetal, bidirectional, multifacial	(de Lombera-Hermida *et al.* 2015a)
Barranco Léon (Gaudix-Baza, Spain)	1292	Unipolar, bidirectional, multifacial, centripetal	(Toro- Moyano *et al.* 2011)
Fuente Nueva 3 (Gaudix-Baza, Spain)	932	Unipolar, bidirectional, multifacial, centripetal	(Toro- Moyano *et al.* 2011)
Pont de Lavaud (Indre, France)	1321	Unipolar, multifacial, centripetal	(Despriée *et al.* 2010)
Cà Belvedere di Montepoggiolo (Forlì, Italy)	520	Unipolar, multidirectional, centripetal	(Arzarello, De Weyer and Peretto 2016)
Le Vallonet (Roquebrune-Cap-Martin, France)	97	Unipolar, bipolar, centripetal	(Cauche 2009)

Table 1. number of lithic pieces published for sites dated around 1 Ma.

2. The Italian peninsula case

The early peopling of the Italian peninsula is attested to by two sites: Pirro Nord in Southern Italy and Cà Belvedere di Montepoggiolo in Northern Italy (Arzarello and Peretto 2010). From a chronological point of view, a temporal gap exists between those two sites (attesting to an early peopling of over one million and around one million years ago) and the other Lower Paleolithic site of Italy. There is not, in fact, clear evidence of peopling between 1 Ma and 600 thousand to 700 thousand years ago. This gap can be related to several causes, such as the lack of the sites' conservation, the lack of research or the effective absence of human presence in Italy. Secondly, some sites do not have a well-defined chronology and are placed inside a large chronological range (Fig. 1).

From a geographical point of view, the oldest sites are concentrated in the Central-East and South-East part of Italy; we have no clear evidence in the North-West.

Concerning the first phase of peopling, the site of Cà Belvedere di Monte Poggiolo, attributed to ~0.85 Ma (Muttoni *et al.* 2011), is characterized by unipolar, multidirectional and centripetal debitage reduction sequences. The shaping is completely absent but some of the blanks are transformed into side scrapers and, mainly, denticulates. The aim of the production is related to flake production with a strong adaptation to the initial morphology of the flint cobbles that represent the only exploited raw material (Peretto *et al.* 1998; Arzarello, De Weyer and Peretto 2016).

Around 0,6-0,7 thousand years, we have in Italy few sites mainly characterized by "Mode 1" lithic complexes. The site of Notarchirico (Basilicata region) is dated at 0.66 Ma (Pereira *et al.* 2015) and characterized by the coexistence of "Acheulean" and "not-Acheulean" elements (Piperno 1999).

Isernia La Pineta (Molise Region), dated to 0.58 Ma (Peretto *et al.* 2015a), is characterized principally by debitage reduction sequences (multidirectional and centripetal) on local raw materials, finalized to flake production (Gallotti and Peretto 2015).

From 0.5-0.4 Ma, Italy starts showing a more continuous peopling; more sites are distributed in the North-East, Central and Southern Peninsula (Peretto *et al.* 1997, 2015b; Falguères *et al.* 2008; Corrado and Magri 2011; Nomade and Pereira 2014;

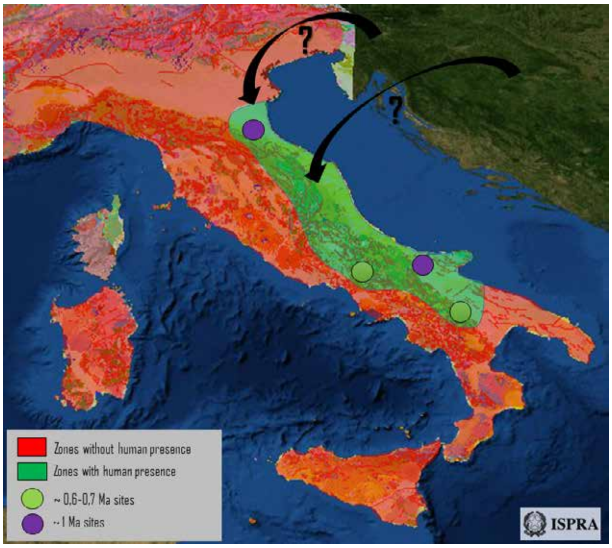


Figure 1. geographical repartition of first prehistorical occupation evidences in the Italian Peninsula (modified after: Servizio Geologico d'Italia).

Aureli *et al.* 2015, 2105b; Nicoud *et al.* 2015). During this phase, the technical production is differentiating and sites with and without handaxes are documented.

3. The Pirro Nord site

The Pirro Nord site is located in the Apricena Municipality (Foggia province, Puglia region). Discovered in the 1960s as a paleontological site, it is situated inside an active quarry of limestone (Cave dell'Erba). Evidence of human presence has been found inside a shaft called P13, situated at the top of the Mesozoic limestone formation (Pavia *et al.* 2012). The fissure's sedimentary filling began with the deposition of big blocks of limestone, followed by a massive, chaotic and rapid process such a debris-flow (Giusti 2013). The lithic industries and faunal remains (some of them showing cutting marks, in the process of study and publication) have been found without a preferential orientation or deposition inside the whole fissure. The taphonomical history (Bagnus 2011; Arzarello *et al.* 2012) of bones and lithic is very similar. They have likely undergone a short transportation, as the cutting edges of lithics are relatively fresh and some bones have been found in anatomical connection. In addition, the presence of cut marks on bones allows us to theorize that the fissure filling comes from a restricted area. The bones and the lithics are often characterized by a Fe-Mn black patina that can be patchy, continuous or completely opaque. The distribution and frequency of the black patina is equal on lithics, bones and limestone stones.

The faunal assemblage, Pirro Nord Faunal Unit (Abbazzi *et al.* 1996; Gliozzi *et al.* 1997; Arzarello *et al.* 2007, 2009, 2012) is characterized by more than 40 species of mammals, most of them carnivores. From the biochronological point of view, on the basis of the entire faunal assemblage, but especially on the basis of the arvicoline *Allophaiomys ruffoi*, the age of Pirro Nord is estimated as falling in the range of 1.3-1.6 Ma (Lopez Garcia *et al.* 2015).

The paleoenvironmental reconstruction, based on macro and micro mammals (Bedetti 2003; Arzarello *et al.* 2009; Blain *et al.* 2015; Lopez Garcia *et al.* 2015) has allowed for the determination that probably, at the moment of the prehistorical occupation, the environment was open and dry but characterized by seasonal wetland.

3.1. The "lithic behavior"

The lithic assemblage is composed of 349 pieces from all debitage phases, from decortication to core abandonment (Arzarello and Peretto 2010; Arzarello *et al.* 2012; Arzarello, Peretto and Moncel 2014; Arzarello, De Weyer and Peretto 2016).

The raw material has been collected in a secondary position (in a limited area situated in the surroundings of the P13 fissure) in the form of flint cobbles from a minimum diameter of 30 cm to a maximum diameter of 90 cm. The flint cobbles are from the Cretaceous succession of the Gargano promontory and have a very good attitude to the knapping. In only two cases, some cobbles with internal tectonic fractures have been exploited (Fig. 2, d). In these cases, the adopted exploitation method is centripetal and the core was discarded after the removal of 3-4 flakes.In some cases, we have also assumed the exploitation of the limestone, but all the limestone "flakes" found in the fissure have a high chemical alteration (as do the other limestone rocks inside the fissure's matrix) and are made of the same limestone as the fissure walls.

For that reason, we prefer to still not consider the limestone “artifacts, and to wait for more evident cases.

The decortication phase is not an independent step in the core reduction, as the general morphology of cortical blanks and the presence of cutting edges allows for speculation that the cortical flakes were considered at the same level as the non-cortical flakes. Considering an estimated volume of all the complete lithic implements (Fig. 3), it is possible to show that the cortical flakes are generally larger than the non-cortical flakes (as predictable, if we consider the morphology of exploited cobbles) and that the cores are not completely exploited, as their final volume still allows for the production of flakes.

To start the lithic production, some cobbles were opened by a split fracture and others by direct percussion with a hard hammer. As expected, the first cobbles produced “kombewa-like” flakes. The exploitation of flakes as cores is attested to by 10 flakes, mostly signifying a centripetal debitage and, secondly, showing unipolar negatives.

Two different exploitation methods have been applied, mostly related to the initial shape and dimension of exploited cobbles.

The big cobbles have been exploited by multidirectional debitage, generally using a 3-4 striking platform used up by unipolar debitage. The obtained flakes have different shapes and dimensions but all are characterized by at least one cutting edge. The number of utilized striking platforms/debitage surfaces is influenced by the core dimension

Figure 2. Pirro Nord lithic industries; a, b) convergent backed flakes produced by centripetal debitage; c) flake produced by unipolar debitage; d) core on fractured raw material with an initiation of centripetal exploitation abandoned probably because of the internal fractures of the raw material (Photos L. Lopes).

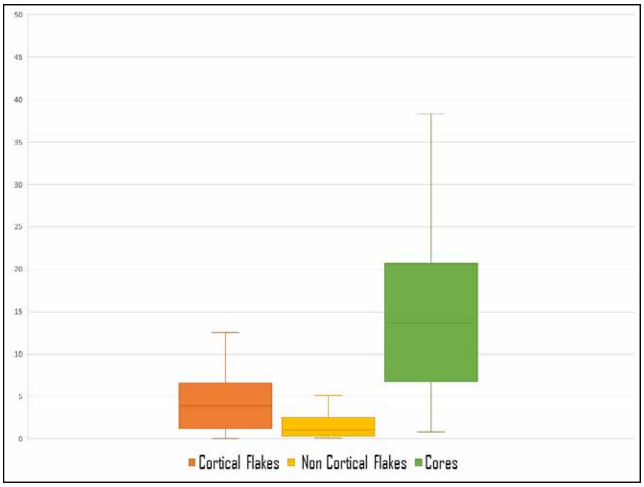


Figure 3. Box plot of cortical flakes, non-cortical flakes and cores areas. Only the complete pieces have been considered. The volume estimation has been done on the basis of the 3 dimensions (length, width, thickness) and on the basis of the flake shape. The flake shape has been simplified inside 4 categories: cube, cuboid, triangular and right prism. The areas are expressed in cm².

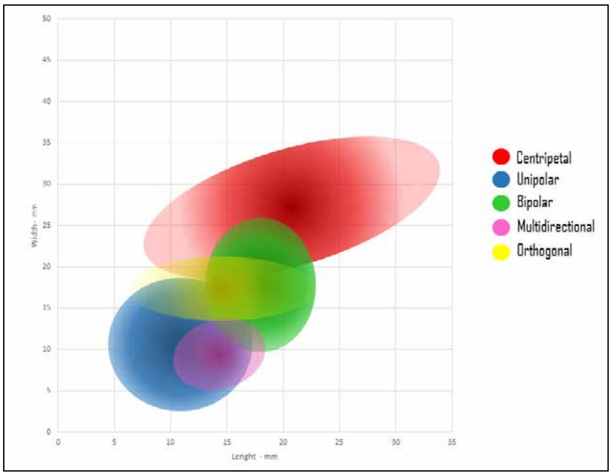


Figure 4. Flakes dimensions. In the graph only complete flakes has been taken into account. The colored ellipses show the area of greatest concentration of flakes for each debitage method.

and morphology. It goes from one single striking platform for the more squared blocks to five for the bigger cobbles.

The smaller cobbles have been exploited by centripetal debitage with a recurrent and repetitive method (Fig. 2, a, b). In most cases, the obtained flakes have a standardized morphology characterized by a *dejeté* point as opposed to a back (cortical or border of core) (Arzarello, Peretto and Moncel 2014; Arzarello, De Weyer and Peretto 2016; Potì 3013).

While the centripetal flakes have been obtained from smaller cobbles, the resulting flakes tend to be larger than the ones coming from the other exploitation methods (Fig. 4). Indeed, the surface exploitation is carried out to obtain flakes that remove half of the debitage surface. This characteristic can add elements to the hypothesis about the high level of standardization of the convergent-backed flakes.

The modification of the cutting edges by a retouch is attested to on 6 flakes, mostly coming from a multidirectional debitage and in one case from a centripetal debitage. The flakes have been transformed into notches (n=1), denticulates (n=3) and side-scrapers (n=2, one of which is a convergent biconvex side-scraper with a direct and short retouch, obtained on the centripetal flake). The retouched flakes have small dimensions and the major axis never exceeds 28 mm, with an average of 23 mm.From a general point of view, the lithic assemblage of Pirro Nord, though it has not been found in a primary position, seems to be homogenous and shows some interesting debitage objectives.

4. General considerations

Even taking into account all the limitations mentioned in the introduction, the oldest European lithic complexes seem to have many common features (Fig. 5). In all sites the raw material is collected near the site and the exploitation methods are influenced by the raw material morphologies. The reduction sequences are generally short, and the principal objective of production is flakes.

The most-used technique is direct percussion by hard hammer. However, in some cases, the bipolar technique is also attested (Despriée *et al.* 2011; Toro-Moyano *et al.*

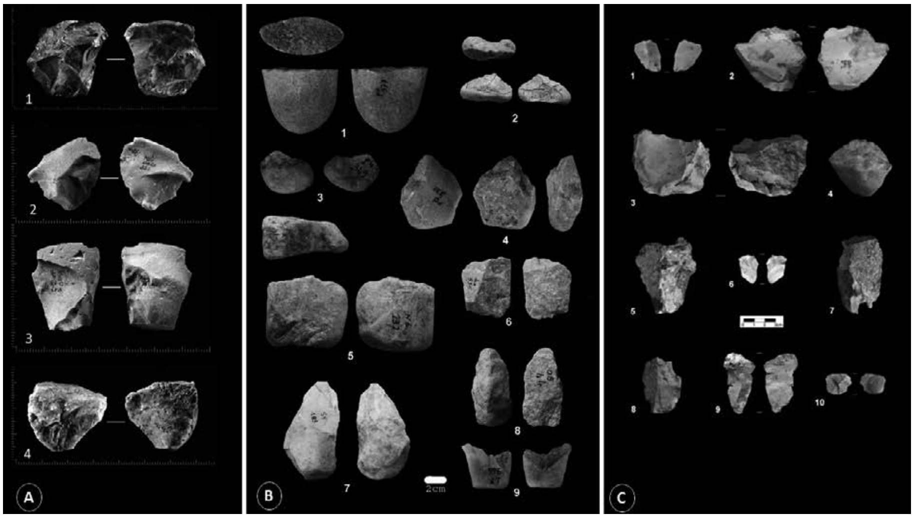


Figure 5. A) lithic industries from Pirro Nord: 1-4 – flakes; B) from Despriée et al. 2010: Types of quartz artefacts recovered on "Pont – de-Lavaud" site 1- broken pebble, 2- pebble with a point made by bifacial flake scars, 3- pebble with a single flake scar, 4- pebble with a point made by unifacial flake scars, 5, 9 – pebbles broken by bipolar percussion, 6, 8 – flakes, 7- pointed tool made by unifacial flake scars; C) from de Lombera-Hermida et al. 2015a : Lithic industry from the Early Pleistocene units of Sima del Elefante.1,2,5,6,7- Flakes, 3 – Core, 4 – Small fractured pebble, 8 – Retouched flake, 9,10- Retouched flake.

2013; Arzarello, De Weyer and Peretto 2016), utilized mainly in the first steps of production. Concerning the methods (Tab. 1), we can find in all sites unipolar, bipolar, orthogonal and multidirectional debitage. It also always presents centripetal debitage but with a different importance and "standardisation".

The primary difference between the oldest European lithic complexes is represented by the presence/absence/abundance of shaping products and retouched blanks.

In Pirro Nord the shaping is absent and the only raw materials exploited are flint cobbles (excluding the dubious limestone flakes and cores). In Cà Belvedere di Montepoggiolo the only exploited raw materials are flint cobbles and the shaping is absent, as attested to by the usewear analysis (Peretto *et al.* 1998).

In Pont de Lavaud the shaping is attested to and the only utilized raw material found directly in the site is quartz. The shaping is mostly finalized to create a point or, in rare cases, an edge. The shaping of points is mainly unifacial (Despriée *et al.* 2010, 2011).

In Fuente Nueva 3 and Barranco Léon the exploited raw materials are flint and limestone; the large configured tools are very rare and not standardized (Barsky *et al.* 2010; Toro-Moyano *et al.* 2011).

In Sima del Elefante the most utilized materials are chert, limestone and quartz; the production objectives are related only to debitage and the retouch (a few implements in the levels TE13 and TE14) are attested to on large-sized flakes (de Lombera-Hermida *et al.* 2015b).In this scenario, the Italian sites are well-integrated; the raw materials influence many of the debitage methods and techniques and the debitage strategies are mostly the same as those described for all sites. The main particularity is the extensive use of centripetal debitage that, especially in Pirro Nord, is made with a fair level of "predetermination".

From a general point of view, the European scene reveals important information about the technical behaviour of early *Homo*; however, the low number of sites must be integrated if we wish to obtain more complete information about technical behaviour.

Acknowledgements

Fieldwork was financially supported by Università degli Studi di Ferrara and Apricena Municipality. The excavations were possible thanks to the concession by the "Soprintendenza Archeologia della Puglia" and the "Ministero dei Beni e delle Attività Culturali" and thanks to the collaboration of Dott.Ssa Anna Maria Tunzi. The excavation was also possible thanks to the kind disposability of Gaetano and Franco dell'Erba.

References

Abbazzi, L., Benvenuti, M. and Boschian, G.1996. The Neogene and Pleistocene succession and the mammal faunal assemblages of an area between Apricena and Poggio Imperiale (Foggia). *Mem della Soc Geol Ital,* 51, 383-402.

Ao, H., Deng, C., and Dekkers, M.J. 2010. Pleistocene environmental evolution in the Nihewan Basin and implication for early human colonization of North China. *Quaternary International,* 223-224, 472-478.

Arzarello, M., Marcolini, F. and Pavia, G. 2007. Evidence of earliest human occurrence in Europe: the site of Pirro Nord (Southern Italy). *Naturwissenschaften,* 94, 107-12.

Arzarello, M., Marcolini, F. and Pavia, G.2009. L'industrie lithique du site Pléistocène inferieur de Pirro Nord (Apricena, Italie du sud) : une occupation humaine entre 1,3 et 1,7 Ma. *Anthropologie.* 113, 47-58.

Arzarello, M., Pavia, G., and Peretto, C. 2012. Evidence of an Early Pleistocene hominin presence at Pirro Nord (Apricena, Foggia, southern Italy): P13 site. *Quaternary International,* 267, 56-61.

Arzarello, M. and Peretto, C. 2010. Out of Africa: The first evidence of Italian peninsula occupation. *Quateranry Interantional.* 223-224, 65-70.

Arzarello, M., Peretto, C. and Moncel M-H. 2014.The Pirro Nord site (Apricena, Fg, Southern Italy) in the context of the first European peopling: Convergences and divergences. *Quaternary International* 389, 255-263.

Arzarello, M., De Weyer, L. and Peretto C. 2016. The first European peopling and the Italian case: Peculiarities and "opportunism." *Quaternary International,* 393, 41-50.

Aureli, D., Contardi, A., Giaccio, B. *et al.* 2015. Palaeoloxodon and Human Interaction: Depositional Setting, Chronology and Archaeology at the Middle Pleistocene Ficoncella Site (Tarquinia, Italy).*PloS one*, *10*(4), e0124498.

Aureli, D., Rocca, R., Lemorini, C. *et al.* 2015. Mode 1 or mode 2? "Small tools" in the technical variability of the European Lower Palaeolithic: The site of Ficoncella (Tarquinia, Lazio, central Italy). *Quaternary Interantional* 393, 169-184.

Baena, J., Lordkipanidze, D., Cuartero, F. *et al.* 2010. Technical and technological complexity in the beginning: The study of Dmanisi lithic assemblage. *Quaternary International,* 223-224, 45-53.

Bagnus, C. 2011,Analisi tafonomica delle associazioni a vertebrati del Pleistocene inferiore di Pirro Nord. PhD dissertation, Faculty of Earth Science, University of Turin.

Barsky, D., Celiberti, V., Cauche, D. *et al.* 2010. Raw material discernment and technological aspects of the Barranco León and Fuente Nueva 3 stone assemblages (Orce southern Spain). *Quaternary International,* 223-224, 201-219.

Bar-Yosef, O. and Goren-Inbar N. 1993. *The Lithic Assemblages of Ubeidiya. A Lower Palaeolithic Site in the Jordan Valley*. Jerusalem: Quedem.

Bedetti, C. 2003. Le avifaune fossili del Plio-Pleistocene italiano: sistematica, paleoecologia ed elementi di biocronologia. 2003. Unpublished PhD dissertation, University of Roma La Sapienza

Belmaker, M. 2006. Community Structure through Time : 'Ubeidiya , a Lower Pleistocene Site as a Case Study. Ph. D. dissertation. Hebrew University.

Bettis, E.A., Milius, A.K., Carpenter, S.J. *et al.* 2009. Way out of Africa: Early Pleistocene paleoenvironments inhabited by Homo erectus in Sangiran, Java. *Journal of Human Evolution.* 56, 11-24.

Blain, H-A., Delfino, M., Berto, C. *et al.* 2015. First record of Pelobates syriacus (Anura, Amphibia) in the early Pleistocene of Italy. *Palaeobiodiversity and Palaeoenvironments* 2015, 1-14.

Cauche, D. 2009. Les stratégies de débitage dans les industries lithiques archaïques des premiers habitants de l'Europe. *Anthropologie,* 113,178-190.

Choi, K. And Driwantoro D. 2007. Shell tool use by early members of Homo erectus in Sangiran, central Java, Indonesia: cut mark evidence. *Journal of Archaeological Science,*34, 48-58.

Corrado, P. and Magri, D. 2011. A late Early Pleistocene pollen record from Fontana Ranuccio (central Italy). *Journal of Quaternary Science,* 26, 335-344.

Despriée, J., Voinchet, P., Tissoux, H. *et al.* 2010, Lower and middle Pleistocene human settlements in the Middle Loire River Basin, Centre Region, France. *Quateranry International ,* 223-224, 345-359.

Despriée, J., Voinchet, P., Tissoux, H. *et al.* 2011. Lower and Middle Pleistocene human settlements recorded in fluvial deposits of the middle Loire River Basin, Centre Region, France. *Quaternary Science Review,* 30, 1474-1485.

Falguères, C., Bahain, J-J., Tozzi, C. *et al.* 2008. ESR/U-series chronology of the Lower Palaeolithic palaeoanthropological site of Visogliano, Trieste, Italy. *Quaternary Geochronology,* 3, 390-398.

Gabunia, L., Antòn, S.C., Lordkipanidze, D. *et al.* 2001. Dmanisi and Dispersal. *Evolutionary Anthrpology* 10, 158-170.

Gabunia, L.K. 2000. Earliest Pleistocene hominid cranial remains from Dmanisi, Republic of Georgia: taxonomy, geological setting, and age. *Science* 288, 1019-25.

Gaillard, C. 2006. Les premiers peuplements d'Asie du Sud : vestiges culturels. *Comptes Rendus PALEOVOL* 5, 359-369.

Gallotti, R. and Peretto C. 2015. The Lower/early Middle Pleistocene small débitage productions in Western Europe: New data from Isernia La Pineta t.3c (Upper Volturno Basin, Italy). *Quaternary International* 357, 264-281.

Gao, X., Wei, Q., Shen, C. *et al.* 2005, New light on the earliest Hominid occupation in East Asia. *Current Anthropology,* 46,115-120.

Giusti, D. 2013. A GIS apporach to the Paleolithic site of Pirro Nord, Apricena, Italy: from data management to spatial analysis through a Wiki documentation. In: ESHE (ed.). *European Society for the Study of Human Evolution*, 96.

Gliozzi, E., Abbazzi, L., Argenti, P. *et al.* 1997. Biochronology of selected mammals, molluscs and ostracods from the Middle Pliocene to the Late Pleistocene in Italy. The state of the art. *Rivista Italiana di Paleontologia e Stratigrafia* 103, 369-388.

Harmand. S., Lewis, J.E., Feibel, C.S. *et al.* 2015. 3.3-million-year-old stone tools from Lomekwi 3, West Turkana, Kenya. *Nature* 521, 310-315.

Hemingway, M.F., Stapert, D. and Dennel, R.W. 1989. Early artefacts from Pakistan? Some questions for the excavators. *Current Anthropology,* 30, 317-322.

de Lombera-Hermida, A., Bargalló, A., Terradillos-Bernal, M. *et al.* 2015a. The lithic industry of Sima del Elefante (Atapuerca, Burgos, Spain) in the context of Early and Middle Pleistocene technology in Europe. *Journal of Human Evolution,* 82, 95-106.

Lopez Garcia, J.M., Luzi, E., Berto, C. *et al.* 2015. Chronological context of the first hominin occurrence in southern Europe : the Allophaiomys ruffoi (Arvicolinae , Rodentia , Mammalia) from Pirro 13 (Pirro Nord , Apulia , Southwestern Italy), *Quaternary Science Review* 107, 260-266.

Mgeladze, A., Lordkipanidze, D., Moncel, M-H. *et al.* 2011. Hominin occupations at the Dmanisi site, Georgia, Southern Caucasus: raw materials and technical behaviours of Europe's first hominins. *Journal of Human Evolution* 60, 571-596.

Muttoni, G., Scardia, G., Kent D. V. *et al.* 2011. First dated human occupation of Italy at ~0.85Ma during the late Early Pleistocene climate transition. *Earth and Planetary Science Letters* 307, 241-252.

Nicoud, E., Aureli, D., Pagli, M. *et al.* 2016. Preliminary data from Valle Giumentina Pleistocene site (Abruzzo, Central Italy): A new approach to a Clactonian and Acheulian sequence. *Quaternary International,* 409, 182-194

Nomade, S., Pereira, A. 2014. Datation 40Ar/39Ar du site de Guado San Nicola. In: Muttillo, B., Lembo, G. and Peretto, C. (eds.). *L'insediamento a Bifacciali Di Guado San Nicola*. Ferrara: Annali dell'Università degli Studi di Ferrara, 49.

Pavia, M., Zunino, M., Coltorti, M. *et al.* 2012. Stratigraphical and palaeontological data from the Early Pleistocene Pirro 10 site of Pirro Nord (Puglia, south eastern Italy). *Quateranry International* 267, 40-55.

Pereira, A., Nomade, S., Voinchet, P. *et al.* 2015. The earliest securely dated hominin fossil in Italy and evidence of Acheulian occupation during glacial MIS 16 at Notarchirico (Venosa, Basilicata, Italy). *Journal of Quaternary Science,* 30/7, 639-650.

Peretto C, Amore O, Antoniazzi A *et al.* 1998. L'industrie lithique de Cà Belvdere i Monte Poggiolo: stratigraphie, matière première, typologie, remontage et traces d'utilisation. *Anthropologie* 102, 343-466.

Peretto, C., Arnaud, J., Moggi-Cecchi, J. *et al.* 2015. A Human Deciduous Tooth and New 40Ar/39Ar Dating Results from the Middle Pleistocene Archaeological Site of Isernia La Pineta, Southern Italy. *PLoS One* 2015a;10:e0140091.

Peretto, C., Arzarello, M., Bahain J-J *et al.* 2015. The Middle Pleistocene site of Guado San Nicola (Monteroduni, Central Italy) on the Lower/Middle Palaeolithic transition. *Quaternary Interntional* 411*,* 301-315.

Peretto, C., La Rosa, M., Liboni, A. *et al.* 1997. Le gisement de Quarto delle Cinfonare dans le cadre du paléolithique inférieur de l'Italie ouest-centrale. *Anthropologie* 101, 597-615.

Piperno, M. 1999. *Notarchirico. Un Sito Del Pleistocene Medio Iniziale Nel Bacino Di Venosa*. Museo Pigo. Piperno M (ed.). Roma: Edizioni Osanna.

Potì, A. 2013. Morpho-geometrical approach to the study of the débordant déjeté flakes of Pirro Nord (Apricena, Foggia). *Proceedings of the European Society for the Study of Human Evolution*. 174.

Repenning, C. and Fejraf, O. 1982. Evidence for earlier date of 'Ubeidiya, Israel, hominid site. *Nature* 299, 344-347.

Semaw, S. 2000. The World's Oldest Stone Artefacts from Gona, Ethiopia: Their Implications for Understanding Stone Technology and Patterns of Human Evolution Between 2·6-1·5 Million Years Ago. *Journal of Archaeological Science* 27, 1197-1214.

Tchernnov, E. 1987. The age of the 'Ubeidiya Formation, an Early Pleistocene hominid site in the Jordan Valley, Israel. *Israel Journal of Earth Sciences* 36, 3-30.

Toro- Moyano, I., Barsky, D., Cauche, D. *et al.* 2011. The archaic stone tool industry from Barranco León and Fuente Nueva 3, (Orce, Spain): Evidence of the earliest hominin presence in southern Europe. *Quaternary Interantional,* 243, 80-91.

Toro-Moyano, I., Martínez-Navarro, B., Agustí, J. *et al.* 2013. The oldest human fossil in Europe, from Orce (Spain). *Journal of Human Evolution* 65, 1-9.

Weiwen, H. and Pu, Z. 2007. Les plus anciennes occupations humaines en Chine. *Anthropologie* 111, 166-181.

Small Tools and the Palaeoloxodon- Homo interaction in the Lower Palaeolithic

The contribution of use-wear analysis

C. Lemorini[1]

Abstract

The aim of this paper is to discuss the role played by small chipped stone tools as part of the toolkit of *Homo* during the Lower Palaeolithic. These apparently negligible small tools may have had an important role on the complex interaction between Homo and *Palaeoloxodon antiquus,* which may have been masked by the general idea of a "bi-face-primacy" during the Lower Palaeolithic. Data coming from use-wear analysis are the primary source of this discussion, integrated with the suggestions offered by recent studies based on technological and techno-morpho-functional analyses.

Keywords: Lower Palaeolithic, Palaeoloxodon, *Homo*, use-wear analysis, techno-morpho-functional analysis.

1. Introduction

The production of small chipped stone tools in the Lower Palaeolithic is documented in a variety of sites in Africa, Asia and Europe during a very wide chronological span from around 1 Mya to 300 kya BP (Agram et al. 2015; Alpeson-Afil & Goren-Inbar 2015; Burdukiewicz and Aron, 2003 and references therein; Sanchéz-Yustos *et al.* 2016).

---

1 Department of Classics, LTFAPA Laboratory, Sapienza University of Rome, P.le A.Moro 5 0015 Rome, Italy. E-mail: cristina.lemorini@uniroma1.it.

in: Borgia, V. and E. Cristiani (eds.) 2018: *Palaeolithic Italy. Advanced studies on early human adaptations in the Apennine peninsula*, Sidestone Press Academics (Leiden), pp. 27-36.

Recent technological and techno-morpho-functional studies of chipped stone industries made of flint, limestone, or quartz have provided new relevant data for the comprehension of the behavioural premises behind this evidence. The production of small items could indicate technical constraints deriving from a limited capacity related to the raw material management and transformation. This seems to be the case for some Western European Lower Pleistocene (from 1.6 to 0.8 Ma) technocomplexes as recently discussed by Galotti and Peretto (2015). Nevertheless, the authors suggest that the more recent technocomplexes of the early Middle Pleistocene (from 800 kya to 600 kya) exhibit features highlighting a shift towards a better managing of the reduction sequence and core volume, allowing to produce flakes with a desired shape. Moreover, techno-morpho-functional analyses has recently shown that the so-called Middle Pleistocene small tools may be the result of different technical trajectories, aimed to create, by means of *débitage* and *façonnage,* different categories of tools with different functional potential (Aureli *et al.* 2015; Chazan 2013).

Small tools are found in sites in which remains of *Palaeoloxodon* are present beginning from Lower Pleistocene (see Sanchéz-Yustos et al. 2016). I want to discuss, through functional data, if and how the small tools had a part in *Palaeoloxodon* exploitation given the fact that recent researches claim the key role played by *Palaeoloxodon* for the evolutionary success of Homo (Ben-Dor *et al.* 2011; Agam and Barkai, 2016 and references therein). Elephant is, in fact, a potential source both for high-energy food (meat and fat) and as raw material (bone). The questions arising from these evidences are: did Homo need a specialized tool kit in order to exploit such specific resources? And if so, are small tools part of this tool kit?

These questions will be addressed through the data coming from two Late Lower Palaeolithic sites located in Central Italy: La Polledrara di Cecanibbio (Rome, Latium) and La Ficoncella (Viterbo, Latium). The choice of these two contexts is justified by various reasons: both sites were recently excavated, both sites are the focus of an interdisciplinary research program and use wear analysis was performed on both the assemblages by the author of this research.

2. Archaeological background

The site of La Polledrara di Cecanibbio is located in the western sector of the Rome basin (Fig. 1). Its fluvial and fluvio-palustrine fossiliferous deposits are part of the Ponte Galeria Sequence (PGS), in particular of the PG6. These sediments originated mainly from the primary and contemporaneous re-sedimentation of volcanic products some episodes of which were recently dated by Marra *et al.* (2014) to 450 ± 6 ka and 447 ± 7 ka. My reasoning will be based on a specific area of the site where what can be considered quite a “snapshot” of one or two butchering sessions around a carcass of *Palaeoloxodon* (Fig. 2) have been excavated (Santucci *et al.* 2016 and references therein).

The deposits of the Ficoncella site are part of the PlioPleistocene Tarquinia basin (Fig. 1), about 27 km wide, which extends for almost 40 km along the Latium Tyrrhenian margin. The excavation of the Ficoncella site, yet pertaining only a small area, yielded a small lithic assemblage, a carcass of Palaeoloxodon antiquus and some other faunal remains.

The archaeological horizon of Ficoncella is comprised between a tephra layer FIC1 attributed to a Sabatini eruption dated to ~499 ka and the FIC2 ignimbrite dated to ~441 ka (see Aureli *et al.*, 2016). The occupation probably took place during MIS 13.1, which precedes the sea-level fall of the MIS 12 glacial period.

3. Materials and methods

The chipped stone tools of La Polledrara di Cecanibbio discussed in this article come from the upper part of the mud deposit in which a quite entire and articulated skeleton of elephant have been found. 304 flint implements, all showing a very good preservation, pertain to this area which include cores (from pebbles smaller than 9cm), *débris*, flakes (127 items) and retouched flakes (28 items). The whole lithic industry was analysed with by means of use-wear approach. As a result, traces of use were observed on 14 retouched flakes, 6 flakes and 4 cores reused as tools.

As far as La Ficoncella site concerns, 129 among the 280 small flakes made of flint and limestone found in the deposit were microscopically analysed. The less fragmented and best preserved items were selected. However, even these latter exhibit various types of alteration among which the most frequent is a "glossy appearance" probably due to the acidity of the soil, that has limited the use interpretation to the macro-traces of use only. On 13 chipped stone tools traces of use were detected: 9 small flakes, 2 small flake fragments, 2 retouched small flakes.

The applied approach is an integration of Low-power and High-power (van Gijn, 2010) that combines the observation and interpretation of both macro-traces, edge-removals and macro edge-rounding, with a stereomicroscope at low magnifications and reflected lighting system (Nikon SMZ equipped with objective 0.5X, oculars 10X zoom range of 0.75X to 7.5X), and micro-traces e polishes, striations, micro edge-rounding e with a metallographic microscope at high magnifications and reflected lighting system (Nikon Eclipse equipped with objectives 10X, 20X and oculars 10X).

4. Discussion

At La Polledara di Cecanibbio the elephant found in the studied area got trapped in a muddy swamp area, an event that probably caused its death.

The exceptional preservation of the flint chipped stone tools allowed to perform use-wear analysis with a great success and to interpret in detail what hominins made with the small tools found nearby the carcass of the elephant.

Two episodes of knapping have been recognized through technological analysis and refitting. The results coming from the refitting showed that the knapping products were moved from the fan of the elephant along its left side before being used and abandoned (see Santucci *et al.* 2016, 3, Fig.1). Except for rare evidences of wood working, the majority of the tools were used for processing soft animal material, not a surprise since the hominins were dealing with a carcass. Nevertheless, the surprise was to realize that a lot of the activities consisted of scraping and not of cutting and, moreover, scraping of hide plus meat (Fig. 3a-c).

Traces of gripping (Fig. 3d) testify that, although small, these tools were used without a handle. Some of them are characterized by cortex, which is an element that improves the gripping potential especially when very greasy materials are processed. Many tools were shaped by retouches that allowed to obtain a regular, sharp and at the same time strong active edge.

So, were these tools shaped in purpose for making what? and why?

The chipped stone tools were in contact with the inner part of the hide that, as use-wear traces suggest, was in a not-dry state. It is not possible to say if the hide belonged to a fresh, recently died, or rotten carcass, however, the skin was certainly not dry. The interpreted action of scraping seems to suggest some sort of treatment of the hide, nevertheless the working of an elephant skin in situ is hard to imagine. The processing of thick skins needs a long procedure of cleaning and softening that takes days if the aim is to obtain a pliable and not a rotten product. At La Polledrara di Cecanibbio, there is no evidence of a campsite nearby the carcass (see for ethnographic examples of campsites for elephants butchering sessions in Haynes and Klimowicz 2015, 22). The presence of hominins seems to have been very short, one or two episodes, at the most, around the carcass, which was probably intercepted during the roaming of the hominins in the area surrounding the site. A prolonged and articulated session of skin treatment is not feasible in this kind of situation. Moreover, we have to keep in mind possible other easier alternatives to obtain a skin product. Pliable skins were obtainable from medium or, especially, small hunted animals holding a skin easy to clean and easy to soften using tools or just by stretching with hands or chewing. So, why scraping fresh or semi-fresh elephant skin? To scrape off something left on a carcass that was exploited for meat during the scavenging activities of other predators, as an example. Nevertheless, the elephant carcass shows very few signs of the activity of predators (Santucci *et al.* 2016, 13), maybe because the muddy ground discouraged big carnivores to approach. An alternative scenario might have been the encounter of the hominins with a rotten carcass whose soft tissues where partly exploited by small carnivores, insects and birds (for similar scenarios in modern times see Haynes and Klimowicz 2015, 24). In this case, it is possible to suggest the scraping off of residual pieces of meat or fat. Moreover, a carcass is an ideal environment, where larvae and insects, which can be considered as an important source of protein for humans, can proliferate. Scraping off residual fat and larvae or insects from an elephant skin does not appear as a difficult scenario to imagine for the site of La Polledrara di Cecanibbio and for other similar contexts.

The example of La Polledrara di Cecanibbio suggests a more careful reflection about the several different interactions that may have happened between *Palaeoloxodon* and Homo and other predators from the death of the animal to its burial.

The carcass of an elephant is exploitable for a very long time for its meat, its fat, its marrow and its bones. Groups of hominins could routinely come back to a carcass of an animal that they killed as a sort of "organic quarry" or run into a carcass at a certain stage of its transformation.

The mutability of this important source of food and raw material and the difficulty to predict the state of the carcass when encountered may have lead to a variety of technical solutions aimed to produce specific types of tools needed on the spot with small and light raw materials, which were easy to find everywhere and to carry at the site (see also the discussions on Sanchéz-Yustos et al. 2016 about the relation between small cutting tools and megafauna).

As an example, the site of La Ficoncella located in the same regional setting of La Polledrara di Cecanibbio (Fig. 1b), and characterised by faunal remains including also *Palaeoloxodon*, displays a set of technical solutions aimed at obtaining very specific tools (Aureli *et al.* 2016).

Besides the "classical" technological analysis, a techno-morpho-functional analysis has been applied to the lithic industry of la Ficoncella. The techno-morho-functional approach has been at first proposed by M.Lepot (Lepot 1993) in a master thesis supervised by E.Boëda. The method has been further refined by L.Bourguignon (2001) and Boëda himself (see Boëda 2013 for an overview). It consists in the evaluation of the technological and morphological parameters that affect the function of a lithic tool. In this way, it is possible produce hypotheses on its intended use. In my opinion, the combination of techno-morpho-functional analysis and use wear/residues analyses (actual function) it is the most complete approach for studying how hominins designed and applied their concept of functionality to their chipped stone tools.

The application of the techno-morpho-functional approach at La Ficoncella has shown two lines of production: one for large flakes made from limestone blocks and one for small flakes made from flint pebbles. In both cases, there is a careful search for the most suitable volume of the raw material for the production of the two sequences.

What is of great interest for our reasoning is the production sequence of the small flakes made of flint. The scholars that carried out of the techno-morpho-functional analysis define this production sequence as "circular". Quoting the authors definition: the "circular" production sequence "is an intermingling of different stages: confection, production and retouch. There is no clear limit between production and confection. The confection is present at different times. The objectives are multiple and the blanks came from different stages of the sequence." (Aureli *et al.* 2016, 16 citation of Fig. 11). In functional terms, it means that combining *débitage* and *façonnage* the hominins of La Ficoncella had the possibility to obtain the desired specific shapes of flakes transforming on the spot the blanks without the need of starting each time a new knapping sequence.

It is clear that this behaviour is extremely effective if one does not know exactly what kind of activities I will need to perform during the foraging routine. Moreover, the case study of La Ficoncella shows that the "circular" production sequence allows to obtain three different morpho-functional types of tools: rectilinear edged unshaped flakes and two different categories of pointed shaped tools: the so-called spina and mini-rostrum.

The use-wear analysis carried out on the lithic industry of La Ficoncella (Lemorini in Aureli *et al.* 2016) has not allowed to obtain so detailed data as for La Polledara di Cecanibbio, due to the glossy appearance that affects the surface of the lithic items. For this reason, it is hard to detect micro wear related to specific uses. Nevertheless, the edge-removals permitted to interpret the use of various unshaped flakes and of a single spina for the cutting of especially medium hard material and soft material in fewer cases. Medium hard material definition may include various types of material as wood, woody plants, hide alone and hide plus meat. That means that these tools could have processed both wood or animal materials, and among it also *Palaeoloxodon* carcasses, with really specific functional purposes as the techno-morpho-functional analysis seems to testify.

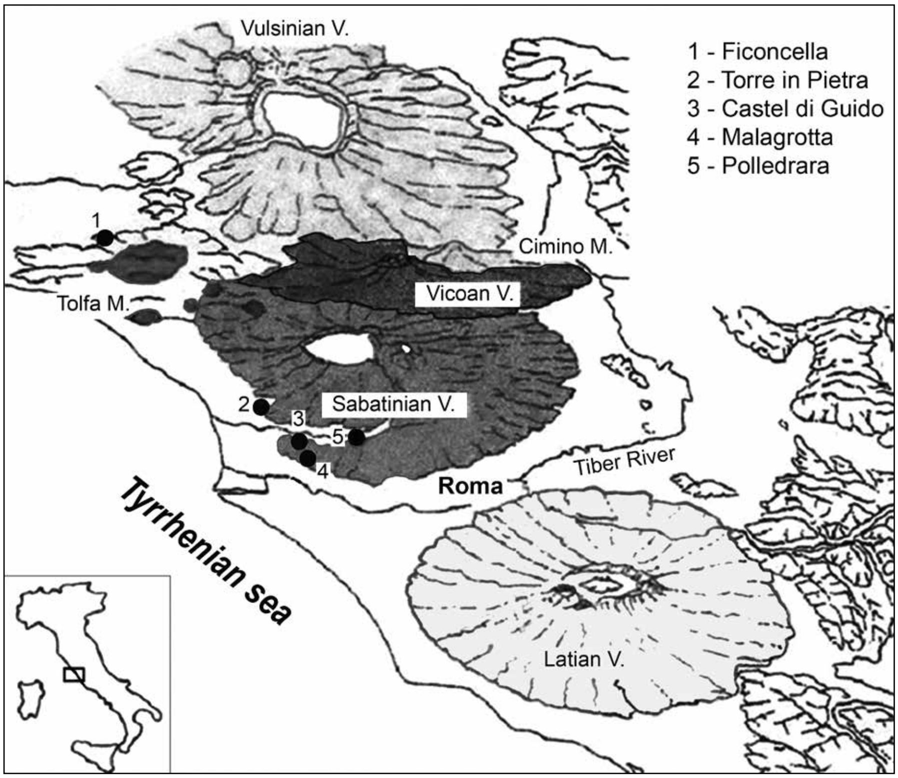


Figure 1. Location of the sites cited in the text and of the other Lower Paleolithic sites of the region (reworking of figure from the La Polledrara of Cecanibbio archive).

Figure 2. View of the site with details of the Palaeoloxodon carcass cited in the text (figure from the La Polledrara of Cecanibbio archive).

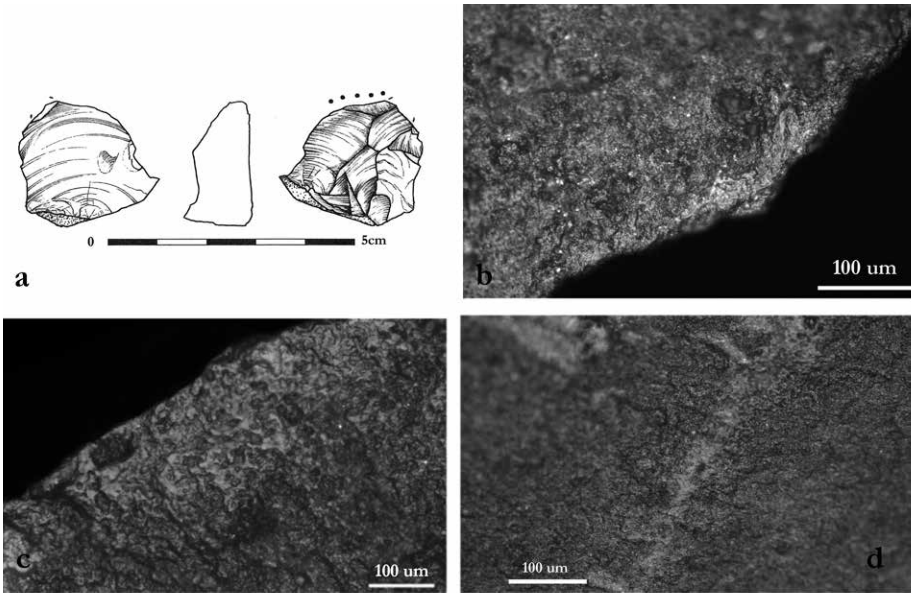


Figure 3. La Polledrara di Cecanibbio, a) small tool n° 20214 with traces of use (…) ; drawn by E.Santucci; b) related use-wear of small tool n° 20214 interpreted as scraping hide; c) use-wear observed on retouched small flake n° 20126 interpreted as mixed action (scraping + cutting) of meat and hide; d) inner surface of small flake n° 20825 interpreted as griping; use-wear pictures by C.Lemorini.

5. Conclusions

The technological and techno-morpho-functional data discussed in this article suggest that during a long-time span including Lower and Middle Pleistocene, small flakes technology turns from a limited mastering of the raw material to an aforethought choice aimed to produce different types of small shaped and unshaped tools with a different functional potential. On the other side, use-wear analysis proves that these tools were used for different tasks, including also the processing of *Palaeoloxodon* carcasses for activities not necessarily dealing with the butchering of a fresh body.

We have to take in consideration that an elephant carcass owns a potential of exploitation unmatched by any other animals in terms of nutritional potential (Ben-Dor *et al.* 2011; Agam and Barkai, 2016 and references therein). Moreover, an elephant can be exploited for its meat, fat, marrow and bones for years. Nevertheless, this exploitation is not static but rather changing depending on the state of the carcass (fresh, rotten, scavenged by other predators.) when found by the hominins.

Could the interaction with this fabulous but mutable resource have stimulated cognitive processes required for better controlling the production of small unshaped or shaped tools in order to cope with the unpredictable potential of an elephant carcass?

If we read this interaction in a Material Engagement perspective (Malaforius 2013) the multifaceted reaction of the elephant carcasses to the hominins exploitation imposes new solutions to a better response of the extended body of Homo, consisting of brain, body and tools. The body schema changes when exploring new ways of exploiting an elephant carcass with new types of small tools.

Certainly, these suggestions need to be tested against other data coming from European and extra-European archaeological sites. Moreover, it is clear that it is not realistic to link the behavioural changes in *Homo erectus* to the sole interaction with elephants. However, it is indisputable that this animal represented an important aspect of the world in which Homo lived and use-wear analysis is now beginning to provide a strong contribute to clarify the connections undergoing between them (see also Chazan 2013, Mosquera *et al.* 2015 and Solodenko *et al.* 2015 for a discussion on this subject).

Acknowledgments
This article is dedicated to Dr. A.P. Anzidei (1946-2017) director of excavations and researches at La Polledrara di Cecanibbio.

References

Agam, A., Marder, O., & Barkai, R. 2015. Small flake production and lithic recycling at late acheulian revadim, Israel. *Quaternary International* 361, 46-60.

Agam, A., Barkai, R. 2016. Not the brain alone: The nutritional potential of elephant heads in Paleolithic sites. *Quaternary International* 406 B, 218-229.

Alperson-Afil, N., Goren-Inbar, N. (2016) Acheulian hafting: Proximal modification of small flint flakes at Gesher Benot Ya'aqov, Israel. *Quaternary International* 411 B, 34-43.

Aureli, D., Rocca, R., Lemorini, C., Modesti, V., Scaramucci, S., Milli, S., Giaccio, B., Marano, F., Palombo, M.R., Contardi, A. 2016. Mode 1 or mode 2? "Small tools" in the technical variability of the European Lower Palaeolithic: The site of Ficoncella (Tarquinia, Lazio, central Italy). *Quaternary International* 393, 169-184.

Ben-Dor, M., Gopher, A., Hershkovitz, I., Barkai, R. 2011. Man the Fat Hunter: The Demise of Homo erectus and the Emergence of a New Hominin Lineage in the Middle Pleistocene (ca. 400 kyr) Levant. *PlosOne* 6/12, 1-12.

Boëda E. 2013. Techno-logique & Technologie. Une Paléo-histoire des objects lithiques tranchats.Préhistoire au Présent. Prigonrieux: Archéo-éditions.

Bourguignon, L., 2001. L'apport de l'exp_erimentation et de l'analyse technomorpho-fonctionnelle à la reconnaissance du processus d'am_enagement de la retouche Quina. In: Bourguignon, L., Ortega, I., Fr_ere-Soutot, M.-Ch (Eds.), Pr_ehistoire et approche exp_erimentale, Prehistoires 5. Editions M.M. Montagnac, Paris, 35-63.

Burdukiewicz J. M, Ronen A. (eds.) 2003 *Lower Palaeolithic Small Tools inn Europe and the Levant*, BAR (I.S.), 239 Q

Chazan, M. 2013. Butchering with small tools: the implications of the Evron Quarrry assemblage for the behavior of *Homo erectus. Antiquity* 87, 350-367.

Galotti, R., Peretto, C. 2015. The Lower/early Middle Pleistocene small débitage production in Western Europe: new data from Isernia La Pineta t.3c (Upper Volturno Basin, Italy). *Quaternary International* 357, 264-281.

van Gijn, A., 2010. Flint in Focus. Lithic Biographies in the Neolithic and Bronze Age. Sidestone press, Leiden.

Haynes, G., Klimowicz, J. 2015. Recent elephant-carcass utilization as a basis for interpreting mammoth exploitation. *Quaternary International* 359, 360, 19-37.

Lepot, M., 1993. Approche techno-fonctionnelle de l'outillage lithique mousterien: essai de classification des parties actives en termes d'efficacite technique : application _a la couche M2e sagittale du Grand Abri de la Ferrassie (fouille Henri Delporte). M_emoire de Maîtrise. Universite de Paris X, Nanterre.

Malafouris, L. 2013. *How Things Shape the Mind: A Theory of Material Engagement,* Cambridge MA.: MIT Press.

Marra, F., Sottili, G., Gaeta, M., Giaccio, B., Jicha, B., Masotta, M., Palladino, D.M., Deocampo, D.M., 2014. Major explosive activity in the Monti Sabatini Volcanic District (central Italy) over the 800e390 ka interval: geochronologicalgeochemical overview and tephrostratigraphic implications. *Quaternary Science Reviews,* 94, 74-101.

Mosquera, M., Saladié, P., Ollé, A. Càceres, I., Huguet, R., Villalaìn, J. J., Carrancho, A., Bourlès, D., Braucher, R., Vallverdù, J. 2015. Barranc de la Boella (Catalonia, Spain): An Acheulean elephant butchering site from the European late Early Pleistocene. *Journal of Quaternary Science* 30/7, 651-666.

Santucci, E., Marano, F., Cerilli, E., Fiore, I., Lemorini, C., Palombo, M.R., Anzidei, A.P., Bulgarelli, G.M. 2016. Palaeoloxodon exploitation at the Middle Pleistocene site of La Polledrara di Cecanibbio (Rome, Italy). *Quaternary International* 406 B, 169-182.

Solodenko, N., Zupancich, A., Nunziante Cesaro, S., Marder, O., Lemorini, C., Barkai, R. 2015. Fat Residue and Use-Wear Found on Acheulian Biface and Scraper Associated with Butchered Elephant Remains at the Site of Revadim, Israel. PLOSone, 10(3): e0118572, 1-17.

Blade and bladelet reduction systems in the Italian Middle Paleolithic

The case of Grotta del Cavallo, (Nardò – Lecce)

Leonardo Carmignani[1, 2] *& Lucia Sarti*[3]

Abstract

Evidence of the presence of blade tool technology has been confirmed in northern Europe from at least the latter part of the Middle Pleistocene (MIS 7-6). During MIS 5 these productions cover a larger area, which includes northwestern Germany, central France, and occasionally the south of France. It is only during MIS 4-3 that the blade production strategy begins to appear in southern Europe, including the Italian peninsula. Based on the present state of research, these three phases appear as on-and-off events without clear evolutionary continuity. The FIIIe and FIIId levels of Grotta del Cavallo in Lecce (Italy) have yielded abundant lithic material predominated by two main reduction systems: the first originating from a Levallois concept by centripetal, unidirectional, and bidirectional methods, and the second stemming from a blade volumetric reduction system. The presence of separate reduction systems aimed at obtaining bladelets highlights the technological variability.

Keywords: Grotta del Cavallo, Blades, Bladelets, Middle Paleolithic.

---

1 IDQP PhD candidate. IPHES, Institut Català de Paleoecologia Humana i Evolució Social, Campus Sescelades (Edifici W3), 43007, Tarragona, Spain; leonardo.carmignani76@gmail.com. Department of History and Art History, Campus Catalunya, Av. Catalunya, 35, 43002, Tarragona, Spain.

2 External Member of UMR 7041 ArScAn, Anthropologie des Techniques, des Espaces et des Territoires au Pliocène et Pléistocène (AnTET), Maison de l'Archéologie et de l'Ethnologie 21 allée de l'Université 92023 Nanterre Cedex, France.

3 Dipartimento di Scienze storiche e dei Beni culturali; Università degli Studi di Siena, Via Roma, 56, Siena. E-mail: sarti@unisi.it.

in: Borgia, V. and E. Cristiani (eds.) 2018: *Palaeolithic Italy. Advanced studies on early human adaptations in the Apennine peninsula*, Sidestone Press Academics (Leiden), pp. 37-58.

1. Introduction

Within the European continent, the oldest evidence of blade production is found in northern Europe during MIS 8/7. These productions are obtained by primarily using two reduction systems: a volumetric concept, such as that noted at the sites of Saint-Valery-sur-Sommes (Heinzelin & Haesaerts 1983), Bapaume-les Osiers (Koehler 2008) and Therdonne (Loch *et al.* 2010) in France, and Rissori in Belgium (Adam 1991); and by a Levallois concept such as that observed at the site of Biache-Saint-Vaast in France (Böeda 1988). At the sites mentioned, blade production is rarely the predominant kind; on the contrary, it is systematically associated with other production systems, among which the most frequent is the Levallois concept aimed at mainly producing flakes.

In MIS 5, following their prolonged disappearance, coinciding with the MIS 6 glaciation peak, these productions returned, occupying a wider area that included north-west Germany with the sites of Tonchesberg (Conard 1990), Rheindhalen (Bosinsky 1986), and Wallertheim (Conard & Adler 1997), and central France, with the sites of Angé (Locht *et al.* 2008) and Vinneuf (Gouédo 1994). These productions are also found, albeit sporadically, in the south of France, at sites such as that of Cantaluette 4 (Blaser at al. 2012).

At the same time, in northern France and Belgium we see a return of blade production at many sites: Riencourt-lès-Bapaume (Ameloot & Hejden 1993), Saint-Germain-des-Vaux (Révillion & Cliquet 1994), Seclin (Révillion & Tuffreau 1994), Bettencourt-Saint-Ouen (Locht 2002), Blangy – Tronville (Depaepe *et al.* 1999), and Etouteville in France (Delagnes & Ropars 1996), and Rocourt in Belgium (Otte1994a).

At all these sites, we detect great variability in blade reduction systems, which prevents us from grouping them under a common denomination. The initial stages of the productions observed for the above industries rarely entailed the preparation of a crested blade. More common was the direct exploitation of the raw material's natural morphology. Unidirectional or bidirectional methods was applied to guide the removals. During the exploitation process, the knapping can follow a *tournant* or s*emi-tournant* rhythm. The raw materials used can be pebbles, roundish nodules, slabs, or flake-cores. In the same way, even if flint is the most common raw material noted, other lithotypes such as quartzarenites, limestones, and jaspers were also used.

The debate on the emergence of these productions, which at present is thought to have taken place during the Middle Pleistocene, is still ongoing. Some authors have suggested that, in some specific cases, blade production could have been an opportunistic method leading to the use optimisation of the raw materials, which may have motivated the production of elongated removals instead of flakes (Conard 1990). This, however, may not have been the case in areas rich in raw materials, where the presence of these productions has also been noted. Other authors have suggested a relationship between blade production and environmental crises (Otte 1994b). The duration of the blade phenomenon and its diffusion to areas that differ greatly from one another suggests that single explanations for the origin and spread of this phenomenon need to be treated with caution.

Unlike in northern Europe, the appearance of laminar production in the south of France and the Italian Peninsula shows some delay. Even if in the south of France blades appear for the first time in MIS 5, such as at Cantalouette IV (Blaser 2012), they become more visible during MIS 4-3, such as at the sites of Abris Du Maras (Moncel 1996), Baume Flandin (Moncel 2005), and Champ Grand (Slimak 1999).

While it is now certain that blades were produced during the Middle Paleolithic, the production of bladelets, obtained by means of an independent reduction system, was much less common and only occurred during the final phases of the Mousterian period. In Europe, some bladelet production has been noted at the sites of El Castillo and Cueva Morin in Spain (Maíllo-Fernández *et al.* 2004), at Champ Grand (Slimak & Lucas 2005) and Combe Grenal in France (Faivre 2012), at Fumane and at Grotta del Cavallo in Italy (Peresani 2011, Carmignani 2010), and at Balver Höhle in Germany (Pastoors & Tafelmaier 2010).

Recently, the presence of bladelet production noted at the site of Riparo del Molare in Italy would push back the date of its first presence to MIS 5 (Aureli and Ronchitelli in this volume).

The presence of laminar production in the Italian peninsula has not been clearly confirmed prior to MIS 4. The chronologies of the sites where the use of blade technology has been noted are in fact concentrated around the final phases of the Middle Paleolithic and, in particular, the first part of MIS 3.

In terms of its geographic distribution, blade production does not seem to be linked to a specific area or a specific environment. In Italy, blade production has been found in the south at the site of Santa Croce and at Grotta del Cavallo (Boscato *et al.* 2011, Carmignani 2010), in the center at Grotta Breuil (Grimaldi 1996), Grotta Reali (Peretto C. Ed. 2012, Arzarello *et al.* 2004), and in the north at Riparo Tagliente (Arzarello & Peretto 2005, 2004), Fumane (Peresani 2011), Grotta di San Francesco, and Madonna dell'Arma (Tavoso 1988, Cauche 2007). The only exception seems to be the site of Cave dell'Olio, which have been dated to MIS 9 (Fontana, Peretto 2009). For the site of San Francesco the chronology remains uncertain.

Generally speaking towards the end of the Mousterian in the Italian peninsula there seems to be greater differentiation in the production systems; among these, blade production is one of the most evident expressions. The origin of this differentiation can be traced back to the wider issue concerning the key role the blade plays in relation to its morpho-functional peculiarity and the preponderant role it has in the Upper Paleolithic.

2. The site

Grotta del Cavallo in the south of Italy is a coastal cave by the Ionian Sea located approximately 10 meters b.s.l. The site contains one of the most important Middle Paleolithic archaeological sequences of the Italian peninsula.

The cave was first studied by Arturo Palma di Cesnola in 1961, who carried out the first test pit which was followed, two years later, by the first excavation campaign (Palma di Cesnola 1963). In the years that followed other excavation campaigns were carried out, highlighting the long Middle and Upper Paleolithic sequences present at the site (Palma di Cesnola 1964, 1965, 1967).

At the end of the 1970s, new works had to take place at the site, as in the interim, illegal excavations had been carried out, thus disturbing the site. It was at this time that the University of Siena, in collaboration with the Soprintendenza ai Beni Archeologici della Puglia, closed the cave. Starting in 1986, L. Sarti re-opened the site and a larg-

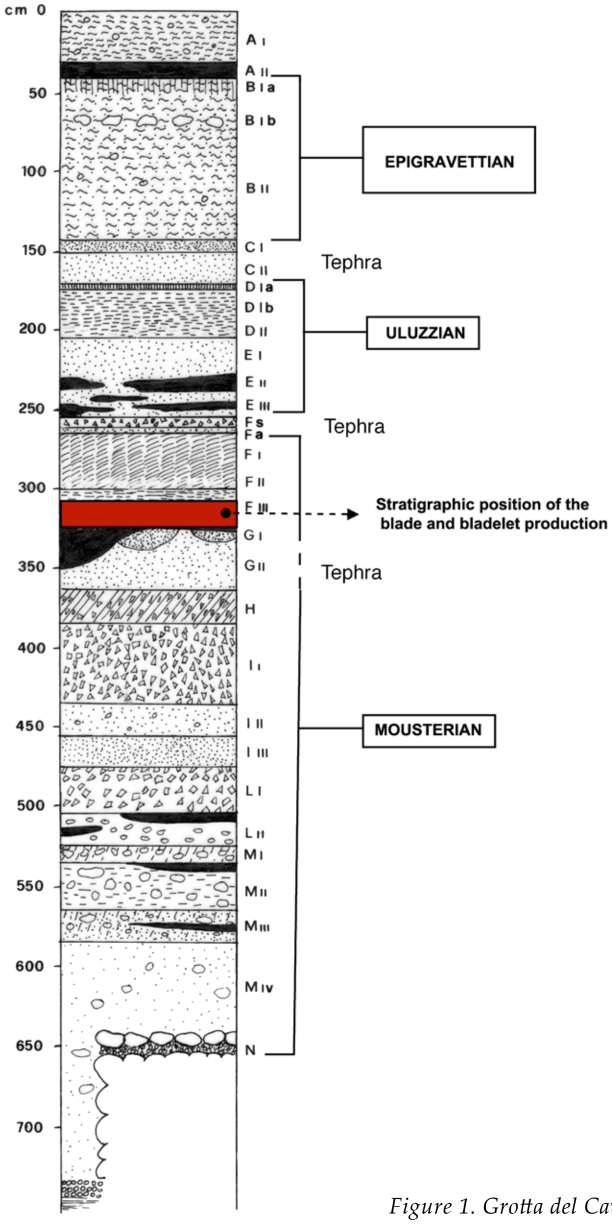


Figure 1. Grotta del Cavallo. Stratigraphic sequence.

er surface (12 sq. m) was excavated. Although the sequence proposed by Palma di Cesnola was confirmed by the new excavations, these also allowed for the stratigraphy to be described in greater detail and permitted the gathering of a greater amount of data (Sarti et al *in press*; Trenti et al *in press*).

Layer FIII, the subject of the present study, was, during its excavation, divided into five sub-levels (FIIIa, FIIIb, FIIIc, FIIId, FIIIe) based on the different concentrations of anthropic evidence.

The laminar production comes from sub-levels FIIIe and FIIId, which rest on a thick layer of tephra (Fig.1). At the top of level FIII, levels FII-FI mark the end of the Mousterian sequence (Sarti *et al.* 1998- 2000).

3. Methods

The lithic products from Grotta del Cavallo were analysed using a *châine opératoire* approach following Pelegrin (1991), and supported by the quantitative presentation of technological categories (Inizan *et al.* 1995). The identification of the Levallois concept follows the guidelines set out by E. Boëda (1994). In terms of the Discoid production, we used the definition put forward by E. Boëda (1993, 1991), also taking into consideration broader criteria (Peresani 1998, Slimak 2003). Given the absence of the refitting reconstruction of the reduction sequences, we used the mental refitting method proposed by Pelegrin (1995). The techniques were identified according to the experimental studies carried out by Pelegrin (1991, 2000). Volumetric and Levallois blade productions were distinguished by means of the volumetric structure analyses (Boëda 1988, 1990, 1991). Diacritical analysis was applied to cores and blanks in order to reconstruct the chronological order of the scars (Dauvois 1973).

Deeply patinated pieces on which the correct reading of the scars was not possible, and pieces with disorganized scars, the positioning of which did not allow us to reliably associate them with a specific reduction sequence, were classified as generic flakes.

4. Reduction systems of level F of Grotta del Cavallo

4.1. Main technological patterns

Sub-levels FIIIe and FIIId produced a large amount of lithic industries mostly concentrated in the FIIIe sub-level (11192 pieces), with smaller numbers found in sub-level FIIId (1151 pieces). A large number of pieces are undetermined fragments and generic flakes which cannot be linked to a specific reduction system. Leaving out the undetermined pieces, the diagnostic material amounts to 4908 pieces in FIIIe and 558 in FIIId (Table 1). The production in both the sub-levels is associated with three main reduction systems: blade and bladelet volumetric systems, and a Levallois system. The Levallois system is present with the centripetal, unidirectional, bidirectional, and convergent methods. Sub-layers FIIIc and FIIIb, although they had less pieces, seem to show the same kinds of production as FIIIe and FIIId. The Mousterian sequence ends with levels FII-FI, highlighting a clear techno-typological break compared to level FIII. In fact, FI-FII levels show the disappearance of blade production and the Levallois concept, which, in turn, are replaced by a Discoid system (Fig. 2). This break, which is visible in the reduction system, is also accompanied by a different management strategy of the raw material (Romagnoli *et al.* 2016).

The lithic industry contains a large amount of retouched tools, which will not be discussed in detail in the present study. In general, the retouched pieces in FIIIe and FIIId mainly comprise Mousterian points and scrapers, while in levels FII and FI, the presence of denticulated pieces is marked, followed by that of splintered pieces. The latter, it should be noted, are completely absent in the lower levels (Sarti *et al. in press*).

	Level FIIIe		Level FIIId	
	n.	%	n.	%
Generic flake >20 mm.	619	*5,5*	64	*5,6*
Generic flake <20 mm.	1325	*11,8*	119	*10,3*
Undetermined fragments >20 mm.	1429	*12,8*	94	*8,2*
Undetermined fragments <20 mm.	2911	*26,0*	316	*27,5*
Determined pieces	4908	*43,9*	558	*48,5*
Total	**11192**	***100***	**1151**	***100***

Table 1. Determined and undetermined pieces.

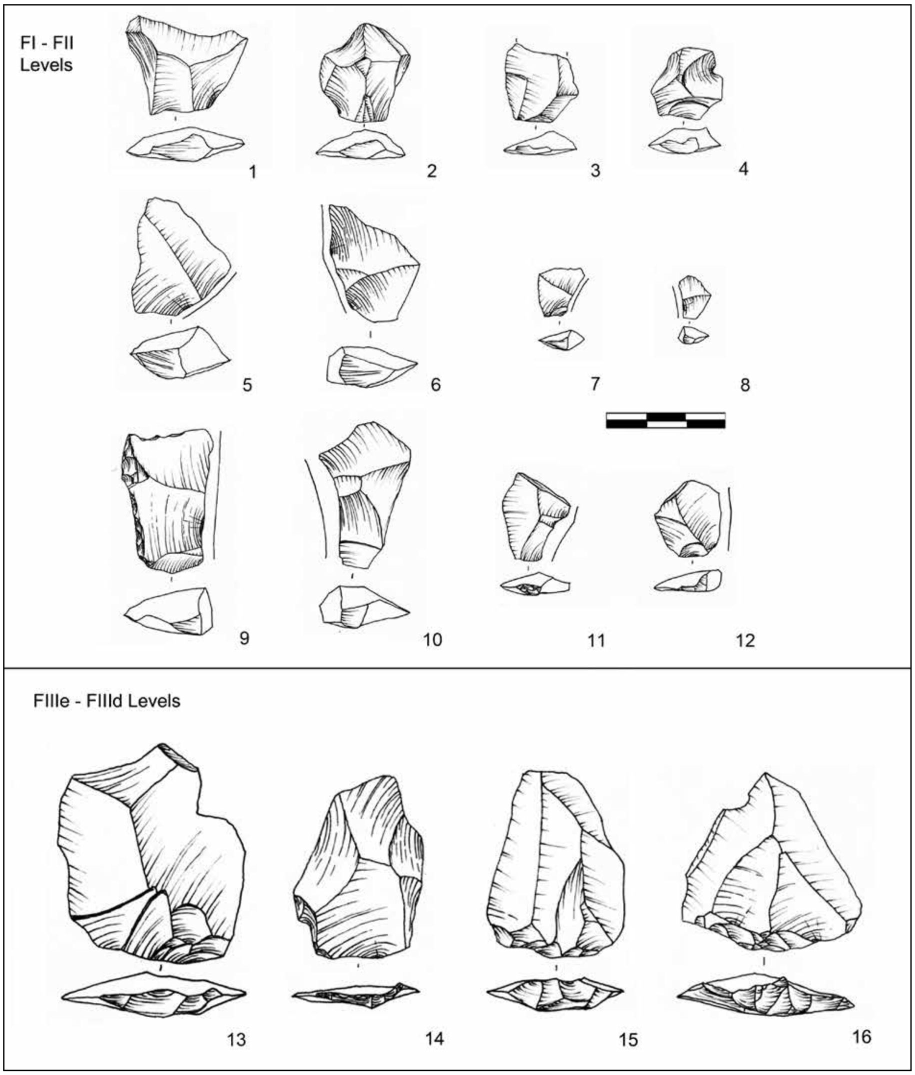


Figure 2. Flake production. (1-12) Discoid production from levels FI – FII, (13-16) Levallois production from the FIIIe-FIIId sub-levels (drawn by L. Carmignani).

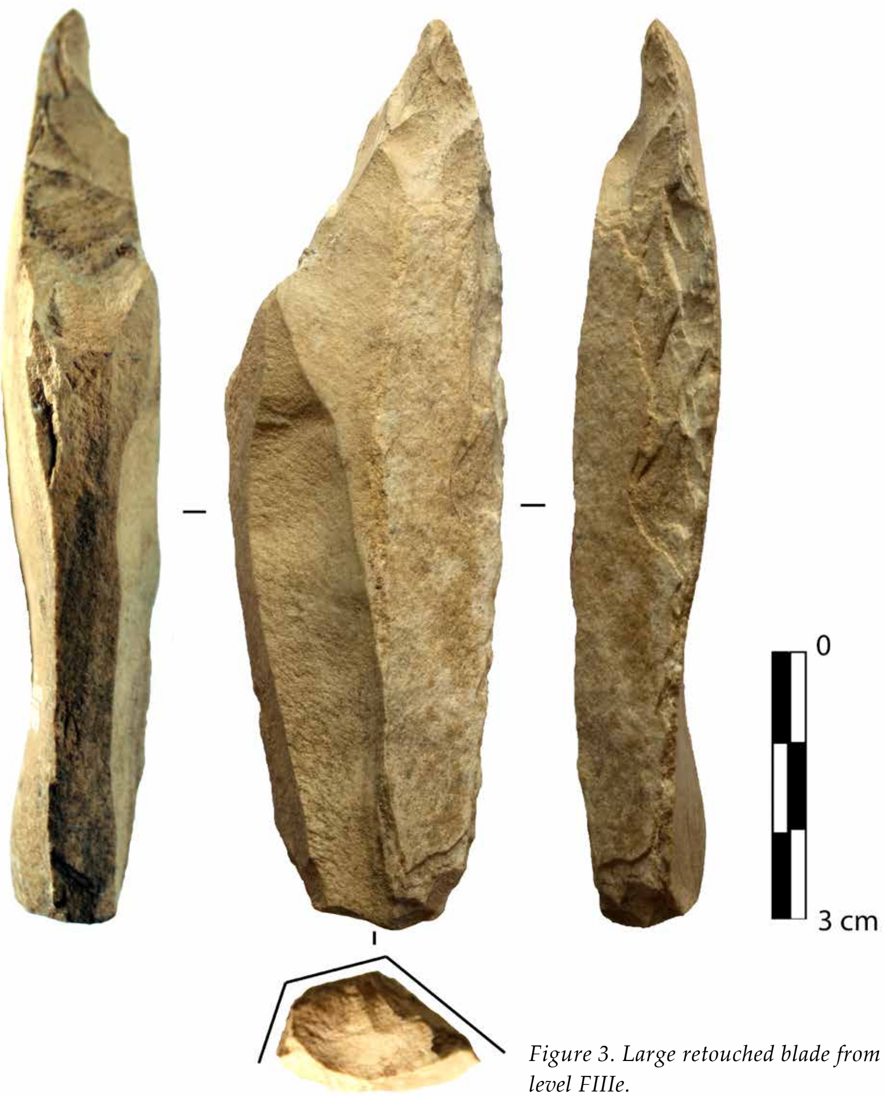


Figure 3. Large retouched blade from level FIIIe.

4.2. Blade and bladelet production systems in sub-levels FIIIe and FIIId

The blade production found in sub-levels FIIIe and FIIId comprises 783 pieces in the case of the former and 64 pieces in the latter (Table 2). Ten cores associated with this production were found in level FIIIe, whereas only two were recovered from FIIId. A large part of the blades are fragmented. Complete blades from level FIIIe amount to 254 pieces (32.4%), while 42 (65.5%) were found in FIIId (Table 3). Except for rare blades, which are over 7cm in length, the majority of the pieces indicate a small or medium-sized production (Fig. 3) (Carmignani 2010).

The raw materials used are limestone slabs collected locally a few hundred meters from the cave (Sarti *et al.* 2017). The reconstruction of the *chaîne opératoire* suggests that all stages of the production were carried out at the site (Table 4). The technique employed during the whole production process was direct percussion with the hard hammer.

	Level FIIIe		Level FIIId	
	n.	%	n.	%
Blade production	783	*16,0*	64	*11,5*
Flake production	4125	*84,0*	494	*88,5*
Total	**4908**	***100***	**558**	***100***

Table 2. Flake and blade production quantification.

	Level FIIIe		Level FIIId	
	n°	%	n°	%
Complete blades	254	*32,9*	42	*67,7*
Distal fragments	96	*12,4*	2	*3,2*
Mesial fragments	104	*13,5*	8	*12,9*
Proximal fragments	140	*18,1*	9	*14,5*
Apex broken	90	*11,6*	1	*1,6*
Base broken	86	*11,1*	0	*0,0*
Siret fracture	3	*0,4*	0	*0,0*
Total	**773**	***100***	**62**	***100***

Table 3. Integrity of blade production.

	Level FIIIe		Level FIIId	
	n.	%	n.	%
Blades with cortex >50 %	57	*9,7*	2	*3,8*
Blades with cortex<50 %	92	*15,6*	10	*18,9*
Blades "*en tranche*"	9	*1,5*	0	*0,0*
Unilateral crested blades	14	*2,4*	0	*0,0*
Bilateral crested blades	12	*2,0*	2	*3,8*
Debordant blades	85	*14,4*	8	*15,1*
Blades	277	*47,0*	28	*52,8*
Rejuvenation blades	33	*5,6*	1	*1,9*
Cores	10	*1,7*	2	*3,8*
Total	**589**	***100***	**53**	**100**

Table 4. Blade production techno-types and cores. Excludes undetermined broken blades.

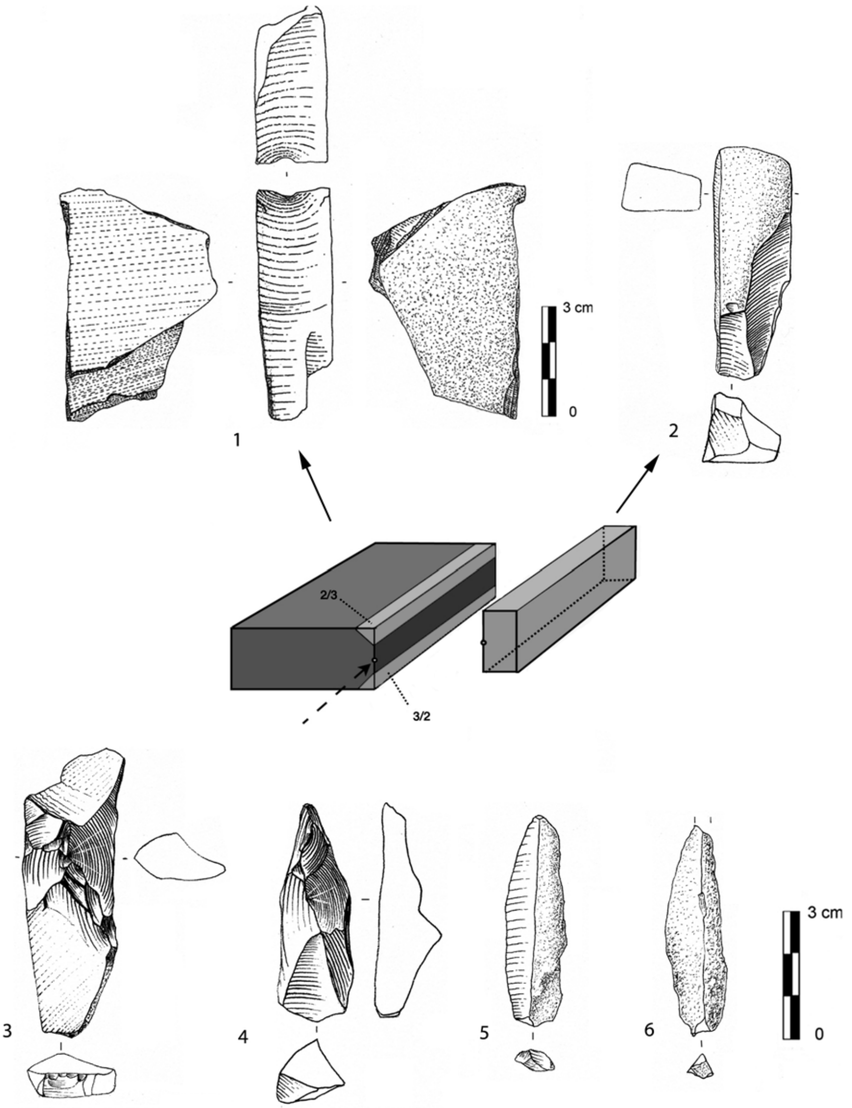


Figure 4. Initial production stage. (1) Core "sur tranche", (2) blank with quadrangular cross section, (3, 4) crested blades with two prepared versants, (5, 6) cortical blades (drawn by C. Tessaro; models by C. Carmignani).

The collected raw materials have a natural prismatic or sub-prismatic morphology that is suited to the direct knapping of blades without the need for a particular preparation of the core. When the configuration of the cores is present, it does not show any standardization, but instead, a wide range of technical solutions are used to correct the eventual imperfections of the block.

The presence of many cortical platforms indicates a direct extraction of removals using a natural striking platform. Preparation of the striking platform takes place at the point when the natural angle does not fulfil the technical requirements.

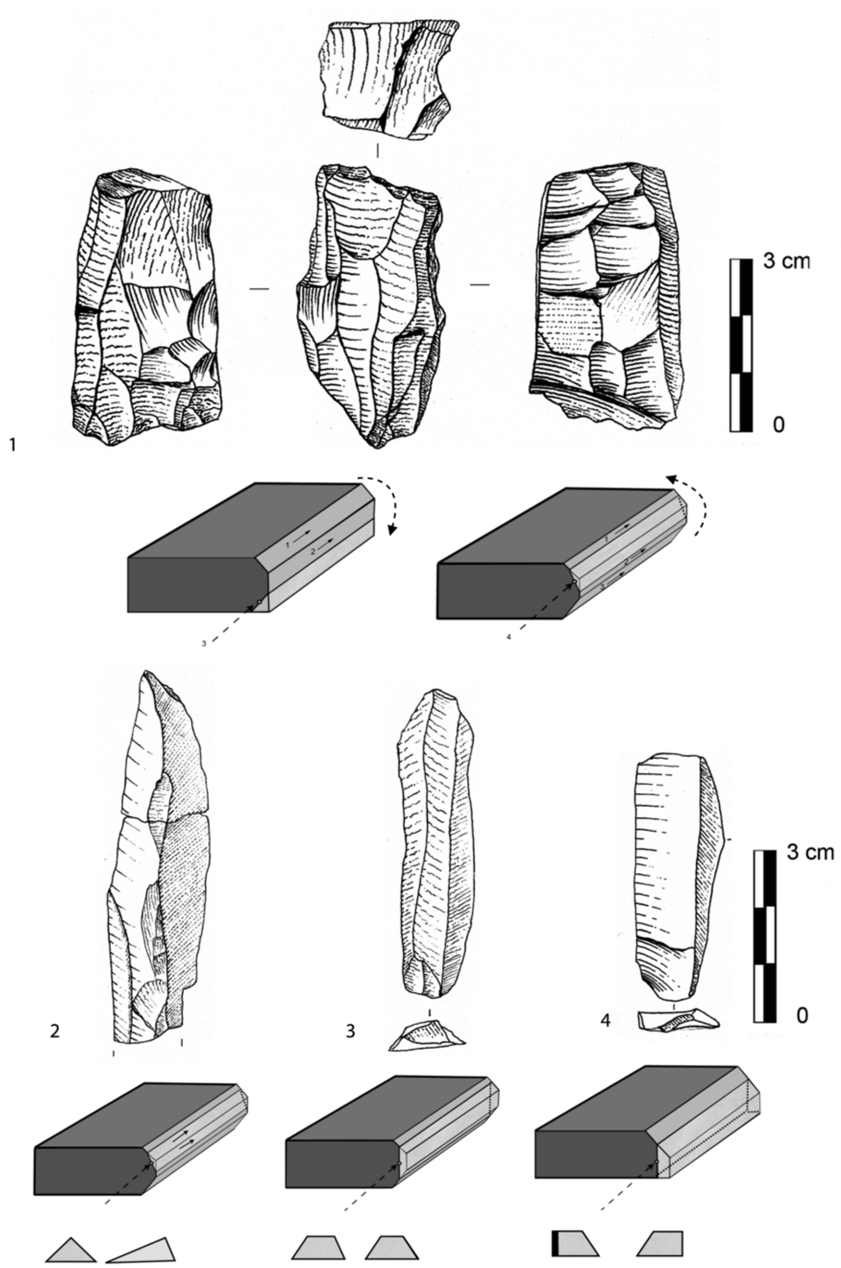


Figure 5. Main production stage. (1) core, (2, 3) blade with symmetrical cross section (4) blade with asymmetrical cross-section (drawn by C. Tessaro, models by C. Carmignani).

In the majority of cases, the initial knapping phase is based on the direct extraction of a cortical blade that exploits the dihedral angle naturally present on the slabs (Fig. 4 no. 6).

A second option, which is very rare, consists of the preparation of a crested blade, which is used as a guide in the first detachment (Fig. 4 nos 3, 4).

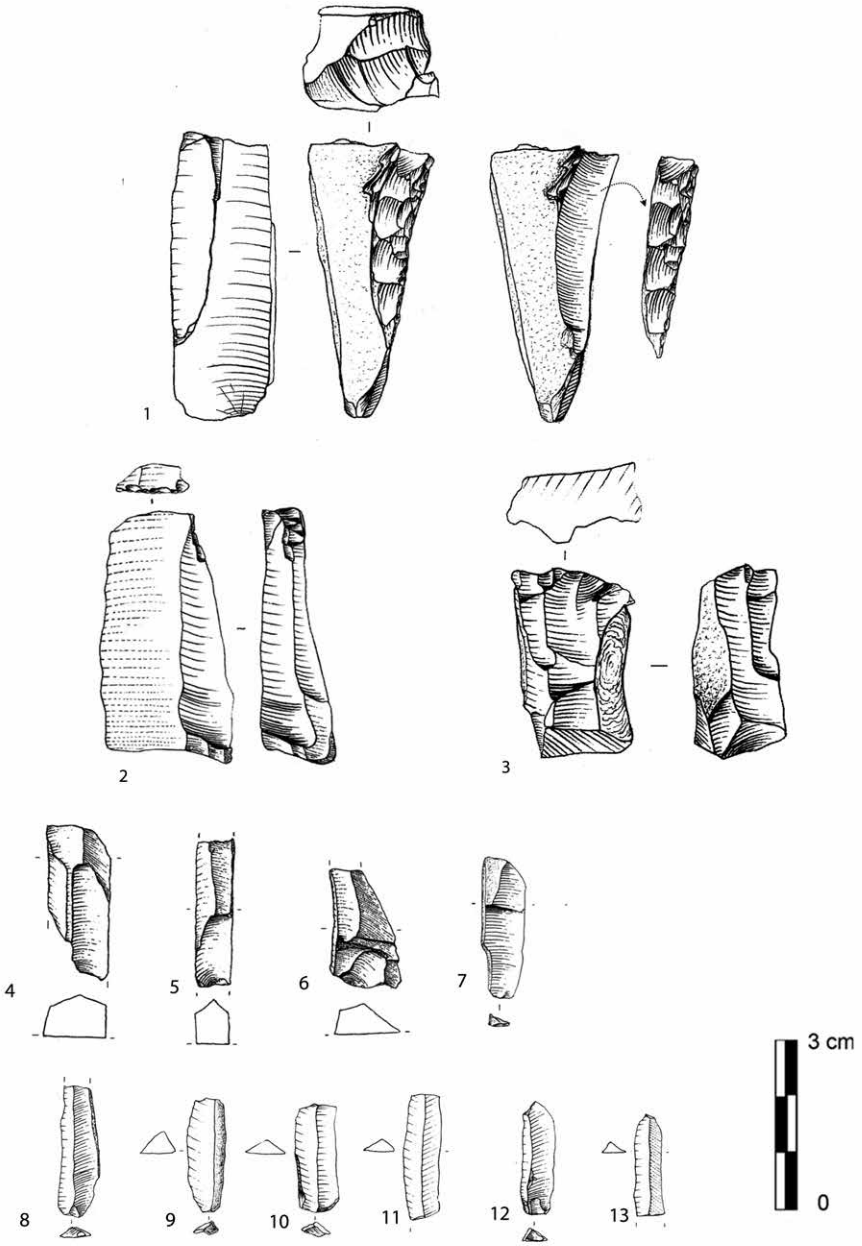


Figure 6. Bladelet production. (1) Core-flake with one refitted bladelet, (2, 3) Bladelet cores (4-7) rejuvenation bladelets, (8-13), bladelets (drawn by C. Tessaro).

Another method, used to initiate the slab exploitation process, includes removing a *tranche,* creating two new dihedrals (Fig. 4 nos 1, 2). This technical solution is also employed to correct eventual accidents occurring during the débitage stage, making it possible to continue the exploitation.

The maintenance of the lateral convexities of the flaking surface is carried out through the extraction of *débordant* blades (pre-determinate/pre-determinant), which guide the exploitation following a semi-tournant rhythm. In rare cases, the creation of a second striking platform opposite the main one is carried out in order to manage the distal convexity. The production system illustrated allows the obtention of two techno-types of blade: blades with symmetrical cross sections and blades with asymmetrical cross sections or debordant blades (Fig. 5 nos 2, 3, 4).

The blades have parallels edges and a straight profile. The direct production of blades with convergent edges is sporadic and can be considered as not predetermined. The convergence is instead often obtained through retouch, which in some cases, modifies the distal part of the blades (Fig. 3).

In sub-level FIIIe, of the 773 elements (intact and fragmented) that can be attributed to blade knapping, 160 have been modified through retouch with a transformation rate of 20.7%.

Besides laminar production, we also encounter the presence of an independent production kind aimed at producing bladelets through the exploitation of flake-cores. The exploitation of bladelet cores is carried out through a short series of unidirectional detachments. We can distinguish three types of volumes used as cores: simple flakes (Fig. 6 n. 2), flakes *with* a quadrangular cross section deriving from an exploitation "*sur tranche*" (Fig. 6 n. 1), and a small number of slab fragments (Fig. 6 n. 3). As is the case in blade production, the configuration of the bladelet cores on flakes is based on the use of some technological expedients that require minimal preparation of the cores.

The initial stage of bladelet production usually entails a first removal that exploits one of the edges of the flake. The preparation of a one-sided crested-bladelet has been noted, but this is a rare occurrence (Fig 6 n. 1).

The lack of a systematic management strategy of the core and, more specifically, a lack of control of the distal convexity often leads to the abandonment of the bladelet cores after a short series of detachments. Flaking accidents are solved through the extraction of a rejuvenation bladelet with the aim of reinitializing the knapping surface, allowing a second series of detachments (Fig. 6 nos 4, 5, 6, 7). Only one core shows a more elaborate management of the volume by rear-lateral removals aimed at the center of the flaking surface (Fig. 5 n. 1).

5. Blade and bladelets in the Italian peninsula during the Middle Paleolithic: A possible summary?

It is important to begin by noting that our attempt to carry out a precise comparison between the blade production of Grotta del Cavallo and other similar evidence present in the Italian peninsula turned out to be an arduous task for different reasons: lack of homogeneity among the data sets, methodological differences in the study of the lithic industries, and lack of a uniform terminology.

Generally, under the term 'blade' or 'bladelet', are all the elements that in an undifferentiated way mainly correspond to a morphometric feature (length > 2width). According to us, this feature is not sufficient to attribute with certainty a group of elongated products to a real systematic and pre-determinate production of blades. A small number of elongated pieces can be obtained in a non-systematic way, even through some reduction systems that are not specifically orientated towards production of blades.

In order to work with a corpus of data that is as homogeneous as possible and for a coherent comparison to be made, we only considered reliable those lithic industries that have been analysed through a technological approach.

The blade production of Grotta del Cavallo is placed within a well-known kind of variability known from the production systems of the Middle Paleolithic. In Italy, from a geographic point of view, volumetric blade productions are present with no particular trends from north to south: in the Apulia region, there are Grotta Santa Croce (Arrighi *et al.* 2009) and Riparo Oscurusciuto (Boscato *et al* 2011), Grotta Reali in Molise (Peretto 2012), Grotta Breuil in Lazio (Bietti & Grimaldi 1993, Grimaldi 1996, Lemorini 2000), and Riparo Tagliente (Arzarello & Peretto 2004, 2005) and Grotta Fumane (Peresani 2011) in the Veneto region.

The technique systematically used is that of direct percussion with a hard hammer. The main method used, with a few specific exceptions, is the unidirectional kind.

As observed in other parts of Europe, the raw material used does not seem to hinder nor favour the production of elongated frames. In fact, volumetric laminar productions are applied on pebbles of different morphologies and dimensions, as well as on slabs, flakes-cores, or nodules (Table 5). We can say the same thing concerning the lithology of the raw materials used, which include flints, jaspers, quartzarenites, or limestones. The initial knapping phases exploit, in almost the majority of cases, the natural morphology of the blocks. Initial configuration of the volume seems to be based on the selection of the correct morphology of the available raw materials. In a few rare cases, such as at Grotta del Cavallo or again at Grotta Reali, the configuration phase can provide the preparation of a crested blade. The recourse to this technical expedient, when present, is, however, quantitatively minor and never assumes a standardized and systematic role. At Grotta del Cavallo, the construction of a crested blade is mostly applied in the advanced production phase to correct flaking accidents.

In terms of quantities, laminar productions are always in the minority and are consistently associated to flake productions obtained by different production systems, among which the Levallois, Discoid, and the SSDA seem to be the most recurring (Table 5).

In the Italian peninsula, during MIS 4 and MIS 3, the spread of blade production by volumetric exploitation seems to coincide with a wider phenomenon, which can be summarised, in general terms, as a tendency towards searching for elongated products.

In fact, during this same time period, a tendency of the Levallois concept to produce blades by unidirectional or bidirectional methods seems to emerge (Table 5). As was noted for the volumetric laminar production, this aspect has also been noted for the entire Italian peninsula, showing no clear patterns: in the Liguria region, at the sites of Riparo Mochi and Barma Grande (Yamada 1997, 2004), in the Veneto region at Fumane (Peresani 2011), in the Campania region at Riparo del Poggio (Caramia, Gambassini 2006) and Castelcivita (Gambassini 1997), and in the Apulia region at Riparo dell'Oscurusciuto (Boscato *et al.* 2011).

This apparent parallelism, which emerges as an interesting research theme, especially in terms of techno-functional aims, has not yet been fully explored.

Regions	Site name	Levels	Blade reduction systems	Raw material	Blade configuration systems	Blade methods	Mains flakes reduction systems associated	Chronology	MIS	References
Liguria	Barma Grande	I3-1	Levallois (blade)	Pebbles	-	-	Discoid	-	3	Yamada 1997
	Riparo Mochi	I sub levels 51-43	Levallois (blade)	Pebbles	-	-	Centripetal Levallois	-	3	Yamada 2004
	San Francesco	-	Volumetric (blade)	-	Crested blade	Unipolar?	-	-	?	Tavoso 1988
	Madonna dell'Arma	levels. I – II	Levallois (blade) + Volumetric (blade)	Pebbles	-	-	Centripetal Levallois	str.II 73100±4400 BP	4	Cauche 2007
Veneto	Riparo Tagliente	I 37-34	Volumetric (blade) - Levallois (blade)	Pebbles Nodule	Selection of natural morphology	Unipolar	Centripetal Levallois "Opportunistic" sensu Arzarello 2004"	-	3	Arzarello, Peretto 2004,2005
	Fumane	A5-A6	Volumetric (blade/bladelet)	Blocks Nodule Slabs	Selection of natural morphology	Unipolar	Centripetal Levallois	A5 14C 40.150±350 A5 14C 41.650±650 A5 14C 40.460±360 A6 U/Th e ESR 38.000±4000	3	Peresani 2011
Tuscany	Grotta del Capriolo	INF SUP	Levallois (blade)	Pebbles Blocks	-	Unipolar	Centripetal Levallois	39.000 U/Th BP	3	Dini,Koheler 2009
	Buca della Iena	A1+B1 B2 B3	Levallois (blade)	Pebbles Blocks	-	-	Centripetal Levallois	41.000 U/Th BP	3	Dini,Koheler 2009
Campania	Riparo del Poggio	9-10	Levallois (blade)	Pebbles	-	-	Centripetal Levallois	str.9 43800±3500 BP	3	Caramia,Gambassini 2006
	Grotta di Castelcivita	XIII-VI	Levallois (blade)	Pebbles	-	Unipolar	Centripetal Levallois	Liv XI 39.100±1300 BP 42.700±900 BP	3	Gambassini 1997
Lazio	Grotta Breuil	3,4,5,6	Bipolar percussion (elongated flakes /blade)	Pebbles	Selection of natural morphology	Unipolar Bipolar	Centripetal reduction systems	US 3-6 36.600 ± 2700 ka BP US 4-7 33.000 ± 4000 BP US 5 35.000 BP (non cal.)	3	Grimaldi 1996 Lemorini 2000 Grimaldi,Spinapolice 2010

Regions	Site name	Levels	Blade reduction systems	Raw material	Blade configuration systems	Blade methods	Mains flakes reduction systems associated	Chronology	MIS	References
Molise	Grotta Reali	2abc 2β/2γ 5	Volumetric (blade/ bladelet) + Levallois (blade)	Slabs Pebbles Nodule	Selection of natural morphology + Crest (rare)	Unipolar	Discoid Levallois (Uni-Bip; Centr; Linear) "Opportunistic" sensu Arzarello 2004"	US 2γ 33.544 ± 540 BP (non cal.) US 5 35.650 ± 600 BP (non cal.) 36.620 ± 260 BP (non cal.) 40.040 ± 590 BP (non cal.)	3	Peretto 2012 Arzarello et. al. 2004
Apulia	Grotta di S.Croce	546 535	Volumetric (blade/ bladelet)	Pebbles, Nodule	Selection of natural morphology	Unipolar	Discoid	-	4	Arrighi et.al. 2009
	Oscurusciuto	1,2,3	Levallois (blade)	Pebbles	Selection of natural morphology	Unipolare	Centripetal Levallois	US 1 38.500±800	3	Boscato *et al.* 2011 Villa et. al. 2009
	Grotta del Cavallo	FIIId FIIIe	Volumetric (blade/ bladelet)	Slabs	Selection of natural morphology + Preparation of crested blades	Unipolar	Levallois (Uni-Bip; Centr; Conv.)	-	4 – 3	Carmignani 2010

Table 5. Sites with blade production during the MIS 4/3 in the Italian peninsula.

In the case of Grotta del Cavallo, the unidirectional and bidirectional Levallois methods, although present, are aimed at the production of quadrangular and sub-quadrangular flakes, which only sporadically reach an index of laminar lengthening. The systematic and predetermined production of blades has been attempted exclusively through the laminar volumetric system. At Grotta del Cavallo, we seem to glimpse a clear distinction, in terms of techno-functional aims, between volumetric blade production and unidirectional-bidirectional Levallois methods. In other cases, as for instance at Riparo Tagliente, both the production systems, Levallois and volumetric, generate blades, but also, in this case, with distinct techno-functional structures (Carmignani *in press*).

Regardless of the production systems employed during MIS 4-3, a common macro phenomenon seems to take shape, which finds its uniqueness in creating blades using different reduction systems; in the case of the Levallois through a re-adaptation of the pre-existing volumetric concept, while, in the case of the volumetric systems, through completely innovative production systems.

In this respect, it will be important in our opinion to compare, in greater detail, the ephemeral bladelet production that appears during the last phase of the Middle Paleolithic with that of the Upper Paleolithic. A recent work that has highlighted a connection between the Châtelperronian and Pro-Aurignacian bladelets at the site of Quinçai (France) encourages future research to point in that direction (Roussel *et al.* 2016).

The last issue that we would like to discuss concerns the geographic setting of these productions. The Middle Paleolithic of the Italian peninsula is systematically found in cave or shelter sites. This differs to the blade production of northern Europe, which is found in open-air sites (Table 5).

It remains to be verified whether this difference is the result of research bias or if instead these locality differences are actually linked to different population dynamics between the central-north and south areas of Europe.

The problems connected to the spread of the laminar phenomenon in the final Mousterian phases in the Italian peninsula need to be investigated, both in terms of the innovative element it represents and its relationship with the pre-existing techno-cultural substratum. Given the current state of research, and even if some general features are emerging, this overview does not allow us to frame the laminar phenomenon within a univocal model. The chronological delay that we see between the laminar production of the Italian peninsula, apparently concentrated in MIS 3, and that of the south of France, already present starting from MIS 5 (*e.g.* Blaser *et al.* 2012), leaves us with different possible scenarios. A comparative study of the laminar production of southern Europe will clarify whether we are facing a phenomenon of technical convergence with different invention and spread centres or, if instead, this phenomenon can be tracked to a single innovative centre from which it spread to other peripheral areas.

References

Adam, A. 1991. Le gisement paléolithique moyen du Rissori à Masnuy-Saint-Jean (Hainaut, Belgique): premiers résultats. In: Tuffreau A. (ed.), Paléolithique et Mésolithique du Nord de la France. Nouvelles recherches: II, CERP, 3, 41-52.

Ameloot-Van der Heijden, N. 1993. L'industrie laminaire du niveau CA du gisement Paléolithique moyen de Riencourt-les-Bapaume. *B.S.P.F.*, 90/ 5, 324-327.

Arrighi, S. Freguglia, M. Ranaldo, F. and Ronchitelli, A. 2009. Production and use in the lithic industry of the Mousterian in Santa Croce (Bisceglie, Italy), *Human Evolution,* 24/2, 91-106.

Arzarello, M. Berardinelli, L. Minelli, A. Pavia, M. Rufo, E. Sala, B. Thun Hohenstein, U. and Peretto, C. 2004. Il sito paleolitico medio di Grotta Reali (Rocchetta al Volturno, Molise, Italia). *Rivista di Scienze Preistoriche LIV*, 249-269.

Arzarello, M. and Peretto, C. 2005. Nouvelles données sur les caractéristiques et l'evolution techno-économique de l'industrie moustérienne de Riparo Tagliente (Verona, Italie), in Les premières peuplements en Europe, a cura di N. Molines, M.H. Moncel, J.L. Monnier, Colloque international, (Rennes, 22-25 septembre 2003), *BAR, International Series* 1364, 281-289.

Arzarello, M. and Peretto, C. 2004. "L'industrie lithique moustérienne ("Tagli 40-42") du Riparo Tagliente (Verone, Italie)". Acts of the XIVth UISPP Congress, University of Liège, Belgium, 2-8 September 2001 10 Section 5: Le Paléolithique Moyen/ The Middle Palaeolithic General sessions and posters edited by Le Secrétariat du Congrès. *BAR International Series* 1239, 169-175.Bertola, S. Peresani, M. Peretto, C. Thun-Hohenstein, U. 1999. Le site paléolithique moyen de la Grotta della Ghiacciaia (Préalpes de Vénétie, Italie du Nord). *L'Anthropologie* 103/3, 377 – 390.

Bietti, A. and Grimaldi, S. 1993. Mousterian assemblages in central Italy: cultural facies or behavioral adaptation? *Quaternaria Nova III,* 21-38.

Blaser, F. Bourguignon, L. Sellami, F. and Rios Garaizar, J. 2012. Une série lithique à composante Laminaire dans le Paléolithique moyen du Sud-Ouest de la France: le site de Cantalouette 4 (Creysse, Dordogne, France). *Bulletin de La Société Préhistorique Française*, *109*/1, 5-33.

Boëda, E. 2013. Techno-logique & Technologie. Une paléo-histoire des objects lithiques tranchants. *Archeo-editions, Coll. Préhistoire au Present.*

Boëda, E.1994. le concept Levallois: variabilité des méthodes. Monographies du CRA n°9, paris, Edition CNRS.

Boëda E. 1993. Le débitage discoïde et le débitage Levallois récurrent centripète. *Bulletin de la Société Préhistorique Française* 90, 392-404.

Boëda E. 1991. Approche de la variabilité des systèmes de production lithique des industries du Paléolithique inférieur et moyen : chronique d'une variabilité attendue. *Technique et culture* 17-18, 37-79.

Boëda E. 1990. De la surface au volume : analyses des conceptions des débitages Levallois et laminaire. In : C. Farizy (Ed.), Paléolithique moyen récent et Plaéolithique supérieur ancien en Europe, Actes du colloques international de Nemours 1988 , *Mémoire du Musée de Préhistoire d'Ile de France,* 3, 63-68.

Boëda E. 1988. Le concept laminaire : rupture et filiation avec le concept Levallois. In : M. Otte (Ed.), L'homme de Neanderthal vol.8, La mutation, acte du colloque de Liège, 47-49.

Boëda, E. 1988. Analyse technologique du débitage du niveau II A. In: le gisement paléolithique moyen de Biache-Saint-Vaast (Pas-de-Calais), vol. 1 (A. Tuffreau et J. Sommé, dir.). *Mém. S.P.F.,t. 21,*185-214.

Boscato, P. Gambassini, P. Ranaldo, F. Ronchitelli, A. 2011. Management of palaeoenvironmental resources and raw materials exploitation at the Middle Palaeolithic site of Oscurusciuto (Ginosa, TA, Southern Italy): Units 1 and 4, in *Neanderthal lifeways, subsistence and technology*, (eds.) Conard, N.J. Richter, J. 150 years of Neanderthal discoveries, Bonn, 21 – 26 July 2006.

Bosinski, G. 1986. Chronostratigraphie du Paléolithique inférieur et moyen en Rhénanie. In *Chronostratigraphie et faciès culturels du Paléolithique inférieur et moyen dans l'Europe du Nord Oues*t, ed. by a. Tuffreau et J. Sommé,. Paris, supplément du bulletin de l'AFEQ, 15-34.

Caramia, F. and Gambassini, P. 2006. Il Musteriano evoluto del Riparo del Poggio (strati 9 e 10) a Marina di Camerata – Salerno. *Rassegna di archeologia preistorica e protostorica,* 22A*,* 67-95.

Carmignani, L. (*in press*). Between the flake and the blade. Associated systems production at Riparo Tagliente (Veneto, Northern Italy): coexistence and interaction of two concepts of tools. *Journal of Lithic Studies*.

Carmignani, L. 2010. L'industria litica del livello FIIIe di Grotta del Cavallo (Nardò, Lecce). Messa in evidenza di una produzione lamino – lamellare in un contesto del Musteriano finale, *Origini, XXXII,* 7-21.

Cauche, D. 2007. « Les cultures moustériennes en Ligurie italienne : analyse du matériel lithique de trois sites en grotte », *L'Anthropologie,* 111, 254-289.

Chabai, V.P. Monigal, K. and Marks, A.E. 2004. The Middle Paleolithic and Early Upper Paleolithic of Eastern Crimea. The Paleolithic of Crimea, III. ERAUL 104.

Chabai, V.P. and Sitlivyj, V. 1994. The blade component in the Middle Palaeolithic of Ukraine : origin and evolution, in: *Les industries laminaires au Paléolithique moyen, Révillion S., Tuffreau A. (Dir.), CNRS Éditions, (Dossier de Documentation archéologique ,* 18, 161-177.

Conard, N.J. 1990. Laminar lithic assemblages from the last interglacial complex in Northwestern Europe, *Journal of anthropological Research*, 46, 243-262.

Conard, N. J. and Adler, D. S. 1997. Lithic Reduction and Hominid Behavior in the Middle Palaeolithic of the Rhineland. *Journal of Anthropological Research*, 53/2, 147-175.

Cook, J. 1986. A blade industry from Stoneham's Pit, Crayford (Kent). In: Collcutt, S.N. Ed. 1986. *The Palaeolithic of Britain and its Nearest Neighbours: Recent Trend*s. Department of Prehistory & Archaeology. – Sheffield, University of Sheffield, 16-19.

Delagnes, A. and Ropars, A. 1996. Paléolithique moyen en Pays de caux (haute-normandie) : le Pucheuil, etoutteville : deux gisements de plein air en milieu loessique. Documents d'archéologie Française, Paris: MSH.

Dauvois M. 1976. Précis de dessin dynamique et structural des industries lithiques préhistoriques. Périgeux: Fanlac.

Depaepe, P. Antoine, P. Guerlin, O. Swinnen, C. 1999. Le gisement paléolithique moyen de Blangy-tronville (Somme). *Revue Archéologique de Picardie*, 3-21.

Dini, M. and Khoeler, H. 2009. The contribution of new methodological approaches to explaining the Final Middle Paleolithic of the Apuane Alps (Tuscany, Italy). *Human evolution,* 24/1, 13-25.

Dini, M. Mezzasalma, S. and Tozzi, C. 2007. Il Paleolitico medio di Grotta La Fabbrica (Parco dell'Uccellina – Grosseto) In: *Atti del Museo di Storia Naturale della Maremma, supplemento al n. 22,* 31-52.

Faivre 2012. A material anecdote but technical reality. Bladelet and small blade production during the recent Middle Paleolithic Combe-Grenal rock shelter. Lithic Technology 37.

Fernandez, J.M.M. Cabrera-Valdès Bernaldo de Quiros, V. 2004. Le débitage lamellaire dans le Moustérien final de Cantabrie (Espagne): le cas de El Castillo et Cueva Morin. *L'Anthropologie, Préhistoire Européenne 108,* 367-395.

Fontana, F. and Peretto, C. 2009. First recognition of predetermined core reduction sequences in the Southern Po Plain area before MIS 8 at the site of Cave dall'Olio (Bologna, Italy): an "ancient series" revisited. *Human Evolution* Vol. 24 – n.1, 43-56.

Forestier, H. 1993. Le clactonien: mise en application d'une nouvelle méthode de débitage s'inscrivant dans la variabilité des système de production lithique au Paléolithique ancien, Paléo 5, p. 53-82.

Gambassini, P. 1997. Il Paleolitico di Castelcivita. Cultura e ambiente. Napoli: Electa.

Gouedo, J. M. 1994. Remontage d'un nucleus à lames du gisement micoquien de Vinneuf (Yonne). *In*: Actes de la table ronde "*Les Industries laminaires au Paléolithique moyen*", Dossier de Documentation Archéologique n° 18, Paris, CNRS Éditions, 77-102.

Grimaldi, S. 1996. Mousterian reduction sequences in central italy. Q*uaternaria Nova,* 6, 279-310.

Heinzelin, J. Haesaerts, P. 1983. Un cas de débitage au Paléolithique ancien: Croix de l'Abbé à Saint-Valéry-sur-Somme. *Gallia Préhistoire, 26*,189-201.

Inizan, M.L., Reduron, M., Roche, H., & Tixier, J. 1995, Technologie de la pierre taillée. Préhistoire de la pierre taillée, 4, CREP, Meudon.

Koehler, H. 2008. L'apport du gisement des Osiers à Bapaume (Pas-de-Calais) au débat sur l'émergence du Paléolithique moyen dans le Nord de la France. *Bulletin de la Société préhistorique française,* 105/ 4, 709-735.

Lemorini, C. 2000. Reconnaître des tactiques d'exploitation du milieu au Paléolithique moyen. La contribution de l'analyse fonctionnelle ; étude fonctionnelle des industries lithiques de la Grotta Breuil (Latium, Italie) et de la Combette (Bonnieux, Vaucluse, France), *BAR international Séries 858.*

Loch, J. 2002. (Eds.) Bettencourt-Saint-Ouen (Somme) : cinq occupations paléolithiques au début de la dernière glaciation. *Documents d'archéologie Française n°90.* Paris: Maison des Sciences de l'homme.

Locht, J.L. Antoine, P. Hérisson, D. Gadebois, G. Debenham, N. 2010. Une occupation de la phase ancienne du Paléolithique moyen à Therdonne (Oise) *Chronostratigraphie, production de pointes Levallois et réduction des nucléus Gallia Préhistoire*, 52, 1-32.

Locht, J.-L. Caspar, J. P. (†)., Djemmali N., Coutard S., Kiefer D., Koelher H., Soressi M., Debenham N., Teheux E., 2008. Le gisement paléolithique moyen d'Angé (Loir-Et-Cher). Industries lithiques et chronostratigraphie. *DFS*, INRAP Centre-ile-de-France, SRA Centre.

Moncel, M.-H. 1996. L'industrie lithique du Paléolithique moyen de l'Abri du Maras (Ardèche) – Fouilles R. Gilles et J. Combier – La question des Moustériens tardifs et du débitage laminaire au Paléolithique moyen. *Gallia Préhistoire* 38, 1- 41.

Moncel, M.-H. 2005. Baume Flandin et Abri du Maras: deux exemples de débitage laminaire du début du Pléistocène supérieur dans la vallée du Rhône (sud-est, France). *L'Anthropologie,* 109, 451 – 480.

Otte, M. 1994a. Rocourt (Liège, Belgique) : industrie laminaire ancienne. In: Revillion, S., Tuffreau, A. (Eds.), Les industries laminaires au Paléolithique Moyen. *Dossier de Documentation Archéologique* 18, 180-186.

Otte, M. 1994b. Origine de l'homme moderne: approche comportementale. *Comptes Rendus de l'Académie des Sciences de Paris,* 318/2, 267-273.

Palma Di Cesnola, A. 1963. Prima campagna di scavi nella Grotta del Cavallo presso Santa Caterina (Lecce), *Rivista di Scienze Preistoriche, XVIII*, 41-73.

Palma Di Cesnola, A. 1964. Seconda campagna di scavi nella grotta del Cavallo presso Santa Caterina (Lecce), *Rivista di Scienze Preistoriche, XIX,* 23-39

Palma Di Cesnola, A. 1965. Notizie preliminari sulla terza campagna di scavi nella Grotta del Cavallo. (Lecce), *Rivista di Scienze Preistoriche, XX*, 291-301.

Palma Di Cesnola, A. 1967. Gli scavi nella Grotta del Cavallo (Lecce) durante il 1966, *Rivista di Scienze Preistoriche, XXI, 1*, 289-301.

Pastoors, A. and Tafelmaier, Y. 2010. Bladelet production, core reduction strategies, and efficiency of core configuration at the Middle Palaeolithic site Balver Höhle (North Rhine Westphalia, Germany), *Quartär 57,* 25-41.

Pelegrin, J. 2000, Les techniques de débitage laminaire au Tardiglaciaire : critères de diagnose et quelques réflexions. In: L'Europe centrale et septentrionale au Tardiglaciaire (Valentin, B., Bodu, P., & Christensen, M., Eds.), Mémoires du Musée de Préhistoire d'Île-de-France 7, Ed. APRAIF, Nemours, 73-86.

Pelegrin, J. 1995, Technologie lithique : Le Châtelperronien de Roc-de-Combe (Lot) et de la Côte (Dordogne). Cahiers du Quaternaire 20, Paris: CNRS éditions.

Pelegrin, J. 1991. Sur une recherche technique expérimentale des techniques de débitage laminaire. In: *Archéologie expérimentale. Tome 2: La Terre: l'os et la pierre, la maison et les champs*, Archéologie aujourd'hui, editions Paris: Errance,18-128.

Peresani, M. 2011. Fifty thousand years of flint knapping and tool shaping across the Mousterian and Uluzzian sequence of Fumane cave. *Quaternary International* 247. 125-150.

Peresani, M. 1998 – La variabilité du débitage discoïde dans la grotte de Fumane (Italie du Nord), Paléo, 10, 123-146.

Peresani, M. 1996. The Levallois reduction strategy at the Cave of San Bernardino (Northern Italy). In Bietti A., Grimaldi S. (eds.) Reduction Processes (châines opératoires) in the European Mousterian. Proceedings International Round Table, *Quaternaria Nova, VI,* 205-236.

Peresani, M. 1995. Sistemi tecnici di produzione litica nel Musteriano d'Italia. Studio tecnologico degli insiemi litici delle unità VI e II della Grotta di San Bernardino (Colli Berici, Veneto). *Rivista di Scienze Preistoriche, XLVII*, 79 -167.

Peresani, M. Porraz, G. 2004. Ré-interprétation et mise en valeur des niveaux moustériens de la Grotte du Broion (Monti Berici,Vénétie). Etude techno économique des industries lithiques. *Rivista di Scienze Preistoriche, LIV,*181- 247.

Peretto, C. (Ed.) 2012. L'insediamento musteriano di Grotta Reali, Rocchetta a Volturno, Molise, Italia. *Annali dell'Università degli Studi di Ferrara, Sez. Museologia Scientifica e Naturalistica, Volume* 8/2.

Romagnoli, F. Trenti, F. Nannini, L. Carmignani, L. Ricci, G. Lo Vetro, D. Martini, F. and Sarti L. 2016. Raw-Material Procurement and Productive Sequences in the Palaeolithic of Southern Italy: the Tyrrhenian and Ionian Areas. In Tomasso, A., Binder, D., Martino, G., Porraz, G., Simon, P., Naudinot, N. (eds) 2016, *Ressources lithiques, productions et transferts entre Alpes et Méditerranée;* Actes de la journée de la Société préhistorique française de Nice, 28-29 mars 2013, pp. 177-197 www.prehistoire.org ISSN : 2263-3847 – ISBN : 2-913745-2-913745-64-4

Roussel, M, Soressi, M, Hublin J-J. 2016. The Châtelperronian conundrum: Blade and bladelet lithic technologies from Quinçay, France. *Journal of Human Evolution,* 95, 13-32.

Révillion, S. 1995. Technologie du débitage laminaire au Paléolithique moyen en Europe septentrionale : état de la question, *Bulletin de la Société préhistorique française,* 92, 425-442.

Revillion, S. and Cliquet, D. 1994. Technologie du débitage laminaire du gisement paléolithique moyen de Saint- Germain-des-Vaux / Port Racine (secteur I) dans le contexte des industries du Paléolithique moyen du Massif Armoricain. In: Revillion, S., Tuffreau, A. (eds.), Les industries laminaires au Paléolithique Moyen. *Dossier de Documentation Archéologique 18,* 45-62.

Revillion, S. and Tuffreau, A. 1994. Valeur et signification du débitage laminaire du gisement paléolithique moyen de Seclin (Nord). In: Revillion, S., Tuffreau, A. (Eds.), Les industries laminaires au Paléolithique Moyen. *Dossier de Documentation Archéologique 18,* 19-43.

Sarti L., Romagnoli F., Carmignani L., Martini F. 2017. Grotta del Cavallo (scavi Sarti): tradizione e innovazione nella sequenza musteriana sulla base dell'indicatore litico, in Radina F. (a cura di), *Preistoria e Protostoria della Puglia*, Studi di preistoria e protostoria – 4, Firenze, 131-138.

Sarti, L., Boscato, P., and Lo Monaco, M. 1998 – 2000. Il Musteriano finale di Grotta del Cavallo nel Salento, studio preliminare, *Origini,* XXII*, 45-109.*

Slimak, L. 1999. Mise en évidence d'une composante laminaire et lamellaire dans un complexe moustérien du sud le France, *Paléo,* 11*,* 89-109.

Slimak, L. 2003. Les débitages Discoïdes moustériens : évaluation d'un concept technologique, in: Discoid lithic technology : advances and implications, Peresani M. (Dir.), Oxford, British archaeological Reports, p. 33-65 (BAR International Series ; 1120).

Slimak, L. and Lucas, G. 2005. Le débitage lamellaire, une invention aurignacienne? In: F. Le Brun-Ricalens (Ed.) Productions lamellaires attribuées à l'Aurignacien. Chaînes opératoires et perspectives technoculturelles. Imprimerie Fr. Faber, Luxemburg, 75-102.

Tavoso, A. 1988. L'outillage du gisement de San Francesco à San Remo (Ligurie, Italie) : nouvel examen. In: L'homme de Néanderthal, vol. 8. La mutation, Liège, 193-210.

Trenti, F. Nannini, L. Carmignani, L. Romagnoli, F. Martini, F. Sarti, L. (in press) Grotta del Cavallo: ipotesi di mobilità dei gruppi umani musteriani sulla base dello sfruttamento delle risorse nel territorio. *XLVII Riunione Scientifica Preistoria e Protostoria della Puglia.*

Villa, P. Boscato, P. Ranaldo, F. Ronchitelli, A. 2009. Stone tools for the hunt: points with impact scars from a Middle Paleolithic site in southern Italy, *Journal of Archaeological Science 36*, 850-859.

Yamada, M. 2004. Derniere production lithique mousterienne de l'Abri Mochi aux Balzi Rossi (Ligurie, Italie). *Quaternaria nova* VII/7. 19-35.

Yamada, M. 1997. L'industrie lithique moustérienne de la Barma Grande aux Balzi Rossi (Ligurie, Italie). *L'Anthropologie,* 101/3. 512-21.

The Lower Tyrrhenian Versant: was it a techno-cultural area during the Middle Palaeolithic?

Evolution of the lithic industries of the Riparo del Molare sequence in the frame of Neanderthal peopling dynamics in Italy

Daniele Aureli[1,2] *& Annamaria Ronchitelli*[1]

Abstract

The study of the Middle Palaeolithic in Italy was completely transformed in recent years by new discoveries and, most of all, by the employment of new methodological approaches. In particular, a more systematic way of interpretating technological, techno-functional and techno-economic aspects of the lithic industries has contributed to an on-going renewal of our knowledge of Neanderthal behaviour.

Within this framework, Southern Italy and, particularly, the Lower Tyrrhenian Versant region offers a very important occasion to feed the scientific debate. Since the 1950s, the long lasting research in this area, especially in Cilento, has produced a rich archaeological record from a wealth of multistratified sites covering the whole chronological range during which Neanderthal cultures developed. Among these sites, Riparo del Molare is extremely important for understanding the emergence of the Levallois phenomenon in Cilento and in Southern Italy in general. This probably happened not earlier than the end of Isotopic Stage 6/beginning of Isotopic Stage 5.

1 Università degli Studi di Siena – Dip. di Scienze Fisiche, della Terra e dell'Ambiente U.R. Preistoria e Antropologia, Via Laterina 8 – 53100 Siena (Italy).

2 Université Paris Ouest Nanterre La Défense, UMR 7041 – ArScAn – équipe AnTET (Anthropologie des techniques des espaces et des territoires aux Pliocène et Pléistocène), Maison René Ginouvès (MAE), 21 allée de l'université, 92023 Nanterre Cedex (France).

in: Borgia, V. and E. Cristiani (eds.) 2018: *Palaeolithic Italy. Advanced studies on early human adaptations in the Apennine peninsula*, Sidestone Press Academics (Leiden), pp. 59-94.

The aim of this work is to provide a general outline of the research project "The Lower Tyrrhenian Versant: a techno-cultural area during the development of the Middle Palaeolithic in Italy?" by presenting a general syntheses on the Middle Palaeolithic in Italy, the evolution of the lithic industries of the region, as well as a preliminary presentation of the Riparo del Molare site and an examination of future research perspectives.

Keywords: Middle Palaeolithic, Levallois, Riparo del Molare.

1. Introduction

According to the interpretative model set forward by Palma di Cesnola, the Italian Middle Palaeolithic, and especially the Mousterian, "would have made a mosaic-like landscape. From the data available up to now, each Mousterian complex seems to have followed a specific evolutionary pattern in the different areas of the Peninsula. This evolution can be traced back phylogenetically to a local pre-Mousterian substratum (clear at least for the most ancient phases) and each complex seems to have preserved in a stable way its territory without sharing it with others. In this view, the Italian Mousterian formation process appears to be multi-linear," (translated by Palma di Cesnola 2001, p.183). According to this same Author, the research question examined in this research (*i.e.* the development of the Middle Palaeolithic in the territory including the modern administrative regions of Campania and Calabria), would represent an independent cultural area, characterized by its own evolution.

New lines of research and novel methodological approaches emerged in the last decades, allowing us to address the following questions: Can we identify a techno-cultural area specific to the geographical zone of the Lower Tyrrhenian Versant during the Middle Palaeolithic? Can specific technical features be identified in this area? Can technological features be characterised through time?

In order to answer these questions, a PhD project was started in 2010 at the Research Unit of Prehistory and Anthropology at the University of Siena. The PhD project was aimed at understanding the concept of cultural entities in Prehistory, defined in space (techno-cultural area) and time (techno-cultural tendencies), with a case study represented by the Middle Palaeolithic evidence from the Lower Tyrrhenian Versant.

Previous interpretative models were reviewed (Caramia 2008; Gambassini and Ronchitelli 1998; Palma di Cesnola 2001) as well as new results obtained in Southern Italy in the recent years by means of a technological approach (Caramia 2008; Carmignani 2011; Klempererova 2012; Ranaldo in progress; Romagnoli 2012).

The choice of lithic material from Riparo del Molare (Boscato and Ronchitelli 2004; Mallegni and Ronchitelli 1987; Ronchitelli 1993; Ronchitelli *et al.* 2010) was driven by different reasons. Firstly, the anthropic levels containing the lithic industries belong to the OIS 5, a chronological moment that is particularly interesting for understanding Middle Palaeolithic evolutionary dynamics. Secondly, the site yielded about twenty occupational levels within a quite well defined chronological span. Those represent a unique data archive for assessing phenomena such as technical rupture and continuity within the same site, techno-economical and site function changes from one level to the other and, in a wider perspective, for defining the technical and economic behaviour of Neanderthal groups which occupied the site.

This paper is thus intended to offer a general picture of the research project "The Lower Tyrrhenian Versant: a techno-cultural area during the development of the Middle Palaeolithic in Italy?" by (1) synthetizing the Middle Palaeolithic evidence in Italy, (2) exploring the context of the examined region and Riparo del Molare site, and (3) outlining future perspectives.

2. The Middle Palaeolithic in Italy: models, syntheses and questions

Before exploring the Middle Palaeolithic evidence in Italy, it seems useful to briefly outline the most recognised interpretative models, the available data and the resulting archaeological questions.

2.1. The Middle Palaeolithic in Italy according to Palma di Cesnola

In Palma di Cesnola's opinion (2001), the evolution of the Middle Palaeolithic in Italy is characterized by three progressive phases. To the end of the Middle Pleistocene according to the author Italian peninsula is characterised by the presence of three different industrial technological complexes: the final Acheulean, defined by the presence of hand-axes; the evolution of Lower Palaeolithic flake-philum (Clactonian and Tayacian industries); and a third unit defined by the term Pre-Mousterian. The latter is considered to incorporate "Rissian or Riss-Wurmian" lithic industries characterised by technical and typological features anticipating the future Mousterian. In these first phases the author identifies the genesis of the Mousterian in Italy. During the next phases, at the beginning of the Würm period, the author recognized a marked geographic distinction between two provinces in Italy: a Central-Northern area, characterized by industries based on the Levallois concept typologically ascribable to the Eastern Charentian Mousterian or Mousterian of Levallois facies; a Central-Southern area, where Levallois débitage is not present during this chronological phase characterised by Charentian Mousterian of Quina type industries. It is only with the beginning of the Wurm II that a third and last evolutionary phase of this process of development of the Mousterian takes shape. At this time the process of regionalization is accentuated, so much so that the author himself has decided to define the techno-cultural panorama of the Italian territory as a "mosaic landscape".

2.2. The Middle Palaeolithic in Italy: the present archaeological data

To gain a rapid overview of the available data on which to base our questions and build our research subject, we review Italian sites dated from OIS 11/10 to OIS 3 and their corresponding lithic industries (Figure 1).

The choice of such a large chronological frame is linked to the rise of the Levallois technology during the Middle Pleistocene in Europe (Adler *et al.* 2014; Álvarez-Alonso 2014; Delagnes and Meignen 2006; Dibble and Bar-Yosef 1995; Doronichev 2016; Fontana *et al.* 2010; Fontana *et al.* 2013; Gamble and Roebroks 1999; Menéndez 2009; Moncel *et al.* 2011; Moncel *et al.* 2012; Peretto *et al.* 2014; Picin *et al.* 2013; Roebroeks and Tuffreau 1999; Soriano 2000; Tuffreau 1982; Wiśniewski 2014).This

SITE	OIS	DATE	TECHNICAL SYSTEM	BIBLIOGRAPHY
Guado San Nicola	OIS 11/10	400±9 Ka (US C)	Handaxe (approx 150), Additional, Discoid, Levallois?	Bahain *et al.* 2014; Muttilo et al 2014; Peretto et al 2014; Peretto et al in press
Castel di Guido	OIS 9	chrono-stratigraphic (350-320 ka)	Handaxe , Additional, Small tools	Radmilli et Boschian 1996; Nicoud 2013; Marra et al 2014
Quarto delle Cinfonare	OIS 9	chrono-stratigraphic (350-320 ka)	Small tools	Peretto et al 1997
Torre in Pietra	OIS 9-7	chrono-stratigraphic (350-320 Ka, liv m) (260-240 ka, liv d)	Handaxe, Additional, Small tools (liv m); Levallois (liv d)	Malatesta 1978; Grimaldi 1998; Nicoud 2013; Marra et al 2014
Cave Dall'Olio	OIS 9	chrono-stratigraphic	Handaxe, Additional, Levallois?	Fontana et al 2010; Fontana et al 2013
La Polledrara	OIS 9	chrono-stratigraphic (325-310 ka)	Small tools	Marra et al 2014; Santucci et al in press
Peverella	OIS 8-7	chrono-stratigraphic (320-220 ka)	Handaxe, Levallois	Fontana et al 2010; Lenzi et Nenzioni 1996
Monte delle Gioie	OIS 8	chrono-stratigraphic (300-290 ka)	Additional, Small tools	Taschini 1967; Palma di Cesnola 2001; Marra et al 2014
Sedia del Diavolo	OIS 8	chrono-stratigraphic (300-290 ka)	Additional, Small tools	Taschini 1967; Palma di Cesnola 2001; Marra et al 2014
Casal de' Pazzi	OIS 7	chrono-stratigraphic (260-240 ka)	Small tools, Additional, 1 Handaxe	Anzidei et al 1984; Anzidei 2001; Marra et al 2014
Paglicci riparo	OIS 7-6-5e	chrono-stratigraphic and fauna	Quinson, Quina, Handaxe, Levallois	Palma di Cesnola 2001; Palma di Cesnola et Freguglia 2005; Galiberti et al 2008
Rosaneto	OIS 7-6-5e (?)	chrono-stratigraphic	Levallois, Handaxe (57)	Bidittu et al 1984; Palma di Cesnola 2004; Spinapolice 2014
San bernardino	OIS 7-6-5-4-3	214-154 ka (VIII-VII); 108±16 ka (IV); 38±5 ka (II)	Levallois	Peresani 1996; Fiore et al 2004; Picin et al 2013
Due Pozzi, Scorneta	OIS 6	chrono-stratigraphic	Levallois, Handaxe	Lenzi et Nenzioni 1996; Fontana et al 2010
Grotta del Poggio	OIS 6	chrono-stratigraphic and fauna	Quina, Quinson	Gambassini et Ronchitelli 1998; Caramia 2008
Cirella	OIS 6 (?)	chrono-stratigraphic and fauna	Levallois	Cuda et Palma di Cesnola 2004; Palma di Cesnola 2004; Spinapolice 2014
Grotta di Torre dell'Alto	OIS 6	chrono-stratigraphic and fauna	Quina, Quinson, Handaxe, Levallois?	Borzatti von Löwenstern et Magaldi 1967; Spinapolice 2008
Grotta del Colombo	OIS 6-5-4 (?)	chrono-stratigraphic and fauna	Quina, Quinson, Discoid, Handaxe (str 4-11), rare Handaxe	Arobba et al 2008
Monte Conero	OIS 6-5-4 (?)	chrono-stratigraphic	Additional, Handaxe, Levallois (str G-F)	Peretto et Scarpante 1982
Svolte dei Popoli	OIS 6-5-4 (?)	chrono-stratigraphic	Levallois, Handaxe	Radmilli 1964
Valle Giumentina	OIS 5 (?)	chrono-stratigraphic	Levallois, Handaxe	Radmilli 1964; Nicoud et al 2015
Via San Francesco	OIS 5 (?)	chrono-stratigraphic	Levallois or Blade	Pirouelle 2006; Negrino et Tozzi 2008
Monte Versa	OIS 5	chrono-stratigraphic	Levallois	Peresani 2001

Figure 1. Main Middle Palaeolithic sites in Italy with the relative data on chronology and lithic industry used to draw the general syntheses put forward in this article.

SITE	OIS	DATE	TECHNICAL SYSTEM	BIBLIOGRAPHY
Erbarella	OIS 5	chrono-stratigraphic	Levallois	Coltorti et Pieruccini 2006; Bisi et al 1982
Boccabianca	OIS 5	chrono-stratigraphic	Handaxe, Levallois	Silvestrini et al 2001
Ponte di Crispiero	OIS 5	chrono-stratigraphic	Levallois	Coltorti et Pieruccini 2006; Coltortii et al 1982
Colonia Montani	OIS 5	chrono-stratigraphic	Levallois	Coltorti et Pieruccini 2006; Bocchini et Coltorti 1982
Riparo del Poggio	OIS 5-4-3	111.8±9.5 Ka (str 17); 43.8±3.5 ka (str 9)	Levallois, Discoid, Blade	Boscato et al 2009; Caramia 2008
Riparo di Santa Caterina	OIS 5	111.3±10 (str 5)	Levallois	Gambassini et Ronchitelli 1998; Caramia 2008
Grotta Grande di Scario	OIS 5	chrono-stratigraphic (135±11 ka trench A unit C)	Levallois	Ronchitelli et al 2011a
Ex Casino	OIS 5-4	chrono-stratigraphic	Levallois	Porraz 2005
Barma Grande	OIS 5-4	chrono-stratigraphic and fauna	Additional, Levallois, Quina	Bulgarelli 1974; Yamada 1997; Cauche 20O2; Onoratini et al 2012
Grotta dei Moscerini	OIS 5-4	79 ka (str 25); 106 ka (str 33);	Levallois, Bipolar	Schwarcz et al 1991; Vitagliano 1984; Kuhn 1995
Riparo del Molare	OIS 5-4	chrono-stratigraphic and fauna	Additional, Levallois	Ronchitelli et al 2010; Gambassini et Ronchitelli 1998
Grotta delle Fate	OIS 5-4-3	74±10 ka; 72±8 ka; 60±7 ka	Levallois	Falgueres et al1990; Negrino Tozzi 2008; Lumley et al 2008
Grotta del Principe	OIS 5-4-3	chrono-stratigraphic and fauna	Levallois	Negrino Tozzi 2008; Lumley et al 2008
Grotta del Broion	OIS 5-4-3	46.4±1.5 ka; 40.6±1.2 ka (liv I)	Levallois	Fiore et al 2004; Peresani et Porraz 2004
Grotta di Fumane	OIS 5-4-3	79±11 Ka (S7); 37.8±0.4 ka (A3)	Levallois, Discoid, Quina, 1 Handaxe	Peresani 2012
Canale Mussolini	OIS 5-4-3	58±5 ka (liv E)	Levallois	Blanc 1956; Taschini 1972; Palma di Cesnola 2001
Grotta del Cavallo	OIS 5-4-3	chrono-stratigraphic and fauna	Discoid, Additional, Levallois (liv F), Blade	Carmignani 2011; Romagnoli 2012
Mario Bernardini	OIS 5-4-3	chrono-stratigraphic	Levallois, Additional	Borzatti von Lowerstern 1970; 1971; Spinapolice 2008
Serra Cicora	OIS 5-4-3	chrono-stratigraphic	Levallois, Additional	Campetti 1986; Spinapolice 2008
Uluzzo C	OIS 5-4-3 (?)	chrono-stratigraphic and faune	rare Levallois?, Quina, Quinson	Borzatti von Lowerstern 1966; Spinapolice 2008
Madonna dell'Arma	OIS 5-4	95±5 ka (liv VII); 88±8.8 ka (foyer IV); 73.1±4.4 ka (liv I)	Levallois, Discoid, Additional, macro-tools?	Cauche 2007
Ciota Ciara	OIS 5-4	chrono-stratigraphic and faune (80-70 ka)	Levallois, Discoid	Arzarello et al 2012; Daffara et al 2014; Berto et al in press
Grotta Guattari	OIS 5-4	77.5±9.5 ka (str 5); 71±27 ka (str 4); 54.2±4.1 ka (str 1)	Levallois, Bipolare	Schwarcz et al 1991;Taschini 1979; Kuhn 1995

Figure 1 (continued). Main Middle Palaeolithic sites in Italy with the relative data on chronology and lithic industry used to draw the general syntheses put forward in this article.

SITE	OIS	DATE	TECHNICAL SYSTEM	BIBLIOGRAPHY
Ghiardo	OIS 4	73±11 ka; 61±9 ka	Levallois, 1 Handaxe (ghiardo cave)	Cremachi et Peretto 1977; Cremaschi et al 2015
Grotta Santa Croce	OIS 4	chrono-stratigraphic and fauna	Discoid, Blade	Arrighi et al 2009; Boscato et al 2010
Arma delle Manie	OIS 4-3	60±9 (VII); 39±6 (IV)	Discoid, Additional, Levallois	Mehidi 2005; Leger 2012; Cauche 2007
Santa Lucia superiore	OIS 4-3	chrono-stratigraphic and fauna	Discoid, Additional, Levallois	Cauche 2007
Riparo Tagliente	OIS 4-3	chrono-stratigraphic and fauna	Levallois, Additional, Discoid, Blade	Fiore et al 2004; Arzarello 2004
Riparo dell'Oscurusciuto	OIS 4-3	55 ka (US 14); 42.7±0.7 ka e 38.5±0.9 ka (US 1);	Levallois	Boscato et al 2011; Ronchitelli et al 2011b; Spagnolo et al in press
Grotta Romanelli	OIS 4-3 (?)	69 ka (liv H); 40±3.2 ka (liv F)	Levallois?, Quina	Sardella et al 2014; Piperno 1975; Spinapolice 2008
Grotta dei Giganti	OIS 4-3 (?)	chrono-stratigraphic	Levallois, Additional	Blanc 1962; Spinapolice 2008
S. Agostino	OIS 3	55 ka (liv 4-3); 53 ka (liv 2); 43 ka (liv1)	Levallois, Bipolar	Schwarcz et al 1991; Tozzi 1970
Buca della Iena	OIS 3	41 ka (Liv C)	Levallois	Pitti et Tozzi 1971; Palma di Cesnola 2001; Dini et Koehler 2009
Grotta del Capriolo	OIS 3	chrono-stratigraphic and fauna	Levallois	Pitti et Tozzi 1971; Palma di Cesnola 2001; Dini et Koehler 2009
Buca del Tasso	OIS 3	chrono-stratigraphic and fauna	Levallois	Palma di Cesnola 2001
Grotta di S. Francesco	OIS 3	chrono-stratigraphic and fauna	Levallois	Boscato et al 1991
Grotta di Gosto	OIS 3	48±4 Ka (str D)	Levallois	Tozzi 1974
La Fabbrica	OIS 3	chrono-stratigraphic	Levallois, Discoid, Additional, Bipolar	Dini et al 2007; Dini 2011
Grotta dei Santi	OIS 3	chrono-stratigraphic and fauna	Levallois	Moroni et al 2010
Grotta del Fossellone	OIS 3	chrono-stratigraphic	Levallois, Bipolar, Blade	Vitagliano et Piperno 1991; Vitagliano 2007;Vitagliano et Bruno 2012
Grotta di Torre Nave	OIS 3	chrono-stratigraphic and faune	Levallois, Blade	Bulgarelli 1972; Palma di Cesnola 2004; Spinapolice 2014
Torre Talao	OIS 3	chrono-stratigraphic and faune	Levallois	Cuda et Palma di Cesnola 2004; Palma di Cesnola 2004; Spinapolice 2014
Rio Secco	OIS 3	51 ka and 43.5 ka	Levallois, Discoid	Peresani et al 2014; Talamo et al 2014
Riparo Mochi	OIS 3	44 ka and 41.8 ka	Levallois, Discoid	Douka et al 2012; Grimaldi et Santaniello 2014
Bombrini	OIS 3	43.8±0.6 ka and 42.9±0.5 ka (liv IV-M4)	Levallois, Discoid	Arobba et Caramiello 2009; Riel Salvatore 2013
Grotta Breuil	OIS 3	36.6±2.7 ka	Levallois, Bipolar	Schwarcz et al 1991; Grimaldi et Spinapolice 2010; Grimaldi et Santaniello 2014

Figure 1 (continued). Main Middle Palaeolithic sites in Italy with the relative data on chronology and lithic industry used to draw the general syntheses put forward in this article.

SITE	OIS	DATE	TECHNICAL SYSTEM	BIBLIOGRAPHY
Castelcivita	OIS 3	42.7±0.9 ka and 39.1±1.3 ka (tg 30)	Levallois	Gambassini 1997; Giaccio et al 2008; Douka et al 2014
Grotta Reali	OIS 3	40±0.5 ka (US 5); 33.5±0.5 ka (US 2γ)	Levallois, Discoid, Blade, Additional	Rufo 2008; Peretto et al 2012
Riparo Mezzena	OIS 3	34.5±0.6 ka (layer III)	Levallois	Longo et al 2012; Giunti et Longo 2008

Figure 1 (continued). Main Middle Palaeolithic sites in Italy with the relative data on chronology and lithic industry used to draw the general syntheses put forward in this article.

wider vision of the evolutionary history of the technical systems which developed during the second half of the Middle Pleistocene and throughout large part of the Upper Pleistocene in Italy will allow us to place the lithic industries under examination in a meaningful context.

In terms of chronology within Italy (Figure 2), although many differences can be noticed in the available archaeological evidence (type of dates, relative or absolute; occupational context, single living floor or palimpsest; geological context, stratified or from surface etc.), there is a quite gradual augmentation of sites across time, starting from OIS 11/10. A wider and more precise record is present for the most recent phase (from OIS 5 onwards).

In terms of geography (Figure 3), a dissimilar distribution is observed from North to South with areas where there is a high concentration of sites, *e.g.* along the Tyrrhenian coast (the Ligurian coast, Pontina plain, Cilento area), the Adriatic coast (Conero Mount and Gargano), in the Salento area and on the Berici hills. In between these areas there are regions where the archaeological record is virtually absent, (*e.g.* Piemonte region, the Po Plain, the Appennines, Calabria region, etc).

The main characteristics of the lithic industries are described here following the conventional subdivision of the Peninsula into North, Centre and South and moving from the most ancient to the most recent isotopic stage. Given the extant terminological and archaeological complexities found in the bibliography, we decided to focus the attention on technical aspects specifically linked to the blank production. Above all, we considered the presence/absence of the Levallois concept. The other types of production concept, such as discoid or laminar, have been reported only when clearly described in literature. For all other flake productions (orthogonal, opportunistic, kombewa, surface-based, etc.) we preferred to employ the term "additional", referring to the techno-genetic and structural approach formulated by Eric Boëda (2013). For the most ancient phases, a distinction is made between the bifacial phenomenon, the small tools, and the Quina and Quinson tool-types.

North Area (Fig. 4): Starting from OIS 9-8, some reference sites are found in the Northern region. The marginal area between the Po Plain and the Apennines, between the districts of Bologna and Imola, is particularly interesting as recent excavations yielded a series of lithic industries, which have been ascribed to a chronological interval set between OIS 9 and 6 (Fontana *et al.* 2010). The site of Cave dell'Olio, ascribable to OIS 9, shows a bifacial component, a volumetric laminar production and, for the first time in this region, a pre-determined production of Levallois type blanks. Later, during OIS 7, the site of Peverella (Lenzi and Nenzioni 1996) shows

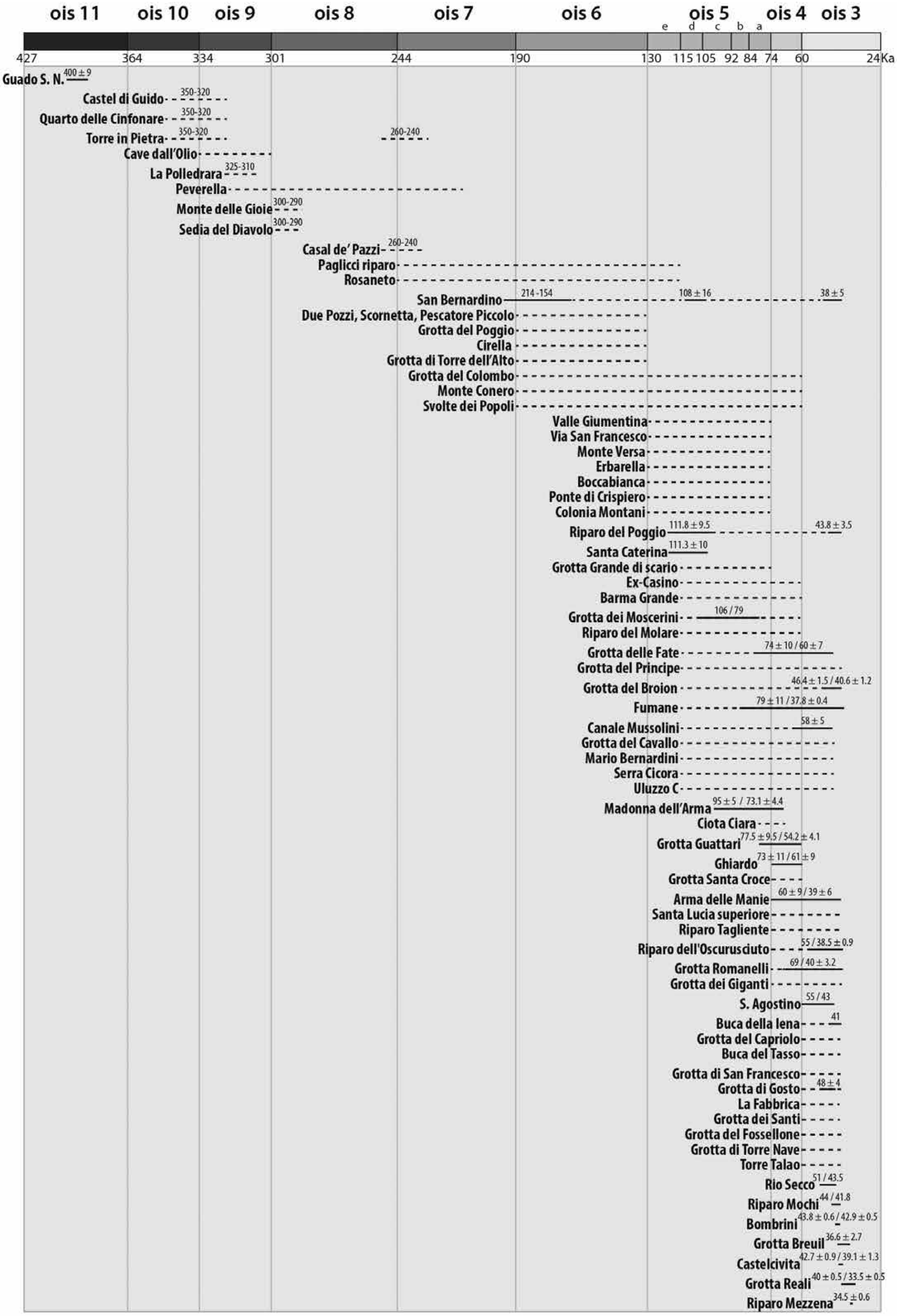


Figure 2. Chronological distribution of the main Middle Palaeolithic sites in Italy used to draw the general syntheses.

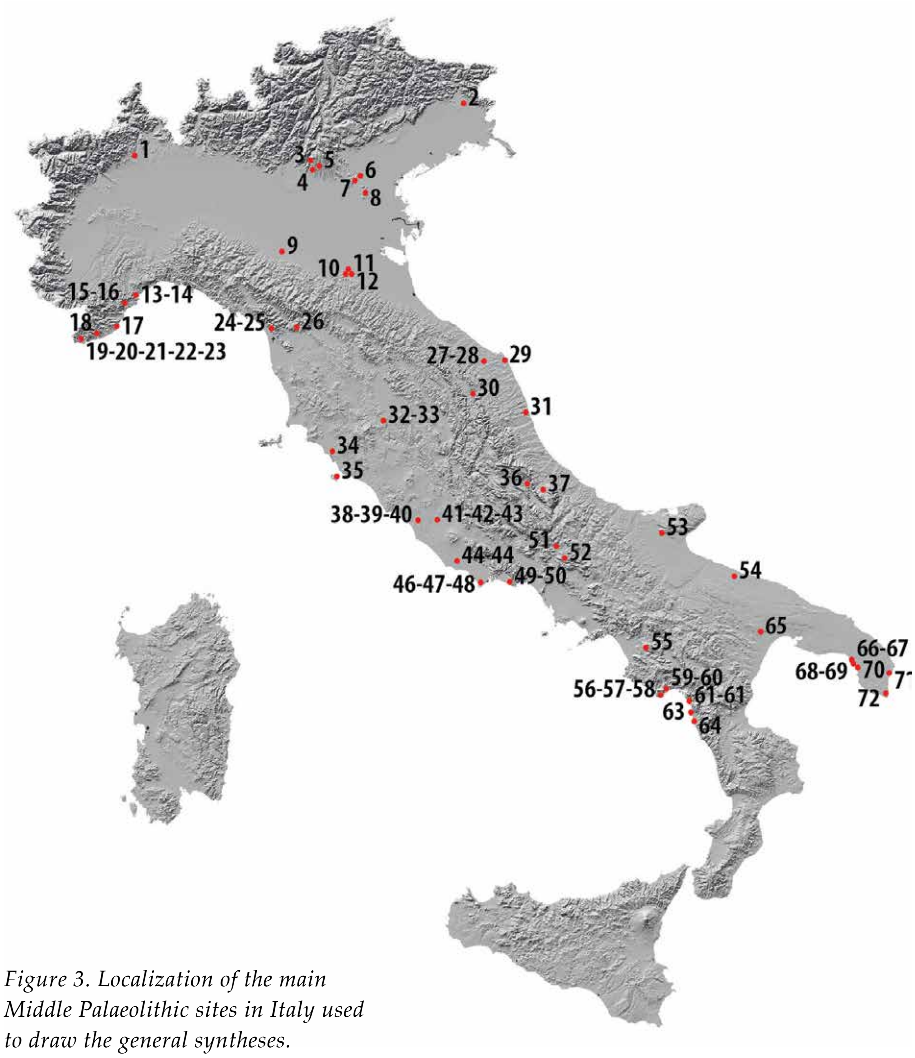


Figure 3. Localization of the main Middle Palaeolithic sites in Italy used to draw the general syntheses.

1. Ciota Ciara; 2. Rio Secco; 3. Grotta di Fumane; 4. Riparo Mezzena; 5. Riparo Tagliente; 6. Grotta del Broion; 7. Grotta di San Bernardino; 8. Monte Versa; 9. Ghiardo; 10. Cave dall'Olio; 11. Due Pozzi, Scorneta; 12. Peverella; 13. Grotta delle Fate; 14. Arma delle Manie; 15. Grotta del Colombo; 16. Santa Lucia; 17. Madonna dell'Arma; 18. Via San Francesco; 19. Riparo Mochi; 20. ex Casino; 21. Riparo Bombrini; 22. Barma Grande; 23. Grotta del Principe; 24. Grotta del Capriolo; 25. Buca della Iena; 26. Buca del Tasso; 27. Erbarella; 28. Colonia Montani; 29. Monte Conero; 30. Ponte di Crispiero; 31. Boccabianca; 32. Grotta di Gosto; 33. Grotta di San Francesco; 34. La Fabbrica; 35. Grotta dei Santi; 36. Svolte dei Popoli; 37. Valle Giumentina; 38. Torre in Pietra; 39. Castel Di Guido; 40. Polledrara di Cecanibbio; 41. Monte delle Gioie; 42. Sedia del Diavolo; 43. Casal de' Pazzi; 44. Quarto delle Cinfonare; 45. Canale Mussolini; 46. Grotta Breuil; 47. Grotta del Fossellone; 48. Grotta Guattari; 49. Grotta dei Moscerini; 50. Grotta di S. Agostino; 51. Grotta Reali; 52. Guado S Nicola; 53. Paglicci riparo; 54. Grotta di Santa Croce; 55. Castelcivita; 56. Grotta del Poggio; 57. Riparo del Poggio; 58. Santa Caterina; 59. Grotta Grande di Scario; 60. Riparo del Molare; 61. Rosaneto; 62. Grotta di Torre Nave; 63. Torre Talao; 64. Cirella; 65. Oscurusciuto; 66. Serra Cicora; 67. Mario Bernardini; 68. Uluzzo C; 69. Grotta del Cavallo; 70. Grotta di Torre dell'Alto; 71. Grotta Romanelli; 72. Grotta dei Giganti.

an already affirmed Levallois production, still accompanied by the bifacial phenomenon. Another key site of this region, with a long stratigraphic succession spanning from OIS 7 to 3, is San Bernardino (Fiore *et al.* 2004; Peresani 1996; Picin *et al.* 2013). The lithic industries coming from the two most ancient levels of the site (Unit VIII and VII) show both a recurrent centripetal and unipolar Levallois production, a number of small tools strongly transformed through retouch with rare elements of "Quinson" type, and the total absence of the bifacial pieces. In Liguria, the industries of Grotta Colombo (Arobba *et al.* 2008) have an uncertain chronological attribution (pre or post OIS 5e) but show features recalling technical aspects pertinent to the most ancient phase, such as discoid components, a strongly retouched tools with Quina and Quinson elements and the presence of some bifacial pieces in the lower part of the sequence (layers 17 to 12). Levallois type productions only start from the most recent part of the sequence (layer 7-1).

In the same region, starting from isotopic stage 5e we assist to an increase in the archaeological record. In Liguria, numerous costal caves yielded several lithic industries preserved in the continental deposits formed after the Tyrrhenian marine transgression (Cauche 2002; Negrino and Tozzi 2008). Amongst these, the sites of Barma Grande (Bulgarelli 1974), Madonna dell'Arma, Arma delle Manie and Santa Lucia (Cauche 2007) allow us, in very general terms, to consider the lithic industries of this region as characterized by a strong presence of the Levallois concept, used in different variants for the production of blanks, and by a classic panoply of Mousterian tools.

Towards the end of the Middle Palaeolithic, discoid type productions are also present, together with an increase in the presence of denticulates (Leger 2012; Negrino and Tozzi 2008). In Piemonte, research has recently restarted at the site of Ciota Ciara at the Mount Fenera, where discoid and Levallois type productions are attested during the final part of OIS 5 (Arzarello *et al.* 2012; Berto *et al.* 2016; Daffara *et al.* 2014). This datum allows us to reconstruct Neanderthal technical behaviour in a particular geographical zone, close to the Alps, which is still little known and characterized by peculiar raw materials. Finally, the site of Grotta Fumane (Peresani 2012), on the Lessini mountains, with its multiple dating (between OIS 5-4-3) and the richness of the archaeological levels, has become a stratigraphic 'reference' for understanding the evolution of Middle Palaeolithic technical systems in the North-Eastern Italy. The alternation of different débitage concepts such as Levallois, discoid, Quina and laminar in its sequence seem to suggest a great diversity of production. A bifacial piece is associated with the Levallois débitage at about 50,000 (level BR-9) and Quina elements appear in central levels of the sequence where the Levallois débitage is totally absent (levels BR-4 and BR-5).

Central Area (Fig. 5): The archaeological context of Guado San Nicola was recently discovered (Muttilo *et al.* 2014; Peretto *et al.* 2014; Peretto *et al.* 2016). It documents the Lower Palaeolithic/Middle Palaeolithic transition in a very ancient phase (end of OIS 11 and the beginning of 10). The lithic industry is based on a façonnage reduction sequence aimed at obtaining bifacial tools (about 150 elements) and apparently shows Levallois débitage, even if in modest quantities and among other flake production systems. This evidence and the one brought to light at Cava dell'Olio open up a discussion on the very definition of the Levallois concept and on its interpretation, particularly in the milieu of the industries found in this first chronological phase, *i.e.*

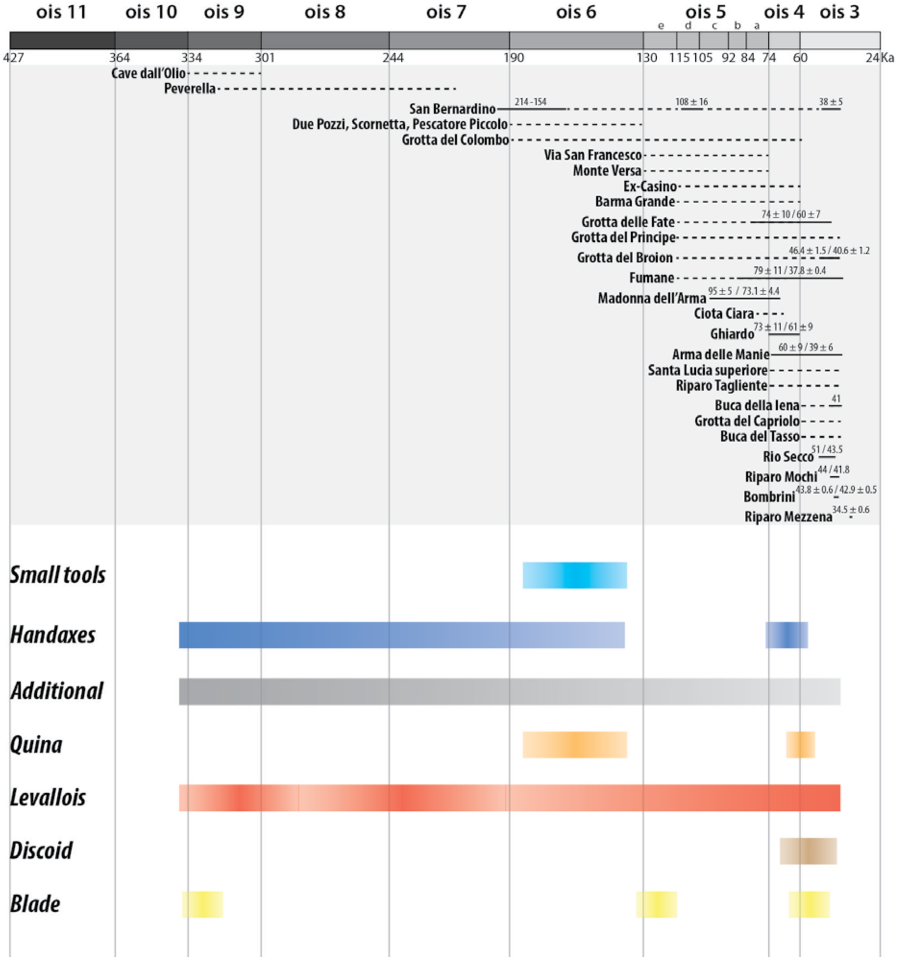


Figure 4. Chronological distribution of the main Middle Palaeolithic sites of Northern Italy and the evolution of the main lithic technical systems.

earlier than OIS 9. In the following OIS 9 and 8, the Levallois concept is absent in the central area of Italy.

Some emblematic examples of this phase are concentrated in the Roman countryside, at level 'm' in the site of Torre in Pietra (Grimaldi 1998; Malatesta 1978; Nicoud 2013) and at Castel di Guido (Nicoud 2013; Radmilli and Boschian 1996). At these sites, lithic industries are characterized by façonnage, represented by bifacial pieces at Torre in Pietra and by bifacially worked pebble tools at Castel di Guido (Nicoud 2013). Small tools made with a high technical investment in the transformation phase are also present. Flake production is exclusively made by means of additional concepts, and the Levallois is totally absent. In the following phase, during OIS 7 and 6, a greater technical variability starts to emerge. This is possibly due to the increase of archaeological evidence in the territory. Only from this moment onwards, the Levallois techno-marker is recorded in this central region of Italy. This is particularly evident with regards to the industry coming from level 'd' of Torre in Pietra (Grimaldi 1998).

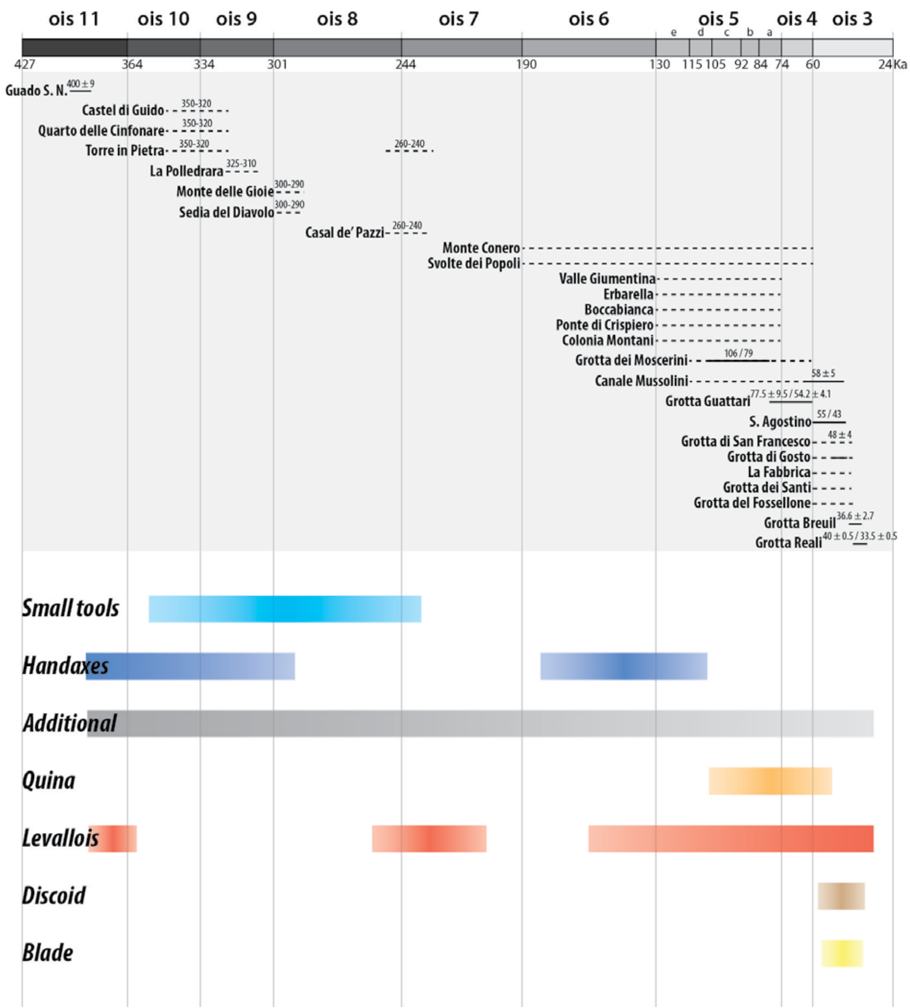


Figure 5. Chronological distribution of the main Middle Palaeolithic sites of Central Italy and the evolution of the main lithic technical systems.

On the basis of available data, the Levallois concept appears on the Adriatic Versant only starting from OIS 5 (Coltorti and Pieruccini 2006; Palma di Cesnola 2001). Several sites in the Marche region directly record this phenomenon, such as Monte Conero (G and F layers) (Peretto and Scarpante 1982), Ponte di Crispiero (Coltorti *et al.* 1982), Erbarella (Bisi *et al.* 1982) and Boccabianca (Silvestini *et al.* 2001). At these sites, a great technical effort is evident in the production of blanks using the Levallois concept and an array of retouched tools typical of Mousterian variability. During this phase, only at Boccabianca the association between Levallois production and some handaxes is still attested. Industries from the Marche region, together with those from the Abruzzi, like Valle Giumentina (level 46) (Nicoud *et al.* 2015; Radmilli 1964; Villa *et al.* 2015) and Svolte dei Popoli (Radmilli 1964), very often lack absolute dating but can be attributed to OIS 5e thanks to the presence of pedomarkers (palaeosoils, in this case) and geological correlations (Coltorti and Pieruccini 2006). In the

Tyrrhenian Versant, the recent phase of the Middle Palaeolithic (after OIS 5e) is better represented, especially in the classical sites of the so-called Pontinian, located in the area south of Rome between the present day Pontina plain and Gaeta, such as Grotta dei Moscerini (Kuhn 1995; Vitagliano 1984), Grotta Guattari (Taschini 1980), Grotta Breuil (Grimaldi and Santaniello 2014; Kuhn 1995) and Sant'Agostino (Tozzi 1970). At these sites we find the specific use of small pebbles as raw material, a Levallois type production, although not predominant, the use of the bipolar technique and a highly retouched toolkit made mostly of scrapers and points.

South Area (Fig. 6): compared to other areas, the southern part of Italy shows less information available for the most ancient phase (OIS 9-8). Within this poorly recorded pre-OIS 5 setting, the stratigraphic sequence discovered in the external shelter at Grotta Paglicci (Boscato and Ronchitelli 2006; Galiberti *et al.* 2008; Palma di Cesnola and Freguglia 2005) provides important data for understanding the techno-cultural evolution, which took place in this region during the final phase of the Middle Pleistocene. The Paglicci site, on the slope of the Gargano promontory, is effectively the reference site for the upper Palaeolithic of Southern Italy. The most ancient levels (4 and 3) of the so-called "Riparo esterno"(literally the "outer shelter") show an occurrence of the bifacial phenomenon associated with the production of small tools, strongly transformed by means of retouch, with elements comprising a dihedral inner face (Quinson) and the total absence of Levallois débitage. Level 2 shows an impressive technical effort in the transformation, through retouch, of tools with elements which seem to recall a technical milieu of Quina type, a decrease in the Quinson type elements and, once again, the sheer absence of Levallois type production (Galiberti *et al.* 2008).

Prior to the OIS 5, in other region of southern Italy lithic industries are characterized by the production of small, thick and strongly retouched tools belonging to the evolved Tayacian. This is the case at Grotta di Torre dell'Alto in the Salento region (Borzatti von Löwerstern 1967) and for the Pre-Mousterian of Grotta del Poggio (Caramia 2008; Gambassini and Ronchitelli 1998) in the Cilento region. These technical expressions witness the last appearances of an evolutionary trajectory which has its roots in the Lower Palaeolithic of Central-Southern Italy and which seems to fade or evolve with the advent of the Levallois in this region. The Levallois seems to appear in a clear way only starting from isotopic stage 5. This can be seen both in the Adriatic side of the Peninsula, in the lithic industries of Level 1 at the Riparo Paglicci (Freguglia and Palma di Cesnola 2006), and in the Tyrrhenian Versant at Riparo del Poggio (Boscato *et al.* 2009) and Riparo del Molare (Aureli in progress; Ronchitelli *et al.* 2010). At the Rosaneto site, Levallois productions are documented in association with the bifacial tools (Bidittu *et al.* 1984; Palma di Cesnola 2004; Spinapolice 2014), however the secondary geochronological context of this site is not very reliable. Although the available, limited data make it very hard to gain a general view of the matter, the most recent phase of the Middle Palaeolithic in Southern Italy (post OIS 5) appears to be characterized by a new variability of technical expression. These include both productions with discoid or laminar productions, as recorded at the Santa Croce site (Arrighi *et al.* 2009) and a strong presence of unipolar type Levallois, as for example at the Oscurusciuto site (Boscato *et al.* 2011; Ranaldo in progress; Ronchitelli *et al.* 2011b; Spagnolo *et al.* 2016). The stratigraphic sequence of Grotta del Cavallo (Carmignani

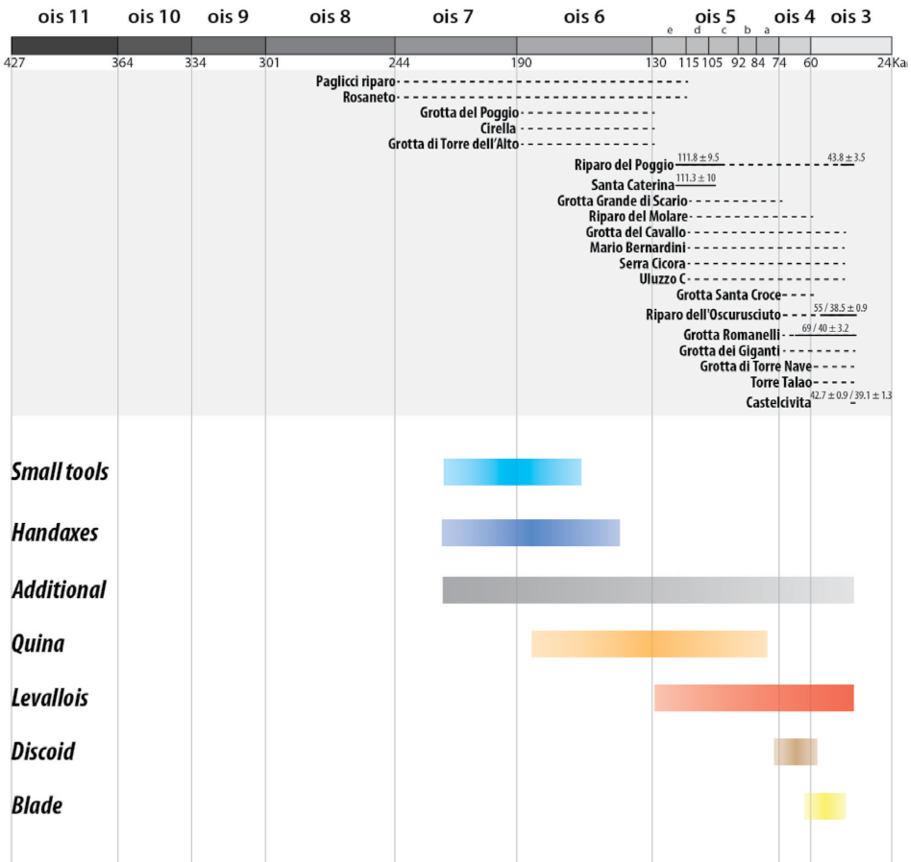


Figure 6. Chronological distribution of the main Middle Palaeolithic sites of Southern Italy and the evolution of the main lithic technical systems.

2011; Romagnoli 2012), in the Salento region, provides an evolution of lithic industries from the Tyrrhenian transgression to the end of the Middle Palaeolithic. This sequence is significant for characterising the heterogeneous cultural expression of the Neanderthal groups who inhabited this specific area through time.

2.3. The Middle Palaeolithic in Italy: the problems

This review of the Italian Middle Palaeolithic by means of the main evidence through time and space (even if presented summarily and concisely) allows us to put forward some reflections.

Undoubtedly, the first datum concerns the rarity of absolute dating, and thus of precise time markers. This lack does not help our understanding and reconstruction of Neanderthal evolutionary dynamics of technical systems. Another negative factor is the presence of wide geographical gaps characterised by scanty archaeological record, as this hinders the understanding of peopling and diffusion dynamics in the Italian Peninsula.

Although at this stage of research the lack of both spatial and chronological data makes it difficult to put forward a detailed synthesis, the archaeological record allows us to point to the following problems (Figure 7):

1. OIS 11-10. The evidence of Levallois production recently found at Guado San Nicola, in central Italy, push well backward the rise of this new modality of "flake making" in the European context. This datum appears today to be isolated in time and space, given that in the same geographical area no Levallois is found in the following phase (OIS 9 and 8) and that this evidence is very far from the hotbed of initial spread in Northern Europe. How does this lithic industry fit in the frame of present knowledge? Does it really fit within a Levallois conception? Can it be interpreted as one of the various hotbeds of innovation found in different areas of Europe, foregoers of the technical history to come? What is its role within the technical variability of the contemporary Lower Palaeolithic?

2. OIS 9-5. The role of Levallois, its coexistence with other technical systems and its diffusion in time and space seem to be chief elements for the understanding of the formation processes of the Middle Palaeolithic in Italy. This new conception in the production of blanks appears in fact to take shape across the Italian territory in an asynchronous way, following a progressive tendency from North to South. In the course of OIS 9-8, it comes out in the Po Plain (Cava dell'Olio); it makes its first appearance in the Roman countryside in OIS 7 (Torre in Pietra, level 'd') and, finally, it is not found earlier than isotopic stage 5 in Southern Italy: in the Gargano (Riparo Paglicci, level 1) and in the Cilento (Riparo del Poggio, level 17 and Riparo del Molare) areas. Does the first Levallois in the North show the same characteristics as that in the Centre and South? What characterizes early Levallois productions? What technical innovations do they bring about? On which "industrial" contexts are they based? How should the chronological gap between North and South of Italy be interpreted? Are we facing a phenomenon of diffusion or one of technical reinventions happening at different moments in different areas? Are there differences or similarities with respect to the European context?

3. OIS 5. In this phase there is, on the one side and with different mode and tempo, the demise of the technical traditions coming from the Lower Palaeolithic "world" such as: the bifacial tools, the productions of strongly retouched small and thick tools and the exclusive production of flakes with additional type conceptions. On the other hand, there is an affirmation and an expansion of the technical variability typical of the Middle Palaeolithic (Levallois, Discoid and Laminar).

This phase seems to represent, especially in the Central-Southern part of the Peninsula, a key moment in the evolution of the technical systems between the Lower and the Middle Palaeolithic. How can we describe it? What are the elements of rupture or continuity in the conceptions of tools? Is it possible to observe some kind of "transfer" in the technical investment of tool making from confection to production? Does the Levallois fill functional gaps left by the previous technical entities (handaxes, small tools, etc.)?

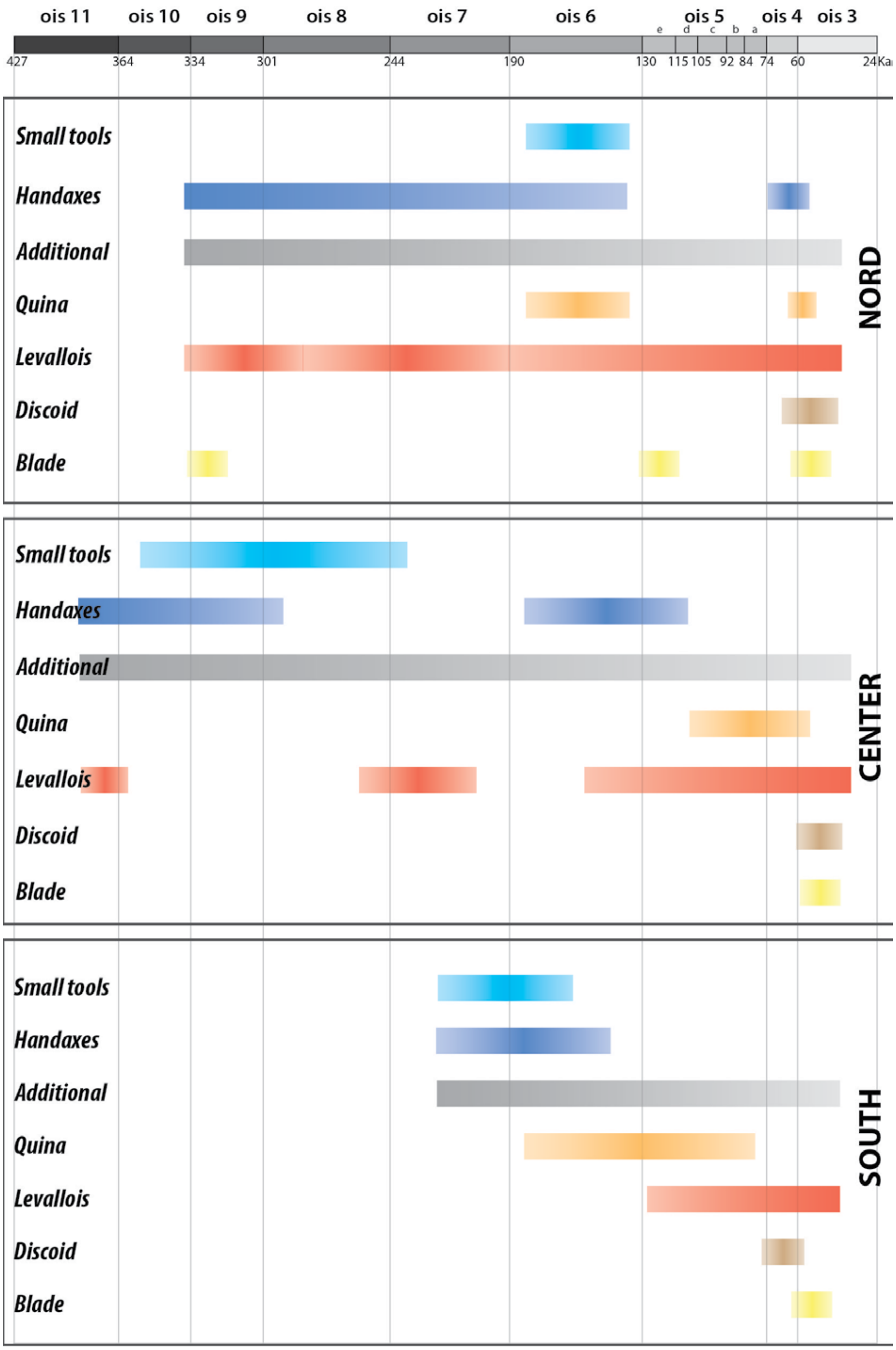


Figure 7. Evolution of the main lithic technical systems in the three areas, Northern, Central and Southern Italy during the Middle Palaeolithic in Italy.

4. OIS 4-3. The process of "Mousterianization" (as defined by Palma di Cesnola for the whole Peninsula) is well under way. Geographical identities characterized by their own evolutionary histories and physiognomies emerge and are linked to the so-called regionalization phenomenon. A techno-cultural landscape starts to come into focus which can be defined as "mosaic like" and which draws to an end the evolutionary history of the Mousterian, accompanying it up to the beginning of the Upper Palaeolithic. How can we interpret this evolutionary tendency, at the present state of the art and with the support of innovative methodological approaches? Are we able to confirm, to modify or to enrich this vision, using a technological approach in the study of lithic assemblages? Which parameters allow us to define differences or resemblances between different geographical areas? How can we define a techno-cultural area? And starting from which elements? Is it possible to see independent evolutions between the different regions? Is the theory of multi-regional evolution of the Middle Palaeolithic in Italy formulated by Palma di Cesnola still valid?

The research project on the Lower Tyrrhenian aims at participating in a dynamic and dialectic way to the scientific debate on the Italian Middle Palaeolithic, developing the questions individuated above.

3. The Lower Tyrrhenian Versant (LTV), was it a techno-cultural area during the Middle Palaeolithic? Evolution of the lithic industries of the Riparo del Molare sequence in the frame of Neanderthal peopling dynamics in Italy

Having defined the synthetic framework of Middle Palaeolithic in Italy and the related questions, let us come to the details of this research subject. The regional evolution will be described and the Riparo del Molare site presented together with a brief description of the lithic industries found therein.

3.1. Looking at the regional evolution of the LTV from current data

The area under examination, comprised between Campania and Calabria regions, takes a central role for the understanding of the evolution of Middle Palaeolithic thanks to the presence of several sites. As also stated by Palma di Cesnola "the Cilento coast, district of Salerno, is doubtlessly one of the most important areas for the knowledge of the Mousterian – as well as of its possible forerunners – on the Tyrrhenian Versant" (translated by Palma di Cesnola 2001, 250). The most relevant sites are concentrated in different areas between Capo Palinuro and the province of Cosenza. Near Capo Palinuro a series of caves (Grotta delle Ossa, Grotta Visco and Grotta delle Ciavole) have been the object of research and excavations ever since the work of A.C. Blanc (Blanc and Segre 1953). Other evidence is concentrated around Marina di Camerota (Grotta Taddeo, Grotta Tina, Grotta della Cala, Grotta e Riparo del Poggio, Grotta di Porto Infreschi) and excavated since the '60s by the Universities of Florence and Siena. A third group of sites is located near Scario (Grotta Grande and Riparo del Molare, excavated by the University of Siena since the '80s). Towards the inland areas of Campania region and southwards in the northern sector of Calabria, archaeological record becomes scantier. Grotta di Castelcivita (Douka 2014; Gambassini 1997) in the Alburni mountains, district of Salerno, and the deposit of Montemiletto in the district of Avellino, were also investigated by the University of Siena from the '70s. Finally, the cave of Torre Nave and the site of Torre Talao (Bulgarelli 1972; Cuda and Palma di Cesnola 2004; Palma di Cesnola 2004), in the district of Cosenza, are, at present, the southernmost Mousterian evidence in the examined area.

Thanks to the study of the regional geomorphological context and the identification of reference pedomarkers, namely the conglomerates that originated from marine transgression, it is possible to establish from a general standpoint, chrono-stratigraphic correlations between various levels of the different sites (Gambassini and Ronchitelli 1998). Some absolute dating, as for example Riparo del Poggio and Santa Caterina (Gambassini and Ronchitelli 1998), help to chronologically establish reference points for the entire evolution of techno-complexes. At the same time, faunal analyses and some detailed sedimentological studies of the various sequences (Boscato *et al.* 2009) improve our knowledge of environmental changes and the formation dynamics of such deposits.

From the point of view of industries, the Authors describe a very interesting evolution of technical expressions (Caramia 2008; Gambassini and Ronchitelli 1998). This seems to start from the so-called "pre-Mousterian", represented specifically in the lithic industries of the Grotta and Riparo del Poggio. These lithic assemblages, which stratigraphically are found after the OIS 7 (UMP=Unità Marina Poggio, Gambassini and Ronchitelli 1998), are characterized by an early facies with frequent denticulates (Grotta del Poggio levels 13-3) and by a second facies with prevalent scrapers with Quina retouch (Grotta del Poggio level 2). An early Mousterian phase, characterized by the appearing of Levallois industries in the region, may occur already near the end of the OIS 6 (S. Caterina) but most certainly with OIS 5. This technical indictor (Levallois) is found in a series of lithic assemblages coming from levels deposited after the Tyrrhenian marine transgression (UMM=Unità Marina Molare=OIS 5e, Gambassini and Ronchitelli 1998), as for instance at Riparo del Poggio (level 17) and at Grotta Grande di Scario (sector A and F) (Ronchitelli *et al.* 2011a) and at Riparo del Molare (Levels 71-36). A second Mousterian phase follows during OIS 4 and is comprised by the lithic industries of the Molare (Levels 35-1) and of Riparo del Poggio (Levels 15-13). This series is closed by a third phase, during OIS 3 occurring, defined by the levels 10 and 9 of the Riparo del Poggio and by the sequence of Castelcivita (Levels 28-18). The Authors consider this Mousterian sequence as characterized by a linear evolution which begins with slightly Charenzian features and appears to make a shift to a typical Mousterian, rich in scrapers, towards the end of the sequence.

3.2. The site of Riparo del Molare

The site of Riparo del Molare is found at present by the Tyrrhenian seaside, along the stretch of coast known as la Masseta di Scario in the municipality of S. Giovanni a Piro (Salerno) on the Tyrrhenian Versant (Figure 8a). Research carried out by the Dipartimento di Scienze Fisiche, della Terra e dell'Ambiente of Siena University, in collaboration with the local Soprintendenza, begun in 1984 and ended in 2001. Through this work, which lasted about twenty years, it was possible to understand the whole stratigraphic sequence which encloses, within 15 meters of thickness, 23 levels of anthropic occupation all ascribable to Neanderthals. The excavation area was extended for 15 square meters at most; unfortunately, part of the deposit towards the sea has been destroyed by the erosion. These levels yielded a very rich archive of information on the technical and economical behaviour expressed by this extinct humanity, in particular lithic and faunal material, fireplaces and dwelling structures preserved in the various layers.

Stratigraphy[3] (Figura 8b) is composed from bottom to top by the ensuing succession (Ronchitelli *et al.* 2010). Two conglomerate levels are found at the base, attesting two marine transgression facies. The lower one is characterized by abundant limestone blocks embodied in a cemented sandy matrix where *Cladochora coespitosa* and *Spondylus* sp. are also found in abundance. This level is about 4 meters thick. On the other hand, the upper conglomerate is made of small limestone pebbles cemented by a scarce sandy matrix: this was used for making historic epoch millstones ("mole"), after which the shelter was given its name. This conglomerate can be attributed very likely to the Eutyrrhenian transgression (OIS 5e) given the presence of some specimen of *Strombus bubonius* and *Patella ferruginea*. Above, the earliest continental deposit is found, comprising levels of sterile red clay with by Fe-Mn oxides (varying in thickness between 1 and 70 cm), alternating with breccia levels corresponding to anthropic frequentation levels (archaeological level 71-36), each varying in thickness between 5 and 10 cm. In almost every occupation episode of the shelter, combustion structures were found associated with a considerable presence of lithic and faunal material. In levels 56 and 43 two unusual features revealing spatial organization were highlighted, while a mandible of a Neanderthal baby aged about 3-4 was found in level 51 (Mallegni and Ronchitelli 1987; 1989). These findings complete the archaeological record of the Riparo del Molare sequence with anthropological data and with information related to space management. The series is closed, in the top part of the stratigraphic sequence where three levels of tephra are found (levels F, E and C), by a new continental deposit (levels 35-1) made of colluvia which attest to the presence of a slope less protected by vegetation and to a progressive cooling of climate (probable OIS 4). The upper part of this latter complex attests to an increase in humidity and to a milder climate. Anthropic frequentation in this phase becomes sporadic.

3.3. The lithic industries of the Riparo del Molare: a preliminary synthesis

The lithic industries found in Riparo del Molare provide a rich body of data allowing us to reconstruct part of the technical and knowledge "universe" of Neanderthal groups who occupied this site and the region of the Lower Tyrrhenian Versant during the Middle Palaeolithic. These productions, coming from a series of occupation episodes repeated in time, amount to a total of 10,000 specimens. Previous studies have revealed the presence of a Levallois reduction sequence in the production of blanks (Ronchitelli *et al.* 2010). Given the importance retained by this "techno-marker", it has been fundamental to focus attention on the actual presence of Levallois productions, describing the technical principles by which such products are obtained. Also of great importance was the investigation and definition of the productions ascribable to the non-Levallois "world", which are at present underestimated or little descried but which have a very

3 To define better the geo-chronological context we began a collaboration with UMR 7194 (CNRS – Museum national d'Histoire naturelle de Paris) and UMR 8212 (CEA-CNRS-UVSQ, Gif-sur-Yvette).

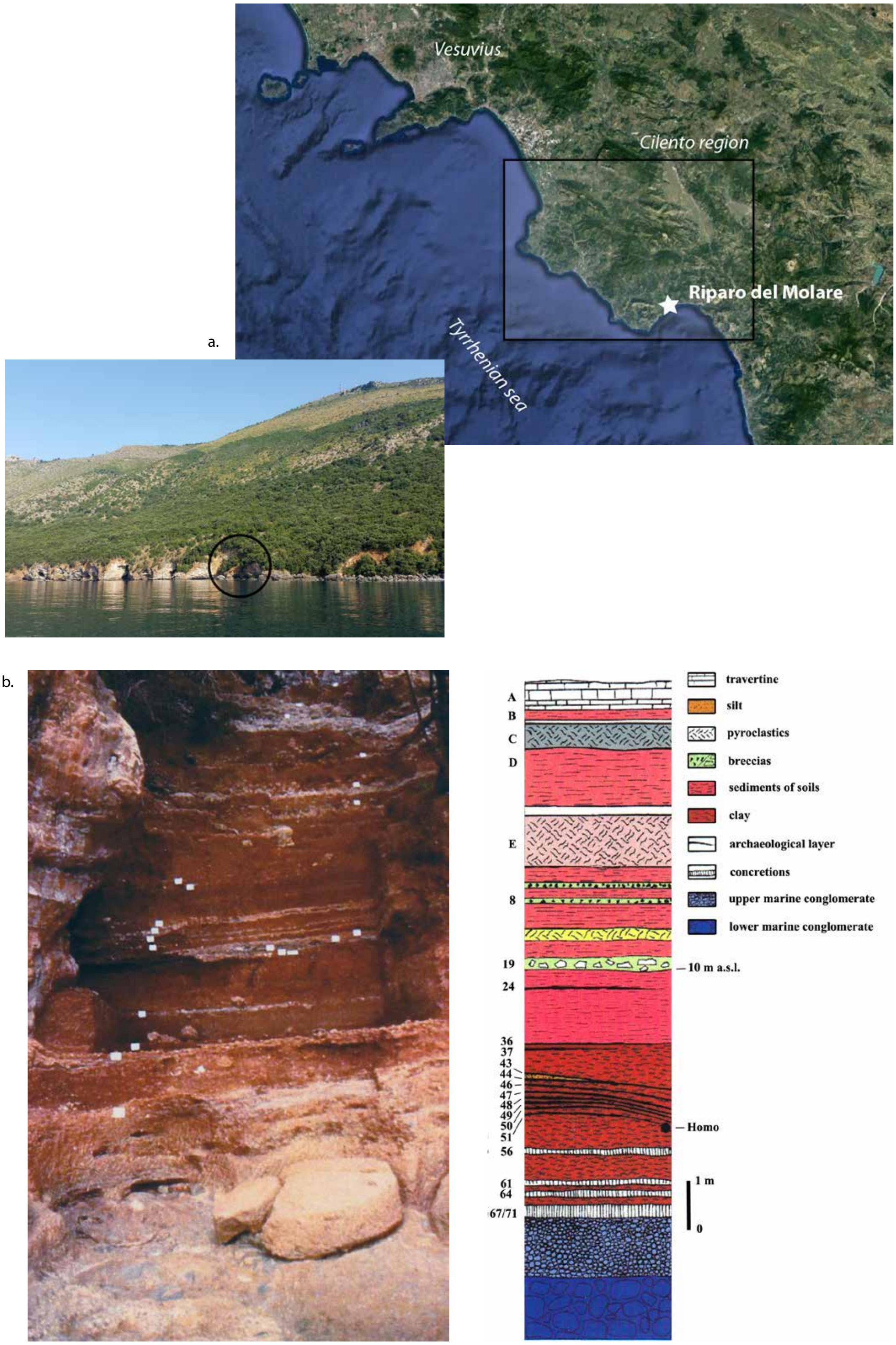


Figure 8: Localization and stratigraphy of the Riparo del Molare site.

important role for the understanding of Neanderthal technical complexity. In order to tackle this question, and to go beyond the limits of a simple tecno-typological description of the flakes production systems (Levallois, discoid, orthogonal, with parallel planes, etc.), we have chosen to use the techno-genetic and techno-functional approach formulated by Eric Boëda (2013).

Even if results of analyses are still being processed, we give below a synthesis of the essential and general features of the lithic assemblage of the Riparo del Molare, describing raw materials employed and blank productions. Blanks transformed through retouch, which form an important part of the lithic assemblage, are not tackled in this work. Also, quantitative aspects of the different components and the verification of possible fluctuations along the sequence, aimed at verifying possible changes through time, will be the object of future publications.

Raw materials: The lack of an exhaustive regional reference syntheses of the different lithotypes present, and of petrographic analysis on the archaeological material under examination, do not allow to precisely argue on the lithic raw material supply dynamics of the groups which inhabited the Shelter. Notwithstanding this, past studies (Caramia 2008), have shed light on the existence in the Cilento territory of various geological formations characterized by the presence of different raw materials (flint, jasper, quartzarenite). The most widespread is a variety of dark-coloured cryptocrystalline flint found as nodules or slabs within a formation of Lias calcarenites. This formation outcrops in different spots within a ray of about ten kilometres from the site. The second most diffused raw material is jasper, which is characterized by the red and green variety, the former being more diffused than the latter. Outcrops of this lithotype are found in the geological formations of the Flysch del Cilento, localized at present north-west of the higher course of the Mingardo river, more than ten kilometres away from the site. The lithotype of quartzarenites is found in low percentages at the site and can probably be assigned to this last provenience. Notwithstanding the different distances of present day outcrops from Riparo del Molare, a supply of raw materials very close to the site can be hypothesized. This hypothesis is backed, on the one hand, by the presence of initial supports imported as pebbles into the site and, on the other, by the presence of marine terraces and fluvial palaeo-alvea near the site. In brief, lithic raw materials employed during the Neanderthal occupations at Riparo del Molare can be summed up in a choice ranging from large pebbles of medium and fine grained quartzite to small pebbles of good quality jasper, leaving the rest to a variegated series of flint found as blocks, nodules and middle-sized pebbles. The latter, except rare occurrences, are of mediocre quality and often show inner fracturing (Figure 9). Hence, we are dealing with a high variety of shapes, volumes, density, homogeneity, elasticity and of potential of the future active cutting-edge.

Blank production: when observing the volumetric structures of cores and of target products, two concept of production can be differentiated: an "additional" and an "integrated" one (Boëda 2013). In the first case, only a sub-volume of the starting block is exploited as a core. In this portion of the block volume, the technical criteria needed for flake production are sought or created (angle F/P-D/S; convexity D/S; arise; recurrence; etc.). When such technical criteria are lost in this sub-volume, either the block gets changed or the same criteria are sought/recreated on another sub-volume of the same block. In the second case, all technical criteria needed for the production

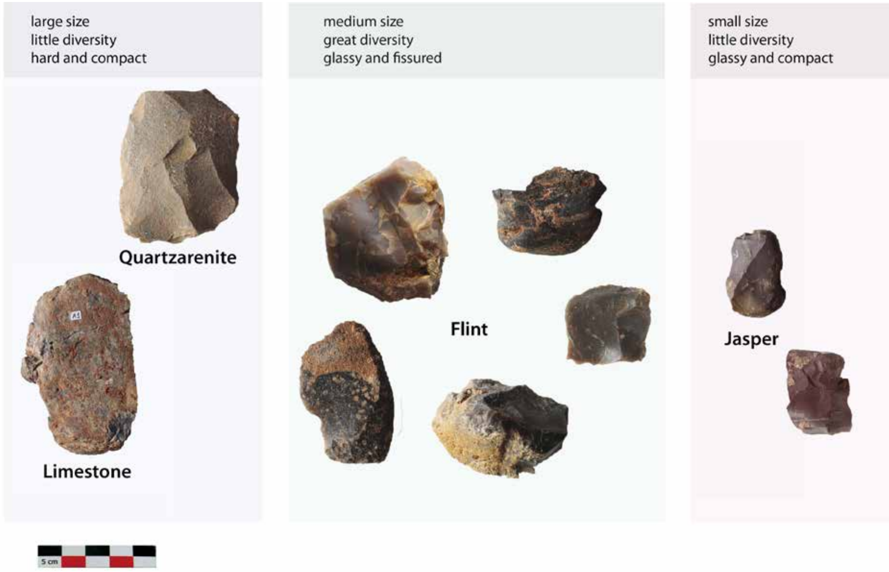


Figure 9: Lithotypes and qualities of raw materials present in the site of Riparo del Molare.

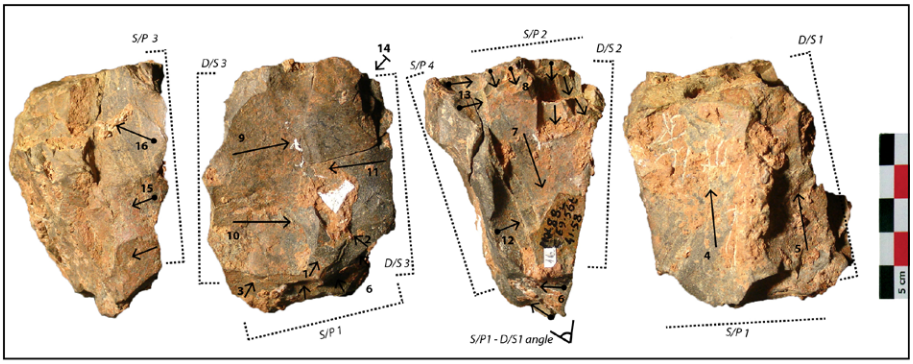
of flakes are created on the starting block, through a phase of initial shaping, before moving to the phase of actual flake production. We have proposed this schematic definition to provide the reader with an *idea* of the meaning given to the terms additional and integrated[4]. These aspects can be explored thoroughly in the scientific production of Boëda (especially Boëda 2013).

In the context of volumetric reduction of additional type, three different reduction sequences are recognized. A first one (Figure 10) is aimed at the production of flakes and elongated flakes of middle and mostly large dimension[5]. This was done using an alternation of surfaces (type C, sensu Boëda, or SSDA, sensu Forestier, 1993). The second (Figure 11) is aimed at the production of middle and small sized elongated and convergent flakes by means of a hierarchization of the surfaces and of a limited management of convexities, which is restricted to the sub-volume chosen for the production of target products (type D, sensu Boëda). The third (Figure 12), present only in a marginal way, is directed to the search of bladelets using, also in this case, a hierarchization of surfaces and a partial management of the convexity limited to the sub-volume selected to produce the target products (type D, sensu Boëda).

In the context of the volumetric reduction of an integrated type, only one reduction sequence of Levallois type is found (Figure 13). In this latter case, flakes, convergent flakes and Levallois blades of different sizes (large, medium and small) are sought. This

4 The methodological approach and the parameters employed in our work will be illustrated in more details in a future article dedicated to the lithic industries of Riparo del Molare.

5 From a dimensional point of view, in the category of the "target blanks", three size classes can be distinguished: large (> 50 mm), middle (50 mm and 25 mm) and small (<25 mm). Generally, even if there are differences between the various archaeological levels, the most frequent size class is that of the middle blanks. Some large blanks may reflect items not produced at the site but rather imported from outside.



Diacritical Analysis

I phase: debitage unit 1	1-2-3: Opening striking platform (S/P 1) 4-5: Flakes production (D/S 1) from (S/P 1) 6: Re-opening striking platform (S/P 1) accident
	Change of debitage unit
II phase: debitage unit 2	7: Flake production (D/S 2) from (S/P 2) 8: Flakes production (D/S 2) accident
	Change of debitage unit
III phase: debitage unit 3	9-10: Flake production (D/S 3) from (S/P 3) 11: Flake production (D/S 3) from (S/P 4) 12-13: Opening striking platform (P/P 4) 14: Flake production (D/S 3) from (S/P 4) 15-16: Re-opening striking platform (P/P 3)

* debitage unit: striking platform (S/P) + debitage surface (D/S)

Volumetrical concept

- Additional concept
- Alternance of surfaces
- No hierarchy of surface
- No management of volume

Starting blok

- Large flint nodule

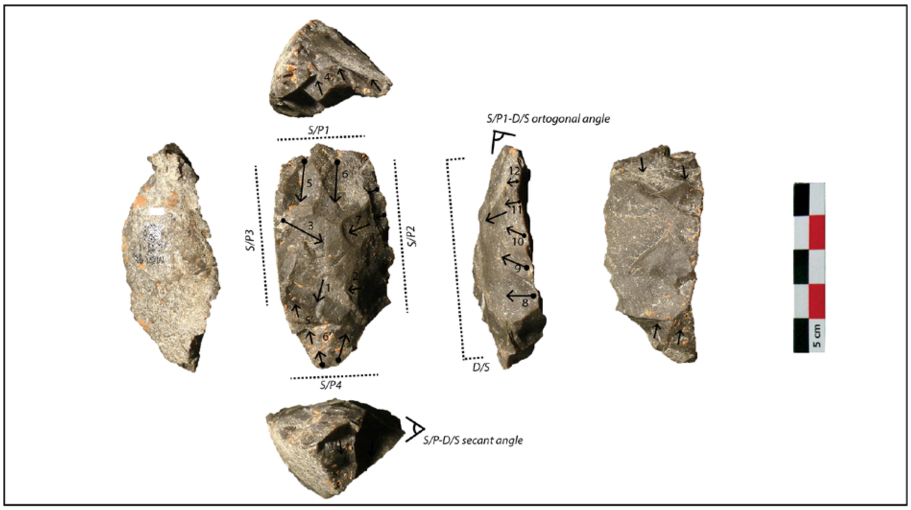
Products reserched

- Flake
- Elongated Flake

Striking platform

- Opening striking platform
- Secant angle S/P1 - D/S1
- Ortogonal angle S/P2 - D/S2

Figure 10. C type additional volumetric structure, reduction sequence of large-medium flakes.



Diacritical Analysis

I phase: production	1: Flake production (D/S) from (S/P1)
II phase: management	2: Lateral convexity management (D/S) from (S/P2) 3: Lateral convexity management (D/S) from (S/P3)
III phase: management	4: Re-opening striking platform (S/P1)
IV phase: production	5-6: Flakes production (D/S) from (S/P1) accident 5'-6': Bipolar blow (D/S) from (S/P4)
VI phase: management or tool confection	7: Re-lateral convexity management (D/S) from (S/P2) 8 to 12: probably denticulade cutting edge confection ?

Volumetrical concept

- Additional concept
- No alternance of surfaces
- Hierarchy of surface
- Convexity management

Starting blok

- Fragment of large flint pebble

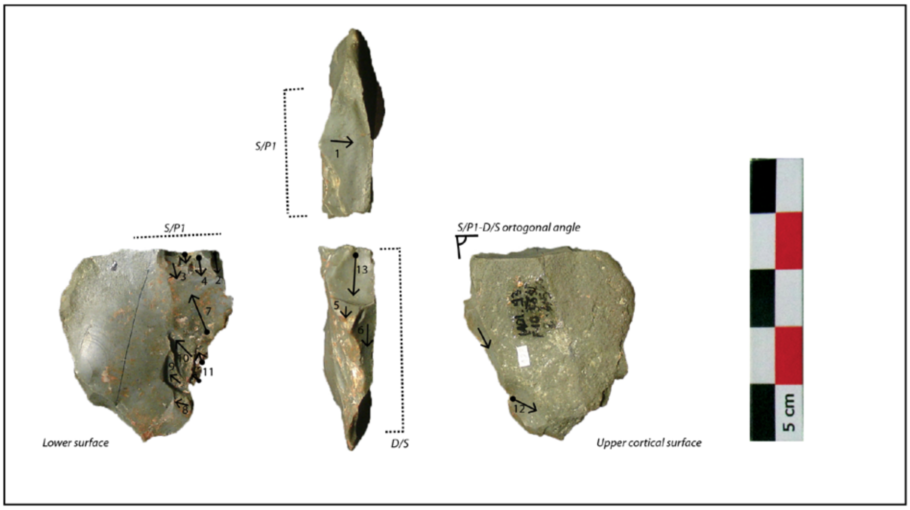
Products reserched

- Elongated Flake
- Convergent Flake
- Flake

Striking platform

- Opening and preparation of striking platform
- Ortogonal angle S/P1-D/S
- Secant angle S/P2 - D/S

Figure 11. D type additional volumetric structure, reduction sequence of medium flakes.



Diacritical Analysis

I phase: management	1: Opening striking platform (S/P)
II phase: management	2to4: Centered convexity management (D/S) from (S/P1)
III phase: production	5-6: Bladelet production (D/S) from (S/P)
IV phase: management	7to12: Centered and distal convexity management (D/S) from (5-6); neo-crest formation
IV phase: production	13: Bladelet production (D/S) from (S/P) accident

Volumetrical concept

- Additional concept
- No alternance of surfaces
- Hierarchy of surface
- Convexity management with neo-crest
- Flake volume core "à tranche"

Starting blok

- Small jasper cortical flake

Products reserched

- Bladelet

Striking platform

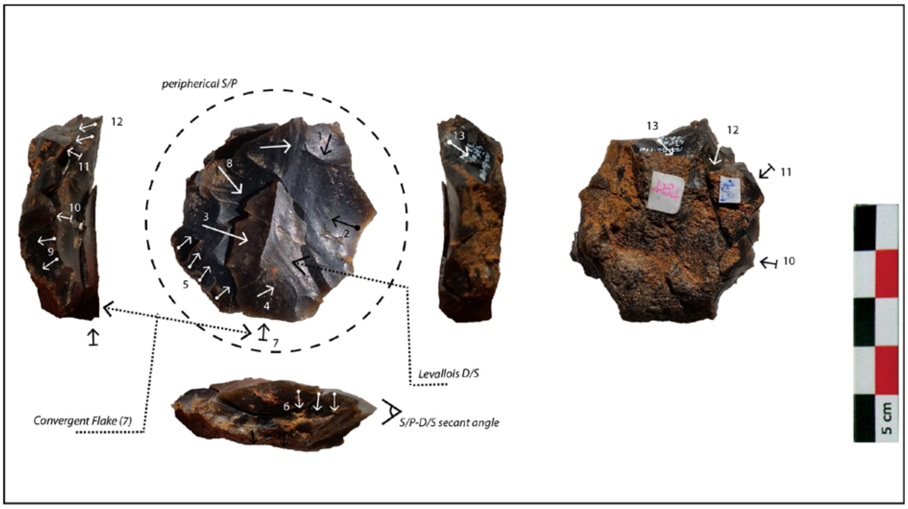
- Opening striking platform
- Ortogonal angle S/P-D/S

Figure 12. D type additional volumetric structure, reduction sequence of bladelets.

is achieved using all of the technical criteria described to define this type of production (type F, sensu Boëda).

In the case of the Riparo del Molare lithic industries, recognizing elements belonging to a Levallois reduction sequence is not straightforward. This aspect will be investigated thoroughly in future works, but the presence of typologically Levallois flakes (Boëda 2013; Boëda *et al.* 2013) coming from additional reduction sequences, on the one side, and the presence of an incomplete Levallois reduction sequence (often only some stages are found: either fully exploited cores or, more often, target flakes), on the other, do not help detecting the Levallois concept in the analysed productions. At the current stage of the research, it appears nonetheless possible to highlight a Levallois technical "savoir faire". Describing how this knowledge is accomplished by the human groups who occupied the site and its diachronic, functional and/or economic meaning will be object of a future work.

Within the context of the Levallois reduction sequence, some target artefacts, whether retouched or not, could be important elements. This is because they are often made on raw materials, which are not present in the assemblage, and by a unipolar Levallois method with little represented stages of the reduction sequence (*e.g.* cores, decortication, management, etc.). They also show dimensional modules larger than the average production.



Diacritical Analysis

I phase: management	1: Lateral convexity management (D/S) from (perip S/P)
II phase: management	2-3: Flake production (D/S) from (perip S/P)
III phase: management	4-5: Lateral convexity management (D/S) from (perip S/P) 6: Re-preparation striking platform (perip S/P)
IV phase: production	7: Convergent Flakes production (D/S) from (perip S/P) 8: Flake production (D/S) from (perip S/P) accident
V phase: management or tool confection	9to13: Re-preparation striking platform (perip S/P)

Volumetrical concept

- Integrated concept
- No alternance of surfaces
- Hierarchy of surface
- Integrated convexity management

Products reserched

- Flake
- Convergent Flake

Striking platform

- Opening and preparation of striking platform
- Secant angle perip S/P- D/S

Starting blok

- Small flint pebble or entame ?

Figure 13. F type integrated volumetric structure, Levallois reduction sequence.

4. Conclusions and future perspectives

As testified by the recent scientific research, the origin of the Levallois in Europe has become a highly debated question in current years. In Italy, recent research made in the sites of Cava dell'Olio and Guado San Nicola have opened the question about the origin and the antiquity of this technical phenomenon in the Peninsula. Together with a problem connected to the antiquity of these industries (for the site of Guado San Nicola, in particular, the origin of Levallois would be pushed back to ca. 400 thousand years ago), the definition of those productions considered as Levallois is equally problematic. Can we see an integrated production in the volumetric reduction of cores of these productions? Or, reversely, can we pick out concepts typical of an additional production by which typologically Levallois products are made? From a diachronic point of view, can we recognize an inner evolution of this phenomenon from these very ancient phases to the more recent ones?

The research project "The Lower Tyrrhenian Versant: a techno-cultural area during the development of the Middle Palaeolithic in Italy?", through the re-analysis of the Riparo del Molare lithic industries will offer new clues for understanding Neanderthal peopling dynamics in the Lower Tyrrhenian Versant.

The presence, at this site, of lithic industries produced during the OIS 5 and characterised by the presence of technical expressions belonging to both a Levallois and an additional type conception, makes it possible to discuss on the very definition of the Levallois concept and of its limits and structural differences with respect to the not-Levallois world.

Furthermore, the intentional production of bladelets, represented by an independent but very ephemeral reduction sequence, appears significant and noteworthy. This, at present, appears to be a kind of evidence never seen before in such an ancient chronological phase. Other works will follow with the aim of describing in detail the technological aspects of these industries, trying in this way to answer the question put forward in this article.

Acknowledgements

The author responsible for the excavation (AR) would like to thank the local Soprintendenza for the support received over the years and the local institutions, in the first instance the S. Giovanni a Piro municipality, for the interest they demonstrated. The colleagues Paolo Gambassini, Paolo Boscato and Adriana Moroni contributed to the research and together with them many students and volunteers made the success of this research possible. We specifically remember friends and irreplaceable collaborators Antonio Mazzoleni, Giuditta Grandinetti, Giuliano Marroni, Renato Mattia, Claudio Alberto Bartoli, Maria Assunta Luperto e Maddalena Serra. A fond memory also for all the workers (especially Antonio Perilli, Aldo Balbi and Ugo Balbi), and Benito di Mauro and his boat, which saved us from billows so many times, Michele Fonseca (longing Cilentano cusine) and to Melina Lombardi for her kindness. Thanks to Nigel Packer for help with the English text.

Contributions

For the realization of this article D.A. set out the research question, made the bibliographic synthesis and analysed the lithic material of Riparo del Molare within the context of his PhD project (26th cycle) at the University of Siena. A.R coordinated investigations at the site of Riparo del Molare and provided the synthesis about the Middle Palaeolithic of the region under examination; both authors wrote the conclusions.

References

Adler, D.S. Wilkinson, K.N. Blockley, S. Mark, D.F. Pinhasi, R. Schmidt-Magee, B.A. Nahapetyan, S. Mallol, C. Berna, F. Glauberman, P.J. Raczynski-Henk, Y. 2014. Early Levallois technology and the Lower to Middle Paleolithic transition in the Southern Caucasus. Science 6204/345, 1609-1613.

Álvarez-Alonso, D. 2014. First Neanderthal settlements in northern Iberia: The Acheulean and the emergence of Mousterian technology in the Cantabrian region. Quaternary International, 326, 288-306.

Arrighi, S. Freguglia, M. Ranaldo, F. Ronchitelli, A. 2009. Production and use in the Lithic Industry of the Mousterian in Santa Croce (Bisceglie, Italy). Human Evolution 24/2, 91-106.

Arzarello, M. 2004. Contributo allo studio del comportamento tecno-economicoe dell'Uomo di Neanderthal: l'industria litica della serie musteriana del Riparo Tagliente (Stallavena di Grezzana, VR, Italia). PhD Thesis, Università di Ferrara.

Arzarello, M. Daffara, S. Berruti, G. Berruto, G. Bertè, D. Berto, C. Gambari, F.M. Peretto, C. 2012. The Mousterian Settlement in the Ciota Ciara Cave: the Oldest Evidence of Homo neanderthalensis in Piedmont (Northern Italy). Journal of Biological Research, 85/1, 71-75.

Arobba, D. Boschian, G. Caramiello, R. Giampietri, A. Negrino, F. Tozzi, C. 2008. La Grotta del Colombo: indagini geoarcheologiche, palinologiche e sull'industria litica, in: Arobba D, Maggi R, Vicino G, (eds). Toirano e la Grotta della Bàsura, Atti del Convegno, Toirano, 26-28 ottobre 2000. Genova-Bordighera: Istituto Internazionale di Studi Liguri, 69-88.

Arobba, D. and Caramiello, R. 2009. Analisi paleobotanica sui sedimenti del Riparo Bombrini (Balzi Rossi, Ventimiglia). Bull. Mus. Anthropol. préhist. Monaco 49, 41-48.

Anzidei, A.P. 2001. Tools from elephant bones at La Polledrara di Cecanibbio and Rebibbia-Casal de' Pazzi, in: Cavarretta, G. Gioia, P. Mussi, M. Palombo, M.R. (eds.). The World of Elephants. Rome: Consiglio Nazionale delle Ricerche, 415-418.

Anzidei, A.P. Bieti, A. Cassoli, P.F. Ruffo, M. Segre, A.G. 1984. Risultati preliminari dello scavo di un deposito pleistocenico in licalità Rebibbia-Casal de' Pazzi (Roma), in: Atti della XXIV Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria, Lazio, 1982. Firenze: Istituto Italiano di Preistoria e Protostoria, 131-139.

Aureli, D. in progress. Il basso versante tirrenico, un'area tecno-culturale durante il Paleolitico medio? Evoluzione delle industrie litiche della sequenza del Riparo del Molare nel quadro delle dinamiche di popolamento neandertaliano in Italia. PhD Thesis, Università degli Studi di Siena.

Bahain, J.-J. Shao, Q. Falguères, C. Garcia, T. Douville, E. Frank, N. 2014. Datation du site de Guado San Nicola par les méthodes de la résonance de spin électronique et du déséquilibre dans les familles de l'uranium combinées (ESR/U-Th), in: Muttillo, B. Lembo, G. Peretto, C. (eds.). L'insediamento a Bifacciali di Guado San Nicola, Monteroduni, Molise. Ferrara: Annali dell'Università di Ferrara, Museologia Scientifica e Naturalistica 10/1, 53-56.

Berto, C. Bertè, D. Luzi, E. López-García, J.M. Pereswiet-Soltan, A. Arzarello, M. 2016. Small and large mammals from the Ciota Ciara cave (Borgosesia, Vercelli, Italy): An Isotope Stage 5 assemblage. Comptes Rendus Palevol 15/6, 669-680.

Biddittu, I. Segre, A.G. Piperno, M. 1984. Rosaneto, Calabria, in I Primi abitanti d'Europa, Catalogo della mostra, Museo Nazionale Preistorico Etnografico « L. Pigorini ». Roma: De Luca, 151-154.

Bisi, E. Coltorti, M. Peretto, C. 1982. Le industrie dell'interglaciale Riss-Wiirm del terrazzo fluviale di Erbarella Jesi, Ancona, in: Il Paleolitico inferiore in Italia, Atti della XXIII riunione scientifica dell'Istituto Italiano di Preistoria e Protostoria, Firenze, maggio 1980. Firenze: Istituto Italiano di Preistoria e Protostoria, 329-359.

Blanc, A.C. 1956. Il più antico reperto fossile umano nel Lazio rinvenuto a Roma: un secondo metatarsale destro umano ed industria paleolitica nelle ghiaie superiori della Sedia del Diavolo (Roma). Quaternaria III, 342-244.

Blanc, A.C. 1962. La Grotta dei Giganti. Quaternaria V, 308-310.

Blanc, A.C. and Segre A. 1953. Excurtion dans les Abruzzes, les Puilles et sur la cote de Salerne, IV Congr. INQUA, Roma-Pisa. Roma.

Bocchini, A. and Coltorti, M. 1982. L'industria di tecnica Levallois e facies Levallois di Colonia Montani nella Vallesina (Ancona), in: Il Paleolitico inferiore in Italia, Atti della XXIII riunione scientifica dell'Istituto Italiano di Preistoria e Protostoria. Firenze: Istituto Italiano di Preistoria e Protostoria, 383-414.

Boëda, E. 2013. Techno-logique & technologie. Une Paléo-histoire des objets lithiques tranchants. Prigonrieux: @ rchéo-éditions.

Boëda, E. Hou, Y.M. Forestier, H. Sarel, J. and Wang, H.M. 2013. Levallois and non-Levallois blade production at Shuidonggou in Ningxia, North China. Quaternary International 295, 191-203.

Borzatti von Löwenstern, E. 1966. Alcuni aspetti del Musteriano del Salento. Rivista di Scienze Preistoriche XXI/2, 203-287.

Borzatti von Löwenstern, E. and Magaldi, D. 1967. Ultime ricerche nella grotta dell'Alto (Santa Caterina – Nardò). Rivista di Scienze Preistoriche XXII/2, 205-250.

Borzatti von Löwenstern, E. 1970. Prima campagna di scavi nella Grotta Mario Bernardini (Nardò-Lecce). Rivista di Scienze Preistoriche XXV/1, 89-125.

Borzatti von Löwenstern, E. 1971. Seconda campagna di scavi nella Grotta Mario Bernardini (Nardò-Lecce). Rivista di Scienze Preistoriche XXVI/1, 31-62.

Boscato, P. Cattani, L. Cuda, M.T. Martini, F. 1991. Il Musteriano della grotta di S. Francesco a Belvedere di Cetona. Rivista di Scienze Preistoriche XLIII, 16-64.

Boscato, P. and Ronchitelli, A. 2004. Paléosurfaces du Paléolithique moyen : l'exemple de Scario (Salerno – Italie du Sud), in: Actes du XIVème Congrès UISPP, Université de Liège, Section 5. BAR, International Series 1239. Oxford: Archaeopress, 283-292.

Boscato, P. and Ronchitelli, A. 2006. La serie esterna di Paglicci. Gli scavi del 2004-2005, in: Gravina, A. (ed). 26° Convegno sulla Preistoria-Protostoria e Storia della Daunia, San Severo 2005. San Severo: Archeoclub d'Italia, 26, 3-16.

Boscato, P. Boschian, G. Caramia, F. Gambassini, P. 2009. Il Riparo del Poggio a Marina di Camerota (Salerno): culture ed ambiente. Rivista di Scienze Preistoriche LIX, 5-40.

Boscato, P. Crezzini, J. Freguglia, M., Gambassini, P., Ranaldo, F., Ronchitelli, A., 2010. Activités de subsistance et exploitation des ressources de l'environnement à S. Croce (Bisceglie e Bari e Italie du Sud): les unités stratigraphiques 546 et 535 du Paléolithique moyen, in: Conard, N.-J. and Delagnes, A. (eds.), Settlement Dynamics of the Middle Palaeolithic and Middle Stone Age, vol. III. Tübingen: Kerns Verlag, 265-282.

Boscato, P. Gambassini, P. Ranaldo, F. Ronchitelli, A., 2011. Management of Paleoenvironmental Resources and Raw materials Exploitation at the Middle Paleolithic Site of Oscurusciuto (Ginosa, Southern Italy): Units 1 and 4, in: Conard, N.J. and Richter, J. (eds). Neanderthal Lifeways, Subsistence and Technology. Springer, 87-98.

Bulgarelli, G.M. 1972, Il Paleolitico della Grotta di Torre Nave (Praia a Mare – Cosenza). Quaternaria XVI, 149-188.

Bulgarelli, G.M. 1974. Industrie musteriane della Barma Grande al Balzi Rossi di Grimaldi (Liguria). Memorie dell'Istituto Italiano di Paleontologia Umana II, 91-129.

Campetti, S. 1986. Il musteriano della Grotta di Serra Cicora A nell'ambito dell'evoluzione del Paleolitico nel Salento. Studi per l'Ecologia del Quaternario 8, 85-115.

Caramia, F. 2008. Il Paleolitico medio del Cilento. La successione delle industrie litiche in area camerotana. PhD Thesis, Università degli Studi di Siena.

Cauche, D. 2002. Les cultures moustériennes en Ligurie italienne : études des industries lithiques des grottes de la Madonna dell'Arma, d'Arma delle Manie et de Santa Lucia Superiore. PhD Thesis, Université de la Méditerranée Aix-Marseille II.

Cauche, D. 2007. Les cultures moustériennes en Ligurie italienne : analyse du matériel lithique de trois sites en grotte. L'Anthropologie 111, 254-289.

Cauche, D. 2012. Productions lithiques et comportements techno-économiques de groupes humains acheuléens et moustériens en région liguro-provençale. C. R. Palevol 11, 519-527.

Carmignani, L. 2011. Le ultime espressioni del Musteriano nell'Italia del Sud-Est. Variabilità tecnologiche e comportamenti tecno-economici in un Contesto Peninsulare. I casi studio di Grotta del Cavallo e Grotta Mario Bernardini. Nardò (Lecce). PhD Thesis, Università degli Studi di Siena.

Coltorti, M. Cremaschi, M. Peretto, C. 1982. Industria di facies Levallois a Ponte di Crispiero (Marche), in: Il Paleolitico inferiore in Italia, Atti della XXIII della riunione scientifica dell'Istituto Italiano di Preistoria e Protostoria, Firenze, maggio 1980. Firenze: Istituto Italiano di Preistoria e Protostoria, 415-428.

Coltorti, M. and Pieruccini, P. 2006. The last interglacial pedocomplexes in the litho- and morpho-stratigraphical framework of the central-northern Apennines (Central Italy). Quaternary International 156-157, 118-132.

Cremaschi, M. and Peretto, C. 1977. Il Paleolitico dell'Emilia e Romagna, in Atti della XIX riunione scientifica dell'Istituto Italiano di Preistoria e Protostoria. Firenze: Istituto Italiano di Preistoria e Protostoria, 15-78.

Cremaschi, M. Zerboni, A. Nicosia, C. Negrino, F. Rodnight, H. Spötl, C. 2015. Age, soil-forming processes, and archaeology of the loess deposits at the Apennine margin of the Po plain (northern Italy): New insights from the Ghiardo area. Quaternary International 376, 173-188.

Cuda, T. and Palma di Cesnola, A. 2004. Le nostre attuali conoscenze sui siti paleolitici di Cirella e Scalea. Atti della XXXVII riunione scientifica dell'Istituto Italiano di Preistoria e Protostoria. Firenze: Istituto Italiano di Preistoria e Protostoria, 67-83.

Daffara, S. Arzarello, M. Berruti, G.L.F. Berruto, G. Bertè, D. Berto, C. Casini, A.I. 2014. The Mousterian lithic assemblage of the Ciota Ciara cave (Piedmont, Northern Italy): exploitation and conditioning of raw materials. Journal of Lithic Studies 1/2, 63-78.

Delagnes, A. and Meignen, L. 2006. Diversity of lithic production systems during the Middle Paleolithic in France, in: Hovers, E. and Kuhn, S.L. (eds). Transitions before the transition. Springer, 85-107.

Dibble, H. and Bar-Yosef, O. 1995. The definition and interpretation of Levallois technology. Madison WI: Prehistory.

Dini, M. 2011. L'industria Musteriana di Grotta La Fabbrica (Grosseto). Origini 33, 7-19.

Dini, M., Mazzasalma, S. Tozzi, C. 2007. Il Paleolitico medio di Grotta La Fabbrica (Parco dell'Uccellina – Grosseto), in: Cavanna C. (ed.). Atti del Museo di Storia Naturale della Maremma, supplemento al n. 22. Grosseto: Grafiche Effesei, 31-52.

Dini, M. and Khoeler H. 2009. The contribution of new methodological approaches to explaining the Final Middle Paleolithic of the Apuane Alps (Tuscany, Italy). Human evolution 24/1, 13-25.

Doronichev, V. 2016. The Pre-Mousterian industrial complex in Europe between 400 and 300 ka: Interpreting its origin and spatiotemporal variability. Quaternary International 409, 222-240.

Douka, K. Grimaldi, S. Boschian, G. del Lucchese, A. Higham, T.F.G. 2012. A new chronostratigraphic framework for the Upper Palaeolithic of Riparo Mochi (Italy). Journal of Human Evolution 62, 286-299.

Douka, K. Higham, T.F. Wood, R. Boscato, P. Gambassini, P. Karkanas, P. Peresani, M. Ronchitelli, A.M. 2014. On the chronology of the Uluzzian. Journal of human evolution 68, 1-13.

Falguères, C. Yokoyama, Y. Bibron, A. 1990. Electron Spin Resonance (ESR) Dating of Hominid-Bearing Deposits in the Caverna delle Fate, Ligure, Italy. Quaternary Research 34, 121-128.

Fiore, I. Gala, M. Tagliacozzo, A. 2004. Ecologyand Subsistence Strategies in the Eastern Italian Alps during the Middle Palaeolithic. International Journal of Osteoarchaeology 14, 273-286.

Fontana, F. Nenzioni, G. Peretto, C. 2010. The southern Po plain area (Italy) in the mid-late Pleistocene: Human occupation and technical behaviours. Quaternary International 223-224, 465-471.

Fontana, F. Moncel, M.H. Nenzioni, G. Onorevoli, G. Peretto, C. Combier, J. 2013. Widespread diffusion of technical innovations around 300,000 years ago in Europe as a reflection of anthropological and social transformations? New comparative data from the western Mediterranean sites of Orgnac (France) and Cave dall'Olio (Italy). Journal of Anthropological Archaeology 32/4, 478-498.

Forestier H. 1993. Le Clactonien: mise en application d'une nouvelle méthode de débitage s'inscrivant dans la variabilité des systèmes de production lithique du Paléolithique ancien. Paléo 5, 53-82.

Freguglia, M. and Palma di Cesnola, A. 2006. L'origine del Musteriano nel Gargano. II: il Premusteriano dello strato 1 EB dell'area esterna del giacimento di Paglicci e considerazioni conclusive. Rivista di scienze preistoriche LVI, 5-38.

Galiberti, A. Palma di Cesnola, A. Freguglia, M. Perrini, L. Giannoni, L. 2008. Le industrie litiche dello strato 2 del Riparo esterno di Paglicci nel saggio del 1971: lo studio tipologico. Bullettino di Paletnologia Italiana 97, 1-56.

Gambassini, P. 1997. Il Paleolitico di Castelcivita. Culture e ambiente. Napoli: Electa Editore.

Gambassini, P. and Ronchitelli, A. 1998. Linee di sviluppo dei complessi del Paleolitico inferiore-medio nel Cilento. Rivista di Scienze Preistoriche XLIX, 357-378.

Gamble, C. and Roebroeks, W. 1999. The Middle Paleolithic: a point of inflexion, in: Roebroeks, W. and Gamble, C. (eds). The Middle Paleolithic occupation of Europe. Leiden: Leiden University Press, pp. 3-21.

Giaccio, B. Isaia, R. Fedele, F.G. Di Canzio, E. Hoffecker, J. Ronchitelli, A. Sinitsyn, A.A. Anikovich, M. Lisitsyn, S.N. 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, 208-226.

Giunti, P. and Longo, L. 2008. Prime considerazioni sulla variabilità del sistema tecnico Levallois dello strato III di Riparo Mezzena (Monti Lessini, Italia settentrionale). Rivista di Scienze Preistoriche LVIII, 5-28.

Grimaldi, S. 1998. Analyse technologique, chaîne opératoire et objectifs techniques. Torre in Pietra (Rome, Italie). Paléo 10, 109-122.

Grimaldi, S. and Spinapolice, E. 2010. The Late Mousterian Of The Grotta Breuil (Monte Circeo, Lazio, Italy): Interpreting New And Ancient Data. in: Burdukiewicz, J.M. and Wiśniewski A. (eds). Proceedings of the International Conference "Middle Palaeolithic Human Activity and Paleoecology: New Discoveries and Ideas", (22-24 June 2006, Wroclaw, Poland). Wroclaw: Acta Universitatis Wratislaviensis 3207 Studia Archeologiczne XLI, 413-424.

Grimaldi, S. and Santaniello, F. New insights into Final Mousterian lithic production in western Italy. Quaternary International 350, 116-129.

Klempererová, H. 2012. Functional analysis applied to the lithic assemblage of the final Middle Palaeolithic and beginning of the Upper Palaeolithic with the aim to reconstruct behavior of ancient human groups. PhD Thesis, Università degli Studi di Siena.

Kuhn, S.L. 1995 Mousterian lithic technology and raw material economy : a cave study. Princeton: Princeton University Press.

Leger, E. 2012. Interpretazione tecnologica ed economica dell'industria litica dell'Arma delle Manie (strati V, IV, III, II). I livelli musteriani dello Stadio Isotopico 3. Master Thesis, Università degli Studi di Ferrara.

Lenzi, F. and Nenzioni, G. 1996. Lettere di pietra – I depositi pleistocenici: sedimenti, industrie e faune del margine appenninico bolognese. Bologna: Editrice Compositori.

Longo, L. Boaretto, E. Caramelli, D. Giunti, P. Lari, M. Milani, L. A. Mannino, A.M. Sala, B. Thun Hohenstein, U. Condemi, S. 2012. Did Neandertals and anatomically modern humans coexist in northern Italy during the late MIS 3? Quaternary International 259, 102-112.

Lumley (de), H. Arobba, D. Cauche, D. Desclaux, E. Echassoux, A. Khatib, S. Ricci, M. Roussel, B. Simon, P. Tozzi, C. Valensi, P. Vicino, G. 2008. Les cultures acheuléennes et moustériennes dans les Alpes-Maritimes et en Ligurie. Bull. Mus. Anthropol. préhist. Monaco, suppl. 1, 11-20.

Malatesta, A. 1978. La serie di Torre in Pietra nel quadro del Pleistocene Romano in Torre in Pietra, Roma. Quaternaria 20, 537-577.

Mallegni, F. and Ronchitelli, A. 1987. Découverte d'une mandibule néanderthalienne à l'Abri du Molare près de Scario (Salerno, Italie) : observations stratigraphiques et palethnologiques, étude anthropologique. L'Anthropologie 91, 163-174.

Mallegni, F. and Ronchitelli, A. 1989. Deciduous teeth of the Neandertal mandible from Molare Shelter, near Scario (Salerno, Italy). American Journal of Physical Anthropology 79, 475-482.

Marra, F. Sottili, G. Gaeta, M. Giaccio, B. Jicha, B. Masotta, M., Palladino, D.M. Deocampo, D.M. 2014. Major explosive activity in the Monti Sabatini Volcanic District (central Italy) over the 800-390 ka interval: Geochronological – geochemical overview and tephrostratigraphic implications. Quaternary Science Reviews 94, 74-101.

Mehidi, N., 2005. Datation de sites moustériens de Ligurie par les méthodes U/Th et RPE : Abri Mochi et Arma delle Manie. PhD Thesis, Muséum National d'Histoire Naturelle de Paris.

Menéndez L. 2009. La transición del modo 2 al modo 3 vista a través de la industria lítica de gran dolina td10 y orgnac 3. Desarrollo tecnológico y posibles implicaciones ocupacionales de los conjuntos. PhD Thesis, Universitat Rovira i Virgili, Tarragona.

Moncel, M.-H. Moigne, A.-M. Youssef, S. Combier, J. 2011. The emergence of Neanderthal technical behaviour: new evidence from Orgnac 3 (Level 1, MIS 8) (South-eastern France). Current Anthropology 52 /1, 37-75.

Moncel, M.-H. Moigne, A.-M. Combier, J. 2012. Towards the Middle Paleolithic in Western Europe: the case of Orgnac 3 (South-Eastern France). Journal of Human Evolution 63, 653-666.

Moroni Lanfredini, A. Freguglia, M. Bernardini, F. Boschian, G. Cavanna, C. Crezzini, J Gambogi, P. Longo, L. Milani, L. Parenti, F. Ricci, S. 2010. Nuove ricerche alla Grotta dei Santi (Monte Argentario, Grosseto), in: Negroni Catacchio, N. (ed). Atti del Nono Incontro di Studi Preistoria e Protostoria in Etruria – Valentano (Vt) – Pitigliano (Gr), 12-14 Settembre 2008. Firenze: Istituto Italiano di Preistoria e Protostoria, 649-662.

Muttillo, B. Lembo, G. Peretto, C. 2014. L'insediamento a bifacciali di Guado S. Nicola, Monteroduni, Molise, Italia. Ferrara: Annali dell'Università di Ferrara, Museologia Scientifica e Naturalistica 10/ 1.

Nicoud, E. 2013. Le paradoxe acheuléen. Paris-Rome: Comité des travaux historiques et scientifiques, Documents Préhistoriques 32, Bibliothèque des Écoles françaises d'Athènes et de Rome 356.

Negrino, F. and Tozzi, C. 2008. Il Paleolitico in Liguria. Bull. Mus. Anthropol. préhist. Monaco, suppl. 1, 21-28.

Onoratini, G. Arellano, A. Del Lucchese, A. Moullé, P.E. Serre, F. 2012. The Barma Grande cave (Grimaldi, Vintimiglia, Italy): From Neandertal, hunter of "Elephas antiquus", to Sapiens with ornaments of mammoth ivory. Quaternary International 255, 141-157.

Palma di Cesnola, A. 2001. Il Paleolitico inferiore e medio in Italia. Firenze: Museo Fiorentino di Preistoria "Paolo Graziosi".

Palma di Cesnola, A. 2004. Il Paleolitico inferiore e medio della Calabria, in: Atti della XXXVII riunione scientifica dell'Istituto Italiano di Preistoria e Protostoria. Firenze: Istituto Italiano di Preistoria e Protostoria, 19-34.

Palma di Cesnola, A. and Freguglia, M. 2005 L'origine del Musteriano nel Gargano. Il premusteriano degli strati 26-28 della Grotta Paglicci. Rivista di Scienze Preistoriche LV, 139-168.

Peresani, M. 1996. The Levallois reduction strategy at the Cave of San Bernardino (Northern Italy), in: Bietti, A. Grimaldi, S. (eds.). Reduction Processes (chaînes opératoires) in the European Mousterian. Quaternaria Nova 5, 205-236.

Peresani, M. 2001. Méthodes, objectifs et flexibilité d'un système de production Levallois dans le Nord de l'Italie. L'Anthropologie 105, 351-368.

Peresani, M. and Porraz, G. 2004. Ré-interprétation et mise en valeur des niveaux moustériens de la Grotte du Broion (Monti Berici, Vénétie). Etude techno-économique des industries lithiques. Rivista di Scienze Preistoriche LI, 181-247.

Peresani, M. 2012. Variability in lithic technology from the recent Middle Palaeolithic to the Uluzzian across the 50ky record of Fumane Cave. Quaternary International 247, 125-150.

Peresani, M. Romandini, M. Duches, R. Jéquier, C. Nannini, N. Pastoors, A. Picin, A. Schmidt, I. Vaquero, M. Weniger, G.-C. 2014 New evidence for the Mousterian and Gravettian at Rio Secco Cave, Italy. Journal of Field Archaeology 39/4, 401-416.

Peretto, C. and Scarpante, L. 1982. Le industrie del Paleolitico inferiore di Monte Conero (Ancona). in Il Paleolitico inferiore in Italia, Atti della XXIII della riunione scientifica dell'Istituto Italiano di Preistoria e Protostoria, Firenze, maggio 1980. Firenze: Istituto Italiano di Preistoria e Protostoria, 361-382.

Peretto, C. La Rosa, M. Liboni, A. Milliken, S. Sozzi, M. Zarattini, A. 1997. Le gisement de Quarto delle Cinfonare dans le cadre du Paléolithique inférieur de l'Italie Ouest-centrale. L'Anthropologie 101, 597-615.

Peretto, C. L'insediamento musteriano di Grotta Reali Rocchetta a Volturno, Molise, Italia. Ferrara: Annali dell'Università di Ferrara, Museologia Scientifica e Naturalistica 8/2.

Peretto, C. Arzarello, M. Bahain, J.-J. Boulbes, N. Coltorti, M. De Bonis, A. Douville, E. Falguères, C. Frank, N. Garcia, T. Lembo, G. Moigne, A.-M. Morra, V. Muttillo, B. Nomade, S. Shao, Q. Perrotta, A. Pieruccini, P. Rufo, M. Sala, B. Scarpati, C. Thun Hohenstein, U. Tessari, U. Turrini, M.C. Vaccaro, C. 2014. L'occupazione umana del Pleistocene medio di Guado San Nicola (Monteroduni, Molise), in: Peretto, C. Arzarello, M. Arnaud, J. (eds.). Variabilità umana tra passato e presente, XX congresso dell'AAI Ferrara, 11-13 settembre 2013. Ferrara: Annali dell'Università di Ferrara Museologia Scientifica e Naturalistica, 23-31.

Peretto, C. Arzarello, M. Bahain, J.J. Boulbes, N. Dolo, J.M. Douville, E. Falguères, C. Frank, N. Garcia, T. Lembo, G. Moigne, A.M. 2016. The Middle Pleistocene site of Guado San Nicola (Monteroduni, Central Italy) on the Lower/Middle Palaeolithic transition. Quaternary International 411/ B, 301-315.

Picin, A. Peresani, M. Falguères, C. Gruppioni, G. Bahain, J.-J., 2013. San Bernardino Cave (Italy) and the Appearance of Levallois Technology in Europe: Results of a Radiometric and Technological Reassessment. Plos ONE 8/10, e76182.

Piperno, M. 1975. L'industria musteriana su calcare di Grotta Romanelli. Roma: Memorie dell'Istituto Italiano di Paleontologia Italiana 2.

Pirouelle, F. 2006. Contribution méthodologique à la datation, par les méthodes Uranium-Thorium (U-Th) et Résonance de Spin Electronique (ESR), de sites Moustériens de Ligurie, de France et de Belgique. PhD Thesis, Muséum National d'Histoire Naturelle de Paris.

Pitti, C. and Tozzi, C. 1971. La Grotta del Capriolo e la Buca della Iena presso Mommio (Camaiore). Sedimenti, fauna, industria litica. Rivista di Scienze Preistoriche XXVI, 213-258.

Porraz, G. 2005. En marge du milieu alpin. Dynamiques de formation des ensembles lithiques et modes d'occupation des territoires au Paléolithique moyen. PhD Thesis, Université de Provence, Aix-Marseille I.

Radmilli, A.M. 1964. Abruzzo preistorico. Il Paleolitico inferiore-medio abruzzese. Firenze: Sansoni.

Radmilli, A.M. and Boschian, G. 1996. Gli scavi a Castel di Guido. Firenze: Istituto Italiano di Preistoria e Protostoria.

Ranaldo F. in progress. Considerazioni sull'interpretazione della variabilità dei sistemi tecnici nel passaggio dal Paleolitico medio a quello superiore nell'Italia meridionale. PhD Thesis, Università degli Studi di Siena.

Riel-Salvatore, J. Ludeke, I.C. Negrino, F. Holt, B.M. 2013. A Spatial Analysis of the Late Mousterian Levels of Riparo Bombrini (Balzi Rossi, Italy). Canadian Journal of Archaeology/Journal Canadien d'Archéologie 37, 70-92.

Roebroeks, W. and Tuffreau, A. 1999. Paleoenvironment and settle- ment patterns of the northwest European Middle Paleolithic, in: Roebroeks, W. and Gamble, C. (eds). The Middle Paleolithic occupation of Europe. Leiden: Leiden University Press, pp. 121-138.

Romagnoli, F. 2012. Risorse litiche e comportamento tecnico dei Neandertaliani: variabilità culturale e adattamento all'ambiente nel Salento. Grotta del Cavallo, strati L-N, e Grotta Mario Bernardini, strato D. PhD Thesis, Università degli Studi di Firenze, Universitat Rovira i Virgili.

Ronchitelli, A. 1993. Paleosuperfici del Paleolitico medio al Molare di Scario (Salerno), in: Atti della XXX Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria. Firenze: Istituto Italiano di Preistoria e Protostoria, 233-246.

Ronchitelli, A. Freguglia, M. Boscato, P. 2010. Paléoécologie et stratégies de subsistance à l'Abri du Molare de Scario (S. Giovanni a Pirro – Salerno – Italie de Sud) : niveaux Paléolithique moyen 44-49, données préliminaires, in: Conard, N.J. and Dlagens, A. (ed.). Settlement Dynamics of the Middle Paleolithic and Middle Stone Age, Volume III. Tübingen: Kerns Verlag, 249-264.

Ronchitelli, A. Boscato, P. Surdi, G. Masini, F. Petruso, D. Accorsi, C.A. Torri, P. 2011a. The Grotta Grande of Scario (Salerno, Italy): Archaeology and environment during the last interglacial (MIS 5) of the Mediterranean region. Quaternary International 231, 95-109.

Ronchitelli, A. Freguglia, M. Longo, L. Moroni Lanfredini, A. Ranaldo, F. 2011b. Studio tecno-funzionale dei supporti a morfologia triangolare dell'US 8 del Riparo L'Oscurusciuto (Ginosa-Taranto). Rivista di scienze preistoriche, LXI, 5-20.

Rufo, E. 2008. Sistemi tecnici di produzione nel Musteriano recente. Analisi tecnologica dell'industria litica del sito di Grotta Reali (Rocchetta a Volturno, Molise, Italia). PhD Thesis, Università degli Studi di Ferrara.

Santucci, E. Marano, F. Cerilli, E. Fiore, I. Lemorini, C. Palombo, M.R. Anzidei, A.P. Bulgarelli, G.M. in press. Palaeoloxodon exploitation at the Middle Pleistocene site of La Polledrara di Cecanibbio (Rome, Italy). Quaternary International.

Sardella, R. Bertè, D. Iurino, D.A. Cherin, M. Tagliacozzo, A. 2014. The wolf from Grotta Romanelli (Apulia, Italy) and its implications in the evolutionary history of Canis lupus in the Late Pleistocene of Southern Italy. Quaternary International 328-329, 179-195.

Schwarcz, H.P. Buhay, W. Grun, R. Stiner, M.C. Kuhn, S. Miller, G.H. 1991. Absolute dating of sites in coastal Lazio. Quaternaria Nova 1, 51-67.

Silvestrini, M. Bassetti, M. Boscato, P. Coltorti, M. Esu, D. Lemorini, C. Magnatti, M. Peresani, M. Rossetti, P. 2001. An Acheulean site of the last Interglacial at Boccabianca (Cupra Marittima, Marche). Rivista di Scienze Preistoriche LI, 21-71.

Soriano S. 2000. Outillage bifacial et outillage sur éclat au Paléolithique ancien et moyen : coexistence et interaction. PhD Thesis, Université Paris X-Nanterre.

Spagnolo, V. Marciani, G. Aureli, D. Berna, F. Boscato, P. Ranaldo, F. Ronchitelli, A. 2016. Between hearths and volcanic ash: The SU 13 palimpsest of the Oscurusciuto rock shelter (Ginosa – Southern Italy): Analytical and interpretative questions. Quaternary International 417, 105-121.

Spinapolice, E. 2008. Technologie lithique et circulation des matières premières au Paléolithique moyen dans le Salento (pouilles, Italie méridionale) : perspectives comportementales. PhD Thesis, Università di Roma "La Sapienza", Université Bordeaux 1.

Spinapolice, E. 2014. Il Paleolitico antico e medio della Calabria, in: Cerzoso, M. and Vanzetti, A. (eds.). Catalogo dell'esposizione del Museo dei Brettii e degli Enotri. Catanzaro: Rubbettino Editore, 35-39.

Talamo, S. Peresani, M. Romandini, M. Duches, R. Jéquier, C., Nannini, N. Pastoors, A. Picin, A. Vaquero, M. Weniger, G.-C. Hublin, J.-J. 2014. Detecting Human Presence at the Border of the Northeastern Italian Pre-Alps. 14C Dating at Rio Secco Cave as Expression of the First Gravettian and the Late Mousterian in the Northern Adriatic Region. Plos ONE 9/4, e95376.

Taschini, M. 1967. Il « protopontiniano» rissiano di Sedia del Diavolo e di Monte delle Gioie. Quaternaria IX, 301-319.

Taschini, M. 1972. Sur le Paléolithique de la plaine Pontine (Latium). Quaternaria XIV, 203-223.

Taschini, M. 1979. L'industrie lithique de Grotta Guattari au Mont Circé (Latium): définition culturelle, typologique et chronologique du Pontinien. Quaternaria XXI, 179-247.

Tavoso, A. 1988. L'outillage du gisement de San Francesco à San Remo (Ligurie, Italie): nouvel examen, in L'homme de Néandertal 8: La Mutation, (Ed). Kozloswski J. K., ERAUL 35, p. 193-210.

Tozzi, C. 1970. La Grotta di S. Agostino (Gaeta), Rivista di Scienze Preistoriche XXV/l, 3-87.

Tozzi, C. 1974. L'industria musteriana della Grotta di Gosto sulla Montagna di Cetona (Siena). Rivista di Scienze Preistoriche XXIX/2, 271-304.

Tuffreau, A. 1982. The transition Lower/Middle Palaeolithic in Northern France, in: Ronen, A. (ed.). The Transition from Lower to Middle Palaeolithic and the Origin of Modern Man. BAR International Series 151.Oxford: Archaeopress, 137-149.

Valadas, H. Chadelle, J.P. Geneste, J.M. Joron, J.L. Meignen, L. Texier, P.-J. 1987. Datations par la thermoluminescence de gisements moustériens du sud de la France. L'Anthropologie 91/1, 211-226.

Vitagliano, S. 1984. Nota sul Pontiniano della Grotta dei Moscerini, Gaeta (Latina), in: Il Paleolitico e il Mesolitico nel Lazio, Atti della XXIV Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria, Roma, ottobre 1982. Firenze: Istituto Italiano di Preistoria e Protostoria, 155-164.

Vitagliano, S. 2007. Il Musteriano evoluto e finale (F27-F23) della Grotta del Fossellone (San Felice Circeo, Latina), in: Strategie di insediamento fra Lazio e Campania in età preistorica e protostorica, Atti della XL Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria, Roma, Napoli, Pompei, 30 novembre-3 dicembre 2005. Firenze: Istituto Italiano di Preistoria e Protostoria, 307-317.

Vitagliano, S. and Piperno, M. 1991. Lithic industry of level 27 beta of the Fossellone cave (S. Felice Circeo, Latina). Quaternaria Nova 1, 289-304.

Vitagliano, S. and Bruno, M. 2012. Late and final mousterian setting in the Fossellone Cave (Latium, Italy): Patterns of settlement, micro-environmental factors and evidence of coloured material in a transitional context. Quaternary International 259, 48-58.

Wiśniewski, A. 2014. The beginnings and diversity of Levallois methods in the early Middle Palaeolithic of Central Europe. Quaternary International, 326, 364-380.

Yamada, M. 1997. L'industrie lithique moustérienne de la Barma Grande aux Balzi Rossi (Ligurie, Italie). L'Anthropologie 101/3, 512-521.

Neanderthal mobility pattern and technological organization in the Salento (Apulia, Italy)

Enza Elena Spinapolice[1]

Abstract

The Salento, in the southeast of Italy, is rich in Mousterian sites and Neanderthal fossils, within the chronological time frame of the Upper Pleistocene. This region is well known for the absence of good quality raw materials. This paper presents results from the technological study of five Mousterian sites (Grotta Romanelli, Grotta Uluzzo C, Grotta Mario Bernardini, Grotta Torre dell'Alto, Grotta dei Giganti), showing technological organization, curation and expediency behaviours, probably related to a logistical mobility. This variability is becoming part of our understanding of Neanderthal behaviour, marked by a fragmentation of stone working in space, time and social dimensions and a planned and complex organisation, until recently considered as distinctive to modern *Homo sapiens*.

Keywords: Apulia (Italy), Mousterian, Neanderthals, raw material, mobility.

1. Introduction

The way lithic artefacts are procured, used, maintained and discarded, is strongly linked to hunter-gatherer resource exploitation strategies (Andrefsky 2009). This is because the use and depletion of lithic implements is influenced by factors such as raw material availability, site economy, site use and group mobility (Nelson 1991). Therefore, studies of lithic technology in restricted areas within a controlled period are useful to determine past hunter-gatherer land use patterns and social systems.

1 Dipartimento di Scienze dell'Antichità, Museo delle Origini, Università Roma La Sapienza; enzaelena.spinapolice@uniroma1.it & Leverhulme Centre for Human Evolutionary Studies, Department of Archaeology & Anthropology, University of Cambridge.

in: Borgia, V. and E. Cristiani (eds.) 2018: *Palaeolithic Italy. Advanced studies on early human adaptations in the Apennine peninsula*, Sidestone Press Academics (Leiden), pp. 95-124.

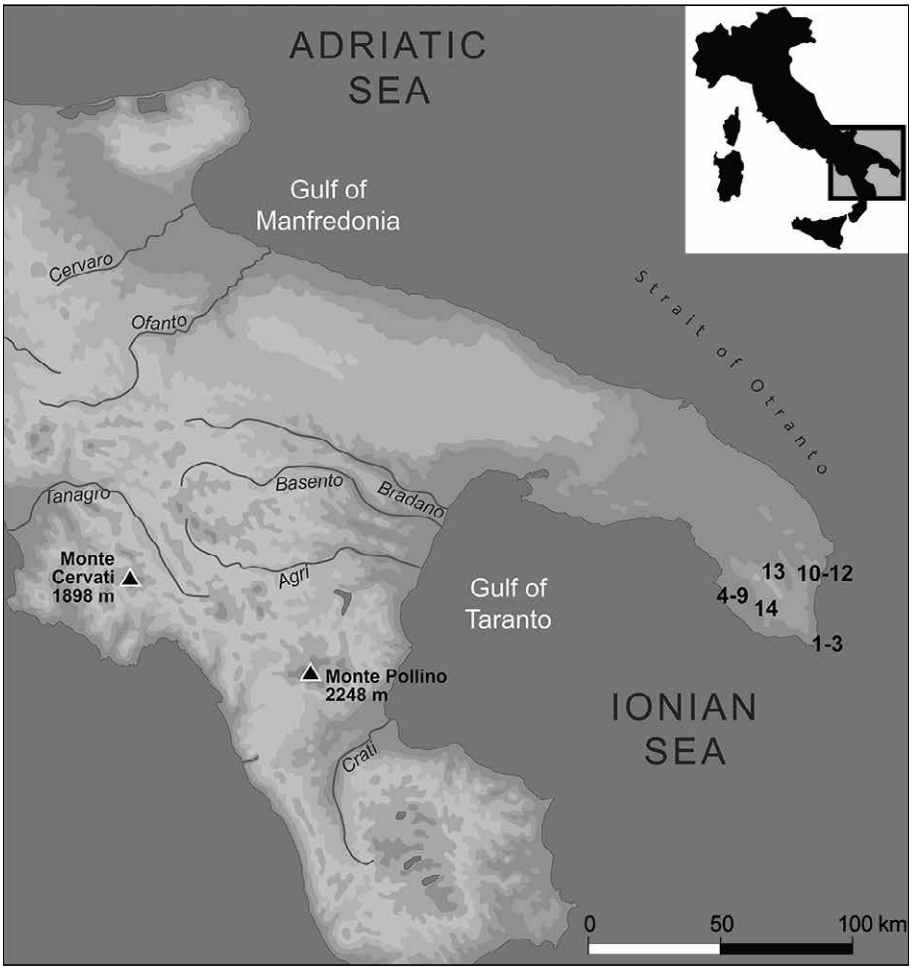


Figure 1. Mousterian sites in the Salento 1) Grotta dei Giganti; 2) Grotta Titti; 3) Grotta del Bambino; 4-9) Grotta del Cavallo, Grotta Uluzzo C, Grotta Torre dell' Alto; Grotta di Capelvenere; Grotta M. Bernardini, Grotta M. Zei; 10-12) Grotta Romanelli, Grotta Zinzulusa, Grotta delle Striare; 13) Fondo Cattie; 14) Grotta S. Ermete.

The present interest in Neanderthal settlement system and land use comes from the intent to understand behavioural differences in comparison with the *Homo sapiens*, particularly in the chronological frame of the Upper Pleistocene, immediately preceding Neanderthal extinction. The Salento is a region in south-eastern Italy that is rich in Upper Pleistocene Mousterian sites and Neanderthal fossils. The record of the prehistoric sites is largely the outcome of the past activity of the Istituto Italiano di Paleontologia Umana (IsIpU) and the Istituto Italiano di Preistoria e Protostoria (IIPP). This region is well known for the absence of good quality raw materials, flint in particular (Bietti, 2006; Bietti and Cancellieri, 2006; Milliken, 1998; Riel- Salvatore and Negrino, 2008). The explicit recognition of this absence and of the presence of long raw material transfer was established (Spinapolice, 2012) after systematic surveys in collaboration with the IsIPU in 2005-2006.

The long distance raw material procurement in the region (Spinapolice, 2012, 2018) makes this territory well suited for a study of raw material economy, linked with the analysis of the organization of technology and of curated behaviour. This paper shows that the scarcity of raw materials implies an intense use of artefacts, an increase in curation behaviour and a differential utilization for locally available raw material and imported ones.

The land use pattern was investigated through the analysis of the technological organization of lithics from five Mousterian sites, proposing a model of a logistical mobility within different site types used by Neanderthals.

2. Materials and methods

The lithics from five Mousterian sites (Fig.1) of the region (Spinapolice 2008, 2009) were analysed (Table 1): 1) Grotta Romanelli (40°0'10.69"N 18°25'52.73"E), one of best known Palaeolithic sites in Italy. (Cardini 1961-1970). The cave opens on the Adriatic coast, a few kilometres from Castro Marina. 2) Grotta dei Giganti (39°47'45" N, 18°20'15" E) is a semi-submerged limestone cavity located on the extreme edge of the Salento peninsula (Blanc 1958-61); 3) Grotta Uluzzo C (40°9'31.28"N, 17°57'35.03"E) is a karstic cave located on the Uluzzo Bay, between Grotta del Cavallo and Grotta di Uluzzo; 4) Grotta Mario Bernardini (~40°10'17.37"N, 17°56'52.60"E) is located near Serra Cicora A, slightly inland from the Bay of Uluzzo (Borzatti von Löwerstern, 1970, 1971); 4) Grotta Torre dell'Alto is located almost at the basis of the eponymous Tower, near Santa Caterina (Nardò) (Borzatti von Lowerstern, 1966; Borzatti von Lowerstern and Magaldi, 1967).

The lithics are analysed here according to the *chaîne opératoire* method (Geneste, 1985, 1988, 1991; Inizan, 1995; Leroi-Gourhan, 1964; Tixier 1978; Pelegrin, 1985), utilizing qualitative, standard quantitative approaches and taphonomy. The concept of *chaîne opératoire* is an ordered and hierarchical representation of the knapping process resulting in the manufacture of stone tools. According to this method, lithic production systems are examined as a sequence of actions embedded in a techno-economic process.

Each lithic object is classified following the knapping stages, from procurement (phase 0), to production (phase 1), use and maintenance (phase 2 and 3, tooling and retooling) and discard and depletion (phase 4). The presence or absence of the products typical of each stage of production (*i.e.*, fully cortical flakes, cortical flakes, plain *débitage* flakes, *débordants* flakes, retouched blanks) is recognized, to profile the assemblage. The identification of these production stages gives insights into the subsistence activities that were carried out at each site and the hypothesis of site function, within the wider frame of territorial exploitation.

Within the above approach, different patterns of site use can be defined, to reconstruct reasonable settlement systems, even in a broad chronological context (Marks and Chabai, 2006; Meignen *et al.*, 2007).

Every knapping product is reelated to a specific knapping sequence. The cores and the negative scars on flakes are particularly informative for the reconstruction of a knapping sequence, in order to link them to specific production methods. The patterns for curation and expediency in the technological system should be recognizable in the

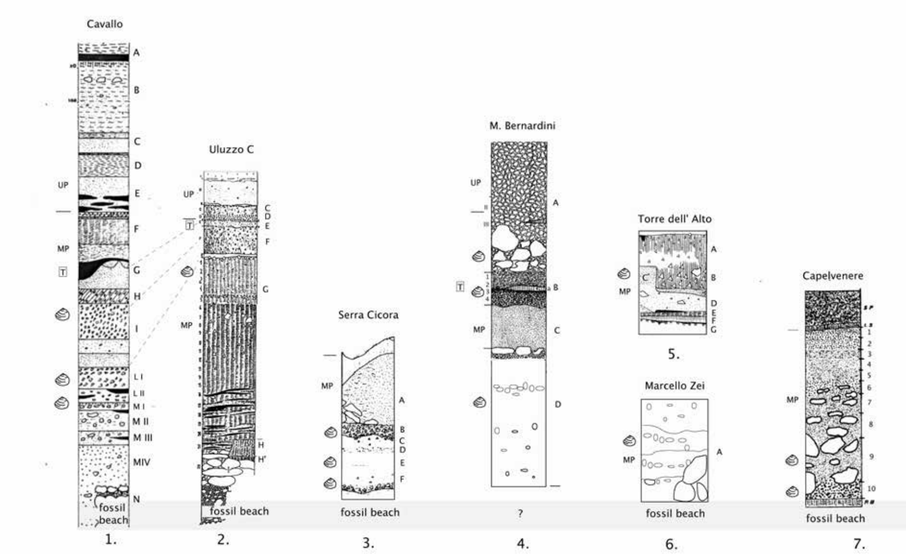


Figure 2. Drawings of stratigraphic sections of the main Mousterian sites. 1. Grotta del Cavallo; 2. Grotta Uluzzo C; 3. Grotta di Serra Cicora A; 4. Grotta Mario Bernardini; 5. Grotta Torre dell'Alto; 6. Grotta Marcello Zei; 7. Grotta di Capelvenere; 8. Grotta Romanelli; 9. Grotta dei Giganti. Modified after Palma di Cesnola (1969), Borzatti von Löwenstern (1966, 1970), Borzatti von Löwenstern and Magaldi (1969), Campetti (1986), Piperno (1976), Spinapolice (2009, (Modified after Douka and Spinapolice 2012)).

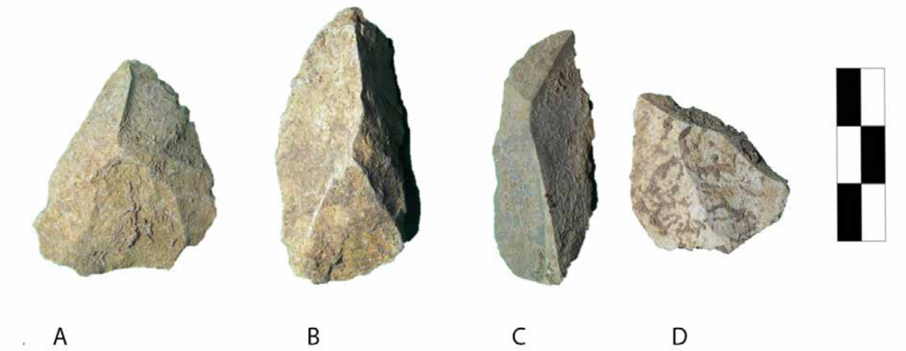


Figure 3. Levallois blanks from Grotta M. Bernardini.

archaeological record through the analysis of core reduction to understand the way in which blanks were produced, tool resharpened and the displacement of raw materials and artefacts across the landscape (Kuhn 1994). In order to achieve this understanding, the surface condition of the lithics is recorded to relate them to possible post- depositional events and use life; retouched artefacts are described: the location and type of retouch were taken into account, and the strategies of reduction, recycling and reuse are tested trough the analysis of double patina and double retouch series and reduction hypothesis based on main dimensions. The length, width and thickness are recorded, following conventional measurements (*i.e.* through the orientation of the lithic item) on all the items. The unidentifiable fragments are classified as chunks, while *débris* are defined as the chips < to 2 cm.

3. Chronology

One of the major problems related to the study of Salento Mousterian is the lack of absolute chronological data, a slightly common matter in the Italian Middle Palaeolithic record (Higham *et al.*, 2009).

The chronology of these assemblages has traditionally been established through typological data combined with environmental data (*e.g.* Palma di Cesnola, 1996), introducing a significant bias in the interpretations. Here we propose a chronological framework based on the known chronological elements.

One of the useful elements to provide a timeline, is the Tyrrhenian transgression (Issel 1914), related with MIS 5e (124 ± 5 ka BP, Lambek, 2004). However, the determination of the sea-level position during the Last Interglacial, is not straightforward. This unit is recognizable at the basis of the archaeological stratigraphic sequences in several sites (Uluzzo C, Romanelli, Giganti, fig.2). Its altitude in Apulia is close to the eustatic level of the sea (Ferranti *et al.*, 2006) and it is assumed to be 7 ± 3 m relative to the present sea (Dai Pra and Hearty, 1988). Actually, the fossil marine beach of Uluzzo C is located at 8 m a.s.l., the Grotta Romanelli at 7.5 m and the Grotta dei Giganti at 5 m. More caves from Salento, not included in this study, have a Tyrrenian beach at the bottom of the sequence (Fig. 2): a marine beach at Grotta del Cavallo is located at 5 m; at Grotta Mr. Zei, a lithodoms line attributed to the Tyrrhenian is visible at 8 m. Large pachyderms, often associated with the OIS5e, are regularly present in those layers. In some sites, such as Grotta Marcello Zei, a second line of lithodomes (result of a second marine transgression) can be related to the OIS7 and located at ~ 9 m, but the sediments linked to this stage have been completely washed away.

The sequence of Grotta dei Giganti is related with the Grotta del Diavolo one, few meters apart, described by Mastronuzzi and colleagues (2007). The stratigraphy contains mostly slope deposits and is marked by three distinct beach levels, occurring at about 3.0, 3.5 and 5.9 m a.s.l., and by several speleothems. The oldest marine level has been dated at ~340 ka; the second beach level at about 5.9 m has a U/Th age determination between 170.3 and 146.5 ka BP. This date has been questioned by Mastronuzzi and colleagues (2007) who, according the geomorphology, propose a date of 125 ka for the beach and relate it to the Eutyrrenian. The third beach level at 3.5 m is overlain by a stalagmite about 78 ka BP. The sequence is capped by a breccia deposits retaining remains of continental cold fauna, which has been referred to the last glacial period.

At Grotta dei Giganti, applying the model drawn for Grotta del Diavolo, the Level A (Fig.2:9) corresponds to the OIS 5,1, the level B and the breccia (Br1) are associated to the OIS 9,3, the level C and the corresponding breccia, together with the speleothem, are related to the OIS 5,5 (Eutyrrenian). The archaeological deposit might then postdate the OIS 5,1. The major problem for these models is related to tectonics, which is supposed to have created major movements that make uncertain the attributions based on the elevation. However, the interpretation from Mastronuzzi and colleagues (2007) claims for a tectonic stability of the coastal cave in the region.

Grotta Romanelli (Blanc, 1920, 1928) opens at a narrow shore platform at about 7.4 m a.s.l. and is related to a notch with algae encrustations and a belt of lithophaga boreholes ending at about 9.8 m a.s.l. (Mastronuzzi *et al.* 2007). The chronology of the lower layers of Grotta Romanelli has repeatedly been questioned, although with an absolute date from the Level G, between 69 and 40 ± 3 ka BP: these ages were considered to be too recent by various authors, including Sala (1980), who attributed the deposit "to the Riss", based on the presence of *Canis mosbachensis* in the breccia in front of the cave. A more recent biochronological interpretation (Sardella *et al.*, 2013), however, do not validate this hypothesis, stating that the *Canis* remains fall into the variability within the *Canis lupus*, and confirms the attribution to the Tyrrenian of the beach located at 8 m (Di Stefano *et al.*, 1992). In this context the lower beach level has been attributed to the Neotyrrenian (90-80 Ka), and the related faunas to the age interval between OIS 5c and OIS 5a.

Another method of dating is to use the volcanic levels as markers, although a cautionary view has been recently expressed (d'Errico and Banks, 2014). The best known example is the "ignimbrite campana"(CI), dated ~40 ka BP, but new markers are increasingly used. The CI erupted from the Phlegrean Fields, near Naples (Giaccio *et al.*, 2008), its distributed tephra products fell over an extensive part of the Italian Peninsula (Fedele *et al.*, 2002) and has been dated using laser 40Ar/39Ar techniques at 39,280 ±110 BP (De Vivo *et al.*, 2001), while Giaccio *et al.* (2006) and Fedele *et al.* (2008) adopt an age of 40,012 BP through comparison against the GISP2 ice core chronology. This tephra layer can be used as a *terminus ante quem*, being present at the top of the Uluzzo C and Mario Bernardini sequences (Giaccio 2008).

The level tephra X 6 (Keller *et al.*, 1978) is a volcanic level of campane origin, that has been dated at 107 ± 2 ka BP and falls at the end of the Last Interglacial in the Lago Grande di Monticchio varve record and other Mediterranean marine cores (Brauer *et al.*, 2007; Paterne *et al.*, 2008; Wulf *et al.*, 2006) and has been recognized in the level G of Grotta del Cavallo. This tephra level is correlated with the OIS 5d, corresponding to a cooling climate during the last interglacial (C24). This gives us a *terminus ante quem* to include the sequences between the OIS 5e and 5d. Volcanic levels which are potentially correlated with tephra X6 are the level γ of Uluzzo C (at the basis of D layer) and the basis of B layer of Mario Bernardini.

If this hypothesis is valid, almost all the analysed series are related to the OIS 5. The faunas appear to be consistent with this framework: the environment, mostly temperate fresh, it is likely for the interglacial period.

The Grotta Torre dell'Alto shows no traces of the Tyrrhenian transgression and generally the faunas suggest a cooler climate. Traditionally this site has been dated to the beginning of the last glaciation, but this interpretation is likely to be reviewed, while if this hypothesis is confirmed, this sequence is the oldest in the region.

In summary, it seems likely that the relative age, as showed by geological features, sets those assemblages as younger than MIS 5e (Mastronuzzi *et al.*, 2007) and older than CI eruption at 40 ka BP (Fedele *et al.*, 2008).

4. Results

4.1. Raw material selection & blank production

The analysis of blank production showed that the reduction methods are varied, however the same range of methods is used in different assemblages and on different raw materials. Moreover, the sample analysed represents a good range of raw material variability, from sites where one type of raw material predominates, to sites where there is a balance among local and non-local raw materials (Table 1).

In terms of the technological traits that are at the basis of the technical choices, a dichotomy was recognised between Levallois / non Levallois. Levallois is the only method constantly present (Table 2), although in different proportions, in all the assemblages. Levallois is a reliable method to produce desired products (Lycett *et al.* 2015), statistically distinguishable (Scerri *et al.* 2015), having a robust working edge, and a great potential for retouch, and moreover this methods gives advantages in terms of raw material economy (*cf.* further). This is not true for other types of reduction methods, such as discoidal (present mainly in Grotta Romanelli) or the anvil percussion (found

	Dataclass	**GG**	**Rom G**	**UC G**	**MBERN**	**TdA**	**Total**
Limestone	natural bloc	1	83	0	1	0	85
	core	5	57	4	17	0	83
	flake	62	622	80	183	21	968
	tool	39	76	204	38	28	385
	chunck/frag	0	0	51	91	10	152
Siliceous limestone	core	2	0	3	11	0	16
	flake	13	3	37	88	5	146
	tool	5	5	268	44	116	438
	chunck/frag	0	1	2	25	14	42
Flint	core	1	0	1	2	0	4
	flake	54	1	40	11	4	110
	tool	111	4	307	5	29	456
	chunck/frag	0	0	17	1	1	19
Quartzite	flake	2	1	0	0	0	3
	tool	1	1	10	0	0	12
Jasper	core				1	0	1
	flake	0	0	2	2	0	4
	tool	1	1	18	1	1	22
	tool	0	0	1	0	0	1
Other	natural bloc	1	0	0	0	0	1
	core	0	0	1	0	0	1
	flake	2	0	2	0	0	4
	tool	5	0	5	0	2	12
	chunck/frag	0	0	0	0	1	1
Total	**dataclass**	**305**	**855**	**1053**	**521**	**232**	**2966**

Table 1. Technological composition and raw materials of analysed assemblages.

N	ROM	UC	MBern	TdA	Gig
Levallois	378	497	261	106	170
opportunistic	232	260	65	65	57
ind	66	87	71	27	63
discoid	69	6	2	0	2
anvil	58	3	3	5	12
komb	7	2	1	0	3
cobble/pebble	45	0	1	0	0

Table 2 . Knapping methods.

	Giganti		Romanelli		Uluzzo C		Torre dell'Alto		Mbern	
N	Local Raw Material	Imported Raw Material	Local Raw Material	Imported Raw Material	Local Raw Material	Imported Raw Material	Local Raw Material	Imported Raw Material	Local Raw Material	Imported Raw Material
0-1	7	3	182	0	36	11	0	0	32	4
2	63	38	506	0	88	16	20	3	469	17
3-4	37	91	95	6	330	206	117	24	62	6
5	7	34	61	0	173	174	30	8	66	3

	Giganti		Romanelli		Uluzzo C		Torre dell'Alto		Mbern	
%	Local Raw Material	Imported Raw Material	Local Raw Material	Imported Raw Material	Local Raw Material	Imported Raw Material	Local Raw Material	Imported Raw Material	Local Raw Material	Imported Raw Material
0-1	6,2	1,8	21,6	0	5,8	2,7	0	0	5,1	13,3
2	55,2	22,9	60	0	14	3,9	12	8,6	74,6	56,7
3-4	32,4	54,8	11,2	100	52,6	50,7	70	68,6	9,8	20
5	6,2	20,5	7,2	0	27,6	42,7	18	22,8	10,5	10

Table 3. Local and non-local raw materials knapping phases (0-1=procurement; 2=production; 3-4=use and maintenance, 5= depletion).

in several sites, always in more or less circumstantial ways). This dichotomy points to great behavioural flexibility and probably to an unexpected complexity. The main factor driving the choice of these production methods appears to be the raw material, in terms of quantity, quality and morphology. Thus, the use of anvils appears to be ideal for blanks with a rounded morphology (pebbles) and the débitage on perpendicular planes is suitable for thin tabular blocks, such as limestone slabs. As for the Levallois method, it is likely that its use is focused on producing thin blanks with sharp edges and maximise the number of flakes from a given block of raw material.

Blank production at all sites is principally on local materials (Table 3), however the limestone cores were probably reduced directly near the raw material sources. The exploitation of limestone is mostly made following the Levallois method (48%), as in **Grotta Romanelli**, where this is the predominant raw material (99%). The whole assemblage includes 57 cores on different raw materials, where the standardized core morphologies (Levallois, N=17 and Discoidal, N=6) are a minority compared to more opportunistic morphologies (N=33). The knapping sequences thus seem very long, reaching the complete exhaustion of the cores. It is likely that irregular cores are here at the very end of the *chaîne opératoire*: these include pseudo-prismatic cores and re-used exhausted Levallois cores. The Levallois sequence follows two dominant recurrent modalities: the centripetal and the unidirectional; the core shaping is done through very thin removals followed by preparation of the débitage surface, completed by débordant flakes and removals perpendicular to the platform. Those flakes are not very diagnostic and they are classified frequently as "*indifferenciés*". The cortical/non-cortical ratio is 2 to 1 and shows a high degree of exploitation of the natural blocks.

In **Grotta Torre dell'Alto,** the most common raw materials are siliceous limestones (58%), followed by limestone (25%). Here, the Levallois method, principally recurrent, is primarily used for blank production (53%), while 32% of the assemblage has not been attributed to a particular reduction method. The same pattern has been observed at **Grotta Mario Bernardini**, where the siliceous limestone and the limestone are the most common raw materials (Fig.3), and are processed principally by a Levallois method (68%), predominantly recurrent centripetal.

Other assemblages are characterised by the production both on local and non-local raw material, as **Grotta dei Giganti** (Spinapolice, 2009), where they are equally present. Here the Levallois method is used on limestone to obtain predetermined Levallois flakes (N=57), often morphologically elongated or Levallois blades (N=9) with unidirectional recurrent or bidirectional modality. Flint Levallois *débitage* is principally recurrent, both unidirectional and centripetal, producing highly standardized blanks, which are often heavily reduced (75%) (see further).

In Grotta **Uluzzo C** flint 37% (N=365), limestone 33% (N=339) and siliceous limestone 30% (N=310) are well represented in the assemblage. However, the total volume of limestone is significantly larger, (4,163,715 mm^3) against the siliceous limestone (mm^3 2,150,087) and the flint (mm^3 1,316,264). In general, the Uluzzo C shows a trend to the utilization of the Levallois method, regardless of the raw material used, for retouch or for use in unmodified form. An overall analysis of determinable blanks revealed a slight predominance of Levallois (N = 497) over other knapping methods (N = 358). Production appears to focus mainly on flakes and elongated flakes: the "typical" Levallois flakes make up 39% of the blanks, 37% retouched and 63% unretouched; 30% of them are obtained with unidirectional method.

It is likely that the limestone cobbles represented the biggest available raw material package size in the region, and were therefore selected to obtain longer blanks. Limestone flakes in the Uluzzo C assemblage are long in average 38,26 (σ12,6) mm and flint flakes only 27,55 (σ19,1) mm, whereas at Grotta dei Giganti while limestone blanks are 35,2 mm long, flint ones are only 17,82 mm.

The limestone cobbles were knapped to obtain predetermined blanks, probably to be used unmodified and they are assumed to be less mobile than flint blanks. However, limestone pebbles are not ubiquitously available in the region (Spinapolice 2012) and it is likely that they were moved. Since the Grotta dei Giganti is distant both from the flint and limestone sources, this site occupies a rather peculiar place in the settlement system. Conversely, the intentional production of very small flakes (<2cm) is attested by the presence of very small Levallois cores (Fig.4 A, B and D) and by flake production from tools (see further).

Figure 4. Exhausted Levallois cores on flint (A, B, D) and "placchetta"(C) . (A, C Uluzzo C; B, D Mario Bernardini).

The knapping of siliceous limestone, using the Levallois method, follows slightly different directions if compared to the limestone. At Uluzzo C this very flat raw material offers low possibilities of surfaces organization and induces a predominance of centripetal modalities to produce convexities (Fig.4, C), without platform preparation.

Non-Levallois production is oriented to the making of thick products, with a variable morphology. Knapping sequences on flakes are recognizable from undifferentiated products knapped from slabs: at Uluzzo C, this modality produced blanks (N=215) and cortical flakes (N=119). The "*faccia ventrale diedra*", pieces with the dihedral ventral surface, are numerous, especially in sites with limestone predominance. Expedient knapping of limestone slabs also occurs exploiting the elongated morphology to produce elongated blanks. Moreover, pseudo-prismatic cores, in Grotta Mario Bernardini (N=4) in Grotta Romanelli (N=1), in Grotta dei Giganti (N=2), in Grotta Uluzzo C (N=1, Fig.5, A) show an intentional volumetric exploitation.

Other opportunistic strategies include anvil percussion, particularly for first stages of cobble and pebble exploitation, such at Romanelli (N=14 cores), at Torre dell'Alto (N=3 cores on limestone pebbles) and at Giganti and Uluzzo C on flint, jasper and quartzite pebbles (GG=5, UC=15), often knapped to produce Quina scrapers.

In Grotta dei Giganti an opportunistic exploitation of *Callista chione* shells for the production of blanks has been outlined (Cristiani and Spinapolice, 2009; Douka and Spinapolice, 2012). This occurs in several sites in the Salento and has been associated with the scarcity of raw material, and not to symbolic behaviour (*contra* Romagnoli *et al.*, 2014).

4.2. Tool production and maintenance

The economic behaviour emerging from the assemblage analyses can be schematized into three sets of tools: expedient, opportunistic and curated. Thus, a raw material economy can be outlined, with a dichotomy of local and non-local raw materials, managed accordingly diverse patterns of raw material provisioning.

The tools on limestone and siliceous limestone are generally poorly reduced and frequently "expedient". Expedient tools (or instant tools, Gould, 1980) are characterized by a poor alteration of their original morphology. Nelson (1991) made a distinction between expedient strategies and opportunistic behaviour, where the latter are unplanned responses to an unanticipated need. Real expedient technologies are instead programmed responses to an expected goal that has minimal technological preparation, a brief period of use and the depletion of tools in the same place of use. When these strategies are used, it is implicit that the raw material is readily available. Thus, expedient technologies reduce transportation costs of raw materials, but also the time spent to repair and re-sharpen tools.

N	GG			ROM			Uluzzo C			M Bern			TdA		
Typology	Limestone	Sil. Lim	Total	Limestone	Sil. Lim	Total	Limestone	Sil. Lim	Total	Limestone	Sil. Lim	Total	Limestone	Sil. Lim	Total
Points	9	1	10	0	2	2	4	3	7	0	0	0	0	0	0
Limaces	3	1	4	0	0	0	10	10	20	0	0	0		3	3
Scrapers	25	5	30	13	0	13	150	193	343	5	8	13	16	80	96
Endscrapers	0	0	0	3	0	3	7	14	21	0	0	0		1	1
Burins	0	0	0	3	0	3	1	3	4	0	0	0	0	0	0
Perçoirs	1	0	1	1	2	3	0	0	0	0	0	0	0	0	0
Notches&dent	0	0	0	29	1	30	4	7	11	27	25	52	4	10	14
Other	0	0	0	5	0	5	2		2	0	0	0	1		1
Retouched flakes	2	0	2	32	0	32	28	37	65	3	10	13	6	19	25

%	GG			ROM			Uluzzo C			M Bern			TdA		
Typology	Limestone	Sil. Lim	Total	Limestone	Sil. Lim	Total	Limestone	Sil. Lim	Total	Limestone	Sil. Lim	Total	Limestone	Sil. Lim	Total
Points	22,5	14,3	21,3	0	40	2,1	2	1,2	1,5	0	0	0	0	0	0
Limaces	7,5	14,3	8,5	0	0	0	4,9	3,7	4,3	0	0	0	0	2,6	2,1
Scrapers	62,5	71,4	63,9	15,1	0	14,3	72,8	72,3	72,5	14,3	18,6	16,7	59,3	70,8	68,6
Endscrapers	0	0	0	3,5	0	3,3	3,4	5,2	4,5	0	0	0	0	0,9	0,7
Burins	0	0	0	3,5	0	3,3	0,4	1,2	0,8	0	0	0	0	0	0
Perçoirs	2,5	0	2,1	1,2	40	3,3	0	0	0	0	0	0	0	0	0
Notches&dent	0	0	0	33,7	20	33	2	2,6	2,3	77,2	58,2	66,6	14,8	8,9	10
Other	0	0	0	5,8	0	5,5	0,9	0	0,4	0	0		3,7	0	0,7
Retouched flakes	5	0	4,2	37,2	0	35,2	13,6	13,8	13,7	8,5	23,2	16,7	22,2	16,8	17,9

Table 4. Typology of local raw materials.

In the sample analysed (Table 4), the expedient behaviour category regroups principally notches & denticulates. In Grotta Romanelli, where the raw material is strictly local, the retouched items are few (11%) and notched pieces are the bulk of the series (N=30, 33%). Those tools can be considered as typically expedient (Costamagno *et al.*, 2006) and they are usually made on locally available raw materials (Thiébaut 2005). Notches and denticulates are often retouched on (predetermined) Levallois blanks and at Romanelli this is the case for 60% of this tool class. The retouch, when present, never led to a radical transformation of the object's morphology and there are no pieces bearing the scars of successive retooling that have significantly altered the volume of the initial blank. The tool making is probably associated here with very short use-lives.

At Mario Bernardini, denticulates form the major category of tools (N = 52), on blanks usually fine (average thickness 6.5 mm) Levallois flakes (78%), presenting for the most part a series of two or three notches, sometimes Clactonian. The raw material is exclusively local: 50% siliceous limestone (N = 27) and 50% limestone (N = 25).

Denticulate tools have been regarded as very mobile in some French Middle Palaeolithic sites (Slimak 2004). Conversely, these pieces are here considered to be highly local and not associated with a mobile toolkit, or linked to reuse and recycling. The pattern of low curation and transport for this tool class has been shown elsewhere (*e.g.* Geneste, 1985, 1988; Turq, 2000).

The scrapers on slabs, found in large quantities especially in the Bay of Uluzzo (Fig.5, B-G) are highly opportunistic. These are manufactured from a local raw material, the blanks are not knapped but are collected in the form of flat slabs in the proximity of the sites and they often have two cortical surfaces. In Uluzzo C, the scrapers on slabs are predominant in the tool kit (N=193), while only one of them is attested in Grotta dei Giganti, suggesting an occasional transport. These tools have been used only for short periods, emanating from an unplanned context related to the occupation strategy of the site. These scraping tools can thus be considered as "opportunistic", sensu Nelson 1991. The retouch is sometimes steep; however, it does not change very much the initial morphology of the blanks. Furthermore, the unretouched slabs are not present at the sites because their natural edges were not functional. The practical purpose of these scrapers, found in very similar types in the Uluzzian (Palma di Cesnola, 1993), remains unknown and there has been no study of their use-wear. The presence of opportunistic scrapers gives some insights about the function of the sites where they are found. While notches and denticulates seem to be linked to short occupations or distinct activity, siliceous limestone scrapers could be related to a more permanent occupation. Scrapers on slabs seem to indicate residential stability: the presence of these tools is expected to be related to processing, manufacturing and maintenance activities common in residential sites. Among the studied sites, Uluzzo C is the one most likely to represent residential occupation, since it is characterized by frequent tools and an important investment in their transformation.

In Uluzzo C, 74% of lithics are retouched, and the retouching equally affects all the technological categories (cortical products, undifferentiated, Levallois). The proportion of retouched items corresponds to different raw materials: 58% of limestone and 83% of the siliceous limestone blanks are retouched. The flint blanks are also frequently retouched (79%). In terms of absolute values, the flint blanks are the most retouched (N = 305, Table 5). It is likely that retouch on these raw materials has not played the same role in the economy of the human groups, given the large differences in their suitability for knapping and efficiency in use.

When the imported raw material are analysed, the data show both curation and maintenance behaviour. First, the tools made on good quality raw materials appear to be more intensively retouched than the ones on local raw material. In Grotta Uluzzo C flint is used for 38% of tools and 47% of retouch flakes is on flint. In Grotta dei Giganti this proportion is higher, as flint represents 69% of tools and 96% of *débris*. Débris is composed for the most part of retouch flakes, and the possible presence of phantom tools (sensu Cahen and Keeley, 1980) has been outlined, as in Mario Bernardini, where a *dèbris* of a good quality brown flint has no correspondence to the assemblage.

Other imported raw materials such as quartzite and jasper, despite being rare, seem to have the same pattern of utilization as flint, and they might come from the same sources (Spinapolice 2012, 2018).

At Torre dell'Alto the rate of tool reduction is not very important. However, because of the provisioning distances and the original morphology of the raw material, the flint tools are the smallest, on average, among the retouched items (flint and jasper 2,53 cm, σ 0,76; sil. limestone 2,79 cm σ 0,57; limestone 3,16 cm σ 0,74). Retouched pieces on siliceous limestone are longer and wider and the morphology of the raw material limits their generally low thickness.

At Grotta dei Giganti 54,8% of the non-local raw materials relates to the transformation stage (N = 115), while only 32% of the local ones are retouched (Table 3, 4). Flint tools are more heavily retouched then limestone ones, both in terms of the density of retouched items/layer and in intensity of retouch itself; in fact only 9 limestone tools show intense retouch, against 37 flint ones. The typology shows that flint tools are the most retouched and reduced tool-types, *i.e.* double scrapers, limaces and convergent scrapers (Table 5, 6).

Additionally, specific tool classes have a particular role in the technological organization. This is the case of the limaces (Fig.6). The limaces, defined by Bordes (1961) as double convergent scrapers, are characteristic of the Salento Middle Paleolithic in Grotta dei Giganti and in other deposits of the region. These tool types are often "proto-limaces" (Fig. 6, 10-14), denominated "*Quinson type*" or "*de la Baume Bonne*" (Bottet and Bottet, 1951). The retouch makes a full circuit of the tool and bulb and platform are removed (Fig. 6, 1-5). Sometimes they maintain some of their dorsal cortex, possibly coming from an opportunistic blank (Fig. 6, 8).

The dimensions of the *limaces*, the degree of reduction, the raw materials, occupy a distinct place. The morphology and the volumetric design of these tools indicated that they are not simply the exhaustion stage of a scraper: this tool represents a flaking / shaping dichotomy and is associated with a complex and anticipatory behaviour.

The corpus includes 79 limaces on different sites mostly on non-local row materials (Table 6): 20 in Grotta dei Giganti (13% of the tool-kit), one at Grotta Romanelli, 5 at Torre dell'Alto (3%) and 53 at Uluzzo C (7%). To test for reduction, the maximum length of the limaces was compared with the length of double and convergent scrapers and of unretouched blanks; the reduction hypothesis was discarded because the average dimensions of the limaces are generally above the average of the corresponding blanks

Non Local RM	GG			ROM				Uluzzo C					M Bern			TdA		
Typology	Flint	Jasper	Total	Flint	Jasper	Quarzite	Total	Flint	Jasper	Quarzite	Granite	Total	Flint	Jasper	Total	Flint	Jasper	Total
Points	12	0	12	2	0	0	2	3	1	1	1	6	0	0	0	0	0	0
Limaces	16	0	16	0	0	1	1	32	1	0	0	33	0	0	0	2		2
Scrapers	54	1	55	2	1	0	3	220	12	8	0	240	2	0	2	22	1	23
Endscrapers	0	0	0	0	0	0	0	7	0	0	0	7	0	0	0	0	0	0
Burins	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Perçoirs	2	0	2	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
Notches&Dent	1	0	1	0	0	0	0	3	4	1	0	8	1	0	1	0	0	0
Other	9	0	9	4	1	1	6	0	0	0	0	0	0	0	0	0	0	0
Retouched flakes	20	0	20	0	0	0	0	39	0	0	0	39	2	1	3	5	0	5

Non Local RM	GG			ROM				Uluzzo C					M Bern			TdA		
Typology	Flint	Jasper	Total	Flint	Jasper	Quarzite	Total	Flint	Jasper	Quarzite	Granite	Total	Flint	Jasper	Total	Flint	Jasper	Total
Points	10,4	0	10,4	25	0	0	16,6	0,9	6	10	100	1,8	0	0	0	0	0	0
Limaces	13,9	0	13,9	0	0	100	8,4	10,5	6	0	0	9,9	0	0	0	6,9	0	6,6
Scrapers	47	100	47	25	100	0	25	72,3	66	80	0	71,9	40	0	33	75,9	100	76,7
Endscrapers	0	0	0	0	0	0		2,3	0	0	0	2	0	0	0	0	0	0
Burins	0,9	0	0,9	0	0	0		0	0	0	0	0	0	0	0	0	0	0
Perçoirs	1,7	0	1,7	0	0	0		0,3	0	0	0	0,3	0	0	0	0	0	0
Notches&Dent	0,9	0	0,9	0	0	0		0,9	22	10	0	2,4	20	0	17	0	0	0
Other	7,8	0	7,8	50	100	100	50	0	0	0	0	0	0	0	0	0	0	0
Retouched flakes	17,4	0	17,4	0	0	0		12,8	0	0	0	11,7	40	100	50	17,2	0	16,7

Table 5. Typology of non-local raw materials.

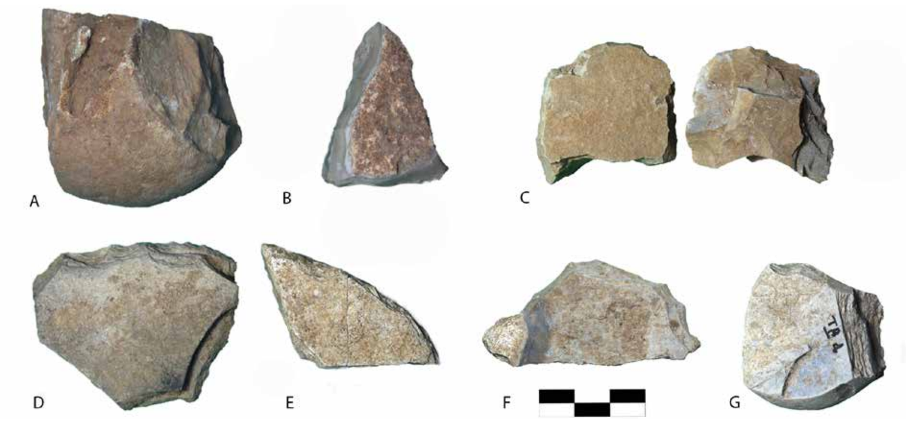


Figure 5. A. Pseudo prismatic core, Uluzzo C; B. Scraper on local flint slab (Uluzzo C); C-G: Scrapers on "placchetta" (D, E Uluzzo C; B, F Mario Bernardini; G Torre dell'Alto).

N	Typology									
Sites	Pointes	Limaces	Scrapers	Endscrapers	Burins	Perçoirs	Notches&Dent	Other	Ret. Flakes	**Total**
GG Local	10	4	30	0	0	1	0	0	2	**47**
GG non local	12	16	55	0	1	2	1	9	20	**116**
GG total	22	20	85	0	1	3	1	9	22	**163**
ROM local	2	0	13	3	3	3	30	5	32	**91**
ROM non local	2	1	3	0	0	0	0	6	0	**12**
ROM total	4	1	16	3	3	3	30	11	32	**103**
UC Local	7	20	343	21	4	0	11	2	65	**473**
UC non loca	6	33	240	7	0	1	8	0	39	**328**
UC Total	13	53	583	28	4	1	19	2	104	**801**
Mbern Local	0	0	13	0	0	0	52	0	13	**78**
Mbern non local	0	0	2	0	0	0	1	0	3	**6**
Mbern Total	0	0	15	0	0	0	53	0	16	**84**
TdA local	0	3	96	1	0	0	14	1	25	**140**
Tda non local	0	2	23	0	0	0	0	0	5	**30**
TdA total	0	5	119	1	0	0	14	1	30	**170**

%	Typology									
Sites	Pointes	Limaces	Scrapers	Endscrapers	Burins	Perçoirs	Notches&Dent	Other	Ret. Flakes	**Total**
GG Local	45	20	35	0	0	36	0	0	9	**29**
GG non local	55	80	65	0	100	64	100	100	91	**72**
GG total	100	100	100	0	100	100	100	100	100	**100**
ROM local	50	0	81	100	100	100	100	45	100	**88**
ROM non local	50	100	19	0	0	0	0	65	0	**12**
ROM total	100	100	100	100	100	100	100	100	100	**100**
UC Local	54	38	59	75	100	0	58	100	62	**59**
UC non loca	46	62	41	25	0	100	42	0	38	**41**
UC Total	100	100	100	100	100	100	100	100	100	**100**
Mbern Local	0	0	87	0	0	0	99	0	82	**93**
Mbern non local	0	0	13	0	0	0	1	0	18	**7**
Mbern Total	0	0	100	0	0	0	100	0	100	**100**
TdA local	0	60	81	100	0	0	100	100	83	**82**
Tda non local	0	40	19	0	0	0	0	0	17	**18**
TdA total	0	100	100	100	0	0	100	100	100	**100**

Table 6. Distribution of tool types per site and raw material.

	L	W	TH
UC 9-12	34,86	23,7	7,74
TdA 9-12	44	19,5	5
GG 9-12	19,46	20,58	18
Rom 9-12	33	48	14
MB 9-12	30	27	8
UC 13-17	29,83	21,91	6,58
GG 13-17	37	20,5	14,5
Rom 13-17	33,5	26	17,5
TdA18-21	33	32,5	10,5
GG 18-21	22,2	15,1	10,5
Rom 18-21	35,75	21,25	9,25
MB 18-21	29,5	19,5	8,5
UC 18-21	31,19	21,81	7,34
UC 8	34,96	18,13	9,73
TdA 8	26,5	18	12
GG 8	31,46	18,62	14,25

Table 7. Average dimensions in mm of single scrapers (9-12), double scrapers (13-17), convergent scrapers (18-22) and limaces (8) per site.

and other scrapers type (Table 7). In addition the largest blanks, longer and thicker, were the subject of more intense retouching compared to smaller tools.

At Uluzzo C the limaces are up to 7%, while the "proto-limaces" are less common (N=5) and are often shaped to obtain very sharp points on both ends, while traces of cortex are seldom seen on the dorsal surface. They frequently have the morphology of double convergent scrapers and are rarely obtained with flatter retouch; in fact the morphologies can be highly variable and the profiles often have a quadrangular section, seldom rounded or polygonal. The ends may be more or less sharp, linked to the raw material quality. Those tools were produced despite the significant expense of the raw materials involved, on blanks likely being transported to the site, ready-made.

The limaces are among the larger tools; they are most often made from good quality raw materials; the nature of the invasive removals extended to the entire piece could suggest the production of usable flakes. These objects have tool vocation but work together as a repository of raw material for the production of small flakes without cortex and faceted platform. Hence, this pattern shows that there is not a definite clear-cut between tools and cores: the great flexibility in the managing of non-local raw materials is coupled with the production of very small flakes and tools. The production of very small flakes from flakes or tool is a well-known behaviour, such as in Qesem cave (Lemorini *et al.* 2015), probably linked with the need to increase the raw material productivity and could be inscribed in a "ramification" process (Rios-Garaizar *et al.*, 2014). The production and use of very small blanks seems to be a recurrent behaviour, consistent with this hypothesis: in Grotta dei Giganti, a core on tool is attested – two blanks have been knapped from a flint scraper; moreover, both in Uluzzo C and Giganti, there are very small scrapers on flint: 3 simple scrapers and 2 retouched flakes at Uluzzo C are less than 2cm long, while several tools (N=12) are only between 2 and

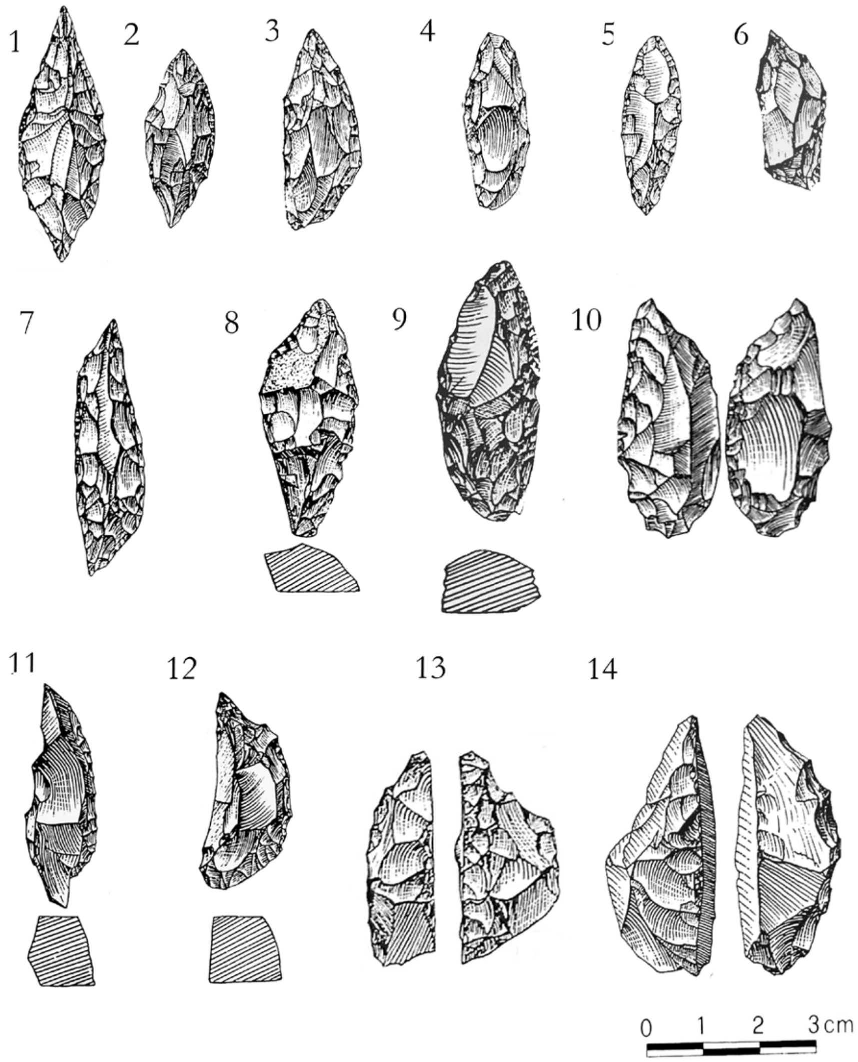


Figure 6. Limaces from Uluzzo C (modified after Borzatti von Löwenstern (1966), Borzatti von Löwenstern and Magaldi (1969).

3 cm long. The use of very small flakes and tools in butchering activities has already been shown in Italian Mousterian (Alahique and Lemorini, 1996), and they could possibly be linked with the "third hand" hypothesis (Spinapolice 2015).

Scrapers are very common in the Middle Palaeolithic (*e.g.*, Geneste, 1985, 1988; Turq, 2000, Costamagno *et al.* 2006) and very mobile in the Salento. The scrapers on non-local raw materials seem to follow a contrasting behavioural pattern compared to local non mobile ones, showing evidence for maintenance and reuse. Quina scrapers are relatively common, often being obtained by half pebbles of flint, jasper or quartzite (Fig.7). The high raw material investment linked to those tools, often having a fully cortical surface, indicates a specific place in the tool-kit, suggesting that those tools were mobile and maintained.

Furthermore, at Grotta dei Giganti, different tool morphologies (Mousterian points and convergent scrapers) seem to form a unique tool class, small in dimensions, characterized by a functional point, made in most cases on imported raw material and probably very mobile (Fig.8).

Almost no abandon of still exploitable item on good quality raw materials is assumed here, and the incorporation in archaeological assemblage principally by loss and depletion, in combination with a maximized use life (Schiffer, 1985; Shott, 1989).

4.3 Tool kit mobility and site economy

Generally, the artefacts that mobile people carry with them should be few in number, small and light (Nelson, 1991; Shott, 1986; Torrence, 1989). For example, Aboriginal hunters, usually carry some versatile implements with them (Gould 1980) and this minimal transported toolkit constitutes the "personal gear" (Binford 1979), frequently made of flexible or multifunctional tools (Bleed 1986).

In the Salento, the lithic items were transported in different forms according to their origin.

The raw materials of local and sub-local origin have been introduced in 1) raw material blocks if the transport distance was very short; 2) partially prepared blocks; 3) as cores or technologically processed products; 4) quality products, such Levallois blanks or tools. The less common products are the cores and the (fully) cortical flakes, related to an initial phase of knapping probably at the location of raw material source.

The non-local raw materials were introduced (in order of frequency): 1) retouched, as scrapers and limaces; 2) cores; 3) unretouched blanks.

First, we will consider the issue of movement of cores. Data from our case study challenge the results of Kuhn (1994) on the portability of small blanks as more effective than cores.

Indeed, in here it seems that the core transport is more common than unretouched blanks. The small cores, transported throughout the displacement of the group, are used as "reserve" of new blanks in situations of acute shortage of raw materials, and this possibility was also predicted by Kuhn (1994). To transport cores instead of flakes indeed presents a number of benefits. First, it prevents the damaging of flakes edges during transport and ensures availability of one or more blanks with sharp edges when the need arises. Then the cores can be used to perform other tasks, such as hammers, grinders or anvils (*e.g.* Thiébaut *et al.*, 2007; Thiébaut *et al.*, 2010). However, the cores on raw material from very remote origin are rare, very exhausted and often fragmentary (3=MB, 2=UC, 1=GG but 28=TdA/B (Borzatti 1966, 1967)).

The movement of tools, in some sites, concerns almost all of the tools on non-local raw material, imported as finished objects and possibly resharpened on site. In some cases, it seems that the retouched blanks, transported over long distances, can also be used as a reservoir of raw materials, as is the case of limaces or bifacially retouched tools, or exhausted tools used as cores. This dual status of cores thus represents a favourable factor for a more intense movement of certain categories of tools. This can be true sometimes for local raw materials: one limestone core on tool is attested in Grotta dei Giganti.

Finally, the presence of unretouched flakes in the sites, not coming from a complete *chaîne opératoire* (by the absence of any phase of core preparation or other flakes from

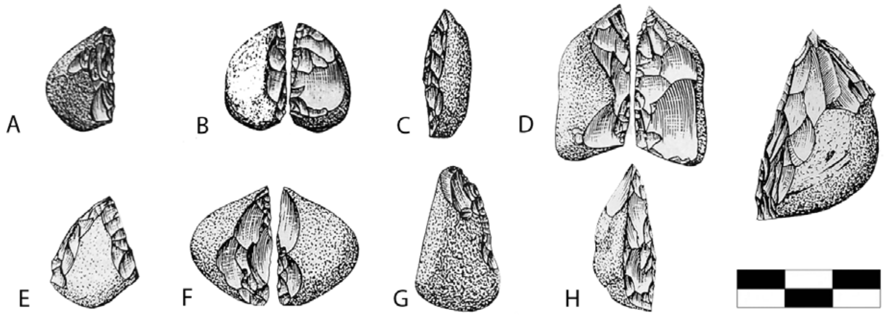


Figure 7. Scrapers on flint pebbles, Torre dell'Alto , modified after Borzatti von Löwenstern and Magaldi (1966, 1967, 1969).

Figure 8. Mousterian points on flint, Grotta dei Giganti.

the same sequence) may be related to the displacement from one site to another of small cores/tools, as well as the movement of the blanks themselves. Therefore, the transport of unretouched blanks cannot be excluded, while the cores/tools remain the most likely object to be moved.

4.4 Site function and distribution

The lithic analysis supports the model that the Mousterian sites in the Salento were a part of one or more settlement system, being related by the same technological organization and the fragmentation of *chaîne opératoires*, and inscribed in a "regional system of behaviour" (Binford 1983; Van Peer 2001). In this land use pattern, it is possible to differentiate residential vs. logistic sites; while residential sites are expected to show thick palimpsest and a complex combination of archaeological remains (Binford, 1980, 1982), the sites inscribed in high mobility, are expected to show a low degree of débris accumulation (Binford 2001): the presence of low remains densities would suggest short occupations (Bamforth and Bleed, 1997). Yellen (1977) notes that the smaller amount of débris was one of the main difference between Kung short-term rainy season camps and the longer occupied dry season camps. Hence, residential sites are characterized by a plurality of repeated occupation more or less separated in time;

activities of acquisition and consumption are performed, indicated by the variety of lithic industry, and space organization, as the presence of fireplaces. In the proposed model, the residential sites are located close to the Uluzzo Bay, because, among the various mineral zones of Salento, it appears the best one on the quality of the raw material (Spinapolice 2012, 2018). The presence of thin veins of local flint (Ranaldo personal communication) plays a major role in this model, while dolomitic limestone and siliceous limestone slabs are also part of this poor, but not hostile environment. In this "mineral area" are clustered the sites with the thicker and denser deposits. It is likely that the main attractions of the Uluzzo bay were related not to the lithic raw materials, but to the possibilities for hunting and gathering provided by the plateau overlying the bay. Thus, an interpretation of Uluzzo C site as residential occupation, probably repeated throughout the year, seems the most likely, at least concerning the G layer. This is characterized by the presence of several overlapping fireplaces, although the available data do not allow any assumption about the space organization inside the cave. It should be noted however that the excavations have involved only the half portion of the total surface (Borzatti von Lowerstern, 1966). New investigation actually are ongoing to clarify some aspects of the site function (Fiorini et al. 2017).

The second possible residential site is Mario Bernardini. Here**,** the *chaîne opératoire* in local raw materials is complete, except for the decortication flakes, showing a high rate of *in situ* raw materials exploitation, including retouch and resharpening (retouch flakes were isolated among the *debris*). Phases related to the abandon of tools (fractures, damage due to combustion, etc.) are represented and 26% of the lithics are fragmented while 50 pieces bear traces of combustion. Conversely, the non-local raw materials (Borzatti von Löwerstern, 1970, 1971) show uncomplete *chaînes opératoires*. This site could be interpreted either as a residential site, or issued as an alternation of residential and logistic occupations.

In the literature, another possible residential site in the same area is Grotta del Cavallo (Palma di Cesnola 2001). Here there is a thick palimpsest, and possible both production and transformation are attested, despite the complete technological analysis of the Mousterian levels is still ongoing.

In Torre dell'Alto an evaluation of the *chaîne opératoire* is not possible from the present sample. The small number of cores, however, shows a fragmentation of the reduction sequence that can partly take place outside the cave. However, frequent activities of knapping are indicated by the large number of materials from the excavation, and processing activities on site are suggested by the presence of retouching flakes. A typological homogeneity characterizes this assemblage, which remains rather different from the other series studied. The D layer from Torre dell'Alto for its stratigraphic characteristics and quantity of the remains, appears as a palimpsest, while it is impossible at present to determine the frequency and the overall length of the occupations. Torre dell'Alto might be a residential site, however the available evidence do not support to inscribe positively the site in the same settlement system, this hypothesis being neither entirely excluded.

Apart from the sites located in the area of Ionian coast, the other sites are probably temporary camps (Binford 1982) and they are linked to the acquisition of resources (hunting camp, gathering location, butchering/processing sites or facilities sites).

Grotta Romanelli shows the full knapping sequence performed on the spot. The observed variability within the layer G is very low and our analysis confirms the hypothesis of a very rapid deposition of this level and the inability to distinguish different human occupations contributing to the site formation. The refitting from the entire stratigraphy of the "bolo" confirms this strong homogeneity, which could be related to one occupation as well as few short events. The presence of pebbles just outside the cave seems to have been one of the criteria that led to the occupation of this cavity. Thus, the intense exploitation of these raw materials underlines an occupation oriented trough production activities. To this must be added the low number of retouched products. The site could be originated from a limited number of occupations, or even a single episode, as also evidenced by the presence of hyena coprolites and carnivores bones (Blanc 1928).

Grotta dei Giganti is located at the southern point of the peninsula, at the higher distance from the good raw material sources (Spinapolice 2008, 2012). Here, the knapping sequence is not complete: the preforms, the cores, the cortical and preparation flakes are almost entirely absent. Activities on site are limited to relatively short sequences of production, with exploitation of a few blocks of low quality local raw materials and production from cores introduced at advanced stages of exploitation (and carried as a personal gear). Apart from cores, a large number of prepared products were imported. The strong presence of retouched pieces and the frequency of retouching flakes, show tools manufacturing and maintenance at the site. The proportion of retouched blanks is quite large, probably reflecting a varied range of activities, which took place in or nearby the cave, requiring a differentiated tool kit. The knapping activities were therefore devoted to the processing and maintenance of products introduced in more or less finished forms. The Giganti lithics may reflect overall high mobility of predetermined and non-predetermined products (*e.g.* limaces) usable for the production of tools and unretouched products. The scarcity of the remains and the absence of a palimpsest points out through a mobile camp; the presence of well-separated levels and brief and repeated occupations in space and time are other elements of high mobility.

Other possible specialized sites in the southern Salento might be the other caves in the Capo di Leuca, Grotta Titti and Grotta del Bambino. Those are located few meters away from Grotta dei Giganti and yielded a Neanderthal human remain (Benazzi *et al.*, 2013; Blanc, 1962) and only few lithics remains (Spinapolice, 2008, 2018).

Two sites are particularly interesting, because they might be part of the same mobility pattern, and they are located inland. Grotta S. Ermete and Grotta Montani (Cremonesi, 1980a, 1980b) are characterized by a very low density of lithic and appear to have been occupied very sporadically: unfortunately, they were only partially excavated and studied. The raw materials are both of the local environment and more distant territories: they are accordingly interpreted as sites with episodic activities.

Thus, we take into account two territorial hypothesis. The first possibility is the existence of two independent territories. The first would be the north of our region, sites of the Bay Uluzzo being on its southern edge, and linked to the provisioning of raw materials in the Bradano basin and in the Central Apulia. The second area could include sites in southern Salento, inscribed in a residential mobility. Thus in this model we have two independent territories, each with a radius of about 50 km.

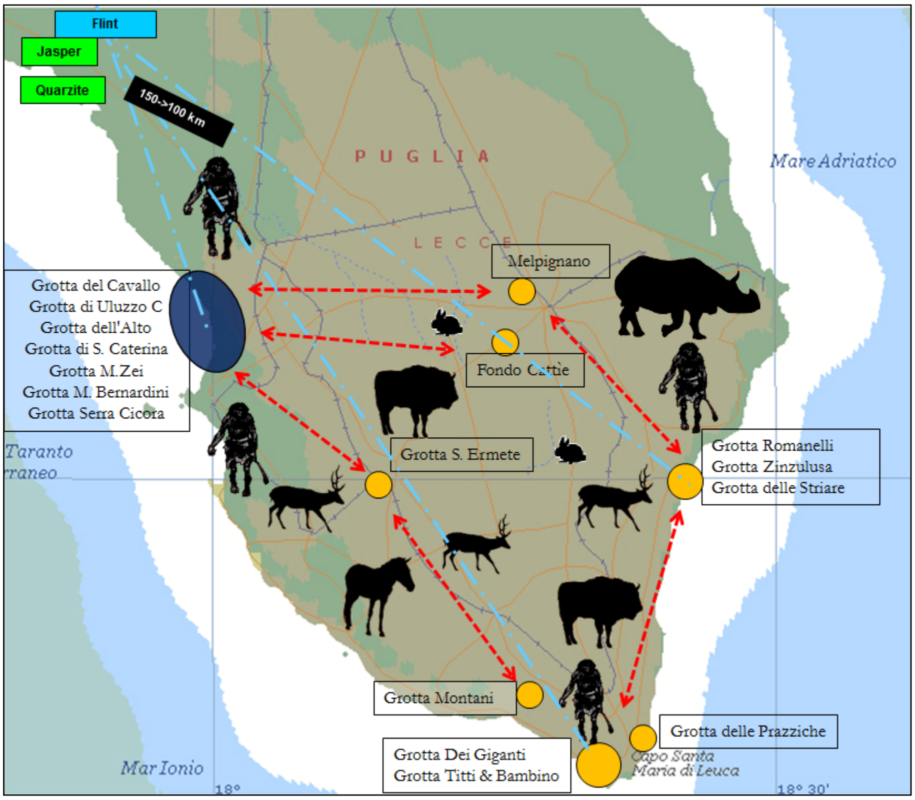


Fig. 9. Proposed territorial model.

Assuming two separate territories, we should however acknowledge a passage of men or objects through the second territory north to reach the sources of supply. Instead, we propose as a most likely the second hypothesis of territorial occupation (Fig.9). This hypothesis incorporates both regional territories in one macro territory crossed by the same groups of Neanderthals. Thus, the residential sites are north on the Ionian coast (*e.g.* Uluzzo C and Cavallo) and all the sites located below this line would be logistics and dedicated to specialized functions. The presence of imported flint in each site testify the (seasonal?) pathways of Neanderthals. Indeed, this hypothesis is supported by the large quantities in very remote raw materials found in the assemblages sites to the south (Giganti, but also San Ermete or Grotta Montani).

The geographical and environmental features of the Salento favoured humans traveling long distances since the landscape does not present major obstacles to overcome, being relatively flat and ease of access.

5. Discussion and conclusion

The availability, size, quality and shape of raw material strongly influence the technical systems during the Middle Palaeolithic. There is a close relationship between raw material economies, technological organization and the degree and modes for mobility (*e.g.* Odell, 2000). Archaeologically, we can recognize the provisioning strategies principally through the study of raw material circulation over a specific area and the study of the site economy (Féblot-Augustins, 1997; Perlès, 1991). The Salento is an appropriate region to analyse this relationship, particularly for the peculiarity in raw material management. So, while the general "Middle Palaeolithic trend" is centred on the exploitation of local raw materials, in very high quantities (between 90 and 100% of assemblages) (Turq *et al.*, 2013), the Salento shows a different pattern (Spinapolice 2012, 2018).

Moreover, mobile toolkits organization can give information about the frequency of movements, resources availability and distribution, and other environmental elements, together with group structure and social organization. The study of technological organization and the ramification of *chaîne opératoires* throughout the landscape (Rios-Garaizar *et al.*, 2014) are powerful tools to study the dynamics of land use and site mobility.

The Salento is a peninsula that extends primarily in length, characterized by a north-south main axis and a width of about 40 km maximum. We described (Spinapolice 2012, 2018) the raw material coming from distant sources, probably not less than 100-150 km away. This remote space is incorporated into the territory of Neanderthal groups since these non-local materials (flint, jasper and quartzite) are present in varying quantities in all the sites examined. Likely their sources are north over the peninsula, and this implies that sites north of the study area (i.e the sites of the Ionian coast) are closest to the sources; conversely, the southernmost sites, are the farthest. The displacement of exotic implements over the Salento was embedded into a system of local sources exploitation and tool maintenance. The utilization of local sources was indeed regulated on the efficiency of the transported toolkits.

The results point out a differential technical behaviour in the managing of lithic resources by Neanderthal, probably linked to the anticipation of need and to a logistical land use.

The assemblages and the tool kits clearly suggest a combination of "curation strategy" (in the form of imported tools and personal gear) and "expedient strategy" (large amounts of tools and blank produced on the spot), that reflect an organized land use and a common strategy in the whole region. The differences in the assemblage composition are partially due to adjustments within the settlement system concerning site type. The residential sites are located on the Ionian coast and show a stronger pattern for expediency, linked to the occupation length. Conversely, the other sites can be interpreted as logistical spots, linked to raw material provisioning (Romanelli), and/or hunting /butchering (Romanelli, Giganti).

Therefore, the maintenance of the flint tools is a part of the Neanderthals occupation strategy, aiming to maximize the use life of those implements whose source was far outside the peninsula. This behaviour was coupled with the choice toward particular tool classes and reduction methods seeking to produce the most efficient blanks (Kuhn, 1992).

This variability is becoming part of our understanding of Neanderthal behaviour, characterized by a fragmentation of stone working in space, time and social dimensions (Turq *et al.*, 2013).

So what is the ultimate result of human occupation in the lower Salento? What purpose identifies a regular displacement of about 50 km from residential sites? The southern Salento lacks immediate access to adequate sources of raw material, but it is rich in resources like game and water, ubiquitously distributed (Spinapolice 2008, 2018). The occupation of the southern area was probably linked to provisioning in non -lithic resources (*i.e.* water, game and vegetal resources). This fits with the hypothesis (Walker and Churchill, 2014) stating that Neanderthals must have relied heavily on animal protein in the plant food poor environment of Pleistocene Europe, home range sizes and levels of logistical mobility being determined by prey abundance and distribution and for that reason, Neanderthal maintained very large territories (1400-5400 km²). The concept of "embeddness" of provisioning of lithic raw materials (Binford 1979) is questioned here. Indeed, the territories of the southern Salento lacking these materials, they are associated to another territorial use model. Supplies of raw materials and game continues on two opposite sides, the first focused towards the north, the second towards the south. The occupation of a vast plain characterized by a high biodiversity can be related to a supply of game. A provisioning of raw materials is however possible for the site of Grotta Romanelli, where intense exploitation of the conglomerate was analysed. This is not the case with other sites that do not have the techno-economic facies of raw material acquisition, but almost exclusively facies of use/transformation.

The strategies employed in Salento finally seem to contradict the assertion that Neanderthals "shop food in the nearest supermarket" (Bar Yosef 2004). The occupation of a region devoid of mineral resources but rich in biodiversity and water is a potential demonstration.

Thanks to the analysis of raw material exploitation and site economy, significant behavioural peculiarities emerged in Neanderthal. A complete faunal study is expected, to test the proposed model at the light of the hunting and butchering data.

Acknowledgments

The author wishes to thank Valentina Borgia and Emanuela Cristiani to organise the symposium. This research was founded as a PhD program by the Universities Rome Sapienza and Bordeaux 1. The access to lithic collections in Rome was guaranteed by the IsIPU. The author is grateful to the Soprintendenza Archeologica della Puglia for providing access to the lithic collections in Taranto. Thanks to E. Scerri for editing and useful comments. Thanks also to E. Claud for fruitful discussion during the PhD in Bordeaux. This work is dedicated to the beloved memory of Amilcare Bietti.

References

Alahique, F., Lemorini, C., 1996. Butchering with stone tools. An experimental approach to use wear analysis and taphonomic studies of the archaeological materials of Grotta Breuil (Monte Circeo, Latium, Italy). *Quaternaria Nova* VI, 393-412.

Andrefsky, W., 2009. The Analysis of Stone Tool Procurement, Production, and Maintenance *Journal of Archaeological Research* 17, 65-103.

Bamforth, D.B., Bleed, P., 1997. Technology, flaked stone technology, and risk. *Archeological Papers of the American Anthropological Association* 7, 109-139.

Bar Yosef, O., 2004. Eat what is there: hunting and gathering in the words of Neanderthals and their neighbours. *International Journal of Osteoarcheology* 14, 333-342.

Benazzi, S., Bailey, S.E., Mallegni, F., 2013. Brief communication: A morphometric analysis of the Neanderthal upper second molar Leuca I. *American Journal of Physical Anthropology* 152, 300-305.

Bietti, A., 2006. Alcune considerazioni sulla differenza tra le strategie di approvvigionamento di materie prime litiche nel Musteriano e nel Paleolitico superiore italiano: qualche esempio. Atti della XXXIX Riunione Scientifica dell'IIPP. Istituto Italiano di Preistoria e Preistoria, Florence, pp. 267-282.

Bietti, A. and Cancellieri, E., 2006. New data from the late Upper Palaeolithic site of Fondo Focone (Ugento, Southern Apulia, Italy): the industry of the "B trench". in: Whallon, R. (Ed.), Late Palaeolithic environments and cultural adaptation around the Adriatic. BAR International Series, 1716, pp. 1-14.

Binford, L.R., 1979. Organization and formation processes: looking at curated technologies. *Journal of Anthropological Research* 35, 255-272.

Binford, L.R., 1980. Willow smoke and dog tails: hunter-gatherer settlement systems and archaeological site formation. *American Antiquity* 45, 1-17.

Binford, L.R., 1982. The Archaeology of place. *Journal of Anthropological Archaeology* 1, 5-31.

Binford, L.R., 1983. In pursuit of the past. Thames and Hudson, London.

Binford, L.R., 2001. Constructing frames of reference: an analytical method for archaeological theory building using hunter-gatherer and environmental data sets. University of California Press.

Blanc, A.C., 1958-61. La Grotta dei Giganti. *Quaternaria* V, 308-310.

Blanc, A.C., 1962. L'ottavo reperto Neanderthaliano d'Italia e il del Salento: un dente infantile associato con industria musteriana e fauna ad elefante e rinoceronte nella Grotta delle Tre Porte al Capo di Leuca. *Quaternaria* V, 313-314.

Blanc, G.A., 1920. Grotta Romanelli I: stratigrafia dei depositi e natura e origine di essi. *Archivio per l'antropologia e l'etnologia* 50, 10.

Blanc, G.A., 1928. Grotta Romanelli II: dati ecologici e paletnologici. *Archivio per l'antropologia e l'etnologia 58*, 365-411.

Bleed, P., 1986. The optimal design of hunting weapons: maintainability or reliability? *American Antiquity* 51, 737-747.

Bordes, F., 1961. Typologie du Paléolithique ancien et moyen. Presses du CNRS, Paris.

Borzatti von Löwerstern, E., 1965. La Grotta- riparo di Uluzzo C. *Rivista di Scienze Preistoriche* XX, 1-31.

Borzatti von Löwerstern, E., 1966. Alcuni aspetti del Musteriano del Salento. *Rivista di Scienze Preistoriche* 21.

Borzatti von Löwerstern, E., 1970. Prima campagna scavi nella Grotta Mario Bernardini (Nardò-Lecce). *Rivista di Scienze Preistoriche* 25, 89-125.

Borzatti von Löwerstern, E., 1971. Seconda campagna scavi nella Grotta Mario Bernardini (Nardò-Lecce). *Rivista di Scienze Preistoriche* 26, 31-62.

Borzatti von Löwerstern, E., Magaldi, D., 1966. Risultati conclusivi dello studio paletnologico e sedimentologico della Grotta di Uluzzo C (Nardò- Lecce). *Rivista di Scienze Preistoriche* 21, 16-64.

Borzatti von Löwerstern, E., Magaldi, D., 1967. Ultime ricerche nella Grotta dell'Alto (S. Caterina, Lecce). *Rivista di Scienze Preistoriche* 22, 205-250.

Borzatti von Löwerstern, E., Magaldi, D., 1969. Risultati conclusivi dello studio paletnologico e sedimentologico della Grotta di Uluzzo C (Nardò- Lecce). *Rivista di Scienze Preistoriche* 21, 16-64.

Bottet, B., Bottet, B., 1951. La Baume Bonne, Quinson. *Bulletin Société Préhistorique Francaise* 48, 261-282.

Brauer, A., Allen, J.R.M., Mingram, J., Dulski, P., Wulf, S., Huntley, B., 2007. Evidence for last interglacial chronology and environmental change from Southern Europe. *Proc. Natl. Acad. Sci.* USA 104, 450-455.

Cahen, D. and Keeley, L.H., 1980. Not less than two, no more than three. *World Archaeology* 12, 166-180.

Costamagno, S., Meignen, L., Beauval C., Vandermeersch B., Maureille B., 2006. Les Pradelles (Marillac-le-Franc, France): A mousterian reindeer hunting camp? *Journal of Anthropological Archaeology* 25, 466-484.

Cremonesi, G., 1980a. Nota preliminare sulla Grotta S. Ermete. Rass.Trim.Banca Agr. Pop. Matino e Lecce VI, 71-75.

Cremonesi, G., 1980b. Saggio di scavo a Grotta Montani (Salve). *Studi d'Antichità* 2, 45-57.

Cristiani, E. and Spinapolice, E., 2009. Approccio tecno-sperimentale all'industria su Callista chione. Nuovi risultati da Grotta dei Giganti (LE), Atti 5° Convegno nazionale di Zooarcheologia, 85-88.

d'Errico, F., Banks, W.E., 2014. Tephra studies and the reconstruction of Middle-to-Upper Paleolithic cultural trajectories. *Quaternary Science Reviews*.

Dai Pra, G., Hearty, P., 1988. I livelli marini pleistocenici del Golfo di Taranto. Sintesi Geocronostratigrafica e tettonica. *Memorie Società Geologica Italiana* 41, 637-644.

De Vivo, B., Rolandi, G., Gans, P.B., Calvert, A., Bohrson, W.A., Spera, F.J., Belkin, H.E., 2001. New constraints on the pyroclastic eruptive history of the Campanian volcanic Plain (Italy). *Mineralogy and Petrology* 73, 47-65.

Di Stefano, G., Petronio, C., Sardella, R., Savelloni, V., Squazzini, E., 1992. Nuove segnalazioni di brecce ossifere nella costa fra Castro Marina e Otranto (Lecce). *Il Quaternario* 5, 3-10.

Douka, K. and Spinapolice, E.E., 2012. Neanderthal shell tool production: evidence from Middle Palaeolithic Italy and Greece. J*ournal of World Prehistory* 25, 45-79.

Féblot-Augustins, J., 1997. La circulation des matières premières au Paléolithique: synthèse des données et perspectives comportementales, ERAUL 75, Liège.

Fedele, F.G., Giaccio, B., Hajdas, I., 2008. Timescales and cultural process at 40,000 BP in the light of the Campanian Ignimbrite eruption, Western Eurasia. *Journal of Human Evolution* 55, 834-857.

Fedele, F.G., Giaccio, B., Isaia, R., Orsi, G., 2002. Ecosystem Impact of the Campanian Ignimbrite Eruption in Late Pleistocene Europe. *Quaternary Research* 57, 420-424.

Ferranti, L., Antonioli, F., Mauz, B., Amorosi, A., Dai Pra, G., Mastronuzzi, G., Monaco, C., Orru, P., Pappalardo, M., Radtke, U., Renda, P., Romano, P., Sansò, P., Verrubbi, V., 2006. Markers of the last interglacial sea-level high stand along the coast of Italy: tectonic implications. *Quaternary International* 145-146, 30-54.

Fiorini, A., Curci, A., Benazzi, S., & Spinapolice, E. E. 2018. Il sistema di documentazione digitale dello scavo archeologico nel sito di Uluzzo C (Nardò, LE). Sezione di Museologia Scientifica e Naturalistica, 13, 68-70.

Geneste, J.M., 1985. Analyse lithique d'industrie moustériennes du Périgord : un approche technologique du comportement des groupes humains du Paléolithique moyen, Université de Bordeaux 1, Bordeaux.

Geneste, J.M., 1988. Systèmes d'approvisionnement en matières premières au Paléolithique moyen et au Paléolithique supérieur en Aquitaine. ERAUL 8, 161-170.

Geneste, J.M., 1991. L'approvisionnement en matières prèmieres dans le systèmes de production lithique: la dimension spatiale de la technologie. *Treballs d'Arquelogia* 1; Tecnologìa y Cadenas Operativas Lìticas.

Giaccio, B., Hajdas, I., Peresani, M., Fedele, F.G., Isaia, R., 2006. The Campanian Ignimbrite and its relevance for the timing of the Middle to Upper Palaeolithic shift in: Conard, N.J. (Ed.), When Neanderthals and Modern Humans Met. Kerns Verlag, Tübingen pp. 343-375.

Giaccio, B., Isaia, R., Fedele, F.G., Di Canzio, E., Hoffecker, J., Ronchitelli, A., Sinitsyn, A.A., Anikovich, M., Lisitsyn, S.N., 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, 208-226.

Gould, R.A., 1980. Living archaeology. Cambridge University Press, Cambridge.

Higham, T., Brock, F., Peresani, M., Broglio, A., Wood, R., Douka, K., 2009. Problems with radiocarbon dating the Middle to Upper Palaeolithic transition in Italy. *Quaternary Science Reviews* 28, 1257-1267.

Inizan, M.-L., Reduron-Ballinger, M., Roche, H. et Tixier, J., 1995. Préhistoire de la pierre taillée t. 4 – Technologie de la pierre taillée. CREP, Meudon.

Issel, A., 1914. Lembi fossiliferi quaternari e recenti nella Sardegna meridionale. *Accademia Nazionale dei Lincei* 23, 1749-1762.

Keller, J., Ryan, W.B.F., Ninkovich, D., Altherr, R., 1978. Explosive volcanic activity in the Mediterranean over the past 200.000 years as recorded in deep-sea sediments. *Geological Society of America Bullettin* 89, 591-604.

Kuhn, S.L., 1992. On planning curated technologies in the Middle Palaeolithic. *Journal of Anthropological Research* 48, 798-809.

Kuhn, S.L., 1994. A formal approach to the design and assembly of mobile toolkits. *American Antiquity* 59, 426-442.

Lambek, K., 2004. Sea level change through the last glacial cycle: geophysical, glaciological and paleogeografic consequences. *Comptes Rendus Geoscience* 336, 677-689.

Leroi-Gourhan, A., 1964. Le geste et la parole I, Technique et langage, Bibliothèque Albin Michel Sciences, Paris.

Lemorini, C., Venditti, F., Assaf, E., Parush, Y., Barkai, R., & Gopher, A. 2015. The function of recycled lithic items at late Lower Paleolithic Qesem Cave, Israel: An overview of the use-wear data. *Quaternary International,* 361, 103-112.

Marks, A.E., Chabai, V.P., 2006. Stasis and Change During the Crimean Middle Paleolithic, in: Hovers, E., Kuhn, S. (Eds.), Transitions Before the Transition, pp. 121-135.

Mastronuzzi, G., Quinif, Y., Sansò, P., Selleri, G., 2007. Middle-Late Pleistocene polyciclic evolution of a stable coastal area (southern Apulia, Italy). *Geomorphology* 86, 393-408.

Meignen, L., Bar Yosef, O., Speth, J., Stiner, M., 2007. Middle Palaeolithic Settlement Patterns in the Levant, in: Hovers, E., Kuhn, S. (Eds.), Transitions before the Transition, pp. 149-170.

Milliken, S., 1998. Hunter gatherer land use in late glacial south-east Italy. *Oxford Journal of Archaeology* 17, 269-276.

Nelson, M.C., 1991. The study of technological organization. *Archaeological Method and Theory* 3, 57-100.

Odell, G.H., 2000. Stone tool research at the end of the Millennium: procurement and technology. *Journal of Field Archaeology* 8, 269-331.

Palma di Cesnola, A., 1993. Il paleolitico Superiore in Italia. Introduzione allo studio. Garlatti e Razzai, Firenze.

Palma di Cesnola, A., 1996. Le Paléolitique inférieur et moyen en Italie. Jerome Millon, Grenoble.

Palma di Cesnola, A., 2001. Il paleolitico inferiore e medio in Italia. Millenni 3.

Paterne, M., Guichard, F., Duplessy, J.C., Siani, G., Sulpizio, R., Labeyrie, J., 2008. A 90,000-200,000 yrs marine tephra record of Italian volcanic activity in the Central Mediterranean Sea. *Journal of Volcanology and Geothermal Research* 177, 187-196.

Pelegrin, J., 1985. Réflexion sur le comportement technique, in: Otte, M. (Ed.), La signification culturelle des industries lithiques. BAR International Series., Oxford, pp. 72-91.

Pelegrin, J., 1995. Technologie lithique: le Chatelperronien de Roc de Combe (Lot) et de la Cote (Dordogne). CNRS, Bordeaux.

Perlès, C., 1991. Économie des matières premières et économie du débitage : deux conceptions opposées?, 25 ans d'Études technologiques es préhistoire. Bilan et respectives. APDCA, Antibes, pp. 35-45.

Piperno, M., 1974. L'industria musteriana su calcare di Grotta Romanelli (Otranto). *Memorie dell'Istituto Italiano di Paleontologia Umana* II, 69-90.

Ranaldo F., 2017. L'arco ionico pugliese tra la fine del Paleolitico medio e gli esordi del Paleolitico superiore: problemi e prospettive di ricerca per la ricostruzione dei sistemi antropici. Atti XLVII Riunione Scientifica IIPP- Preistoria e Protostoria della Puglia, Ostuni 2012.

Riel- Salvatore, J. and Negrino, F., 2008. Early Upper Paleolithic Population Dynamics and Raw Material Procurement Patterns in Italy. 205-224.

Riel-Salvatore, J., 2007. The Uluzzian and the Middle-Upper Palaeolithic Transition in southern Italy, PhD thesis, Arizona State University Tucson.

Rios-Garaizar, J., Eixea, A., Villaverde, V., 2014. Ramification of lithic production and the search of small tools in Iberian Peninsula Middle Paleolithic. *Quaternary International.*

Romagnoli, F., Martini, F., Sarti, L., 2014. Neanderthal Use of Callista chione Shells as Raw Material for Retouched Tools in South-east Italy: Analysis of Grotta del Cavallo Layer L Assemblage with a New Methodology. *Journal of Archaeological Method and Theory*, 1-31.

Sala, B., 1980. Faune a grossi mammiferi nel Pleistocene superiore. I vertebrati fossili italiani, Verona, pp. 235-238.

Sardella, R., Bertè, D., Iurino, D.A., Cherin, M., Tagliacozzo, A., 2013. The wolf from Grotta Romanelli (Apulia, Italy) and its implications in the evolutionary history of *Canis lupus* in the Late Pleistocene of Southern Italy. *Quaternary International* 328, 179-195.

Schiffer, M.B., 1985. Is There a "Pompeii Premise" in Archaeology? *Journal of Anthropological Research* 41, 18-41.

Shott, 1989. On tool class use lives and the formation of archeological assemblages. *American Antiquity* 50, 9-30.

Shott, M., 1986. Technological organization and settlement mobility. *Journal of Anthropological Research* 42, 15-51.

Slimak, L., 2004. Les dernières expressions du Moustérien entre Loire et Rhône. Université de Provence, Aix-en-Provence, p. 875.

Spinapolice, E., 2008. Technologie lithique et circulation des matières premières au Paléolithique moyen dans le Salento (Pouilles, Italie méridionale) : perspectives comportementales. Università di Roma "La Sapienza" – Université de Bordeaux 1, p. 485.

Spinapolice, E., 2009. Lithic industries and raw material in southern Italy mousterian: an exemple from Grotta dei Giganti (Salento, Apulia), in: Sternke, F. (Ed.), Non-flint raw material use in prehistory. BAR International Series, Oxford, pp. 177-186.

Spinapolice, E.E., 2012. Raw material economy in Salento (Apulia, Italy): new perspectives on Neanderthal mobility patterns. *Journal of Archaeological Science* 39, 680-689.

Spinapolice, E. E. 2015. Third hand: a testable hypothesis. *Journal of Anthropological Sciences* 93, 169-171.

Spinapolice, E.E. 2018. Les Néandertaliens du talon Technologie lithique et mobilité au Paléolithique moyen dans le Salento (Pouilles, Italie méridionale). Archaeopress, Oxford, 224 pp.

Thiébaut, C., 2005. Le Moustérien à denticulés : Variabilité ou diversité techno-économique ?, UFR Archéologie et Histoire de l'art. Université d'Aix-Marseille I – Université de Provence, Aix en Provence, p. 644.

Thiébaut, C., Claud, E., Coudenneau, A., Coumont, M.P., Asselin, A., Beauval, C., Chacón, M., Costamagno, S., Daulny, L., Gerbe, M., Mallye, J.B., Maury, S., Mourre, V., Plisson, H., Provenzano, N., Streit, L., 2007. Des traces et des hommes. Rapport 2007. Projet Collectif de Recherche (Programme 3).

Thiébaut, C., Claud, E., Mourre, V., Chacon, M.G., Asselin, G., Brenet, M., Paravel, B., 2010. Le recyclage et la réutilisation de nucléus et de bifaces au Paléolithique moyen en Europe occidentale : quelles fonctions et quelles implications culturelles. *Palethnologie*, 341.

Tixier, J., 1978. Méthode pour l'étude des outillages lithiques : notice sur les travaux scientifiques de J. Tixier. Université de Paris X – Nanterre, p. 118 p.

Torrence, R., 1989. Time, energy and stone tools, New Direction in Archaeology. Cambridge University Press, Cambridge, p. 125.

Turq, A., 2000. L'approvisionnement en matières premières lithiques. *Paléo*, 391-415.

Turq, A., Roebroeks, W., Bourguignon, L., Faivre, J.-P., 2013. The fragmented character of Middle Palaeolithic stone tool technology. *Journal of Human Evolution* 65, 641-655.

Van Peer, P., 2001. Observations on the Palaeolithic of the south-western Fezzan and thoughts on the origin of the Aterian, in: Garcea, E.A.A. (Ed.), Uan Tabu in the Settlement History of the Libyan Sahara. All'Insegna del Giglio, Firenze, pp. 51-62.
Walker, C.S., Churchill, S.E., 2014. Territory size in Canis lupus: implications for Neanderthal mobility, Reconstructing Mobility. Springer, pp. 209-226.
Wulf, S., Brauer, A., Mingram, J., Zolitschka, B., Negendank, J., 2006. Distal tephras in the sediments of Monticchio maar lakes, in: Principe, C. (Ed.), La geologia del Monte Vulture. Regione Basilicata. Consiglio Nazionale delle Ricerche, Roma, pp. 105-122.
Yellen, J.E., 1977. Archaeological approaches to the present: models for reconstructing the past. New York: Academic Press.

The socio-economic significance of Neanderthal shell technology

A new perspective on Middle Palaeolithic adaptation to intertidal zones from disregarded tools

Francesca Romagnoli[1]

Abstract

Shell technology was a Mediterranean technical behaviour that showed a peculiar Neanderthal adaptation to littoral areas and reflects the capacity of this human species to exploit a wide range of coastal resources that have traditionally been considered to be specific to *Homo sapiens*. The diffusion of this technology in Southern peninsular Europe makes it interesting for the investigation of Neanderthal behaviour as it relates to several factors, including the available resources, environment, economy, mobility, technical traditions, and capacity to generate adaptive information. These tools have been disregarded since their first identification in the late 1950s. In last few years, the author has worked on this topic and created a specific terminology to describe these items and a new, multidisciplinary, analytical methodology for analysis. The aim was to study shell technology with regard to the whole techno-complex and to allow comparisons both between sites and between shell and lithic assemblages. A summary of these studies is presented in the current paper, which focuses on four main topics: (i) the importance of experimental protocols in archaeological research, (ii) the relationship between economy and technology, (iii) the flexibility of the whole technical system, and (iv) the mechanisms of technological innovation. The results of these systematic investigations have contributed to the comprehension of the shell as a raw material

1 Departamento de Prehistoria y Arqueología, Universidad Autónoma de Madrid, Ciudad Universitaria de Cantoblanco, 28049 Madrid, Spain. Email: francesca.romagnoli@uam.es; f.romagnoli2@gmail.com.

in: Borgia, V. and E. Cristiani (eds.) 2018: *Palaeolithic Italy. Advanced studies on early human adaptations in the Apennine peninsula*, Sidestone Press Academics (Leiden), pp. 125-146.

and have shown the great potential of this new line of research to discuss central questions in Middle Palaeolithic research. New perspectives are provided on the study of Neanderthal behavioural variability, economic and social dynamics, and mechanisms of technical innovation.

Keywords: *Callista chione*, shell tool, Grotta del Cavallo, Italy, raw material, experimental archaeology, techno-functional analysis, use-wear, adaptive behaviour.

1. Introduction

Along the Mediterranean seashores Neanderthals frequently used marine valve shells, *Callista chione*, to manufacture retouched tools. This technology have been confirmed in thirteen sites in Southern Europe that are spread between the Marine Isotopic Stage (MIS) 5 – MIS 3 (Table 1). At present, this technical behaviour has only been dated on the basis of faunal association and sedimentary data, and the lack of chronometric data has made it difficult to establish the contemporaneity between the sites. Despite the differences in taxa frequency among the sites, the faunal associations are mainly indicative of woodlands and the more open landscapes that are associated with coastal planes (see Douka and Spinapolice 2012 for a bibliographic review of the environmental data). Although the Neanderthal retouched shell tools have been long since identified (Blanc 1958-1961), these artefacts have been neither analysed nor described in detail beyond the generic definition of 'shell scrapers' until now.

The research on Neanderthal shell tools that has been conducted in the last years by the author in collaboration with several colleagues from Italy, Spain and France, adopted a new behavioural approach that was integrated with the analysis of the wide-range organisation of stone tool techno-complexes. This research provided an original, detailed analysis of Middle Palaeolithic shell technology. The results contributed to clarify Neanderthal technical variability, which is still one of the central topics in Palaeolithic studies. Furthermore, the results contributed to the knowledge of Neanderthal eco-

Mousterian sites with retouched shell tools	Country	Chronology	Main references
Kalamakia Cave	Greece (Mani Peninsula)	MIS 5	Darlas 2007
Riparo Mochi	Italy (Liguria)	MIS 5	Blanc 1958-61; Vicino 1974
Barma Grande	Italy (Liguria)	MIS 5	Vicino 1974
Ex Casinò	Italy (Liguria)	MIS 5	Oxilia 1974; Vicino 1974
Grotta dei Moscerini	Italy (Lazio)	MIS 5-MIS 3	Vitagliano 1984; Stiner 1994
Grotta di Serra Cicora	Italy (Apulia)	MIS 5- MIS 4	Dantoni, 1980
Grotta del Cavallo	Italy (Apulia)	MIS 5e-MIS 4	Romagnoli *et al.* 2015
Grotta Marcello Zei	Italy (Apulia)	MIS 5-MIS 4	Dantoni and Nardi 1980
Grotta di Capelvenere	Italy (Apulia)	MIS 5-MIS 4?	Giusti 1979
Grotta di Uluzzo C	Italy (Apulia)	MIS 4	Borzatti von Löwenstern and Magaldi 1969
Grotta dei Giganti	Italy (Apulia)	MIS 4?	Blanc 1958-61
Grotta Mario Bernardini	Italy (Apulia)	MIS 4-MIS 3	Borzatti von Löwenstern 1971
Grotta di Torre dell'Alto	Italy (Apulia)	MIS 4 (-MIS 3?)	Borzatti von Löwenstern and Magaldi 1969

Table 1. Middle Palaeolithic sites with shell tools.

Figure 1. Archaeological Callista chione tools from Grotta del Cavallo. The tools were well preserved, and negatives of the retouching were clearly readable (from Romagnoli et al., 2015, 2016a, modified).

nomic strategies and social dynamics, providing a new perspective on the cognitive and adaptive capacity of these pre-Sapiens European populations and their technological systems in coastal areas.

This innovative research was based on the analysis of records that were found during recent excavations at Grotta del Cavallo (south-east Italy, layer L MIS5e-MIS4; Sarti *et al.* 2002), which generated a reference methodology to be used in following studies. The recent excavation that was performed during the 1990s, which provided high microstratigraphic detail, the sieving of sediments and the excavation of the surface, allowed for the recovery of a significant number of elements (126 *Callista chione* retouched pieces that correspond to 374 gr, as well as several unretouched fragments that correspond to 275 gr). Furthermore, the pieces were well preserved from taphonomic processes, with highly visible growth lines of the valve and clearly readable negatives of retouching (Fig. 1).

The study centred on five main questions:

1. Did Neanderthals apply a selection of the taxa that were used for manufacturing tools according to specific features of the valve?
2. Was the use of shell as a raw material integrated into the techno-economical system of the human group, or was it an expedient behaviour to answer to an immediate need?
3. What were the advantages and disadvantages of using shell as a raw material in comparison with stone resources?
4. Were the morpho-technical characteristics of the shell tools determined by the natural shape of the valve, or were they due to specific functional constraints given the selection of the valve?
5. In which activities and with what mode of operation was the shell tool most efficient and effective?

This new wide-range approach has contributed to the understanding of shell as a raw material. It has also expanded the knowledge of the dynamics of technical change during the Middle Palaeolithic era and contributed to the interpretation of Neanderthal variability from a socio-economic viewpoint, providing an original perspective for this central topic in prehistory.

In this paper the summary of the new knowledge on Mediterranean shell technology is presented and implications for interpreting past human behaviour are discussed. Perspectives in the study of Middle Palaeolithic shell technology are also discussed. Indeed, the results of this first study created the basis for further detailed comparisons between sites to determine whether the production and use of these tools along the Mediterranean shore was due to contacts between human groups that lived along the coastal landscapes or, conversely, it was the result of local independent adaptive behaviour that was supported by the flexibility of the technical system and the cognitive capacities of the Neanderthals.

2. How could the behavioural study of shell technology shed new light on Neanderthal capability and conduct? Some concepts from an economic perspective

Middle Palaeolithic shell tools were the expression of a modality of adaptation of Neanderthals to the marine coastal environment. These artefacts were undoubtedly tools. Technology has played a fundamental role in human evolution. From the beginning it was strictly related to many factors that include land use strategies, available resources, economic constraints, risk assessment, energy and time costs, shared knowledge, mechanisms of knowledge transmission, and group size (Semaw *et al.* 1997; de la Torre 2004; Delagnes *et al.* 2005; Stout *et al.* 2010; Harmand *et al.* 2015). All of these elements, which comprising climate, environment and ecosystems, were continuously in a process of change and required flexibility from both the technological system and the humans that used technology to fulfil their needs. The variable degree of technological flexibility determines the capacity of any technological system to adapt to changing conditions and maintaining its structural characteristics. Hominids, in turn, always had a highly flexible behaviour and were able to obtain a great variety of possible adaptive solutions to guarantee and expand population fitness including raw material diversification.

In economic science, technology is an endogenous factor in an economy (Carlsson and Stankiewicz 1991) and it is a fundamental element in economic growth. Technological innovation is linked to adaptive capacity through the expansion of the economic opportunity sets (Jacobsson and Johnson 2000). The innovation process and the diffusion of new ideas and knowledge is a collective phenomenon, but it is also a personal occurrence (Saxenian 1994), and the technological strategy of a human group is based on the assessment of risk that also makes possible and promotes specific social mechanisms (Kasperson *et al.* 1988; Fig. 2).

From a production perspective, Palaeolithic technology requires four elements (van der Leeuw 2000). 'Conceptualisation' includes the shape of the tool, the production phases and their logical order; 'the executive function' includes the skills and strategies that are applied by humans to realise the conceptual project; the physical properties of

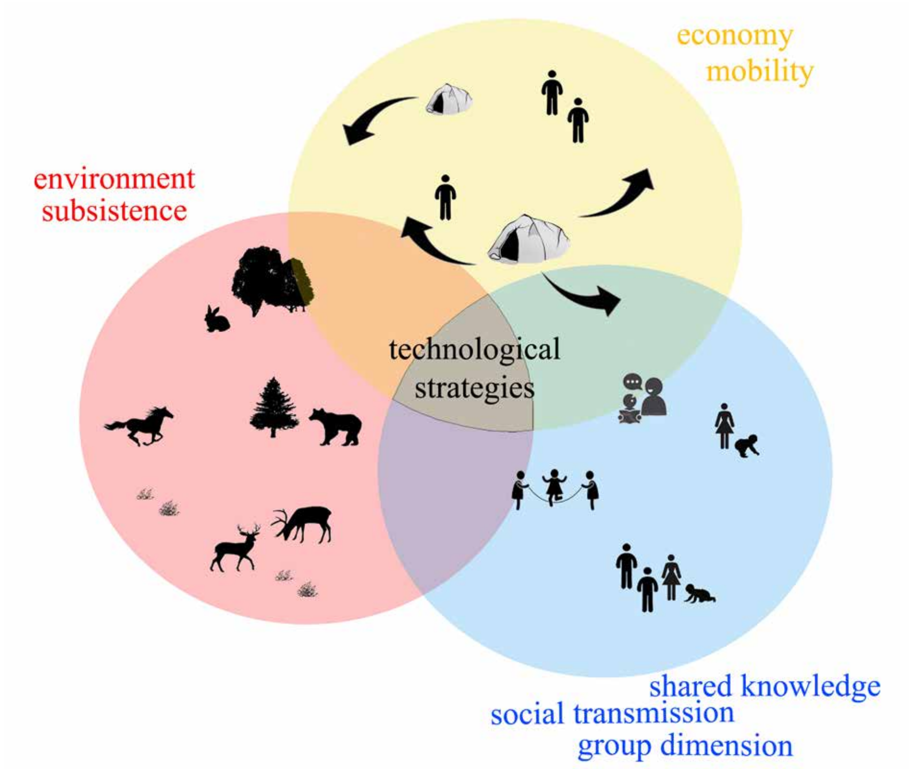


Figure 2. Human technology is strictly related to many factors that are continuously in a process of change. Adaptive solutions, including raw material diversification, allow for the guarantee and expansion of population fitness.

'raw material' affect the executive functions; and 'the tool' is the aim of production and is manufactured to satisfy human needs. All of these elements are partially related to the individual craftsman's capacity for problem solving.

Each of the structural elements that are described above imposes specific constraints. Such constraints can be categorised as material, operational, and strategic according to the phase of productive process, technical knowledge, available resources, tools characteristics, and the economic and social organisation of the group (Torrence 1989; Hayden *et al.* 1996; Fitzhugh 2001; Kuhn and Miller 2015).

Finally, the context of the whole technological organisation must be considered. To interpret novel artefacts, the role and nature of the new technology must be analysed at a micro-scale using a dynamic approach due the flexibility of both the technological system and human behaviour and with comparison among all of the technologies that are part of the economy of a specific human group (Saxenian 1994).

In the last few years, while several studies have suggested the capacity of Neanderthals for non-utilitarian behaviours (*e.g.*:, Soressi and d'Errico 2007; Zilhão *et al.* 2010; Caron *et al.* 2011; Morin and Laroulandie 2012; Peresani *et al.* 2013; Romandini *et al.* 2014), few others have shown that this human species had the capacity for technical innovation. This capacity is highlighted by the production of new tools using hafting and multiple components (Rots 2009; Pawlik and Thissen 2011), and new raw material such as wood (Solé *et al.* 2013). Shell technology falls within this last category. The difficulty in the obtaining of sufficient data in the ancient archaeological record to discuss how and why new technology was developed by ancient hominins makes Neanderthal shell technology a relevant field of investigation.

3. Methods

Terminology and methodology were created by merging certain principles and concepts of the natural sciences and lithic technology into a new, multidisciplinary design that included taxonomy, taphonomy, the morpho-metrical analysis of shell tools, the techno-functional analysis of the cutting edge, the study of use-wear traces (mainly of macro-traces and the microscopic analysis of polishing formation processes, location, and characteristics), and experimental archaeology (Romagnoli *et al.* 2015, 2016a, 2017; Fig. 3). These different methods were strictly linked together. Furthermore, to determine techno-economic behaviour the study of shell assemblage had to be carried out in parallel with the technological analysis of the lithic assemblage investigating economy, technology (the technical options that are selected by humans), and technique (*sensu* Tixier *et al.* 1980).

The analysis of the lithic assemblage included Raw Material Unit analysis to identify products that are related to the exploitation of a single raw material block (Roebroeks 1988; Larson and Kornfeld 1997), diacritic analysis to identify the logical sequence of each removal in the whole assemblage, and the morpho-technical analysis of each technical category (products that are related to the first phase of exploitation of the block, products of plain production, products of '*mise en forme*',

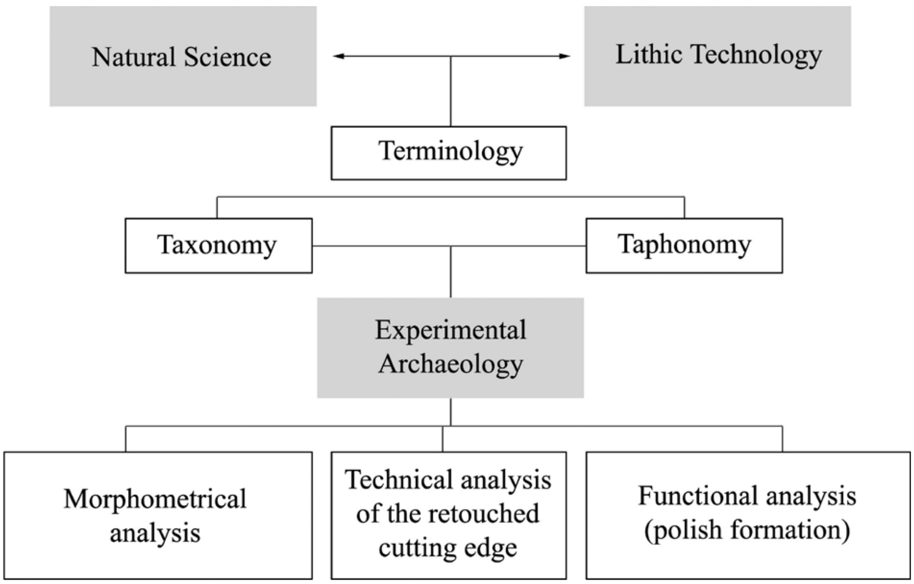


Figure 3. A new specific, multidisciplinary methodology has been created by merging certain concepts and the terminology of the natural sciences and lithic technology. The aim was to propose an analytical method that allowed comparisons between shell and lithic assemblages to interpret shell technology from a behavioural perspective.

cores; Inizan *et al.* 1999). The analyses were carried out in parallel with the study of the geological landscape, the cataloguing of the variety of knappable stones, the identification of the ones that were selected by Neanderthals, the testing of their physical constraints, the study of their location in the landscape with regard to the fragmented characteristics of each productive sequence to reconstruct mobility strategies, economic organisation, costs of production, recycling behaviour, and risk analysis (Romagnoli 2015; Romagnoli *et al.* 2016b).

An important role in methodology has been played by experimental archaeology. The direct experience of shell technology (*sensu* Reynolds 1999) was the earliest approach to (i) verify if 'retouch' was related to voluntary human modification of the valve's edge, or if it accidentally originated during the opening of the bivalve, or even if it was the result of natural processes; (ii) appreciate the constraints that are imposed by the raw material, both during manufacture and during use; (iii) evaluate the possible difference in shell performance after heating and burning; (iv) learn the variability of possible uses and the strength of shell tools; (v) propose hypotheses to be tested through experiments; and (vi) select the variables that are the most adequate to test such hypotheses with a consecutive experimental, actualistic approach (Outram 2008; Romagnoli *et al.* 2015, 2016a, 2017). The quality of the archaeological data, the wide-range analysis of techno-economic behaviour and the number of pieces were the unavoidable premises for the application of experimental archaeology within a solid scientific framework and the creation of a reference work for the further development of this research topic.

The experiments used the fresh whole valves of *Callista chione* from the aquaculture of the Ionian Sea, the southern Tyrrhenian Sea, and the English Channel. The valves were selected with dimensions along the anterior-posterior axis that were comparable to the ones that were reconstructed for the original archaeological tools and approximately corresponded to 80 mm. The experiments sought to identify the technique for retouch, to evaluate the functional potential and the strength of the tools, and to understand the performance of the raw material in both manufacturing and use in relation to their physical properties (Romagnoli *et al.* 2016a, 2017).

The research was organised in successive steps to investigate several aspects of the shell technology.

1. *The production sequence*. The production was reconstructed from the finding of the raw material to the abandonment of the tools. Taxonomic, taphomic, and morpho-technical analyses using low and high-resolution were applied (Romagnoli *et al.* 2015).

2. *The technological costs*. The analysis of the modalities of recycling behaviour within the whole techno-complex, including shell manufacturing, was carried out to evaluate the costs of procuring and knapping raw materials and maintaining tools. The analysis was carried out taking into consideration the distance of the raw materials sources, the technology that was applied by the Neanderthals, and the tool's use-life, with regard to both stone and shell tools (Romagnoli 2015).

3. *The technical gestures and procedures for retouching*. In this phase the analysis was mainly focused on the internal structure of the valve (Szabó 2008), experimentation (50 fresh valves), the analysis of the negatives of retouch both on archaeological and experimental tools (morphology, dimensions, orientation, the localisation of their point of impact), and the analysis of archaeological hammers (type, association and the localisation of percussion marks and striations; Romagnoli *et al.* 2016a).

4. *The economic value of shell tools within the mobility strategy of the human group and the organisation of the whole techno-complex*. Economic, technological and technical behaviour were analysed both for lithic and shell assemblages (Romagnoli *et al.* 2016a, b).

5. *The functional potential of shell tools*. Wood (*Ligustrum vulgare*, *Pinus* and *Buxus*), hide, deer hide with hair, and meat were worked during 15-minute sections and analysed before and after use at high magnifications to determine the formation process of polished surfaces (50x, 200x, 500x, and 1000x). Recording several variables (see Romagnoli *et al.* 2017 for details), we tested three hypotheses: (i) the tools were efficient and effective on specific worked material; (ii) the tools were efficient and effective with specific kinetics according to both the morphology of the valve and the technical characteristics of the retouched cutting edge; and (iii) the tools were subject to valve breakage during use.

4. A new understanding of technical adaptation in intertidal zones

Along the Mediterranean shores, the Neanderthal only used *Callista chione* valves to manufacture retouched tools. Other taxa of marine shells were collected in the archaeological deposits in association with shell tools, which suggests a complex frequentation of the littoral area for a varied range of activities (Vicino 1974; Stiner 1993; Romagnoli *et al.* 2015). *Callista chione* is a large edible marine bivalve with a strong shell (Vasconcelos *et al.* 2011). The valve is made up of three layers. The periostracum is the outer layer, and it has the function of protecting the mollusc from predation. The bivalve has a crossed lamellar internal structure, with aragonite lamellae that are organised in three hierarchical orders, each with crystals that are aligned along a different inclination (Kogure *et al.* 2014). This structure is advantageous in preventing cracks from spreading and in resisting abrasion (Avery and Etter 2006). The analysis that was performed by the author on hundreds of fresh valves showed that Middle Palaeolithic items had a greater thickness than the present ones (with an average difference of 1 mm), most likely due to different temperatures and the salinity of the sea water. Further experiments with fossil shells will probably provide a better understanding of the crossed lamellar structure in relation to human modifications. However, to have reproduced comparable retouch and morpho-technical characteristics of the cutting edge with fresh valves suggests that the possible use by Neanderthals of ancient shells that were collected on Tyrrhenian beaches did not significantly change the performance of the shell. That could be due to the low organic component in the crossed lamellar structure, which is minimally affected by the decay process (Zuschin *et al.* 2003).

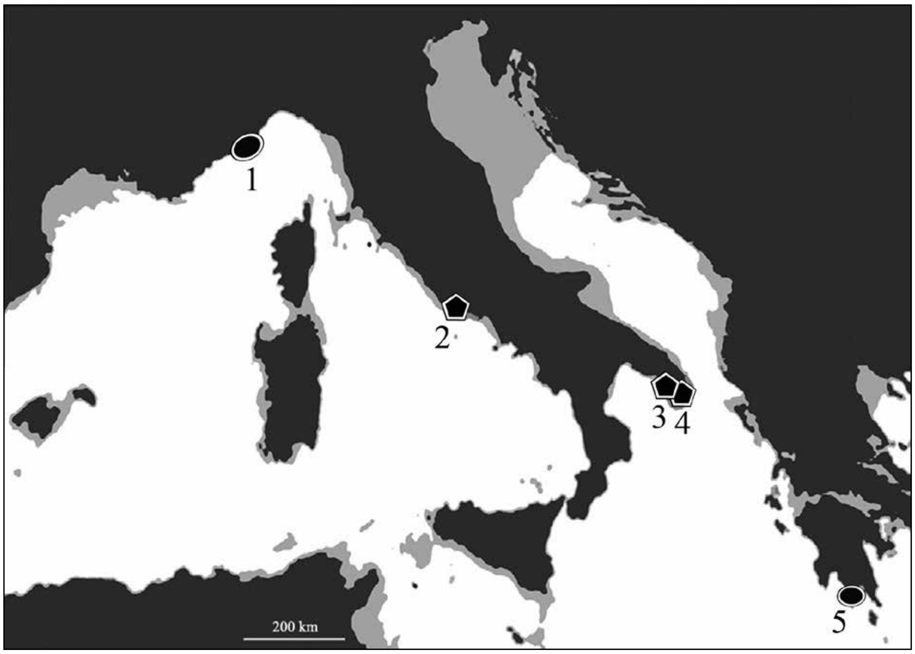


Figure 4. The location of the Middle Palaeolithic sites with shell technology. The light grey areas show emerged lands at sea level -100 m. The pentagons indicate sites where shell tools were associated with Quina stone retouch. 1: Riparo Mochi, Barma Grande, and ex-Casinó; 2: Grotta dei Moscerini; 3: Grotta del Cavallo, grotta di Uluzzo C, Grotta di serra Cicora, Grotta Mario Bernardini, Grotta di Torre dell'Alto, and Grotta Marcello Zei; 4: Grotta di Capelvenere and Grotta dei Giganti; 5: Kalamakia Cave.

According to data from Grotta del Cavallo (Romagnoli *et al.* 2015; Fig. 4), Grotta-Riparo Marcello Zei (Dantoni 1980) and Kalamakia Cave (Darlas 2007) the Neanderthals used valves that were approximately 80 mm along the anterior-posterior axis for retouching. According to studies that were carried out by Vasconcelos *et al.* (2011), this dimension is highly favourable with regard to shell resistance, especially to breakage, in the application of uniform force along the valve, as in the case of shell tools. Indeed, the data suggest that the Neanderthals selected whole valves and retouched them on the ventral margin on the internal surface creating a long continuous convex cutting edge (Romagnoli *et al.* 2015, 2016a). Taphonomic data are actually available only for Grotta dei Moscerini and Grotta del Cavallo. In the latter site, it has been shown that Neanderthals collected the valves after the death of the molluscs, as demonstrated by Bryozoa encrustations and bio-eroder damage on the internal surface of the shell (Romagnoli *et al.* 2015). That strategy implies the selection of the valve close to a typometric standard in response to a specific functional aim from the beginning of the productive sequence. At Grotta dei Moscerini the presence of burned fragments has been interpreted as the result of the alimentary consumption of this marine resource (Stiner 1993). The lack of a technological multidisciplinary study of these items does not allow us to exclude that the burning damage was produced accidentally after the use of the tools nor that, as suggested by Grotta del Cavallo, the functional productive sequence was independent from alimentary consumption.

Experiments have allowed the identification of the retouching technique as being comprised of two different stages. In the first stage a flat stone pebble (limestone or sandstone) is used to hit the ventral margin of the valve with the rounded surface of the pebble to create a denticulated edge. In the successive stage the flat surface of the pebble was used to regularise the active edge, thus creating a stepped scalar retouch. The application of force using a tangential gesture, adding a reorientation during the second stage (*à infléchissement*, Bourguignon 2001), produced characteristic marks on the stone hammer that have been identified on archaeological items (Romagnoli *et al.* 2016a). During the knapping procedure the hand that holds the valve must employ a force opposite to the one applied by the hammer: the fingers must press on the internal surface of the shell to prevent cracks. Furthermore the shell must be kept highly tilted to allow the impact between the hammer and the valve to be as close as possible to the ventral margin at the intersection between the internal surface and the periostracum. The inclination is imposed by the structure of the shell. Due to the orientation of the aragonite crystals, a percussion on the external surface determines a break that runs along the growth lines, which prevents the continuation of the manufacturing.

The type of hammer, the location and the association of percussion marks and striations on the hammers, the technical gestures and the morpho-technical characteristics of the retouched cutting edge are all elements that are comparable to the ones that define Quina stone retouch (Bertola *et al.* 1999; Bourguignon 2001; Baena Preysler and Carrión Santafé 2010). Furthermore, at Grotta del Cavallo the analysis of lithic assemblage using a behavioural approach has shown that the human group was highly mobile on a large territory from the north-west to the south-east. The Neanderthals fragmented their technical activities along the landscape, transporting toolkits to the site most probably due to planned activities within a logistical strategy (Romagnoli 2015; Romagnoli *et al.* 2016b). This economic organisation has been recognised as being typical of Quina techno-complexes, as defined in the south-west of France during MIS 4- MIS 3 (Turq 1992; Bourguignon *et al.* 2004, 2006; Faivre 2008; Delagnes and Rendu 2011). Viewing the whole record of Middle Palaeolithic sites that show shell technology, in a total of thirteen sites, nine showed the association of shell tools and Quina / demi-Quina stone retouch (see Romagnoli *et al.* 2016a and bibliography therein; Fig. 4), which suggests that the Quina techno-complex played a role in the inception of *Callista chione* technological innovation and could have been related to Neanderthal coastal adaptation in southern central Europe. From an evolutionary perspective little is yet known about Quina system. Several French authors have provided detailed economic, technological and technical behaviour of this techno-complex in a specific geographical and chronological range (south-west of France, MIS4-MIS3: Turq 1992; Bourguignon 1997; Moncel 2001; Faivre 2008; Delagnes and Rendu, 2011). However, the internal variability of Quina techno-complexes has never been identified at a European scale of analysis. In addition, the evolution of this system is still unknown, and it remains unclear whether there was any relationship among its presence in the Levant at MIS 11 (Copeland and Hours 1983; Barkai and Gopher 2013; Lemorini *et al.* 2015), in western Europe at MIS 9 (Bourguignon *et al.* 2008; Vieillevigne *et al.* 2008), and finally the spread in Italy, France and north of Iberian Peninsula at MIS 4-MIS3 (see Baena *et al.* 2014 for bibliography). Similarly, the meaning of its coexistence with other technological traditions is not still understood. In this respect the current investigation of shell technology contributes to the enrichment of the knowledge of European variability and the discussion of the economic and social meaning of the organisation of technology on a different range of environments than has traditionally been associated with 'Quina behaviour', including in this definition all of the structural characteristics that are associated in the archaeological context: high human mobility; the fragmentation of productive sequences; the stepped, scalar retouch that is usually associated with tools with a long use life and that are used for intense work (Romagnoli *et al.* 2017, 2016a).

From a functional viewpoint shell tools were ergonomic, and it was easy to change the grasp during tasks (Romagnoli *et al.* 2015a). The type of grasp was allowed to vary during use in terms of (i) the force applied, (ii) the working angle, and (iii) the curve of the trajectory, which guaranteed the versatility of the cutting edge. Furthermore, due to the high strength of the valve, it was possible to perform intense work on several different working materials. *Callista chione* tools had a long use life due to the structure of the shell, which permitted auto-resharpening during use. The auto-resharpening had several effects including an increase in the tool's effectiveness, a reduced risk of ruptures during retouching, the effectiveness of both large tools and short fragments, the ability to perform repetitive work, and enhanced effectiveness in many actions. The tool's effectiveness on different working materials has also been shown on the archaeological shell items through the analysis of the characteristics and location of polished surfaces (Romagnoli *et al.* 2017). The efficiency and effectiveness were also correlated to kinetic standardisation. Two movements were the most efficient due to the technical characteristics of retouching and the morpho-technical attributes of the tools: longitudinal linear movement to cut and transverse movement along a convex trajectory to shave off (*cf.* whittling; Romagnoli *et al.* 2017). The performance of intense and repetitive work and a long use life of the tool are typical of Quina and demi-Quina stone scrapers (Bourguignon 2001; Hiscock *et al.* 2009; Baena Preysler and Carrión Santafé 2010; Lemorini *et al.* 2015).

At present there is no consensus among researchers on the functional role of Quina scrapers. The functional work with shell tools could also contribute to a better understanding of Quina techno-complex from a tool design perspective. Future studies are needed to more deeply explore this topic and to understand the use of the Quina and "Quina" shell toolkit as integrated within the whole set of Neanderthal production as well as to understand the typical scalar stepped retouch of archaeological items as a result of a complex recurrence of retouch, use and auto-resharpening. In the author's opinion is of interest to highlight the advantages that are offered by a set of multitasking, maintainable, and resistant tools taking into account high mobility, time stress constraints and the likelihood of a low craft specialisation within the human group. Within this scenario expedient recycling behaviour, which has been demonstrated both in lithic and shell assemblage at Grotta del Cavallo (Romagnoli 2015), acquire a significant economic value. Indeed, anyone within the human group could participate in the tasks without the need to control the whole productive process because of the long use life of the tool and its versatility. In this respect the voluntary fragmentation of shell tools could have been due to the need to 'multiply the hands' participating in tasks after the first phase of tool life in which it was used as a large tool. The anthropic fragmentation has been shown by percussion marks on the external rounded surface of the shell, close to the umbo, and through experimentation (Romagnoli *et al.* 2015, 2017). Furthermore, although shell technology required specific motor skills, technical knowledge, and the knowledge of the physical quality of the raw material, the technical procedures to manufacture *Callista chione* tools were shared within the human group as attested by Quina and demi-Quina stone retouch. This may suggest that many individuals within the group could have easily mastered shell technology. Recently Davidson (2016) has criticised the use of similarity of form in prehistory as proxy for a "cultural" classification. He suggested that it is much more interesting (and I would add that it is also more complex) not to simply classify according to similarity but to ask of the archaeological record, "what was it that was learned within the group, such that the process of knapping produced a similarity of outcome?" (Davidson 2016: 109). In this perspective technology must be analysed considering social mechanisms (Kasperson *et al.* 1988), adaptive capacity of the group (Jacobsson and Johnson 2000), effects on economic growth (Carlsson and Stankiewicz 1991), and the structural characterisation and constraints of production (van der Leeuw 2000).

Considering shell technology and Quina behaviour from the new perspective that is presented in this paper sheds new light on this technological innovation. Shell technology and Quina techno-complex present analogous material, operational and strategic constraints so that shell technology was perfectly integrated into the economic and social system because of the flexibility of the shared technical tradition, which allowed for an increase in average fitness. In other words it was an expression of the human adaptive capacity due to cultural learning (Boyd *et al.* 2011).

5. Conclusion and perspectives: from single sites to coastal Mediterranean patterns

The interest in shells in ancient prehistory has increased in recent years, and human adaptation to coastal environments have been investigated from different viewpoints. *Homo sapiens'* capacity to adapt to coastal ecosystems is believed to be linked with modern behaviour in Africa (Jerardino and Marean 2010; Kyriacou *et al.* 2014; Marean 2014) and to be a key factor in their dispersal following a coastal route from Africa to South Asia (Bailey *et al.* 2011; 2015; Erlandson and Braje 2015). The data from southern Spain suggest that this adaptation had already been established since MIS 6 at approximately 150 kya, in the same chronological range as the African Middle Stone Age (Cortés-Sánchez *et al.* 2011), as part of the European Middle Palaeolithic behaviour of acquisition and consumption of a wide range of dietary resources, which has been ignored until very recently.

In addition to alimentary consumption, shell remains in the archaeological record can also be related to non-utilitarian purposes since at least the African Middle Stone Age and European Neanderthal cultures (*e.g.*, Perlès and Vanhaeren 2010; Zilhão *et al.* 2010; Peresani *et al.* 2013; Vanhaeren *et al.* 2013; Cristiani *et al.* 2014). More and more often, together with the use of highly elaborate methods for the use-wear analysis of malacological remains (Cristiani *et al.* 2005; Lammers-Keijsers 2008; Mansur and Clemente 2009; Cuenca Solana *et al.* 2015; Romagnoli *et al.* 2017), shells have been identified as tools on all of the continents, most likely since more than 1 Mya and with clearest evidence since the Middle Pleistocene (Choi and Driwantoro 2007; Cuenca

Solana *et al.* 2013; Szabó 2013; Joordens *et al.* 2014). In the last few years, the exploitation of coastal intertidal resources has also been also well established along the Mediterranean basin between MIS 5 – MIS 3 (Fa 2008; Rickards *et al.* 2008; Brown *et al.* 2011; Colonese *et al.* 2011; Ramos *et al.* 2011, among others).

The Neanderthals also used marine shellfish for their functional needs, which demonstrates a high knowledge of the available resources and a high adaptive capacity to different ecological niches. Shell technology was not an occasional, irregular behaviour. The use of shell as a raw material was fully integrated into the economic and technical system, and the application of stable procedures by the Neanderthals made this system recognizable in the archaeological record. The presence of this technology only in isolated layers and defined chronological spots suggests that this behaviour, although it was possibly facilitated by a raw material shortage, was not determined by a lack in resource availability. The available data are actually uneven for shell and associated lithic technology in the several sites where *Callista chione* tools have been found. This patchy scenario prevents the reconstruction of a Mediterranean behaviour. In this respect the author's research is the first systematic and innovative work that has created an analytical multidisciplinary method to be applied in future studies. The results of geological, stone tools, and shell studies have highlighted a relationship between the innovation of shell technology and Quina economic and technical behaviour. Shell technology was advantageous for highly mobile human groups, which had economic systems that were characterised by time stress constraints. Their flexible technical system allowed the introduction of such innovation within shared knowledge, which improved the human capacity of create adaptive information and expanding the economic opportunity set.

This research opened new perspective in European prehistory:

- The creation of a well-structured experimental protocol allowed for a better understanding of shell as a raw material and the development of polished surfaces on retouched shell tools. The process of formation of use-wear traces is a new research line in Europe, and few studies have investigated the relationship between valve structure, edge performance and use-wear traces (Cuenca Solana *et al.* 2015 and bibliography therein).

- The results contributed to the knowledge of Neanderthal behavioural variability, which is a central topic in prehistory. Furthermore, demonstrated capacity for adaptation to the coastal ecosystems improving knowledge about intertidal hominin exploitation before *Homo sapiens*. The potential of shell tools for a discussion of the Neanderthal capacity of innovation, economic, productive, and social elements recognised shell technology as a privileged field of investigation within the study of Middle Palaeolithic behaviour.

- The presence of shell technology at several sites along the central Mediterranean makes it interesting in the investigation of its evolutionary dynamics. Was its spread due to contacts between human groups that lived in the coastal landscapes or, conversely, its spread was the results of local independent adaptive behaviour supported by the flexibility of the technical system and the cognitive capacities of the Neanderthals? This research has been a first step on the topic, and a further understanding of this behaviour requires a systematic dating of the sites, a multidisciplinary study that reconstructs paleoenvironmental conditions and foraging areas, in association with the holistic approach that is presented here for the analysis of human mobility, technical and economic strategies.

Acknowledgements

The author is grateful to the editors for their invitation to participate in this volume.

This research has been founded by H2020 MSCA GA No 653667; HAR2013 -48784-C3-3-P, HAR2013-48784-C3-1-P and HAR2016-76760-C3-2-P-2 of the Spanish Ministerio de Economía y Competitividad.

The excavation at Grotta del Cavallo was supported by the Università di Firenze, the Università di Siena, and the Museo Fiorentino di Preistoria "Paolo Graziosi". The studies in the cave were conducted in collaboration with Soprintendenza per i Beni Archeologici della Puglia, and they were directed by Lucia Sarti. My heartfelt thanks go to her for her confidence in my study, which facilitated access to the collections and the field reports, and to all of the students and the researchers that were involved with me in the recovery and study of the archaeological, geological and paleontological record at Grotta del Cavallo.

Many people collaborated and discussed ideas and the results with me, which generated improvement and new directions in the research. I am very grateful to Fabio Martini, Jacques Pelegrin, Cristina Lemorini, André Colonese, Catherine Perlès and Isabelle Sidera who first collaborated in studies with raw materials and who were helpful in discussing theoretical and procedural topics during the drawing of the methodology. A limitless thank you goes to Javier Baena, who shared knowledge, expertise and time with me during the experimentation and who contributed to the maturation of the research through inspiring discussion. I am also very grateful to the Laboratorio de Arqueología Experimental and to the students of Universidad Autónoma de Madrid who enthusiastically collaborated in the functional experimentation and to the collaborators of the Laboratorio Docente de Prehistoria y Arqueología, especially Ana Isabel Pardo Naranjo. Thanks to the anonymous reviewers who gave me suggestions to improve the paper.

References

Avery, R., Etter, R.J. 2006. Microstructural differences in the reinforcement of a gastropod shell against predation. *Marine Ecology Progress Series* 323, 159-170.

Baena Preysler, J., Carrión Santafé, E. 2010. Experimental approach to the function and technology of quina side-scrapers, in: Nami, H.G. (ed.), *Experiments and Interpretation of Traditional Technologies: Essays in Honor of Errett Callahan*. Buenos Aires, 171-202.

Baena, J., Moncel, M.H., Cuartero, F., Chacón Navarro, M.G., Rubio, D. 2014. Late Middle Pleistocene Genesis of Neanderthal technology in Western Europe: the case of Payre site (South East France). *Quaternary International* (in press). http://dx.doi.org/10.1016/j.quaint.2014.08.031.

Bailei, G.N., Reynolds, S.G., King, G.C.P. 2011. Landscapes of human evolution: models and methods of tectonic geomorphology and the reconstruction of hominin landscapes. *Journal of Human Evolution* 60, 257-280.

Bailey, G.N., Dev, M.H., Inglis, R.H., Meredith-Williams, M.G., Momber, G., Sakellariou, D., Sinclair, A.G.M., Rousakis, G., Al Ghamdi, S., Alsharekh, A.M. 2015. Blue Arabia: Palaeolithic and underwater survey in SW Saudi Arabia and the role of coasts in Pleitocene dispersals. *Quaternary International* 382, 42-57.

Barkai, R., Gopher, A. 2013. Cultural and biological transformations in the Middle Pleistocene Levant: a view from Qesem Cave, Israel, in: Akazawa, T., Nishiaki, Y., Aoki, K. (eds.), *Dynamics of Learning in Neanderthals and Modern Humans*, vol. 1. Springer, Japan, 115-137.

Bertola, S., Peresani, M., Peretto, C., Thun-Hoenstein, U. 1999. Le site Paléolithique moyen de la grotta Ghiacciaia (Préalpes de Vénétie, Italie du Nord). *L'Anthropologie* 103, 377e390.

Blanc, A.C. 1958-1961. Campagna di scavo nelle Grotte di Capo di Leuca. *Quaternaria* V, 308-313.

Borzatti von Löwenstern, E. 1971. Seconda campagna di scavi nella Grotta Mario Bernardini (Nardò – Lecce). *Rivista di Scienze Preistoriche* XXVI, 31-62.

Borzatti von Löwenstern, E., Magaldi, D. 1969. Risultati conclusivi dello studio paletnologico e sedimentologico della Grotta di Uluzzo C (Nardò – Lecce). *Rivista di Scienze Preistoriche* XXIV, 15-64.

Bourguignon, L. 1997. Le Moustérien de type Quina: nouvelle définition d'une entité technique (Ph.D. dissertation). Université Parigi X-Nanterre.

Bourguignon, L. 2001. Apports de l'expérimentation et de l'analyse technomorpho-fonctionnelle à la reconnaissance du processus d'aménagement de la retouche Quina, in: Bourguignon, L., Ortega, I., Frêre-Sautot, M.C. (eds.), *Préhistoire et approche expérimentale*. Monographies de M. Mergoil (Montagnac), 35-66.

Bourguignon, L., Delagnes, A., Meignen, L. 2006. Systèmes de production lithique, gestion des outillages et territoires au Paléolithique moyen où se trouve la complexité? in: Astruc, L., Bon, F., Léa, V., Milcent, P.-Y., Philibert, S. (eds.), *Normes techniques et pratiques sociales. De la simplicité des outillages pré-et protohistoriques*. Actes des XXVI Rencontres d'Archéologie et d'Histoire d'Antibes. APDCA, 75e86.

Bourguignon, L., Djema, H., Bertran, P., Lahaye, C., Guibert, P. 2008. Le gisement Salien de Petit-Bost (Neuvic, Dordogne) à l'origine du Moustérien d'Aquitaine? in: Jaubert, J., Bordes, J.G., Ortega, I. (eds.), *Les sociétés du Paléolithique dans un Grand Sud-Ouest de la France: nouveaux gisements, nouveaux résultats, nouvelles méthodes*. Mémoire de la Société Préhistorique Française XLVII, 41-55.

Bourguignon, L., Turq, A., Faivre, J.-P. 2004. Ramifications des chaînes opératoires: spécificité du Moustérien? *Paléo* 16, 37-48.

Boyd, R., Richerson, P.J., Henrich, J. 2011. The cultural niche: why social learning is essential for human adaptation. *Proceedings of the National Academy of Sciences of the United States of America* 108, 10918-10925.

Brown, K., Fa, D.A., Finlayson, G., Finlayson, C. 2011. Small game and marine resource exploitation by Neanderthals: the evidence from Gibraltar, in:. Bicho, N.F., Haws, J.A., Davis, L.G. (eds.), *Trekking the shore: changing coastlines and the antiquity of coastal settlement*. Springer New York: Interdisciplinary Contributions to Archaeology, 247-272.

Carlsson, B., Stankiewicz, R. 1991. On the nature, function and composition of technological systems. *Journal of Evolutionary Economics* 1, 93-118.

Caron F., d'Errico F., Del Moral P., Santos F., Zilhão J. 2011. The reality of Neanderthal symbolic behavior at the Grotte du Renne, Arcy-sur-Cure, France. *Plos One* 6, e21545.

Choi, K., Driwantoro, D. 2007. Shell tool use by early members of Homo erectus in Sangiran, central Java, Indonesia: cut-mark evidence. *Journal of Archaeological Science* 34, 48-58.

Colonese, A.C.,Mannino, M.A., Bar-Yosef Mayer, D.E., Fa, D.A., Finlayson, J.C., Lubell, D., Stiner, M. 2011. Marine mollusc exploitation in Mediterranean prehistory: an overview. *Quaternary International* 239, 86-103.

Copeland, L., Hours, F. 1983. Le Yabroudien d'El Khowm (Syrie) et sa place dans le Paléolithique du Levant. *Paléorient* 9, 21-37.

Cortés-Sánchez, M., Morales-Muñiz, A., Simón-Vallejo, M. D., Lozano-Francisco, M. C., Vera Peláez, J. L., Finlayson, C., Rodríguez-Vidal, J., Delgado-Huertas, A., Jiménez-Espejo, F.J., Martínez-Ruiz, F., Martínez-Aguirre, M.A., Pascual-Granged, A.J., Bergadà-Zapata, M.M., Gibaja-Bao, J.F., Riquelme-Cantal, J.A., López-Sáez, J.A., Rodrigo-Gámiz, M., Sakai, S., Sugisaki, S., Finlayson, G., Fa, D.A., Bicho, N.F. 2011. Earliest known use of marine resources by Neanderthals. *Plos One* 6, e24026.

Cristiani, E., Farbstein, R., Miracle, P. 2014. Ornamental traditions in the Eastern Adriadic: the Upper Palaeolithic and Mesolithic personal adornments from Vela Spila (Croatia). *Journal of Anthropological Archaeology* 36, 21-31.

Cristiani, E., Lemorini, C., Martini, F., Sarti, L. 2005. Scrapers of *Callista chione* from Grotta del Cavallo (Middle Palaeolithic cave in Apulia): evaluating use-wear potential, in: Luik, H., Choyke, A.M., Batey, C. E., Lõugas, L. (eds.), *From hooves to horns, from mollusc to mammoth: manufacture and use of bone artefacts from prehistoric times to the present*. Oxbow Books, Oxford, 319-324.

Cuenca-Solana, D., Gutiérrez-Zugasti, F.I., González-Morales, M.R., Setién-Marquinez, J., Ruiz-Martinez, E., García-Moreno, A., Clemente-Conte, I. 2013. Shell technology, rock art, and the role of marine resources during the Upper Palaeolithic. *Current Anthropology* 54, 370-380.

Cuenca-Solana, D., Gutiérrez-Zugasti, I, González-Morales, M.R. 2015. Use-wear analysis: an optimal methodology for the study of shell tools. *Quaternary International* (in press), http://dx.doi.org/10.1016/j.quaint.2015.09.090.

Dantoni, G. 1980. I livelli musteriani con strumenti su valva di *Callista* (Callista) *chione* (L.) nel Salento. *Studi per l'Ecologia del Quaternario* 2, 67-75.

Dantoni, G., Nardi, N. 1980. La Grotta riparo "Marcello Zei" (Santa Caterina, Nardò). *Studi per l'Ecologia del Quaternario* 2, 97-119.

Darlas, A. 2007. Le Moustérien de Grèce à la lumière des récentes recherches. *L'Anthropologie* 111, 346-366.

Davidson, I. 2016. Stone tools: evidence of something in between culture and cumulative culture? in Haidle, M.N., Conard, N.J., Bolus, M. (eds.), *The nature of culture: based on an interdisciplinary Symposium 'The Nature of Culture'*. Tübingen, Germany. Vertebrate Paleobiology and Paleoanthropology, 99-120.

Delagnes, A., Rendu, W. 2011. Shifts in Neanderthal mobility, technology and subsistence strategies in western France. *Journal of Archaeological Science* 38, 1771-1783.

Douka, K., Spinapolice, E. 2012. Neanderthal shell tool production: evidence from Middle Palaeolithic Italy and Greece. *Journal of World Prehistory* 25, 45-79.

Erlandson, J.M., Braje, T.J. 2015. Coasting out of Africa: the potential of mangrove forests and marine habitats to facilitate human coastal expansion via the Southern Dispersal Route. *Quaternary International* 382, 31-41.

Fa, D.A. 2008. Effects of tidal amplitude on intertidal resource availability and dispersal pressure in prehistoric human coastal populations: the Mediterranean-Atlantic transition. *Quaternary Science Reviews* 27, 2194-2209.

Faivre, J.P. 2008. Organisation techno-économique des systèmes de production dans le Paléolithique moyen récent du Nord-est Aquitain: Combe-Grenal et Les Fieux (Ph.D. dissertation). Université Bordeaux I, Bordeaux.

Fitzhugh, B. 2001. Risk and invention in human technological evolution. *Journal of Anthropological Archaeology* 20, 125-167.

Giusti, M. 1979. La Grotta di Capelvenere a S. Caterina – Nardò (Campagna di scavo 1974). *Studi per l'Ecologia del Quaternario* 1, 19-40.

Hayden, B., Franco, N., Spafford, J. 1996. Evaluating lithic strategies and design criteria., in: Odell, G.H. (ed.), *Stone tools: theoretical insights into human Prehistory*. Plenum Press, New York, 9-45.

Hiscock, P., Turq, A., Faivre, J.-P., Bourguignon, L. 2009. Quina procurement and tool production, in: Adams, B., Blade, B.S. (eds.), *Lithic Materials and Paleolithic Societies*. Blackwell Publishing Ltd, 232-246.

Inizan, M.L., Reduron-Ballinger, M., Roche, H., Tixier, J. 1999. *Technology and Terminology of Knapped Stone*. Préhistoire de la Pierre Taillée, Tome 5. CREP, Nanterre.

Jacobsson, S., Johnson, A. 2000. The diffusion of renewable energy technology: an analytical framework and key issues for research. *Energy Policy* 28, 625-640.

Jerardino, A., Marean, C.W. 2010. Shellfish gathering, marine paleoecology and modern human behaviour: perspective from cave PP13B, Pinnacle Point, South Africa. *Journal of Human Evolution* 59, 412-424.

Joordens, J.C.A., d'Errico, F., Wesselingh, F.P., Munro, S., de Vos, J., Wallinga, J., Ankjærgaard, C., Reimann, T., Wijbrans, J.R., Kuiper, K.F., Mücher, H.J., Coqueugniot, H., Prié, V., Joonsten, I., van Os, B., Schulp, A.S., Panuel, M., van der Haas, V., Lustenhouwer, W., Reijmer, J.J.G., Roebroeks, W. 2014. *Homo erectus* at Trinil on Java used shells for tool production and engraving. *Nature* 518, 228-231.

Kasperson, R.E., Renn, O., Slovic, P., Brown, H.S., Emel, J., Goble, R., Kasperson, J.X., Ratick, S. 1988. The social amplification of risk: a conceptual framework. *Risk Analysis* 8, 177-187.

Kogure, T., Suzuki, M., Kim, H., Mukai, H., Checa, A.G., Sasaki, T., Nagasawa, H. 2014. Twin density of aragonite in molluscan shells characterized using X-ray diffraction and transmission electron microscopy. *Journal of Crystal Growth* 397, 39-46.

Kuhn, S.L., Miller, D.S. 2015. Artifacts as patches: the Marginal Value Theorem and stone tool life histories, in: Goodale, N., Andrefsky, W.Jr. (eds.), *Lithic technological systems and Evolutionary Theory*. Cambridge University Press, 172-197.

Kyriacou, K., Parkington, J.E., Marais, A.D., Braun, D.R. 2014. Nutrition, modernity and the archaeological record: coastal resources and nutrition among Middle Stone Age hunter-gatherers on the western Cape coast of South Africa. *Journal of Human Evolution* 77, 64-73.

Lammers-Keijsers, Y.M. 2008. *Tracing traces from present to past. A functional analysis of pre-Columbian shell and stone artefacts from Anse a la Gourde and Morel*. Leiden University Press, Guadalupe.

Larson, M.L., Kornfeld, M. 1997. Chipped stone nodules: theory, method, and examples. *Lithic Technology* 22, 4-18.

Lemorini, C., Bourguignon, L., Zupancich, A., Gopher, A., Barkai, R. 2015. A scraper's life history: morpho-techno-functional and use-wear analysis of Quina and demi-Quina scrapers from Qesem Cave, Israel. *Quaternary International* (in press). http://dx.doi.org/10.1016/j.quaint.2015.05.013.

Mansur, M.E., Clemente, I. 2009. ¿Tecnologías invisibles? Confección, uso y conservación de instrumentos de valva en Tierra del Fuego, in: Oliva, F., de Grandis, N., Rodríguez, J. (eds.), *Arqueología Argentina en los inicios de un nuevo siglo*. XIV Congreso Nacional de Arqueología Argentina, Universidad Nacional de Rosario, Tomo II, 359-367.

Marean, C.W. 2014. The origins and significance of coastal resource use in Africa and Western Eurasia. *Journal of Human Evolution* 77, 17-40.

Moncel, M.H. 2001. Le Moustérien de type Quina de la Grotte du Figuier (Ardéche). Fouilles P. et A. Huchard et R. Gilles. Des occupation en grotte de courtes durées por une exploitation locale de l'environnement. *Bulletin de la Societé Préhistorique Française* 98, 593-614.

Morin E., Laroulandie V. 2012. Presumed symbolic use of diurnal raptors by Neanderthals. *Plos One* 7, e32856.

Outram, A.K. 2008. Introduction to experimental archaeology. *World Archaeology* 40, 1-6.

Oxilia, M. 1974. Nota sulla presenza di industria su valve di Meretrix chione Linneo nei livelli Riss-Würm dello scavo dell'ex-Casinó. *Atti XVI Riunione Scientifica IIPP*, 84-90.

Pawlik, A.F., Thissen, J.P. 2011. Hafted armatures and multi-component tool design at the Micoquian site of Inden-Altdorf, Germany. *Journal of Archaeological Science* 38, 1699-1708.

Peresani, M., Vanhaeren, M., Quaggiotto, E., Queffelec, A., d'Errico, F. 2013. An ochered fossil marine shell from the Mousterian of the Fumane Cave, Italy. *Plos One* 8, e68572.

Perlès, C., Vanhaeren, M. 2010. Black Cyclope neritea marine shell ornaments in the Upper Palaeolithic and Mesolithic of Franchthi (Argolid, Greece): arguments for an intentional heat treatment. *Journal of Field Archaeology* 35, 314-325.

Ramos, J., Domínguez-Bella, S., Cantillo, J.J., Soriguer, M., Pérez, M., Hernando, J., Vijande, E., Zabala, C., Clemente, I., Bernal, D. 2011. Marine resources exploitation by Palaeolithic hunter-fisher-gatherers and Neolithic tribal societies in the historical region of the Strait of Gibraltar. *Quaternary International* 239, 104-113.

Reynolds, P.J. 1999. The nature of experiment in archaeology, in: Harding, A.F. (ed.), *Experiment and design in archaeology*. Oxbow Books, 156-162.

Richards, M., Harvati, K., Grimes, V., Smith, C., Smith, T., Hublin, J.J., Karkanas, P., Panagopoulou, E. 2008. Strontium isotope evidence of Neanderthal mobility at the site of Lakonis, Greece, using laser-ablation PIMMS. *Journal of Archaeological Science* 35, 1251-1256.

Roebroeks, W. 1988, *From find scatters to early hominid behaviour. A study of Middle Palaeolithic riverside settlements at Maastricht-Belvedere (Netherlands)*. Analecta Praehistorica Leidensia 21, Leiden.

Romagnoli, F. 2015. A second life: recycling production waste during the Middle Palaeolithic in layer L at Grotta del Cavallo (Lecce, Southeast Italy). *Quaternary International* 361, 200-211.

Romagnoli, F., Baena, J., Pardo Naranjo, A.I., Sarti, L. 2017. Evaluating the performance of the cutting edge of Neanderthal shell tools: a new experimental approach. Use, mode of operation, and strength of *Callista chione* from a behavioural, Quina perspective. *Quaternary International* 427, 216-228.

Romagnoli, F., Martini, F., Sarti, L. 2015. Neanderthal use of *Callista chione* shells as raw material for retouched tools in south-east Italy: analysis of Grotta del Cavallo layer L assemblage with a new methodology. *Journal of Archaeological Method and Theory* 22, 1007-1037.

Romagnoli, F., Baena, J., Sarti, L. 2016a. Neanderthal retouched shell tools and Quina economic and technical strategies: an integrated behaviour. *Quaternary International* 407, 29-44.

Romagnoli, F., Trenti, F., Nannini, L., Carmignani, L., Ricci, G., Lo Vetro, D., Martini, F., Sarti, L. 2016b, Raw material procurement and productive sequences in the Palaeolithic of southern Italy: the Tyrrhenian and the Ionian areas, in: Tomasso A., Binder D., Martino G., Simon P., Porraz G., Naudinot N. (eds.), *Ressources lithiques, productions et transferts entre Alpes et Méditerranée*. Société Préhistorique Française, Les Séances de la SPF 5, Nice, 185-206.

Romandini, M., Peresani, M., Laroulandie, V., Metz, L., Pastoors, A., Vaquero, M., Slimak, L. 2014. Convergent evidence of eagle talons used by late Neanderthals in Europe: a further assessment on symbolism. *Plos One* 9, e101278.

Rots, V. 2009. The functional analysis of the Mousterian and Micoquian assemblages of Sesselfelsgrotte, Germany: aspects of tool use and hafting in the European Late Middle Palaeolithic. *Quartär* 56, 37-66.

Sarti, L., Boscato, P., Martini, F., Spagnoletti, A.P. 2002. Il Musteriano di Grotta del Cavallo. Strati H e I: studio preliminare. *Rivista di Scienze Preistoriche* LII, 21-109.

Saxenian, A.L. 1994. *Regional advantage. Culture and competition in Silicon Valley and Route 128*. Harvard University Press, Cambridge.

Solé, A., Allué, E., Carbonell, E. 2013. Heart-related wood remains from Abric Romaní layer M (Capellades, Spain). *Journal of Anthropological Research* 69, 535-559.

Soressi M., d'Errico F. 2007. Pigment, gravures, parures: les comportements symboliques controversés des Néandertaliens, in: Vandermeersch B., Maureille B. (eds.), *Les Néandertaliens. Biologie et cultures*. Paris: Éditions CTHS, 297-309.

Stiner, M.C. 1993. Small animal exploitation and its relation to hunting, scavenging, and gathering in the Italian Mousterian, in: Peterkin, G.L., Bricker, H., Mellars, P. (eds.), *Hunting and animal exploitation in the Later Palaeolithic and Mesolithic of* Eurasia. Archaeological Papers of the American Anthropological Association n. 4, 101-119.

Stiner, M.C. 1994. *Honor among thieves: a zooarchaeological study of Neanderthal ecology*. Princeton: Princeton University Press.

Szabó, K. 2008. Shell as raw material: mechanical properties and working techniques in the tropical Indo-West Pacific. *Archaeofauna* 17, 125-138.

Szabó, K. 2013. Identifying worked shell: a consideration of methodological issues with particular reference to Pleistocene contexts, in: Bailey, G.N., Hardy, K., Camara, A. (eds.), *Shell energy*. Oxbow Books, Oxford, 277-286.

Tixier, J., Inizian, M.-L., Roche, H. 1980. *Préhistoire de la pierre taillée. Terminologie et technologie*, Tome I. Centre de Recherches et d'Études Préhistoriques.

Torrence, R. 1989. *Time, Energy and Stone Tools*. Cambridge University Press, Cambridge.

Turq, A. 1992. Raw materials and technological studies of the Quina Mousterian in Perigord, in: Dibble, H.L., Mellars, P. (eds.), *The Middle Palaeolithic. Adaptation, Behaviour and Variability*. University of Pennsylvania Museum, Philadelphia, 75-85.

van der Leeuw, S.E. 2000. Making tools from stone and clay, in: Murray, T., Anderson, A. (eds.), *Australian archaeologist: collected papers in Honour of J. Allen*. ANU Press, Canberra, 69-88.

Vanhaeren, M., d'Errico, F., van Niekerk, K.L., Henshilwood, C.S., Erasmus, R.M. 2013. Thinking strings: additional evidence for personal ornament use in the Middle Stone Age at Blombos Cave, South Africa. *Journal of Human Evolution* 64, 500-517.

Vasconcelos, P., Morgado-André, A., Morgado-André, C., Gaspar, M.B. 2011. Shell strength and fishing damage to the smooth clam (Callista chione): simulating impacts caused by bivalve dredging. *ICES Journal of Marine Science* 68, 32-42.

Vicino, G. 1974. La spiaggia tirreniana dei Balzi Rossi nei recenti scavi nella zona dell'ex – Casinò. *Atti XVI Riunione Scientifica IIPP*, 75-90.

Vieillevigne, E., Bourguignon, L., Ortega, I., Guibert, P. 2008. Analyse croisée des données chronologiques et des industries lithiques dans le grand sud-ouest de la France (OIS 10 à 3). *Paléo* 20, 145-166.

Vitagliano, S. 1984. Nota sul pontiniano della Grotta dei Moscerini, Gaeta (Latina). *Atti XXIV Riunione Scientifica IIPP*, 155-164.

Zilhão, J., Angelucci, D. E., Badal-García, E., D'Errico, F., Daniel, F., Dayet, L., Douka, K., Higham, T.F.G., Martínez-Sanchéz, M.J., Montes-Bernárdez, R., Murcia-Mascarós, S., Pérez-Sirvent, C., Roldán-García, C., Vanhaeren, M., Villaverde, V., Wood, R., Japata, J. 2010. Symbolic use of marine shells and mineral pigments by Iberian Neanderthals. *Proceedings of the National Academy of Sciences* 107, 1023-1028.

Zuschin, M., Stachowitsch, M., Stanton Jr., R.J. 2003. Patterns and processes of shell fragmentation in modern and ancient marine environments. *Earth Science Reviews* 63, 33-82.

The Middle-Upper Paleolithic transition interpreted through the Italian human remains

Stefano Benazzi[1]

Abstract

The Middle-Upper Paleolithic transition in Europe is still intensely debated. The interpretation of 'transitional' and Early Upper Paleolithic cultures influences our understanding of evolutionary issues such as the timing of arrival of anatomically modern humans in Europe, their potential interactions with Neanderthals, Neanderthal's cognitive abilities and the reasons for their extinction. The doubts about the makers of these cultures are not resolved because of 1) the limited number of accurate, well-documented/well-dated excavations, 2) the lack of large-scale comparison of the results and 3) the paucity of well-preserved human remains dated to the transitional period. In this context, the Italian human fossil record dated to the transitional period plays an important role, although represented by few isolated teeth. These findings, which are associated with both Uluzzian and Protoaurignacian cultures, are pivotal to decipher the biological shift that occurred in Western Europe around 45,000-35,000 years ago.

Keywords: Uluzzian, Protoaurignacian, Modern humans, Neanderthals, Italy.

1. Introduction

Anatomical modern humans (AMHs) represent the only extant members of the genus *Homo* (*i.e.*, *Homo sapiens*). Fossil, genetic and archaeological evidence support an African origin of *H. sapiens* around 300,000 years ago (ya) (Hublin et al., 2017; see also Pearson, 2013, for a review), even though the exact time of migration and the

1 Department of Cultural Heritage, University of Bologna, Via degli Ariani 1, 48121 Ravenna, Italy & Department of Human Evolution, Max Planck Institute for Evolutionary Anthropology, Deutscher Platz 6, 04103 Leipzig, Germany. Email: stefano.benazzi@unibo.it.

in: Borgia, V. and E. Cristiani (eds.) 2018: *Palaeolithic Italy. Advanced studies on early human adaptations in the Apennine peninsula*, Sidestone Press Academics (Leiden), pp. 147-160.

geographic routes followed in the movements out of Africa into Eurasia are still matters of contention (*e.g.*, Beyin, 2011; Petraglia *et al.*, 2012; Groucutt *et al.*, 2015). Findings from Qafzeh and Skhul in Israel document the dispersal of early *H. sapiens* into the Levant through the "Nile corridor" (the so called "Northern route") by approximately 130,000-100,000 ya, during the warm Marine Isotope Stage (MIS) 5 (Mercier *et al.*, 1995), or even earlier (Hershkovitz et al., 2018). Moreover, the site of Jebel Faya (United Arab Emirates) suggests that *H. sapiens* crossed the Bab al Mandab Straits (from East Africa to Arabia) by about 125,000 ya, the so called "Southern route" (Armitage *et al.*, 2011). Human remains from Fuyan Cave in Daoxian (southern China), dated to between 120,000-80,000 ya, suggest a fast early eastward dispersal of these populations (Liu *et al.*, 2015). Nevertheless early *H. sapiens* was likely unable to enter Europe, possibly owing to competition with European Neanderthals (Liu *et al.*, 2015).

Further waves of AMHs out of Africa into Eurasia occurred ca. 55,000 ya along the Levant corridor (Hershkovitz *et al.*, 2015). Moreover, AMH skeletal remains were recovered from Central, East, and Southeast Asia and Australia around 45,000-40,000 ya. These remains include a femur from Ust'-Ishim, western Siberia, dated to ca. 45,000 ya (Fu *et al.*, 2014), a partial human skeleton from Tianyuan Cave, China, dated to ca. 42,000-39,000 ya (Shang *et al.*, 2007), a modern human cranial fragment from Niah Cave, Borneo, dated to ca. 45,000 ya (Higham *et al.*, 2008), and several human remains from Lake Mungo, Australia, which dates are debated, but may be as old as 46,000 ya (Bowler *et al.*, 2003).

The exact timing and pattern of the biological and cultural shifts that occurred in Europe around 50,000 to 35,000 ya remain a matter of intensive debated in paleoanthropology (*e.g.*, Mellars, 2006; Hoffecker, 2009; Hublin, 2015). From an archaeological perspective, this period (also referred to as the Middle-to-Upper Palaeolithic transition, "MUPT") documents dramatic changes in human behaviour and the appearance of various new cultures (*e.g.*, the Châtelperronian in central and south western France and northern Spain, the Uluzzian in Italy and Greece, the Szeletian in Czech Republic and Slovakia) that replaced pre-existing Mousterian cultures (Mellars, 2006). Some scholars (*e.g.*, Mellars, 2005) suggested that these changes, coinciding with the origins of modern human behavior in Europe, are directly related to the appearance and dispersal of AMH. Modern human behavior is characterized by the exploitation of a wider range of (marine and terrestrial) faunal and vegetal resources, as well as typical stone tool production and a wider geographical range of lithic raw material procurement than Neanderthals (Churchill, 2014). The variability of lithic raw material and, in general, subsistence strategies might account for different mobility patterns between AMHs and Neanderthals. Nonetheless, other scholars believed that cultural innovations were independently achieved by Neanderthals, and that AMH entered Europe after Neanderthals had disappeared (d'Errico *et al.*, 1998; Zilhão, 2007). Moreover, Neanderthals might have been characterized by a more complex sociocultural behavior than previously thought. For example, recent studies suggested that Neanderthal had a more varied diet than previously thought (Fiorenza *et al.*, 2011), including a wide range of plant foods (Henry *et al.*, 2014), and possibly cooked foods (Henry *et al.*, 2011).

From a biological perspective, results from ancient DNA suggest that gene flow from Neanderthals into non-African AMHs occurred before the divergence of the different Eurasian populations (Green *et al.*, 2010; Currat and Excoffier, 2011). This admixture, albeit of low magnitude (1.5-2.1%), occurred ca. 60,000 ya, mainly in Southwest Asia (Prüfer *et al.*, 2014). A study of present-day genomes (*e.g.*, Noonan *et al.*, 2006) has shown that although Neanderthals were widespread in Europe no evidence was found that they interbred with AMH in Europe. This would support the arguments that the two groups 1) did not chronologically and/or geographically overlap and 2) did not culturally interact in Europe. An alternative view (Fu *et al.*, 2015) is that admixture between early AMH populations and local Neanderthals occurred in Europe as well, but that these pioneering AMHs were later replaced by other AMH groups and thus did not contribute much genetically to later European populations.

The origin and significance of the cultural changes and biological interaction between AMH and Neanderthal are yet to be understood, and continue inspiring of the work of numerous scholars (Bailey *et al.*, 2009; Bar-Yosef and Bordes, 2010; Benazzi, 2012; Higham *et al.*, 2014; Hublin, 2015). The interaction between AMH and other extinct hominin species, in particular our closest relatives, the Neanderthals (Sankararaman *et al.*, 2014; Vernot and Akey, 2014), have surely influenced AMH and therefore also today's humankind both culturally and biologically. The current scientific debate focuses on a number of crucial issues including 1) whether AMH and Neanderthal coexisted in Europe; 2) whether or not the appearance of AMH coincided with the transition from Middle to Upper Paleolithic; 3) whether or not AMH colonized areas after Neanderthal populations had already left or there was interaction (*e.g.*, cultural transmission or possible competition) between these hominin groups; 4) whether AMH ecological success is intrinsically related to a suite of behavioral and cognitive abilities that are unique to AMH, favoring its migration and eco-geographic adaptation; 5) whether the migration of AMH in Europe was promoted by temporary climate ameliorations (interstadial periods) within the marine isotope stage 3 (MIS3: 57,000-30,000 ya).

This review aims to underline some of the major factors that undermine our understanding of the transitional period in Europe, and emphasizes the importance of the Italian human fossils to unravel the biological shift that occurred in Western Europe around 45,000-35,000 ya.

2. Factors limiting the understanding of the transitional period

Several factors concur to foster the uncertainties on the time and mode of the earliest migration of AMH in Europe and the demise of Neanderthals. First, only few within the several European archaeological sites dated to the MUPT, have been accurately investigated, or are well-documented and precisely dated (Higham *et al.*, 2009). Obviously, state-of-the-art excavation methods and dating techniques are pivotal for interpreting an archaeological deposit, namely evaluating its integrity and assessing the chronological age of each culture (*e.g.*, final Mousterian, transitional, Early Upper Paleolithic cultures), in order to place the site in its own climatic and environmental context, and ultimately to compare its bearing to those from other sites.

Second, there is a general lack of effort in large-scale comparison of the information obtained from deposits dated to the MUPT (*e.g.*, lithic manufacturing techniques and raw material procurement, faunal exploitation strategies). For example, there are no rigorous studies aiming to compare the Uluzzian with the Châtelperronian, or the Uluzzian from northern Italy to that from southern Italy.

Third, only 24 European archaeological sites have yielded fragmented human remains dated to between 50,000-35,000 ya. With few exceptions, most of the human remains are unsuitable for the current debate, either because their taxonomic attribution is unknown or because they are not associated with specific technocomplexes, or their association with a technocomplex is debated (*e.g.*, Churchill and Smith, 2000; Bailey *et al.*, 2009).

3. The European human remains dated to between 50,000-35,000 ya

Based on the little evidence available, it is a very challenging task to attribute each transitional and Early Upper Paleolithic culture within the time range 50,000-35,000 ya to either Neanderthal or AMH.

Between 50,000-45,000 ya, nine sites in Europe yielded human remains: six of the latter are Neanderthals (El Sidron, Zafarraya and Devil's Tower in Spain, Le Moustier in France, Kůlna in Czech Republic and Lakonis in Greece), one mandibular fragment, currently lost, from the Initial Upper Paleolithic of Bacho Kiro cave (Bulgaria) is taxonomically unknown, and four teeth (presumably associated with the Szeletian) are either taxonomically unidentified (three teeth from Remete cave, Hungary) or not certainly attributed to the Szeletian (one molar from Dzeravá Skala, Slovakia, showing AMH features) (for an overview, see Hublin, 2015). Despite the uncertain classification and cultural attribution of both the "Szeletian" teeth and the lost mandibular fragment from Bacho Kiro cave, the other few human remains suggest that between 50,000-45,000 ya only Neanderthals were present in South-Western Europe.

Between ca. 45,000-40,000 ya, 12 European sites yielded human remains. Among the six remains attributed to Neanderthal, two (*i.e.*, Saint Cesaire and Arcy sur Cure, France) are potentially associated with the Châtelperronian (*e.g.* Hublin *et al.*, 2012, but see Bar-Yosef and Bordes, 2010; Higham *et al.*, 2010), two are associated with Mousterian culture (*i.e.*, Sima de Las Palomas, Spain; Les Rochers-de-Villeneuve, France) (Beauval *et al.*, 2005; Walker *et al.*, 2008), while the integrity of the assemblages is questioned for the remaining two (*i.e.*, Spy, Belgium; Vindija, Croatia) (*e.g.*, Bailey *et al.*, 2009; Hublin, 2015). The human findings from the other six sites (*i.e.*, Peştera cu Oase, Romania; Istállóskő Cave, Hungary; Grotta del Cavallo, Grotta di Fumane and Riparo Bombrini, Italy; Kent's Cavern, England) have been the focus of recent studies, which generally suggested an affiliation of the associated human remains to AMH (*e.g.*, Trinkaus *et al.*, 2003; Bailey *et al.*, 2009; Benazzi *et al.*, 2011; 2015; Higham *et al.*, 2011; but for Kent's Cavern see White and Pettitt, 2012).

In summary, it is evident that the time period between 45,000-40,000 ya is pivotal to disentangle to cultural and biological shift in Europe. Indeed, Neanderthals disappeared around 41,000-39,000 ya (Higham *et al.*, 2014), and even though human remains dated to between 40,000-35,000 ya are still sporadic, those available are attributed to AMH and are generally associated with either Early Aurignacian (La Quina-Aval and Brassempouy, France; *e.g.*, Bailey and Hublin, 2005; Verna *et al.*, 2012) or Classic Aurignacian culture (Mladeč, Czech Republic; Wild *et al.*, 2005).

Unfortunately, the AMH from Peştera cu Oase, Istállóskő Cave and Kent's Cavern are not associated to any technocomplex. Notably, the Italian human remains from Grotta del Cavallo were retrieved in association with the Uluzzian culture, and those from Grotta di Fumane and Riparo Bombrini to the Protoaurignacian culture. Thus, these human fossils provide a unique opportunity to investigate on the earliest times of AMH in southern Europe and to identify the makers of these cultures.

4. The Italian human remains dated to ca. 45,000-40,000 ya

Uluzzian

In 1964, fieldworks in the lowest Uluzzian levels of Grotta del Cavallo (Apulia, southern Italy) yielded two human deciduous teeth: Cavallo B, a deciduous left upper first molar (dm^1) found in layer EIII (archaic Uluzzian), and Cavallo C, a deciduous left upper second molar (dm^2) found 15-20 cm above Cavallo B, in layer EII-I (evolved Uluzzian) (Fig. 1) (Palma di Cesnola and Messeri, 1967).

Interestingly, even though the first and unique description of these findings attributed Cavallo B to AMH and Cavallo C to Neanderthal (Palma di Cesnola and Messeri, 1967), most scholars took no notice of it and considered both teeth as Neanderthals (Churchill and Smith, 2000). As a logical consequence, Neanderthal was associated to the Uluzzian, and the shell beads at Grotta del Cavallo served to strengthen the believe that Neanderthal produced personal ornaments (Zilhão, 2007). This led to the idea that the incoming AMH imitated Neanderthal's behavior

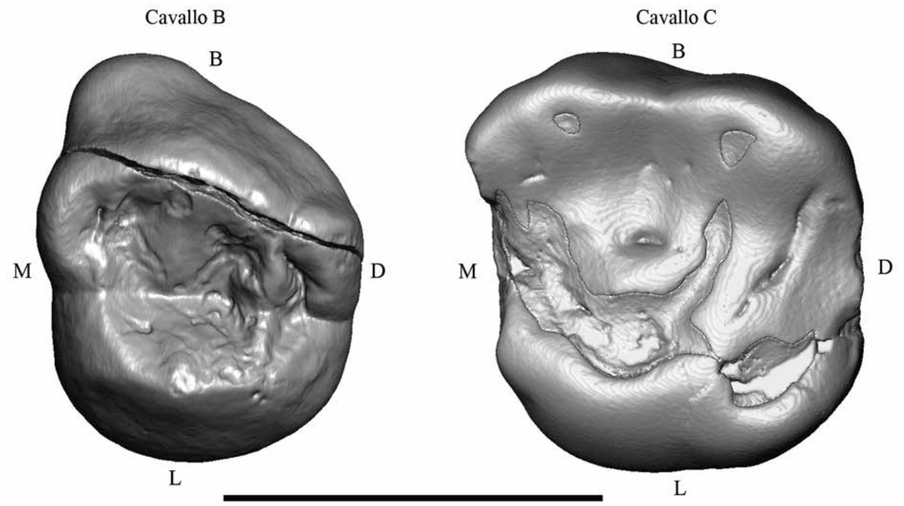


Figure 1. Three-dimensional digital models of the human deciduous teeth from the Uluzzian levels of Grotta del Cavallo in occlusal view: Cavallo B (deciduous left upper first molar) on the left; Cavallo C (deciduous left upper second molar) on the right. B, buccal; D, distal; L, lingual; M, mesial. The black bar is equivalent to 1 cm.

rather than the opposite (Zilhão, 2006). Since the integrity of the deposits in Grotta del Cavallo and the association of the deciduous molars with implements and ornaments were never questioned, Grotta del Cavallo used to be considered the Uluzzian emblematic site, and therefore a sound proof that Neanderthal was the maker of the transitional cultures (Zilhão, 2007).

In 2011 the deciduous molars from Grotta del Cavallo were re-analyzed using state-of-the-art morphometric methods (Benazzi *et al.*, 2011). Strikingly, based on the morphology of crown and cervical outlines and on relative enamel thickness, both teeth were assigned to AMH beyond doubt. Two recent studies (Bailey *et al.*, 2014; Fornai *et al.*, 2014) provided further evidence in support to this claim. Moreover, 14C dating on shell beads collected from Grotta del Cavallo constrained the Uluzzian molars to ca. 45,000-43,000 ya, making of them the earliest European AMH currently known.

These results suggested that AMHs and Neanderthals overlapped in Europe for at least 5,000 years, and undermine the hypothesis that cultural innovations were independently achieved by Neanderthals, with important implications for our understanding of Neanderthal behavior and cognitive abilities. Obviously, since the findings reported from Cavallo have challenged several beliefs (*e.g.*, d'Errico *et al.*, 1998; Zilhão, 2006; 2007), the topic has stimulated intense debate among specialists, and even unfounded attempts to draw doubts on the reliability of the findings and stratigraphic integrity of Grotta del Cavallo (Zilhão *et al.*, 2015, but see Ronchitelli *et al.*, 2014).

In the Uluzzian layer A3I in Grotta di Fumane, a further human tooth labelled Fumane 6, *i.e.* a fragment of a permanent molar (probably the mesio-lingual portion of a lower molar), has been retrieved (Fig. 2). Unfortunately, this finding has not provided any useful information to the ongoing debate on the transitional period, for the following reasons. First, the integrity of the context in which Fumane 6 was discovered is uncertain, because the Uluzzian layer A3I showed dispersion of Protoaurignacian stone implements due to post-depositional disturbance. Second, this tooth does not show any morphological features useful for taxonomic discrimination (Benazzi *et al.*, 2014).

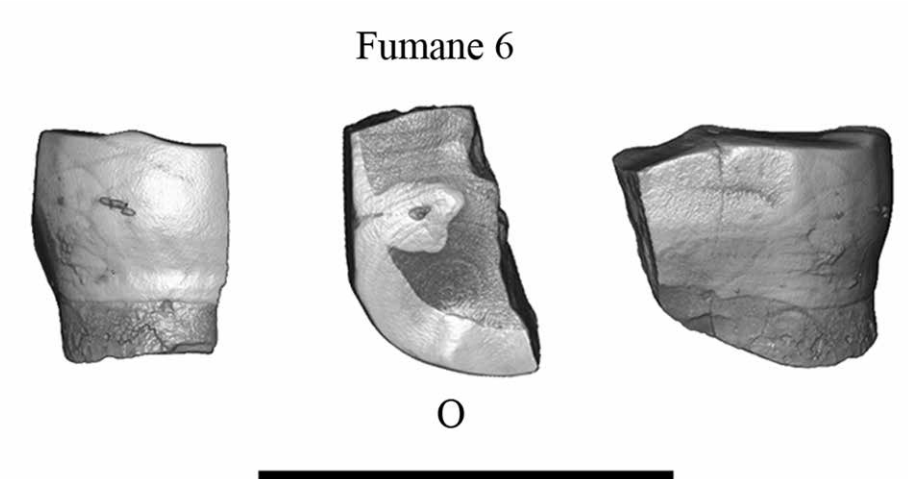


Figure 2. 3D digital model of the molar fragment from the Uluzzian layer A3I of Grotta di Fumane. O, occlusal. The black bar is equivalent to 1 cm.

Protoaurignacian

The Protoaurignacian appeared around 42,000-41,000 ya in Southwest and South-Central Europe (Fig. 3; Higham *et al.*, 2009; Douka *et al.*, 2012; Benazzi *et al.*, 2015), and as observed for the transitional cultures, the makers of this culture was unknown due to the paucity of diagnostic human remains in direct association. Indeed, so far only two deciduous human teeth have been found in Protoaurignacian context: a low-

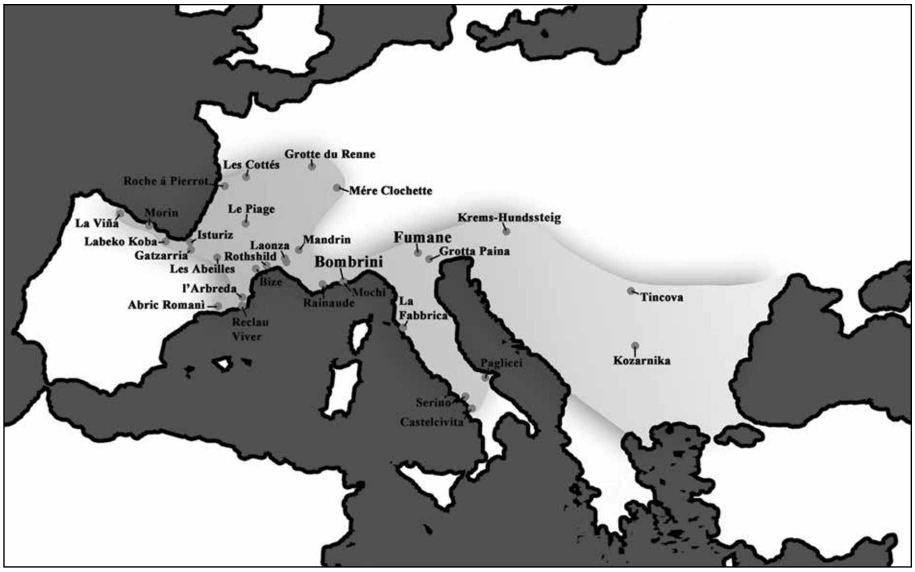


Figure 3. Geographical distribution of the Protoaurignacian. The human remains associated with the Protoaurignacian were unearthed from Riparo Bombrini (Ventimiglia, Italy) and Grotta di Fumane (Western Lessini Mountains, Italy).

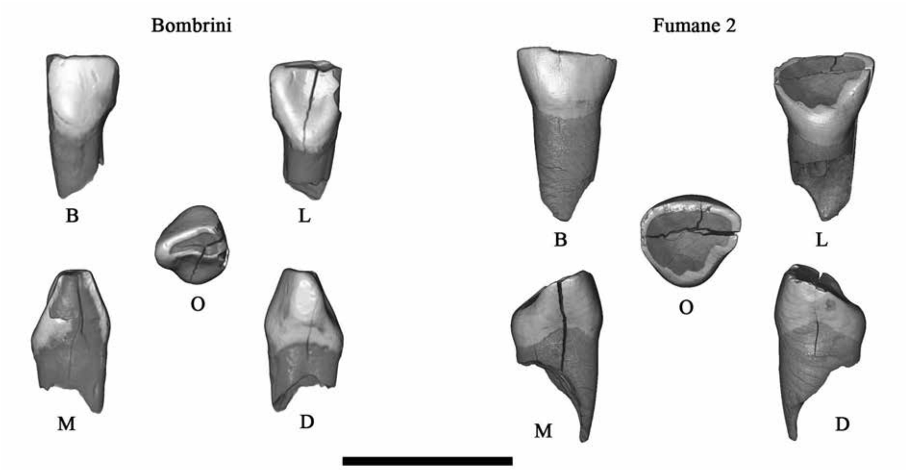


Figure 4. Three-dimensional digital models of the Protoaurignacian human remains: Bombrini 1 (lower left lateral deciduous incisor) on the left; Fumane 2 (upper right lateral deciduous incisor) on the right. B, buccal; D, distal; L, lingual; M, mesial; O, occlusal. The black bar is equivalent to 1 cm.

er left lateral deciduous incisor (Ldi$_2$; labelled Bombrini 1; Fig. 4) found in 1976 in Riparo Bombrini (Western Ligurian Alps, Italy) (Formicola, 1989); an upper right lateral deciduous incisor (Rdi^2, labelled Fumane 2; Fig. 4) found in 1992 in Grotta di Fumane (Western Lessini Mountains, Italy) (Bartolomei *et al.*, 1992). At present, these represent the oldest human remains in an Aurignacian-related archaeological context.

To establish the identity of the makers of the Protoaurignacian, Benazzi *et al.* (2015) used a digital approach to analyze the 3D enamel thickness components of Bombrini 1, and were able to study the mitochondrial DNA from Fumane 2 specimen. Both methods suggested the teeth belong to AMH. Based on previous 14C dating of the Protoaurignacian levels of Grotta di Fumane (Higham *et al.*, 2009) and new 14C dating of Riparo Bombrini, both Bombrini 1 and Fumane 2 were dated ca. 41,000-40,000 ya (Benazzi *et al.*, 2015). Thus, these Protoaurignacian human remains were demonstrated to be among the oldest AMH in Europe, overlapping in time with the last Neanderthals (Higham *et al.*, 2014).

5. Conclusions

The paucity of European human remains dated to ca. 50,000-35,000 ya prevents any conclusive understanding of the cultural and biological shift characterizing the Middle-Upper Paleolithic transition. The evidence available suggests that before 45,000 ya only Neanderthals were present in Western, Central and Southern Europe, while AMH had not migrated Westwards beyond the Near East (Hershkovitz *et al.*, 2015). An early AMH occupation in East Europe has been suggested, even though the issue is debated (for a review see Hublin, 2015). Interestingly, Mousterian cultures dominate the archaeological contexts in Western, Central and Southern Europe, without substantial discontinuity with earlier periods. All the information suggests that crucial cultural and biological changes occurred in Europe between ca. 45,000 – 40,000 ya. Human remains from Peştera cu Oase, Istállóskő, Grotta del Cavallo, Grotta di Fumane, Riparo Bombrini and potentially Kent's Cavern suggest that AMHs were in Europe during this time period, as also suggested by Upper Paleolithic (*i.e.*, Early Aurignacian) archaeological sites such as Willendorf II (Austria), dated to around 43,500 ya (Nigst *et al.*, 2014). It is worthwhile to note that it is in this period, for which the evidence of AMH fossils are more abundant, that the transitional cultures (*e.g.*, Châtelperronian, Uluzzian) appeared in Europe. It has been suggested that these cultures were independently produced by Neanderthals (d'Errico *et al.*, 1998; Zilhao, 2007), but this claim has been considered to be an "*impossible coincidence*" (Mellars, 2005). Moreover, the association of the Neanderthal human remains of Arcy sur Cure and Saint Cesaire with the Châtelperronian culture are debated (Bar-Yosef and Bordes, 2010; Higham *et al.*, 2010), and the two deciduous teeth unearthed from the lowest Uluzzian levels of Grotta del Cavallo, mistakenly attributed to Neanderthals, turned out to belong to AMH (Benazzi *et al.*, 2011), suggesting that the Uluzzian was produced by modern humans.

To summarize, even though we cannot surely reject the hypothesis that Neanderthals were the makers of some of the transitional cultures, current evidence suggests that rapid cultural changes occurred between 45,000 – 40,000 ya in Europe in conjunction with the arrival of AMH. These newcomers may have produced these cultures, or alternatively may have influenced Neanderthal behavior. Obviously, we cannot exclude that NEA-AMH hybrid individuals were among the makers of these cultures, still the presence of hybrids would confirm that AMHs were in Europe ca. 45,000 ya. Even though some scholars are still reluctant to accept an earliest migration of AMH in Europe against any evidence (Zilhão *et al.*, 2015), the Italian human remains currently suggest that both the Uluzzian and the Protoaurignacian cultures were produced by AMH (Benazzi *et al.*, 2011; 2015). Finally, because the last Neanderthals date ca. 41,000-39,000 ya (Higham *et al.*, 2014), it is reasonable to assume that AMHs were directly or indirectly responsible for the Neanderthal's demise, as suggested by Benazzi and colleagues (2015).

Much more is to be understood about the transitional period between Middle to Upper Paleolithic in the Italian peninsula and in Europe, therefore new excavations and thorough investigation of old and new findings are necessary.

Acknowledgements

The author is grateful to Cinzia Fornai for the important comments that significantly improved the manuscript. The author is supported by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 724046 - SUCCESS).

References

Armitage, S.J., Jasim, S.A., Marks, A.E., Parker, A.G., Usik, V.I., Uerpmann, H.P. 2011. The southern route "out of Africa": evidence for an early expansion of modern humans into Arabia. *Science* 331, 453-456.

Bailey, S.E., Hublin, J.-J., 2005. Who made the Early Aurignacian? A reconsideration of the Brassempouy dental remains. *Bulletins et mémoires de la Société d'Anthropologie de Paris* 17, 115-121.

Bailey, S.E., Weaver, T.D., Hublin, J.-J. 2009. Who made the Aurignacian and other early Upper Paleolithic industries? *Journal of Human Evolution* 57, 11-26.

Bailey, S.E., Benazzi, S., Souday, C., Astorino, C., Paul, K., Hublin, J.-J. 2014. Taxonomic differences in deciduous upper second molar crown outlines of *Homo sapiens*, *Homo neanderthalensis*, and *Homo erectus*. *Journal of Human Evolution* 72, 1-9.

Bar-Yosef, O., Bordes, J.G. 2010. Who were the makers of the Châtelperronian culture? *Journal of Human Evolution* 59, 586-593.

Bartolomei, G., Broglio, A., Cassoli, P., Castelletti, L., Cremaschi, M., Giacobini, G., Malerba, G., Maspero, A., Peresani, M., Sartorelli, A., Tagliacozzo, A. 1992. La Grotte-Abri de Fumane: Un site Aurignacien au sud des Alps. *Preistoria Alpina* 28,131-79.

Beauval, C., Maureille, B., Lacrampe-Cuyaubère, F., Serre, D., Peressinotto, D., Bordes, J.G., Cochard, D., Couchoud, I., Dubrasquet, D., Laroulandie, V., Lenoble, A., Mallye, J.B., Pasty, S., Primault, J., Rohland, N., Pääbo, S., Trinkaus, E. 2005. A late Neanderthal femur from Les Rochers-de-Villeneuve, France. *Proceedings of the National Academy of Sciences USA* 102, 7085-90.

Benazzi, S., Douka, K., Fornai, C., Bauer, C.C., Kullmer, O., Svoboda, J., Pap, I., Mallegni, F., Bayle, P., Coquerelle, M., Condemi, S., Ronchitelli, A., Harvati, K., Weber, G.W. 2011. Early dispersal of modern humans in Europe and implications for Neanderthal behaviour. *Nature* 479, 525-528.

Benazzi, S. 2012. The first modern Europeans. *Journal of Anthropological Science* 90, 3-6.

Benazzi, S., Bailey, S.E., Peresani, M., Mannino, M.A., Romandini, M., Richards, M.P., Hublin, J.-J. 2014. Middle Paleolithic and Uluzzian human remains from Fumane Cave, Italy. *Journal of Human Evolution* 70, 61-68.

Benazzi, S., Slon, S., 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., Hublin, J.-J. 2015. The Makers of the Protoaurignacian and Implications for Neanderthal Extinction. *Science* 348, 793-6.

Beyin, A. 2011. Upper Pleistocene Human Dispersals out of Africa: A Review of the Current State of the Debate. *International Journal of Evolutionary Biology* 2011, 615094.

Boscato, P., Crezzini, J., 2012. Middle-Upper Palaeolithic transition in Southern Italy: Uluzzian macromammals from Grotta del Cavallo (Apulia). *Quaternary International* 252, 90-98.

Bowler, J.M., Johnston, H., Olley, J.M., Prescott, J.R., Roberts, R.G., Shawcross, W., Spooner, N.A. 2003. New ages for human occupation and climatic change at Lake Mungo, Australia. *Nature* 421, 837-40.

Churchill, S.E., Smith, F.H. 2000. Makers of the early Aurignacian of Europe. *American Journal of Physical Anthropology* 113, 61-115.

Churchill, S.E. 2014. *Thin On The Ground. Neanderthal Biology, Archaeology and Ecology.* Oxford: Wiley-Blackwell.

Currat, M., Excoffier, L. 2011. Strong reproductive isolation between humans and Neanderthals inferred from observed patterns of introgression. *Proceedings of the National Academy of Sciences USA* 108, 15129-34.

d'Errico, F., Zilhao, J., Julien, M., Baffier, D., Pelegrin, J. 1998. Neanderthal acculturation in Western Europe? A critical review of the evidence and its interpretation. *Current Anthropology* 39 (suppl.), S1 – S44.

d'Errico, F., Borgia, V., Ronchitelli, A. 2012. Uluzzian bone technology and its implications for the origin of behavioural modernity. *Quaternary International* 259, 59-71.

Douka, K., Grimaldi, S., Boschian, G., del Lucchese, A., Higham, T.F. 2012. A new chronostratigraphic framework for the Upper Palaeolithic of Riparo Mochi (Italy). *Journal of Human Evolution* 62, 286-99.

Douka, K., Higham, T.F.G., Wood, R., Boscato, P., Gambassini, P., Karkanas, P., Peresani, M., Ronchitelli, A.M., 2014. On the chronology of the Uluzzian. *Journal of Human Evolution* 68, 1-13.

Fiorenza L, Benazzi S, Tausch J, Kullmer O, Bromage TG, Schrenk F. 2011. Molar macrowear reveals Neanderthal eco-geographic dietary variation. *PLoS ONE* 6, e14769.

Formicola, V. 1989. Early aurignacian deciduous incisor from Riparo Bombrini at Balzi Rossi (Grimaldi, Italy). *Rivista di Antropologia* 67, 287-292.

Fornai, C., Benazzi, S., Svoboda, J., Pap, I., Harvati, K., Weber, G.W. 2014. Enamel thickness variation of deciduous first and second upper molars in modern humans and Neanderthals. *Journal of Human Evolution* 76, 83-91.

Fu, Q., Li, H., Moorjani, P., Jay, F., Slepchenko, S.M., Bondarev, A.A., Johnson, P.L., 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., Slatkin, M., Hublin, J.J., Reich, D., Kelso, J., Viola, T.B., Pääbo, S. 2014. Genome sequence of a 45,000-year-old modern human from western Siberia. *Nature* 514, 445-9.

Fu, Q., Hajdinjak, M., Moldovan, O.T., Constantin, S., Mallick, S., Skoglund, P., Patterson, N., Rohland, N., Lazaridis, I., Nickel, B., Viola, B., Prüfer, K., Meyer, M., Kelso, J., Reich, D., Pääbo, S. 2015. An early modern human from Romaniawith a recent Neanderthal ancestor. *Nature* 524, 216-9.

Green, R.E., Krause, J., Briggs, A.W., Maricic, T., Stenzel, U., Kircher, M., Patterson, N., Li, H., Zhai, W., Fritz, M.H., Hansen, N.F., Durand, E.Y., Malaspinas, A.S., Jensen, J.D., Marques-Bonet, T., Alkan, C., Prüfer, K., Meyer, M., Burbano, H.A., Good, J.M., Schultz, R., Aximu-Petri, A., Butthof, A., Höber, B., Höffner, B., Siegemund, M., Weihmann, A., Nusbaum, C., Lander, E.S., Russ, C., Novod, N., Affourtit, J., Egholm, M., Verna, C., Rudan, P., Brajkovic, D., Kucan, Z., Gusic, I., Doronichev, V.B., Golovanova, L.V., Lalueza-Fox, C., de la Rasilla, M., Fortea, J., Rosas, A., Schmitz, R.W., Johnson, P.L., Eichler, E.E., Falush, D., Birney, E., Mullikin, J.C., Slatkin, M., Nielsen, R., Kelso, J., Lachmann, M., Reich, D., Pääbo, S. 2010. A draft sequence of the Neanderthal genome. *Science* 328, 710-22.

Groucutt, H.S., Petraglia, M.D., Bailey, G., Scerri, E.M., Parton, A., Clark-Balzan, L., Jennings, R.P., Lewis, L., Blinkhorn, J., Drake, N.A., Breeze, P.S., Inglis, R.H., Devès, M.H., Meredith-Williams, M., Boivin, N., Thomas, M.G., Scally, A. 2015. Rethinking the dispersal of *Homo sapiens* out of Africa. *Evolutionary Anthropology* 24, 149-64.

Henry, A.G., Brooks, A.S., Piperno, D.R. 2011. Microfossils in calculus demonstrate consumption of plants and cooked foods in Neanderthal diets (Shanidar III, Iraq; Spy I and II, Belgium). *Proceedings of the National Academy of Sciences USA* 108, 486-91.

Henry, A.G., Brooks, A.S., Piperno, D.R. 2014. Plant foods and the dietary ecology of Neanderthals and early modern humans. *Journal of Human Evolution* 69, 44-54.

Hershkovitz, I., Marder, O., Ayalon, A., Bar-Matthews, M., Yasur, G., Boaretto, E., Caracuta, V., Alex, B., Frumkin, A., Goder-Goldberger, M., Gunz, P., Holloway, R.L., Latimer, B., Lavi, R., Matthews, A., Slon, V., Mayer, D.B., Berna, F., Bar-Oz, G., Yeshurun, R., May, H., Hans, M.G., Weber, G.W., Barzilai, O. 2015. Levantine cranium from Manot Cave (Israel) foreshadows the first European modern humans. *Nature* 520, 216-9.

Hershkovitz, I., Weber, G.W., Quam, R., Duval, M., Grün, R., Kinsley, L., Ayalon, A., Bar-Matthews, M., Valladas, H., Mercier, N., Arsuaga, J.L., Martinón-Torres, M., Bermúdez de Castro, J.M., Fornai, C., Martín-Francés, L., Sarig, R., May, H., Krenn, V.A., Slon, V., Rodríguez, L., García, R., Lorenzo, C., Carretero, J.M., Frumkin, A., Shahack-Gross, R., Bar-Yosef Mayer, D.E., Cui, Y., Wu, X., Peled, N., Groman-Yaroslavski, I., Weissbrod, L., Yeshurun, R., Tsatskin, A., Zaidner, Y., Weinstein-Evron, M. 2018. *The earliest modern humans outside Africa*. Science 359, 456-459.

Higham, T., Barton, H., Turney, C.S.M., Barker, G., Ramsey, C.B., Brock, F. 2008. Radiocarbon dating of charcoal from tropical sequence: results from the Niah Great Cave, Sarawak, and their broader implications. *Journal of Quaternary Science* 24, 189-197.

Higham, T., Brock, F., Peresani, M., Broglio, A., Wood, R., Douka, K. 2009. Problems with radiocarbon dating the Middle and Upper Palaeolithic transition in Italy. *Quaternary Science Reviews* 28, 1257-1267.

Higham, T., Jacobi, R., Julien, M., David, F., Basell, L., Wood, R., Davies, W., Ramsey, C.B. 2010. Chronology of the Grotte du Renne (France) and implications for the context of ornaments and human remains within the Châtelperronian. *Proceedings of the National Academy of Sciences USA* 107, 20234-9.

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., Fagan, M. 2011. The earliest evidence for anatomically modern humans in northwestern Europe. *Nature* 479, 521-524.

Higham, T., Douka, K., Wood, R., Ramsey, C.B., Brock, F., Basell, L., Camps, M., Arrizabalaga, A., Baena, J., Barroso-Ruiz, C., Bergman, C., Boitard, C., Boscato, P., Caparros, M., Conard, N.J., Draily, C., Froment, A., Galvan, B., Gambassini, P., Garcia-Moreno, A., Grimaldi, S., Haesaerts, P., Holt, B., Iriarte-Chiapusso, M.-J., Jelinek, A., Jorda Pardo, J.F., Maillo-Fernandez, J.-M., Marom, A., Maroto, J., Menendez, M., Metz, L., Morin, E., Moroni, A., Negrino, F., Panagopoulou, E., Peresani, M., Pirson, S., de la Rasilla, M., Riel-Salvatore, J., Ronchitelli, A., Santamaria, D., Semal, P., Slimak, L., Soler, J., Soler, N., Villaluenga, A., Pinhasi, R., Jacobi, R., 2014. The timing and spatiotemporal patterning of Neanderthal disappearance. *Nature* 512, 306-309.

Hoffecker, J.F. 2009. Out of Africa: modern human origins special feature: the spread of modern humans in Europe. *Proceedings of the National Academy of Sciences USA* 106, 16040-16045.

Hublin, J.J., Talamo, S., Julien, M., David, F., Connet, N., Bodu, P., Vandermeersch, B., Richards, M.P. 2012. *Proceedings of the National Academy of Sciences USA* 109, 18743-8.

Hublin, J.J. 2015. The Modern Human Colonization of Western Eurasia: When and Where? *Quaternary Science Reviews* 18, 194-210.

Hublin J.J., Ben-Ncer, A., Bailey, S.E., Freidline, S.E., Neubauer, S., Skinner, M.M., Bergmann, I., Le Cabec, A., Benazzi, S., Harvati, K., Gunz, P. 2017. *New fossils from Jebel Irhoud, Morocco and the pan-African origin of Homo sapiens*. Nature 546, 289-292.

Liu, W., Martinón-Torres, M., Cai, Y.J., Xing, S., Tong, H.W., Pei, S.W., Sier, M.J., Wu, X.H., Edwards, R.L., Cheng, H., Li, Y.Y., Yang, X.X., de Castro, J.M., Wu, X.J. 2015. The earliest unequivocally modern humans in southern China. *Nature* 526, 696-9.

Mellars, P. 2005. The impossible coincidence: a single-species model for the origins of modern human behavior in Europe. *Evolutionary Anthropology* 14, 12-27.

Mellars, P. 2006. A new radiocarbon revolution and the dispersal of modern humans in Eurasia. *Nature* 439, 931-935.

Mercier, N., Valladas, H., Valladas, G. 1995. Flint thermoluminescence dates from the CFR Laboratory at Grif: contributions to the study of the Middle Palaeolithic. *Quaternary Science Reviews* 14, 351-364.

Nigst, P.R., Haesaerts, P., Damblon, F., Frank-Fellner, C., Mallol, C., Viola, B., Götzinger, M., Niven, L., Trnka, G., Hublin JJ. 2014. Early modern human settlement of Europe north of the Alps occurred 43,500 years ago in a cold steppe-type environment. *Proceedings of the National Academy of Sciences USA* 111, 14394-9.

Noonan, J.P., Coop, G., Kudaravalli, S., Smith, D., Krause, J., Alessi, J., Chen, F., Platt, D., Pääbo, S., Pritchard, J.K., Rubin, E.M. 2006. Sequencing and analysis of Neanderthal genomic DNA. *Science* 314, 1113-8.

Palma di Cesnola, A., Messeri, M.P. 1967. Quatre dents humaines paléolithiques trouvées dans des cavernes de l'Italie Méridionale. *L'Anthropologie* 71, 249-262.

Pearson, O.M. 2013. Africa: The Cradle of Modern People, in: Smith, F.H., Ahern, J.C.M. (eds.), *The Origins of Modern Humans: Biology Reconsidered*. Hoboken: John Wiley & Sons, pp. 1-43.

Petraglia, M.D., Alsharekh, A., Breeze, P., Clarkson, C., Crassard, R., Drake, N.A., Groucutt, H.S., Jennings, R., Parker, A.G., Parton, A., Roberts, R.G., Shipton, C., Matheson, C., Al-Omari, A., Veall, M.A. 2012. Hominin dispersal into the Nefud Desert and Middle palaeolithic settlement along the Jubbah Palaeolake, Northern Arabia. *PLoS One* 7, e49840.

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., 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., Pääbo, S. 2014. The complete genome sequence of a Neanderthal from the Altai Mountains. *Nature* 505, 43-9.

Riel-Salvatore, J., 2009. What Is A 'Transitional' Industry? The Uluzzian of Southern Italy as a Case Study, in: Camps, M., Chauhan, P. (eds.), *Sourcebook of Paleolithic Transitions: Methods, Theories, and Interpretations*. New York: Springer, pp. 377-396.

Ronchitelli, A., Benazzi, S., Boscato, P., Douka, K., 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, 107-111.

Sankararaman, S., Mallick, S., Dannemann, M., Prüfer, K., Kelso, J., Pääbo, S., Patterson, N., Reich, D. 2014. The genomic landscape of Neanderthal ancestry in present-day humans. *Nature* 507, 354-7.

Shackleton, J.C., v. Andel, T.H., Runnels, C.N. 1984. Coastal paleogeography of the Central and Western Mediterranean during the last 125,000 years and its archaeological implications. *Journal of Field Archaeology* 11, 307-315.

Shang, H., Tong, H., Zhang, S., Chen, F., Trinkaus, E. 2007. An early modern human from Tianyuan Cave, Zhoukoudian, China. *Proceedings of the National Academy of Sciences USA* 104, 6573-8.

Trinkaus, E., Moldovan, O., Milota, S., Bîlgăr, A., Sarcina, L., Athreya, S., Bailey, S.E., Rodrigo, R., Mircea, G., Higham, T., Ramsey, C.B., van der Plicht, J. 2003. An early modern human from the Peştera cu Oase, Romania. *Proceedings of the National Academy of Sciences USA* 100, 11231-6

van Andel, T.H., Davies, W. 2003. Neanderthals and modern humans in the European landscape during the last glaciation: archaeological results of the Stage 3 Project. Cambridge: McDonald Institute for Archaeological Research.

Verna, C., Dujardin, V., Trinkaus, E. 2012. The Early Aurignacian human remains from La Quina-Aval (France). *Journal of Human Evolution* 62, 605-17.

Vernot, B., Akey, J.M. 2014. Resurrecting surviving Neanderthal lineages from modern human genomes. *Science* 343, 1017-21.

Walker, M.J., Gibert, J., López, M.V., Lombardi, A.V., Pérez-Pérez, A., Zapata, J., Ortega, J., Higham, T., Pike, A., Schwenninger, J.L., Zilhão, J., Trinkaus, E. 2008. Late Neanderthals in southeastern Iberia: Sima de las Palomas del Cabezo Gordo, Murcia, Spain. *Proceedings of the National Academy of Sciences USA* 105, 20631-6.

White, M., 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, 1-30.

Wild, E.M., Teschler-Nicola, M., Kutschera, W., Steier, P., Trinkaus, E., Wanek, W. 2005. Direct dating of Early Upper Palaeolithic human remains from Mladec. *Nature* 435, 332-335.

Zilhão, J. 2006. Neanderthals and Moderns Mixed, and It Matters. *Evolutionary Anthropology* 15, 183-195.

Zilhão, J. 2007. The Emergence of Ornaments and Art: An Archaeological Perspective on the Origins of "Behavioral Modernity." Journal of Archaeological Research 15, 1-54.

Zilhão, J., Banks, W.E., d'Errico, F., Gioia, P. 2015. Analysis of Site Formation and Assemblage Integrity Does Not Support Attribution of the Uluzzian to Modern Humans at Grotta del Cavallo. *PLoS One* 10, e0131181.

From Neanderthals to Anatomically Modern Humans in Liguria (Italy): the current state of knowledge

Fabio Negrino[1] *& Julien Riel-Salvatore*[2 3]

Abstract

Liguria is a coastal region in northwest Italy bordered by high mountains that descend sharply toward the Mediterranean Sea and that has very limited expanses of coastal plain. The Eastern Ligurian record is known only from open-air sites, while several deeply stratified caves and shelters exist in the Western part of the region. The Mousterian is quite well known throughout Liguria while the earliest Upper Palaeolithic record, in contrast, is known from only a few Protoaurignacian assemblages, an industry indisputably associated with anatomically modern humans. With the possible exception of the assemblage from Via San Francesco (Sanremo), characterized by laminar débitage and Upper Palaeolithic-like formal tools, to date, no Uluzzian or other "transitional" industries have been reported. Recent radiocarbon dates place the disappearance of the Neanderthals in Liguria around 42 ky cal. BP, and the most recent Mousterian deposits are clearly separated by sedimentary discontinuities from the oldest Protoaurignacian ones that date back to about 41.5 ky cal. BP, as highlighted at the Riparo Mochi and Riparo Bombrini (Balzi Rossi). There is no evidence of contact or admixture and the transition between these two cultural worlds is sharp and seemingly very rapid, as if modern humans perhaps colonised an empty land. After the Protoaurignacian, the Classic Aurignacian is docu-

1 Dipartimento di Antichità, Filosofia, Storia – Università di Genova, Italy; E-mail: fabio.negrino@unige.it.

2 Département d'Anthropologie, Université de Montréal, Canada; E-mail: julien.riel-salvatore@umontreal.ca.

3 Fabio Negrino wrote the paper; Julien Riel-Salvatore, as co-director of the excavations at Riparo Bombrini and Arma Veirana, participated in the discussion of the results and commented on the manuscript. J. R.-S. also translated the paper from Italian to English.

in: Borgia, V. and E. Cristiani (eds.) 2018: *Palaeolithic Italy. Advanced studies on early human adaptations in the Apennine peninsula*, Sidestone Press Academics (Leiden), pp. 161-182.

mented at the Balzi Rossi from about 35-36 ky BP to 30 Ky cal. BP, again in a situation that marks a probable discontinuity between the two cultural phases.

Keywords: Neanderthal, Anatomically Modern Human, Mousterian, Protoaurignacian, Classic Aurignacian, Liguria, Italy.

1. Introduction

The nature of the transition from the Middle to the Upper Palaeolithic and the concomitant biological shift from Neanderthals to Anatomically Modern Humans (henceforth, AMH/AMHs) remains one of the major debates in palaeoanthropology. Recent research on the topic is yielding increasingly fine-grained data, especially as concerns the chronology of the transition interval. For instance, in the Italian peninsula, recent advances suggest the independent origin of the Uluzzian, as a product of the AMHs, and its partial contemporaneity with the Protoaurignacian (Benazzi *et al.* 2011). This would confirm the idea that the Uluzzian was not the result of acculturation of Neanderthals by modern humans (*cf.* Riel-Salvatore 2009, 2010), but a true AMH culture. This interpretation has however recently been challenged by the interpretation of the Uluzzian-like industry from the Grotta di Fumane (Douka *et al.* 2012; Peresani 2008) as rooted in local Mousterian (Peresani *et al.* 2016), as well as by strong criticism on the association between human teeth and Uluzzian artifacts at Grotta del Cavallo on which the case for an AMH attribution rests (Zilhão *et al.* 2015).

The interest in the ultimate origins and chronology of so-called 'transitional' industries has been accompanied by much new research on industries associated with early European modern humans, notably the Protoaurignacian and the Early Aurignacian (*Aurignacien ancien*) (Douka *et al.* 2012; Banks *et al.* 2013; Hublin 2014; Nigst *et al.* 2014). This work has in many cases focused on the reanalysis or reexcavation of sites originally explored several decades ago to provide better context to the cultural facies identified in this pioneering work (Fig. 1).

One such site is Riparo Mochi, in the region of Liguria, in northwestern Italy. Reanalysis of the Protoaurignacian material recovered there in the 1950s recently showed it to be among the earliest Upper Palaeolithic sequences in Europe (Alhaique *et al.* 2000; Grimaldi *et al.* 2014; Kuhn and Stiner 1998). This was confirmed by targeted dating assays conducted in recent years which established that it is the currently earliest known Protoaurignacian site along the putative 'Mediterranean route' of modern human dispersals into Europe (Douka *et al.* 2012). This has shined a new light on the 'transitional' record of the region of Liguria as a whole, since the region has yielded comparatively few other Mousterian and Protoaurignacian sites whose significance is heightened by their potential concordance with the Mochi sequence. This paper thus presents a detailed critical overview of the evidence from this key region.

Liguria is located along one of the main proposed routes for the diffusion of AMH into Europe; as such, the recent upsurge in interest in modern human origins research and our species' conquest of the planet have given the region a central place in renewed research on the topic (Bertola *et al.* 2013; Douka *et al.* 2014; Higham *et al.* 2014; Hublin 2014).

Geographically, Liguria is best seen as a long mountain range that connects the Apennines to the Alps characterized by steep, deeply incised valleys and bordered by very limited expanses of coastal plain. Its position at the northern edge of the Tyrrhenian Sea has also contributed to make it an important refugium zone due to its relatively stable and mild climate even during the coldest phases of the Last Glacial (Negrino and Tozzi 2008; Negrino *et al.* in press/a). The Apennines and southern extension of the Ligurian and Maritime Alps would have exacerbated the challenges posed to foragers by the absence of a continuous coastal plain and selected for mobility strategies along select crests. This confluence of topography and human geography have resulted in the bidirectional dispersal of goods (*e.g.*, lithic raw material) and people along an East-West axis that linked peninsular Italy and Provence (Negrino *et al.* 2016; Negrino and Starnini 2003; Porraz and Negrino 2008; Porraz *et al.* 2010).

Additionally, Liguria is rich in karstic formations that have yielded a large number of caves and rockshelters that contain deposits allowing in-depth investigations of Late Pleistocene human adaptations. As a result, since the 19th Century, the region has been the focus of research by numerous scholars who, using the methods available to them at the time, have excavated a series of key sites, especially in the rich and storied site complex of the Balzi Rossi (Ventimiglia, Imperia) located near the Franco-Italian border (Del Lucchese *et al.* 2007).

The archaeological record of the Late Middle Palaeolithic of Liguria is mostly found at sites in the western part of the region, which have also yielded several Neanderthal fossil remains (de Lumley 2013a, 2013b; Holt *et al.* 2012). In contrast, the Protoaurignacian is known from three localities (at the sites of Riparo Bombrini and Riparo Mochi at the Balzi Rossi, and at the sites of Arma delle Manie and at Arma degli Zerbi, in the municipality of Finale Ligure); Grotte de l'Observatoire, located in the Principality of Monaco not far from the Italian border, also comprises Protoaurignacian deposits (Boule and De Villeneuve 1927; Onoratini *et al.* 1999: Onoratini and Simon 2006; Porraz *et al.* 2010). In spite of this relative scarcity, these sites are extremely important to our understanding of the settlement dynamics of the region by AMHs.

New excavations focusing on the transition from Neanderthals to AMH began in the 1990s at Riparo Mochi, in 2002 at Riparo Bombrini and in 2015 at the newly discovered site of Arma Veirana, located roughly 10km from the coast in the hilly Ligurian hinterland (Negrino *et al.* 2016; Negrino *et al.* in press/b). While this last site will provide us with a first glance at the record of the transitional in an area that has not yet been explored, the former two are separated by only a few dozen meters in the famed Balzi Rossi locality, which comprises deposits stretching from MIS 7 (Rossoni-Notter *et al.* 2016c, 2016d) to MIS 2 at the end of the Last Glacial. These recent ongoing field programmes have yielded important new data on the Transition and they have led to new studies of unpublished material collected in prior excavations at this sites and other sites (Arobba and Caramiello 2009; Benazzi *et al.* 2015; Bertola *et al.* 2013; Bietti and Negrino 2008; Blanc 1938; Cauche 2002; Del Lucchese and Negrino 2008; Douka *et al.* 2012; Higham *et al.* 2014; Holt *et al.* in preparation; Grimaldi 2014; Grimaldi and Santaniello 2014; Grimaldi *et al.* 2014; Negrino and Riel-Salvatore, in press; Negrino and Tozzi 2008; Onoratini 2004; Onoratini and Raux 1992; Porraz and

Negrino 2008; Riel-Salvatore and Negrino 2009, in press; Riel-Salvatore *et al.* 2013; Tejero and Grimaldi 2015; Tozzi and Negrino 2008).

On the topic of chronology, bones recovered alongside an AMH deciduous incisor during the 1976 excavations of the Protoaurignacian levels of Riparo Bombrini (*cf.* Vicino 1984, Formicola 1984, 1989) have recently been dated by AMS in the context of a modern reanalysis of that tooth (Benazzi *et al.* 2015). These dates have greatly refined our understanding of the chrono-climatic context of the technocomplexes dating to MIS3 documented at the site and of the links between the Protoaurignacian and the later Classic (or "Early") Aurignacian, the latter of which is currently known in Liguria only at the Balzi Rossi (Bietti and Negrino 2008; Mussi *et al.* 2006).

In Liguria, the transition from the Mousterian to the Protoaurignacian is best understood as a rapid biological and cultural replacement marked by dramatic changes in the techno-economic and symbolic spheres. This break is further highlighted by recent work on the material from Via San Francesco (Sanremo, Imperia) which has often been considered a 'transitional' phase of the Mousterian on the basis of its abundant laminar component and Upper Palaeolithic tool types (Tavoso 1988). This chrono-cultural attribution has in fact been undermined by recent ESR determinations indicating it may date back to as far back as MIS 6 (Pirouelle 2006). If this age is borne out by additional dates, this will force a significant rethinking of the industry's characteristics and of its cultural interpretation (Bietti and Negrino 2007).

In this paper, we thus present a review of the implications of the results of this abundance of new research on our comprehension of the Late Mousterian and Early Upper Palaeolithic of Liguria, while situating it in the wider context of the Transition in Italy.

2. At the end of Midde Palaeolithic

Assemblages that can be assigned to the Late Mousterian with some degree of certainty are known from the Balzi Rossi (Riparo Bombrini, Riparo Mochi), from Arma Veirana and from Arma delle Manie (Arobba *et al.* 1976; Cauche 2002). Other possible Late Mousterian assemblages come from some of the other Balzi Rossi sites (*i.e.*, Grotta dei Fanciulli, Grotta del Caviglione, Grotta del Principe and Ex-Birreria) which unfortunately still lack radiometric dates and detailed lithic analyses (Bachechi and Revedin 1996; Cremaschi *et al.* 1991; Negrino 2002; Onoratini *et al.* 2012; Rossoni-Notter 2011; Rossoni-Notter *at al.* 2016a, 2016b).

The most reliable data pertinent to our understanding of the final expressions of the Mousterian in Liguria are unquestionably those from Riparo Mochi and Riparo Bombrini, both of which have been the focus of recent excavations and have yielded new absolute dates. As mentioned, the two sites are separated by only a few dozen meters, suggesting they might well have been part of a single extensive occupation of the base of the cliffs of the Balzi Rossi during the Pleistocene. At Riparo Mochi, the topmost Mousterian layers (Cuts 56-25 in Cardini's level I) are the ones that have yielded assemblages assigned to the Late Mousterian (Grimaldi and Santaniello 2014). A recent technological analysis shows that there is a marked techno-economic difference between these cuts and those found below Cut 56. Interestingly, from the bottom to the top of the sequence, there is a gradual decrease in the laminarity of assemblages that seems to go hand-in-hand with a reduction of the size of blanks; throughout, local raw materials overwhelmingly dominate the lithic industry, while allochthonous raw materials are very rare and reach their highest frequency (5%) only in the cold episode of Cuts 44/46, where mammoth and elk are documented (Grimaldi and Santaniello 2014). Cut 31, which is one of the last expressions of the Mousterian at the site, is an especially good indicator of these trends, having yielded a lithic assemblage dominated by small, irregular flakes bearing centripetal removals. The upper cuts' operational sequences appear to always lead to the production of small flakes struck from discoid cores whereas Levallois products are rarer. Additionally, Cut 31 appears to correspond (or at most slightly postdate) to a phase of massive vault collapse similar to that observed at the top of the Mousterian sequence at Riparo Bombrini (see below). Cuts 30-25 yielded progressively scanter assemblages comprising so few pieces that Cardini attributed them to a distinct, 'semi-sterile' level (Level H). Recent excavations at the site have further established that there is a marked break between the Mousterian and the overlying Protoaurignacian of Level G (Douka *et al.* 2014).

This situation is largely paralleled in the sequence recently brought to light at Riparo Bombrini (Holt *et al.* in preparation). At this site, the latest Mousterian corresponds to levels MS1-2 ("Mousterian Semisterile" or "Level IV – Upper Part") which immediately underlies the Protoaurignacian of A1-3 ("Levels II-III"), from which it is separated by an erosional horizon (Fig. 2). Level IV Upper Part is a 30-40 cm thick layer of clayey loam sedimentary matrix encasing coarse clasts, including several large blocks of roof fall. A few patches of charcoal indicate that hearths were lit towards the back of the shelter. Techno-typologically, the scarce lithic artifacts recovered from this level can be attributed to the Mousterian; notably, a few Discoid cores are documented. Almost all lithics are made on local raw materials. The scant traces of human activity and the presence of large carnivore coprolites combine to suggest that the shelter was, at that time, occupied only sporadically.

The deeper levels (M1-7 or "Level IV – Lower part") have been explored to a depth of about 70 cm. Comprising conspicuous quantities of roof spall, the sedimentary matrix becomes increasingly redder and clayey as one goes down the stratigraphy. These levels have yielded abundant lithic assemblages which, in some levels, are concentrated spatially towards the back wall of the shelter, close to conspicuous hearths. A preliminary analysis of the spatial distribution of different artifact classes in the shelter indicates that it was divided into distinct activity areas within and outside its prehistoric dripline (Riel-Salvatore *et al.* 2013). The lithic industry is made almost exclusively on local or circumlocal raw materials and comprises mostly small flakes and production debris. Flakes and cores attributable to the Discoid method are both found throughout the sequence although the Levallois method is also documented to a lesser degree, being used mostly to manufacture larger blanks. Retouched tools are rare and dominated by sidescrapers and denticulates. The faunal assemblages recovered from those levels are heavily fragmented and often burned; they document a varied faunal spectrum comprising cervids, caprids, equids, bovids, as well as examples of boar, rhinoceros and bear. The presence of shellfish brought to the site and fragmented in order to consume them is especially noteworthy: *Phorcus turbinatus* is the most frequent species, indicating that the site's occupants were collecting these small gastropods in rocky intertidal zones (Del Lucchese and Negrino 2008; Negrino *et al.* in press/a).

Palynological, microfaunal and faunal analyses indicate a gradual shift from humid and temperate conditions in the lower levels to a colder, more rigorous climatic regime in the upper levels of the Mousterian (Arobba and Caramiello 2009). The presence of large blocks of vault collapse in the terminal Mousterian levels provides further support for this climatic reconstruction.

Riparo Bombrini is also the only Late Mousterian site in Liguria to have been directly dated. Radiocarbon dates on charcoal and marine shells indicate that the Late Mousterian at the site dates to between roughly 44 and 41 ky BP (Higham *et al.* 2014; Holt *et al.* in preparation).

Moving eastward along the coast, the only site to have yielded material that can be attributed to a late phase of the Mousterian is Arma delle Manie, although the exact age of those deposits is still disputed (Arobba *et al.* 1976; Mehidi 2005). It is nonetheless very likely that levels I-III date to MIS 3, as palynological analysis shows that they are characterized by relatively temperate conditions. The lithic industry indicates an almost complete reliance on poor quality local raw materials that likely forced toolmakers to rely predominantly on the Discoid method, although here again, a few Levallois and laminar elements are documented (Peresani 2003). The presence of the Discoid method in the lower levels (IV-VII) provides circumstantial evidence that this core preparation method is most likely a response to local environmental factors rather than a strictly cultural signal. The faunal spectrum is dominated by red deer, the most common prey in the Late Mousterian of Liguria (Psathi 2003; Valensi and Psathi 2004; Valensi *et al.* 2004).

Finally, in the newly discovered site of Arma Veirana, in the Neva Valley, a Late Mousterian level has been documented during the first field season that took place in 2015 (Negrino *et al.* 2016). Like at Riparo Mochi, Riparo Bombrini and Arma delle Manie, the lithic assemblage from this level at Arma Veirana comprises both Discoid and Levallois elements, along with a rich faunal collection.

3. The appearance of AMHs: the Protoaurignacian evidence

First defined in 1966 by George Laplace (Laplace 1966), the Protoaurignacian is one of the cultural manifestations of the initial AMH migration into Europe. It is characterized by important technological and symbolic innovations that contrast markedly with the preceding Mousterian. It is found over an area that stretches from Atlantic and Mediterranean Spain to southern France and the Italian peninsula, with episodic reports of its presence in Austria and the Balkans (Bon 2006; Hublin 2014; Teyssandier 2007). The industry is distinguished by the production of Dufour bladelets, that is, straight, elongated bladelets subsequently modified by direct inverse or alternate retouch. Laminar production seamlessly grades into bladelet production with no evident discontinuity. While the Protoaurignacian is also characterized by an abundance of bone tools, ochre and personal ornaments (including numerous perforated shells), it is also devoid of the defining elements of the Early and Classic Aurignacian (*i.e.*, split-based points, robust blades with heavy retouch, etc.) (Bon *et al.* 2010; Le Brun-Ricalens 2005).

As indicated above, the two main reference sites for our understanding of the Protoaurignacian in Liguria are Riparo Mochi and Riparo Bombrini, along with the

Grotte de l'Observatoire, located in the Principality of Monaco. Available calibrated AMS radiocarbon dates bracket the Late Mousterian and Protoaurignacian at Bombrini between 42,580±610 cal BP (level M4, cut 13) and 36,710±580 cal BP (level A1, cut 2), which agrees perfectly with the available dates from Riparo Mochi. In sum, in Liguria, the Protoaurignacian – or at least its main distinctive techno-typological attributes – persists for a long interval of roughly 5,000 years, from 41.5 to 36.5 ky cal BP (Benazzi *et al.* 2015; Douka *et al.* 2012; Higham *et al.* 2014; Holt *et al.* in preparation; Negrino *et al.* 2016). These dates also reveal that Riparo Bombrini so far only documents the latter (post 40 ky BP) part of the Protoaurignacian, while its earliest phases are present at neighboring Riparo Mochi (Fig. 3). In this regard, it is however warranted to highlight that there exist some discrepancies between the actual radiocarbon ages on bone and charcoal samples obtained by the Max Planck Institute and Beta Analytics laboratories (Benazzi *et al.* 2015) and those on shells obtained by Oxford (Higham *et al.* 2014). This is especially true for the Mousterian, where the Oxford dates are systematically more recent, leading to an apparent substantial chronological overlap with the oldest dates for the Protoaurignacian. Ongoing dating programmes at both sites will hopefully help clarify this issue in short order and thus lead to a better understanding of the exact timing of the transition at the Balzi Rossi.

As concerns the material culture, the Protoaurignacian at the Balzi Rossi and at the Grotte de l'Observatoire is documented by a record constituted by thousands of lithic implements, including usually prismatic bladelet cores, endscrapers, splintered pieces and several hundred Dufour bladelets (Fig. 4). These bladelets are usually found fragmented and only very rarely display characteristic point morphologies, although ongoing analyses have identified a few, some of which even bear impact fractures (Riel-Salvatore and Negrino 2017). Additionally, a recent use-wear analysis of some retouched flakes from the Protoaurignacian at Mochi indicates the presence of flint flakes used as "knives" (Grimaldi 2014).

Mollusk shells are very abundant, with many having been intentionally perforated, likely for use as beads in various personal ornaments. Bone, soapstone (steatite) and fossil belemnites were also worked into other kinds of beads and ornaments (Fig. 4), and Riparo Mochi has yielded a canid or felid tooth drilled for suspension; at both sites, red ochre is conspicuous in its presence (Bertola *et al.* 2013; Bietti and Negrino 2008; Kuhn and Stiner 1998; Holt *et al.* in preparation). The presence of steatite demonstrates that this kind of raw material was used beginning in the Early Upper Palaeolithic, well before the Gravettian (*cf.* Onoratini *et al.* 2016). Given the color and texture of the pieces in our sample, their most probable provenance is from the Apennine between Liguria and Emilia, where large steatite outcrops exist (Chella 2002; Gernone and Maggi 1998; Negrino *et al.* 2017a).

Another element that distinguishes the Protoaurignacian from the preceding Mousterian is the increasing presence quantity of fine-grained exotic lithic raw materials procured from sources covering a truly staggering region stretching from the Rhône Valley (*e.g.*, flints from the Vaucluse) to the Marche region (*e.g.*, flints from the Scaglia rossa formations) (Negrino *et al.* 2016; Negrino and Starnini 2003; Porraz *et al.* 2010). At the Balzi Rossi, exotic lithotypes account for about 5-10% of the overall lithic assemblages, and up to 20-30% of retouched tools, while at the Grotte de l'Observatoire exotic Provencal flints prevail. These exotic materials include flints

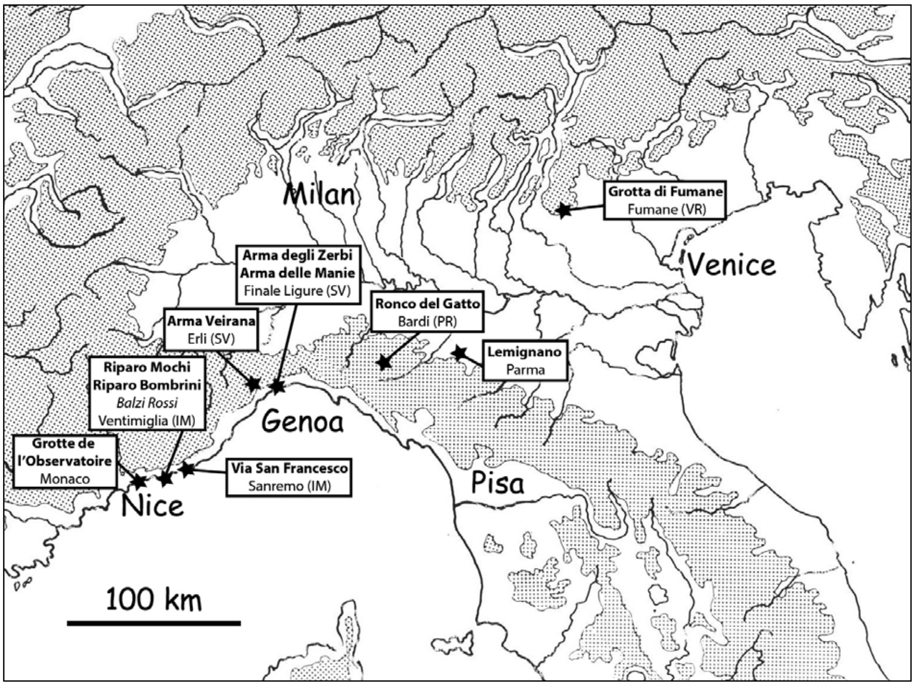


Figure 1. Location of the sites cited in the text.

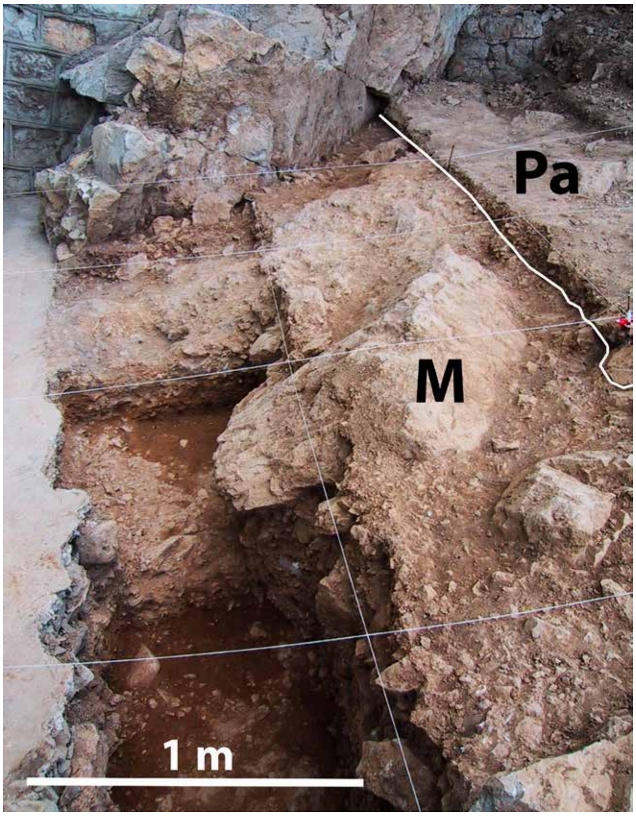
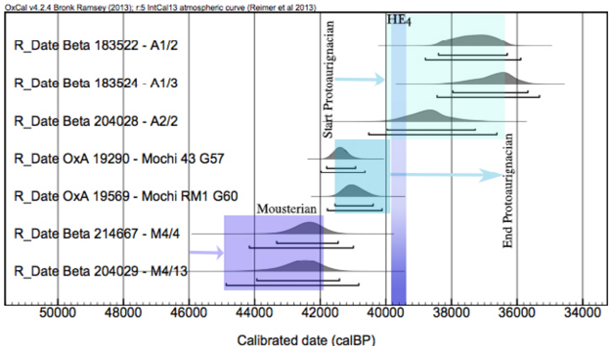


Figure 2. Riparo Bombrini (Balzi Rossi, Ventimiglia – IM -): picture of the site (2005 excavation). The white line highlights the discontinuity between Levels A1-3 (Pa=Protoaurignacian) and Levels M1-7/Ms1-2 (M=Mousterian). Photo by Fabio Negrino.

Figure 3. *Calibrated radiocarbon dates from Riparo Bombrini (A1/2, A1/3, A2/2, M4/4 and M4/13) and Riparo Mochi (43 G57 and RM1 G60)(OxCal 4.2, Curve Int Cal 13; 95.4% – Bronk Ramsey 2013; Reimer et al. 2013).*



from Provence acquired from outcrops some 200km distant as-the-crow-flies as well as radiolarites and flints from sources east of Liguria, notably in the Marche region, more than 400km away. A particularly noteworthy discovery was made during the 2015 field season at Riparo Bombrini when a sidescraper on Pre-Alpine flint was recovered, providing the first definite evidence that at least sporadic contact, direct or indirect, took place between human groups from the Tyrrhenian-Apennine region and groups from northeastern Italy (Negrino *et al.* 2016). However, the prevalence of raw material transfers along the Vaucluse-Marche axis indicates the presence of a cultural corridor along the ridges of the Ligurian Alps and the Apennines that permitted sustained relationships between the various forager groups that occupied it. The existence of such a cultural area is further suggested by the study of personal ornaments, the uniformity of which indicates to some researchers that it was even characterized by a distinct ethno-linguistic identity (Vanhaeren and d'Errico 2006). The rarely crossed boundaries of this area would have been the Rhône Valley (which apparently already served the same function during the Mousterian) and the Po Plain to the north, for which the sidescraper mentioned above constitute the only indisputable evidence of transgression and contact between the two areas to date. The rough terrain of the Rhône-Marche corridor, comprised as it is by an uninterrupted series of Alpine and Apennine mountains, further suggests to us that it was inhabited by a network of interlinked small groups occupying different point along it rather than by a few larger groups that moved along its entire extent.

Overall, then, the Protoaurignacian as evidenced at the Balzi Rossi and at Grotte de l'Observatoire can be seen as the manifestation of groups who already possessed thorough knowledge of the resources available in the territories they occupied. This includes the small lithic assemblage (ca. 200 implements) recovered from the deepest Protoaurignacian unit at Mochi (PA1, Unit GH) from which Dufour bladelets are altogether missing but apparently nonetheless includes the whole range of lithotypes available in the Rhône-Marche corridor (Grimaldi *et al.* 2014). With regards to colonization dynamics as articulated by Rockman (2003), in our view, the available archaeological data from these sites reflect the more advanced, "social" phase of Protoaurignacian colonization of the region when we can already detect the "transformation of the environment into a human landscape"(Rockman 2003, 4). To date, we have no definite evidence of a true "first colonization" from well-excavated stratigraphic contexts, either because this evidence is missing altogether at these sites or it has been eroded by post-depositional processes. The observation that Unit PA1 at Mochi shows a more intensive use of local lithic resources, which may correspond to such a phase, remains to be confirmed by additional work.

4. Changing cultural tradition: the Classic Aurignacian

While relatively well defined, the Protoaurignacian nonetheless displays some regional techno-typological variants, such as the "micropoints" found in the highest levels at Grotta di Castelcivita (Gambassini 1997). This variability is, however, eventually supplanted by new lithic production strategies and techno-typological elements that are typical of the Classic Aurignacian in France and of the Early Aurignacian more broadly (Bon *et al.* 2010; Liolios 2006). Palma di Cesnola labels this new cultural phenomenon in Italy as "Aurignacian with bone points" (*Aurignaziano a punte ossee* – Palma di Cesnola 1993), on the basis of the split-based points that characterize it, along with carenated and nosed endscrapers, busked burins, twisted retouched bladelets (of Roc de Combe type) and large blades bearing heavy, invasive retouch. Classic Dufour bladelets are absent.

In Liguria, the Classic Aurignacian is so far only known from the Balzi Rossi. Beyond Riparo Mochi (levels E and F), it has been identified in the assemblages collected during old excavations at Grotta dei Fanciulli (levels I and K), at Grotta del Caviglione, at Barma Grande and at the now-destroyed site of Bausu da Ture (Mussi *et al.* 2006). Recently published dates also suggest that the highest part of the Bombrini sequence (*i.e.*, Level I) likely can also be attributed to this phase (Benazzi *et al.* 2015), although this part of the sequence was only documented in the area of the site originally excavated by G. Vicino in 1976 where it is present as a remarkable shell midden comprised almost exclusively of mussel shells; the assemblage itself is however devoid of diagnostic techno-typological elements (Vicino 1984).

Overall, there thus appears to be a sharp break with the preceding Protoaurignacian, as is also suggested by a notable gap in radiocarbon dates (Douka *et al.* 2014). That said, in the Riparo Mochi sequence, dates more concordant with a Protoaurignacian attribution have been reported for the base of Level F where techno-typological features already attest to the presence of the Classic Aurignacian. The presence of a few Dufour bladelets in Level F is another indicator suggestive of possible displacements across the layers, an eventuality only new modern excavation will be able to resolve.

As concerns raw material transfers, these mirror those documented in the Protoaurignacian, with exotic lithotypes from across the Rhône-Marche corridor comprising an important part of the lithic assemblages (Negrino 2002; Negrino and Starnini 2003).

Geographically, the nearest sites to have yielded Classic Aurignacian assemblages are both located in Provence (France) (Onoratini and Raux 1992) and western Emilia. This latter region is particularly rich in good quality lithic raw materials and includes some of the large open-air workshops at the site of Ronco del Gatto (Mount Pràbera, Bardi, Parma) (Negrino *et al.* 2017a) that document extensive extraction activities of the local radiolarites and their subsequent diffusion across the region (see also Riel-Salvatore and Negrino 2009). Another Emilian site, the one of Lemignano (Parma), is instead located a bit further north on the Apennine piedmont and is distinguished by

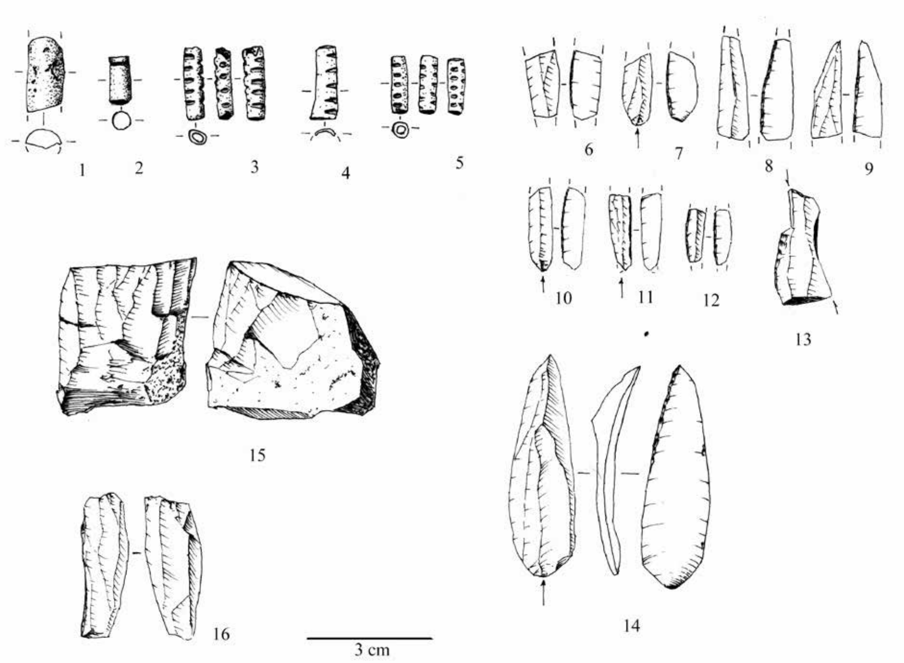


Figure 4. Protoaurignacian artifacts from Riparo Bombrini (Balzi Rossi). Fragments of fossilized belemnites, one of them exhibiting a shallow transversal incision (1-2); incised bird bone diaphysis (3-5); Dufour bladelets in different local or exotic flint types (6-12); burin on retouch opposed to burin on fracture, Provencal flint (13); inverse retouched point, Provencal flint (Bedoulian flint, Vaucluse) (14); bladelet core, local flint ("I Ciotti" flint) (15); bladelet core, Provencal flint (16). Drawings by Fabio Negrino.

the presence of endscrapers and of carenated burins, some of which have a distinctive busked morphology which is quite rare in the broader context of the Italian Aurignacian (Ghiretti *at al.* 1989; Negrino *et al.* 2017b). In the rest of the peninsula, the Classic Aurignacian is found in only a few sites (Mussi *et al.* 2006; Palma di Cesnola 1993) where its characteristics clearly distinguish it from the Protoaurignacian and appear to mark a sharp techno-economic and cultural shift. The Classic Aurignacian is certainly found as far south as Latium (*e.g.*, Grotta del Fossellone) and northern Puglia (*e.g.*, the open-air site of Caruso), with more southerly putative instances (*e.g.*, Fontana Nuova and Cavallo caves) being subject to debate (see Riel-Salvatore and Negrino 2009: 215).

5. Conclusions

Due to its position as Italy's western gateway along the natural corridor linking the Adriatic area and the Balkans to southern France, Liguria certainly represents a choice region on which to focus research to better understand the dynamics of AMH colonization and the disappearance of Neanderthals. As shown by its faunal and floral record, Liguria also served as a biogeographic refugium during the coldest moments of the Last Glacial. This would have made the region especially attractive to populations from neighboring areas associated with more rigorous conditions, which may have led to a higher population density that, especially during the Upper Palaeolithic, gave rise to an active network across which foragers exchanged tools and raw materials over very large distances, evidence of a tightly woven system of interconnected bands belonging to a complex cultural network.

In contrast, population density seems to have decreased during the terminal moments of the Mousterian, at least at the Balzi Rossi. This demographic phenomenon coincides with a peak in cold conditions likely dating to roughly 42 ky BP, or roughly the interval between interstadials GI 11 and GI 10 of the NGRIP $\delta^{18}O$ record (Andersen *et al.* 2006; Svensson *et al.* 2006). The most recent Mousterian assemblages are associated with the predominance of the Discoid method alongside the Levallois method, an overall decrease in laminarity among end products, and an overwhelmingly local pattern of lithic raw material procurement. This pattern is echoed by the record of other Ligurian sites, notably at Arma Veirana, where locally available quartz cobbles were the main raw material used in stone tool production.

At Riparo Bombrini and Riparo Mochi, the transition from the Mousterian to the Protoaurignacian corresponds to a *paraconformity* caused either by erosional phenomena or a depositional hiatus above which the first Protoaurignacian appears fully-fledged. Field observations at Bombrini along with those made by one of us (F.N.) in 1999 during a targeted excavation of squares A0-A1-Z1-Y1 at Riparo Mochi both indicate the absence of mixing with the underlying Mousterian, suggesting a relatively important temporal separation between the two cultural manifestations. There is no evidence of any 'transitional' industry or of contacts between the two cultures, with the sharp replacement observed suggesting that AMH settled at the Balzi Rossi and in the surrounding area as in a region that had already been abandoned by Neanderthals for some time. The differences between the Mousterian and Protoaurignacian are pronounced: the latter is associated with bladelets, osseous industry, personal ornaments, abundant red ochre, and a high frequency of fine-grained allochtonous lithotypes. There is no precursor for any of these behaviors in the Mousterian, underscoring the radical break between the two.

Another important element to underscore is that, even in the oldest Upper Palaeolithic levels, the lithic industry clearly displays a fully Protoaurignacian character embedded in a wide exchange network stretching hundreds of kilometers to the East and West. We are thus faced with a situation where we cannot at present identify archaeologically the initial "locational" and "limitational" phases of Protoaurignacian colonization, which Rockman defines as, respectively, focused on the "locations and physical characteristics of necessary resources (*e.g.*, the size of the lithic source outcrop)" and on the "boundaries and costs of necessary resources (*e.g.*, the harvesting potential of ripe vegetation, extremity of seasonal variation)" (Rockman 2003, 4). The absence of evidence from the known sequences leads us to believe that this first phase of colonization has yet to be documented in Liguria. The presence of lithotypes from both France and the Marche in fact suggests that the known Protoaurignacian record indicates foragers quite familiar with (and adapted to) the region. In contrast, we could expect pertinent archaeological evidence of a first phase of colonization to be characterized by both local lithotypes and exotic lithotypes from only one of the neighbouring regions, which would yield precious information about the mode and tempo of the colonization dynamics.

As far as the origins of the Protoaurignacian are concerned, the question remains open for now. A western origin is a possibility that would help explain why the Protoaurignacian is found later in south-central Italy where the Uluzzian *sensu stricto* is the earliest Upper Palaeolithic manifestation and appears to last until about 40-39 ky cal BP (Douka *et al.* 2014, Higham *et al.* 2014). The lack of evidence to support this westerly origin, however, means that an origin in the Balkans currently remains the most likely (Broglio *et al.* in press). This, however, raises the questions of why Protoaurignacian sites are so scant in the Balkans and of why there should exist such important techno-economic differences in the Protoaurignacian record of the Veneto and that of Liguria, the latter of which is much more similar to that documented in France and Spain (Falcucci *et al.* 2016).

Chronometric dates are currently of little help to resolve this question, since the oldest dates from Riparo Mochi are for all intents and purposes coeval with those from the sites of Isturitz in France and Kozarnika in Bulgaria (Szmidt *et al.* 2010; Tsanova *et al.* 2012). These dates also raise the issue that the Protoaurignacian in Liguria must have been at least partially contemporaneous with putative Uluzzian groups in Tuscany and the Veneto who were noticeably more local and staid in their adaptations. The AMS dates from Riparo Mochi and Riparo Bombrini, bolstered by those published recently for Grotta di Fumane, also indicate that the Protoaurignacian was an extremely long-lived cultural phenomenon in Liguria, lasting until ca. 36.5 ky BP. This contrasts markedly with the situation westward of the Rhône, where the Early Aurignacian established itself rapidly around 39 ky BP, bringing with it the techno-typological characters of the following Classic Aurignacian (Banks *et al.* 2013; Higham *et al.* 2016).

The Classic Aurignacian is extremely rare in Liguria, being so far documented only at the Balzi Rossi and, even there, having been excavated using modern methods only at Riparo Mochi. Even the Protoaurignacian-Classic Aurignacian transition, however, appears to have been a relatively sudden event, with the first elements diagnostic of the latter, including two split-based bone points, appearing at the boundary between Levels F and G at Mochi (spits 49-50) (Tejero and Grimaldi 2015).

In sum, due to its geographical position, Liguria appears to have been somewhat peripheral to the Uluzzian to the east and the Châtelperronian to the west, which may explain the late perduration of the Mousterian in the region. While the Uluzzian has been attributed by some to AMH, the Châtelperronian is generally agreed to have been made by Neanderthals (Welker *et al.* 2016). A potential second wave of AMH migrants associated with the Protoaurignacian would have marked that hominin's first arrival in Liguria and coincided with the disappearance of Neanderthals and a clear break with the Mousterian tradition. How this process unfolded is still unclear, however: it is conceivable that Neanderthals had disappeared from coastal Liguria or had largely abandoned that part of the region, just as it is that they would have been present in low numbers and played a role in the process of Protoaurignacian colonization, even if there is currently no known trace of such interactions. These various scenarios are not mutually exclusive: the arrival of AMH groups in Liguria could have been accompanied by the displacement of Neanderthal groups towards more hilly inland areas where they would have eventually disappeared while AMH would have continued to occupy coastal areas. Future and ongoing work at the Balzi Rossi, Arma Veirana, Arma degli Zerbi and Arma della Manie, as well as new sites in the region, will help to resolve the numerous questions raised here and which highlight Liguria's central position in clarifying our understanding of the dynamics of Neanderthal extinction and AMH diffusion in Europe.

Acknowledgements

The authors thank Valentina Borgia and Emanuela Cristiani for inviting them to participate in the "Out of Italy" conference, and the *Soprintendenza Archeologia, Belle Arti e Paesaggio per la città metropolitana di Genova e le province di Imperia, Savona e La Spezia* for facilitating and supporting fieldwork. We would like also to thank both reviewers for their insightful comments on the paper. Recent fieldwork at Bombrini was funded by the *Fonds Québécois pour la Recherche – Société et Culture* (grant 2016-NP-193048) (to J. R.-S) and by the ERC Consolidator grant 2016, n. 724046-Success.

References

Alhaique, F., Bietti, A., Del Lucchese, A., Grimaldi, S., Manzi, G., Martini, S., Negrino, F. and Recchi, A. 2000. Biological and cultural variability at the Neanderthal/modern human transition in Italian archaeological sites. *Rivista di Antropologia* 78, 105-116.

Andersen, K. K., Svensson, A., Johnsen, S. J., Rasmussen, S. O., Bigler, M., Röthlisberger, R., Ruth, U., Siggaard-Andersen, M.-L., Steffensen, J. P., Dahl-Jensen, D., Vinther, B. M. and Claussen, H. B. 2006. The Greenland ice core chronology 2005, 15e42 ka. Part 1: constructing the time scale. *Quaternary Science Reviews* 25, 3246-3257.

Arobba, D. and Caramiello, R. 2009. Analisi paleobotanica sui sedimenti del Riparo Bombrini (Balzi Rossi, Ventimiglia). *Bulletin du Musée d'Anthropologie préhistorique de Monaco* 49, 41-48.

Arobba, D., Giuggiola, O., Imperiale, G., Lamberti, A., Oxilia, M. and Vicino, G. 1976. Le Mànie, in: *Archeologia in Liguria, Scavi e scoperte 1967-75*. Genova: Soprintendenza Archeologica della Liguria, 133-144.

Bachechi, L. and Revedin, A. 1996. I livelli musteriani di Grotta dei Fanciulli (Liguria, Italia), in: *Proceedings of the XIII Congress UISPP*, vol. 2. Forlì: ABACO, 247-254.

Banks, W. E., d'Errico, F. and Zilhão, J. 2013. Human-climate interaction during the Early Upper Palaeolithic: Testing the hypothesis of an adaptive shift between the Proto-Aurignacian and the Early Aurignacian. *Journal of Human Evolution* 64(1), 39-55.

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, 525-528.

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 Neanderthal extinction. *Science* 348, 793-796.

Bertola, S., Broglio, A., Cristiani, E., De Stefani, M., Gurioli, F., Negrino, F., Romandini, M. and Vanhaeren, M. 2013. La diffusione del primo Aurignaziano a sud dell'arco alpino. *Preistoria Alpina* 47, 123-152.

Bietti, A. and Negrino, F. 2007. "Transitional" Industries from Neanderthals to Anatomically Modern Humans in Continental Italy: Present State of Knowledge, in: Riel-Salvatore, J. and Clark, G. A. (eds.), *New Approaches to the Study of Early Upper Paleolithic "Transitional" Industries in Western Eurasia. Transitions Great and Small*, B.A.R. S1620. Oxford: BAR Publishing, 41-60.

Bietti, A. and Negrino, F. 2008. L'Aurignacien et le Gravettien du Riparo Mochi, l'Aurignacien du Riparo Bombrini: comparaisons et nouvelle perspectives, in: Lumley, H. de and Hurel, A. (eds.), *Histoire et actualité de l'oeuvre scientifique de S.A.S. Le Prince Albert Ier de Monaco – 1895- 2005: bilan et perspectives des connaissances sur les peuplements néandertaliens et les premiers hommes modernes de l'Europe méditerranéenne*. Paris: Archives de l'Institut de Paléontologie Humaine, Mémoire 39, 133-140.

Blanc, A. C. 1938. Nuovo giacimento paleolitico e mesolitico ai Balzi Rossi di Grimaldi. *Rendiconti dell'Accademia Nazionale dei Lincei* 28, VI, 2, 107-113.

Bon, F. 2006. Les termes de l'Aurignacien. *Espacio, Tiempo y Forma, Serie I, Prehistoria y Arqueología 15*, 39-65.

Bon, F, Teyssandier, N. and Bordes, J.-G. 2010. La signification culturelle des équipements lithiques, in: Otte, M. (ed.), *Les Aurignaciens*. Paris: éditions Errance, 49-72.

Boule, M. and De Villeneuve, L. 1927. *La Grotte de L'Observatoire à Monaco*. Paris: Archives de l'Institut de Paléontologie Humaine, Mémoire 1.

Broglio, A., Bertola, S. and Negrino, F. in press. The role of the Northern Adriatic region in the Protoaurignacian spread towards Mediterranean Europe, in: *Volume in honour of Janusz Kozlowski*. Cracow.

Bronk Ramsey, C., 2013. *OxCal Version 4.2.2*. University of Oxford Radiocarbon Accelerator Unit. Computer Program, Available at: c14.arch.ox.ac.uk/embed.php?-File=oxcal.html.

Cauche, D. 2002. *Les cultures moustériennes en Ligurie italienne: étude des industries lithiques des grottes de la Madonna dell'Arma, d'Arma delle Manie et de Santa Lucia superior*, PhD Thesis. Marseille: Université de la Méditerranée (Aix-Marseille II).

Chella, P. 2002. I manufatti in steatite, in: Campana, N. and Maggi, R. (eds.), *Archeologia in Valle Lagorara. Diecimila anni di storia intorno a una cava di diaspro*, Origines. Florence: Istituto Italiano di Preistoria e Protostoria, 265-280.

Cremaschi, M., Del Lucchese, A., Negrino, F., Ottomano, C. and Wilkens, B. 1991. Ventimiglia (Imperia). Località Balzi Rossi. Nuovi dati sulla successione stratigrafica del ciclo interglaciale-glaciale-postglaciale. Scavi 1990. *Bollettino di Archeologia* 8, 47-50.

Del Lucchese, A., Negrino, F., Simone, S. and Vicino, G. 2007. Le Pléistocène moyen et supérieur des grottes de Grimaldi (Vintimille, Italie): bilan de plus

de 150 ans de recherches, in: Évin, J. (ed.), *Un siècle de construction du discours scientifique en Préhistoire: actes du 26e Congrès SPF, Avignon-Bonnieux, Centenaire, sept. 2004*. Paris: Société préhistorique française, 177-184.

Del Lucchese, A. and Negrino, F. 2008. Riparo Bombrini, Balzi Rossi (Ventimiglia), in: Del Lucchese, A. and Gambaro, L. (eds.), *Archeologia in Liguria, nuova serie – Volume I – 2004-2005*. Genova: Soprintendenza per i Beni Archeologici della Liguria, 238-240.

de Lumley, A. and Giacobini, G. 2013a. Les néandertaliens de la Caverna delle Fate (Finale Ligure, Italie). I – Chronostratigraphie, restes squelettiques. *L'Anthropologie* 117(3), 273-304.

de Lumley, A. and Giacobini, G. 2013b. Les néandertaliens de la Caverna delle Fate (Finale Ligure, Italie). II – Les dents. *L'Anthropologie* 117(3), 305-344.

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), 286-299.

Douka, K., Higham, T.F.G., Wood, R., Boscato, P., Gambassini, P., Karkanas, P., Peresani, M. and Ronchitelli, A.M. 2014. On the chronology of the Uluzzian. *Journal of Human Evolution* 68/1, 1-13.

Falcucci, A., Peresani, M., Roussel, M., Normand, C. and Soressi, M. 2016, What's the point? Retouched bladelet variability in the Protoaurignacian. Results from Fumane, Isturitz, and Les Cottés. *Archaeological and Anthropological Sciences*, doi:10.1007/s12520-016-0365-5.

Formicola, V. 1984. Un incisivo umano dal deposito aurignaziano del Riparo Bombrini ai Balzi Rossi. *Rivista Ingauna Intemelia* 39, 11-12.

Formicola, V. 1989. Early aurignacian deciduous incisor from Riparo Bombrini at Balzi Rossi (Grimaldi, Italy). *Rivista di Antropologia* 67, 287-292.

Gambassini, P. 1997 (ed.). *Il Paleolitico di Castelcivita, culture e ambiente*. Naples: Electa.

Gernone, G. and Maggi, R. 1998. Lavorazione della steatite alla Pianaccia di Suvero (Alta Val di Vara, La Spezia), in: Nicolis, F. and Mottes, E. (eds.), *Simbolo ed enigma. Il bicchiere campaniforme e l'Italia nella preistoria europea del III millennio a.C.*. Trento: Provincia Autonoma di Trento, Servizio Beni Culturali, Ufficio Beni Archeologici, 95-97.

Ghiretti, A., Lanzingher, M. and Negrino, F. 1989. I ritrovamenti aurignaziani di Lemignano nella pianura parmense: notizie preliminari. *Preistoria Alpina* 25, 231-234.

Grimaldi, S. 2014. The Proto-Aurignacian "knifes" of the Riparo Mochi (Balzi Rossi, Italy), in: Marreiros, J., Gibaja, J. and Bicho, N. (eds.), *Proceedings of the International Conference on Use-Wear analysis*, Use-Wear 2012 (Faro, Portugal). Cambridge: Cambridge Publishing Scholars (in press).

Grimaldi, S., Porraz, G. and Santaniello, F. 2014. Raw material procurement and land use in the northern Mediterranean Arc: insight from the first Proto-Aurignacian of Riparo Mochi (Balzi Rossi, Italy). *Quartär* 61, 113-127.

Grimaldi, S. and Santaniello, F. 2014. New insights into Final Mousterian lithic production in western Italy. *Quaternary International* 350, 116-129.

Higham, T., Douka, K., Wood, R., Devièse, T., Frouin, M., Schwenninger, J.-L., Hopkins, R. and Comeskey, D. 2016. Chronology of the European Aurignacian: towards spatio-temporal mapping of the early spread of modern humans. *Proceedings of the European Society for the study of Human Evolution* (ESHE) 5, 124.

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* 512 (7514), 306-309.

Holt, B.M., Aggott, Z., Vicino, G. and Semprebon, G. 2012. A human tooth from the Mousterian site of Arma delle Mànie. *Bulletin du Musée d'Anthropologie Préhistorique de Monaco* 52, 43-46.

Holt, B.M., Negrino, F., Riel-Salvatore, J., Formicola, V., Vicino, G., Churchill, S.E., Arellano, A., Arobba, D., Boschian, G., Cristiani, E. and Di Canzio, E. in preparation. The Neanderthal-Anatomically Modern Human transition in Nortwest Italy: new evidences from Riparo Bombrini (Balzi Rossi, Liguria, Italy). *Quaternary International*.

Hublin, J.-J. 2014. The modern human colonization of western Eurasia: when and where? *Quaternary Science Reviews* 118, 194-210.

Kuhn, S. L. and Stiner, M. C. 1998. The Earliest Aurignacian of Riparo Mochi (Liguria, Italy). *Current Anthropology* 39, suppl. 3, 175-188.

Laplace, G. 1966. *Recherches sur l'origine et l'évolution des complexes leptolithiques*, Collection de l'École française de Rome 4. Rome: École française de Rome.

Le Brun-Ricalens, F. 2005 (ed.). *Productions lamellaires attribuées à l'Aurignacien: chaînes opératoires et perspectives technoculturelles*, ArchéoLogiques 1. Luxembourg: Musée National d'Histoire et d'Art.

Liolios, D. 2006. Reflections on the role of bone tools in the definition of the Early Aurignacian, in: Bar-Yosef. O. and Zilhão. J. (eds.), *Towards a definition of the Aurignacian*, Trabalhos de Arqueologia, 45. Lisbona: Direção Geral do Património Cultural, 37-52.

Mehidi, N. 2005. *Datation de sites moustériens de Ligurie par les méthodes U/Th et RPE: Abri Mochi et Arma delle Manie*, PhD Thesis. Paris: Muséum d'Histoire Naturelle, Département de Préhistoire.

Mussi, M., Gioia, P. and Negrino, F. 2006. Ten small sites: the diversity of the Italian Aurignacian, in: Bar-Yosef. O. and Zilhão. J. (eds.), *Towards a definition of the Aurignacian*, Trabalhos de Arqueologia, 45. Lisbona: Direção Geral do Património Cultural, 189-209.

Negrino, F. 2002. *Modificazioni tecno-tipologiche ed utilizzo delle materie prime nell'Appennino tosco-emiliano e nell'arco ligure tra Paleolitico medio e Paleolitico superiore antico*, PhD Thesis. Rome: Università La Sapienza.

Negrino, F., Arellano, A., Valensi, P., Grimaldi, G., Onoratini, G., Peresani, M., Psathi, E., Riel-Salvatore, J. and Simon, P. in press/a. Quale fauna per quale industria: approvvigionamento alimentare e variabilità tecno-economica tra Paleolitico medio recente e Paleolitico superiore antico in Liguria, in: Belardelli, C., Bondioli, L., Cazzella, A., Cremaschi, M., Damiani, I., De Grossi Mazzorin, J., de Marinis, R.

C., Giacobini, G., Marzatico, F., Revedin, A. and Rottoli, M. (eds.), *Preistoria del cibo – L'alimentazione nella preistoria e nella protostoria*, Atti L Riunione Scientifica, Roma, 5-9 ottobre 2015. Firenze: Istituto Italiano di Preistoria e Protostoria.

Negrino, F., Benazzi, S., Hodgkins, J., Holt, B., Miller, C., Orr, C., Peresani, M., Riel-Salvatore, J., Strait, D., Gravel-Miguel, C., De Santis, H., Leger, E., Martini, S., Perroni, E., Laliberté, A., Pothier Bouchard, G., Starnini, E. and Zerboni, A. 2016. On-going research and first data from Middle and Upper Palaeolithic sites of Liguria region. In: Negrino, F., Fontana, F., Moroni, A. and Riel-Salvatore, J. (eds.), *The Palaeolithic and Mesolithic in Italy: new research and perspectives – Abstract Book*, First Annual Meeting of Prehistory and Protohistory, Genova (Italy), 4th-5th February 2016. Firenze: Istituto Italiano di Preistoria e Protostoria, 52-54. (And in press 2016, *Bulletin du Musée d'Anthropologie préhistorique de Monaco*).

Negrino, F., Benazzi, S., Hodgkins, J., Miller, C., Orr, C., Peresani, M., Riel-Salvatore, J., Strait D. and De Santis H. in press/b. Arma Veirana (Erli, Savona), in: *Archeologia in Liguria, nuova serie – Volume VI – 2014-2015*. Genova: Soprintendenza Archeologia della Liguria.

Negrino, F, Colombo, M., Cremaschi, M., Serradimigni, M., Tozzi, C. and Ghiretti, A. 2017a. Estese officine litiche del Paleolitico medio-superiore sui rilievi appenninici di Monte Lama-Castellaccio-Pràrbera (Bardi, Parma), in: *Preistoria e Protostoria dell'Emilia-Romagna I*, Studi di Preistoria e Protostoria 3. Firenze: Istituto Italiano di Preistoria e Protostoria, 59-68.

Negrino, F, Cremaschi, M. and Ghiretti, A. 2017b. Lemignano: una stazione aurignaziana del Pedeappennino parmense, in: *Preistoria e Protostoria dell'Emilia-Romagna I*, Studi di Preistoria e Protostoria 3. Firenze: Istituto Italiano di Preistoria e Protostoria, 69-76.

Negrino, F. and Riel-Salvatore, J. in press. Riparo Bombrini (Ventimiglia, Imperia), in: *Archeologia in Liguria, nuova serie – Volume VI – 2014-2015*. Genova: Soprintendenza Archeologia della Liguria.

Negrino, F., Riel-Salvatore, J. and Bertola, S. 2016. Colonization dynamics and the diffusion of the Protoaurignacian in Italy and Southern France: The Rhône-Marche corridor and its chrono-cultural implications. *Proceedings of the European Society for the study of Human Evolution* (ESHE) 5, 172.

Negrino, F. and Starnini, E. 2003. Patterns of lithic raw material exploitation in Liguria from the Palaeolithic to the Copper Age. *Préhistoire du Sud-Ouest*, supplément n.5, 235-243.

Negrino, F. and Tozzi, C. 2008. Il Paleolitico in Liguria, in: Binder, D., Delestre, X. and Pergola, P. (eds.), *Archéologies transfrontalières – Alpes du Sud, Côte d'Azur, Piémont, Ligurie – Bilan et perspectives de recherche*, Actes du colloque de Nice, 13-15 december 2007. Bulletin du Musée d'Anthropologie Préhistorique de Monaco, suppl. n.1, 21-28.

Nigst, P. R., Haesaertsc, P., Damblonc, F., Frank-Fellnerd, C., Mallole, C., Viola, B., Götzingerh, M., Nivena, L., Trnkai, G. and Hublin, J.-J. 2014. Early modern human settlement of Europe north of the Alps occurred 43,500 years ago in a cold steppe-type environment. *PNAS* 111, 14394-14399.

Onoratini, G. 2004. Le Protoaurignacien, première culture de l'Homme Moderne de Provence et Ligurie. *L'anthropologie* 108, 239-249.

Onoratini, G., Arellano, A., Del Lucchese, A., Moullé, P.-E. and Serre, F. 2012. The Barma Grande cave (Grimaldi, Vintimille, Italy): from Neanderthal, hunter of "Elephas antiquus", to Sapiens with ornaments of mammoth ivory. *Quaternary international* 255, 141-157.

Onoratini, G. and Raux, A. 1992. Les cultures du Paléolithique supérieur ancien de Provence orientale. *Bulletin du Musée d'Anthropologie préhistorique de Monaco* 35, 65-114.

Onoratini, G., Raux, A., Giacobini, G. and Malerba, G. 2016. Objets d'art gravettiens en stéatite du Massif de l'Estérel. Étude descriptive et technologique et corrélations chrono-culturelles. *L'anthropologie* 120, 513-536.

Onoratini, G. and Simon, P. 2006. Le Protoaurignacien de la Grotte de l'Observatoire (Principauté de Monaco), in: Sanchidrian Torti, J.L., Marquez Alcantara, A.M. and Fullola i Pericot, J.M. (eds.), *La Cuenca Mediterranea durante el Paleolitico Superior*, IV Simposio de Prehistoria Cueva de Nerja, 430-443.

Onoratini, G., Simon, P. and Simone, S. 1999. Mise en évidence du Protoaurignacien à la grotte de l'Observatoire (Principauté de Monaco). *Bulletin du Musée d'Anthropologie préhistorique de Monaco* 40, 43-56.

Palma di Cesnola, A. 1993. *Il Paleolitico superiore in Italia*. Florence: Garlatti e Razzai Editori.

Peresani, M. 2003. *An initial overview of the middle Palaeolithic discoid industries in Central-Northern Italy*, in: Peresani M. (ed.), *Discoid lithic technology – advances and implications*, B.A.R. 1120. Oxford: BAR Publishing, 209-223.

Peresani, M. 2008. A new cultural frontier for the last Neanderthals: the Uluzzian in Northern Italy. *Current Anthropology* 49, 725-731.

Peresani, M., Cristiani, E., Romandini, M. 2016. The Uluzzian technology of Grotta di Fumane and its implication for reconstructing cultural dynamics in the Middle-Upper Palaeolithic transition of Western Eurasia. *Journal of Human Evolution* 91, 36-56.

Pirouelle, F. 2006. *Contribution méthodologique à la data- tion, par les méthodes Uranium-Thorium (U-TH) et résonance de spin électronique (ESR), de sites moustériens de Ligurie, de France et de Belgique*, PhD Thesis. Paris: Muséum d'Histoire Naturelle, Département de Préhistoire.

Porraz, G. and Negrino, F. 2008. Espaces économiques et approvisionnement minéral au Paléolithiques moyen dans l'aire liguro-provençale, in: Binder, D., Delestre, X. and Pergola, P. (eds.), *Archéologies transfrontalières – Alpes du Sud, Côte d'Azur, Piémont, Ligurie – Bilan et perspectives de recherche*, Actes du colloque de Nice, 13-15 december 2007. Bulletin du Musée d'Anthropologie Préhistorique de Monaco, suppl. n.1, 29-39.

Porraz, G., Simon, P. and Pasquini, A. 2010. Identité technique et comportements économiques des groupes proto-aurignaciens à la Grotte de l'Observatoire (Principauté de Monaco). *Gallia Préhistoire* 52, 33-59.

Psathi, E. 2003. *Les sites moustériens de la Caverna delle Fate et de l'Arma delle Manie (Ligurie, Italie). Etude Paléontologique et archéozoologique des faunes des grands mammifères*, PhD Thesis. Paris: Muséum d'Histoire Naturelle, Département de Préhistoire.

Reimer, P. J., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P. G., Bronk Ramsey, C., Grootes, P. M., Guilderson, T. P., Haflidason, H., Hajdas, I., Hattž, C., Heaton, T. J., Hoffmann, D. L., Hogg, A. G., Hughen, K. A., Kaiser, K. F., Kromer, B., Manning, S. W., Niu, M., Reimer, R. W., Richards, D. A., Scott, E. M., Southon, J. R., Staff, R. A., Turney, C. S. M. and van der Plicht, J. 2013. IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0-50,000 Years cal BP. *Radiocarbon*, 55(4), 1869-1887.

Riel-Salvatore, J. 2009. What Is A 'Transitional' Industry? The Uluzzian of Southern Italy as a Case Study, in Camps, M. and Chauhan, P. (eds.), *Sourcebook of Paleolithic Transitions: Methods, Theories, and Interpretations*. New York: Springer, 377-396.

Riel-Salvatore, J. 2010. A Niche Construction Perspective on the Middle – Upper Paleolithic Transition in Italy. *Journal of Archaeological Method and Theory* 17, 323-355.

Riel-Salvatore, J., Ludeke, I. C., Negrino, F. and Holt, B. M. 2013. A spatial analysis of the Late Mousterian levels of Riparo Bombrini (Balzi Rossi, Italy). *Canadian Journal of Archaeology* 37(1), 70-92.

Riel-Salvatore, J. and Negrino, F. 2009. Early Upper Paleolithic population dynamics and raw material procurement patterns in Italy, in: Camps, M. and Szmidt, C. (eds), *The Mediterranean from 50000 to 25000 BP – Turning points and new directions*. Oxford: Oxbow Books, 211-230.

Riel-Salvatore, J. and Negrino, F. 2017. Proto-Aurignacian lithic technology, mobility and human niche construction: A case study from Riparo Bombrini, Italiy, in: Robinson, E. and Sellet, F. (eds.), *Lithic Technological Organization and Paleoenvironmental Change*. New York: Springer, 163-187.

Rockman, M. 2003. Knowledge and learning in the archaeology of colonization, in: Rockman, M. and Steele, J. (eds.), *Colonization of Unfamiliar Landscapes: The archaeology of adaptation*. New York: Routledge, 3-24.

Rossoni-Notter, E. 2011. *Les cultures moustériennes des Balzi Rossi, Grimaldi, Ligurie. Les collections du Prince Albert 1er de Monaco*, PhD Thesis. Perpignan: Université de Perpignan.

Rossoni-Notter, E., Cauche, D., Notter O. and Simon, P. 2016a. Les industries moustériennes de la Grotte du Cavillon, in: de Lumley, H. (ed.), *La Grotte du Cavillon sous la falaise des Baousse Rousse Grimaldi, Vintimille, Italie, Tome I – Les niveaux moustériens et Paléolithiques supérieurs*. Paris: CNRS Éditions, 281-419.

Rossoni-Notter, E., Notter, O. and Simon, P. 2016b. Mousterian in Balzi Rossi (Ventimiglia, Liguria, Italy): New insights and old collections. *Quaternary International* (2016), http://dx.doi.org/10.1016/j.quaint.2015.12.059.

Rossoni-Notter, E., Notter, O., Simone, S. and Simone, P. 2016c. Acheulean breccia of Prince cave (Liguria, Italy): new insights and regional issues. *Quaternary International* 411, 236-253.

Rossoni-Notter, E., Notter, O., Simone, S. and Simone, P. 2016d. Balzi Rossi (Liguria, Italy): research studies of the Museum of Prehistoric Anthropology of Monaco regarding Acheulean and Mousterian technic behaviors. New insights and future programs in Prince cave. In: Negrino, F., Fontana, F., Moroni, A. and Riel-Salvatore, J. (eds.), *The Palaeolithic and Mesolithic in Italy: new research and perspectives – Abstract Book*, First Annual Meeting of Prehistory and Protohistory, Genova (Italy), 4th-5th February 2016. Firenze: Istituto Italiano di Preistoria e Protostoria, 35-37. (And in press 2016, *Bulletin du Musée d'Anthropologie préhistorique de Monaco*).

Svensson, A., Andersen, K. K., Bigler, M., Clausen, H. B., Dahl-Jensen, D., Davies, S. M., Johnsen, S. J., Muscheler, R., Rasmussen, S. O., Röthlisberger, R., Peder Steffensen, J. and Vinther, B. M. 2006. The Greenland ice core chronology 2005, 15- 42 ka. Part 2: comparison to other records. *Quaternary Science Reviews* 25, 3258-3267.

Szmidt, C. C., Normand, C., Burr, G. S., Hodgins, G. W. L. and LaMotta S. 2010. AMS 14C dating the Protoaurignacian/Early Aurignacian of Isturitz, France. Implications for Neanderthal – modern human interaction and the timing of technical and cultural innovations in Europe. *Journal of Archaeological Science* 37, 758-768.

Tavoso, A. 1988. L'outillage du gisement de San Francesco à San Remo (Ligurie, Italie): nouvel examen, in Otte, M. and Kozlowsky, J. (eds.), *L'Homme de Neanderthal – La Mutation*, vol. 8, ERAUL 35. Liegi: ERAUL, 193-210.

Tejero, J-M. and Grimaldi, S. 2015. Assessing bone and antler exploitation at Riparo Mochi (Balzi Rossi, Italy): Implications for the characterization of the Aurignacian in South-western Europe. *Journal of Archaeological Science* 61, 59-77.

Teyssandier, N., 2007. L'émergence du Paléolithique supérieur en Europe: mutations culturelles et rythmes d'évolution. *Paléo* 19, 367 -389.

Tozzi, C. and Negrino, F. 2008. Nouvelles données sur les cultures moustériennes des grottes de Grimaldi, in: Lumley, H. de and Hurel, A. (eds.), *Histoire et actualité de l'oeuvre scientifique de S.A.S. Le Prince Albert Ier de Monaco – 1895- 2005: bilan et perspectives des connaissances sur les peuplements néandertaliens et les premiers hommes modernes de l'Europe méditerranéenne*. Paris: Archives de l'Institut de Paléontologie Humaine, Mémoire 39, 101-107.

Tsanova, T., Zwyns, N., Eizenberg, L., Teyssandier, N., Le Brun-Ricalens and F., Otte, M. 2012. Le plus petit dénominateur commun : réflexion sur la variabilité des ensembles lamellaires du Paléolithique supérieur ancien d'Eurasie. Un bilan autour des exemples de Kozarnika (Est des Balkans) et Yafteh (Zagros central). *L'anthropologie* 116, 469-509.

Valensi, P. and Psathi, E. 2004. Faunal exploitation during the Middle Palaeolithic in South-eastern France and North-western Italy. *International Journal of Osteoarchaeology* 14, 256-272.

Valensi, P., Psathi, E. and Lacombat, F. 2004. *Le cerf élaphe dans les sites du Paléolithique moyen du Sud-Est de la France et de Ligurie. Intérêts biostratigraphique, environnemental et taphonomique*, B.A.R. 1271. Oxford: BAR Publishing, 97-106.

Vanhaeren, M. and d'Errico, F. 2006. Aurignacian ethno-linguistic geography of Europe revealed by personal ornaments. *Journal of Archaeological Science* 33, 1105-1128.

Vicino, G. 1984. Lo scavo paleolitico al Riparo Bombrini (Balzi Rossi di Grimaldi, Ventimiglia). *Rivista Ingauna Intemelia* 39, 1-10.

Welker, F., Hajdinjak, M., Talamo, S., Jaouen, K., Dannemann, M., David, F., Julien, M., Meyer, M., Kelso, J., Barnes, I., Brace, S., Kamminga, P., Fischer, R., Kessler, B. M., Stewart, J. R., Pääbo, S., Collins, M. J. and Hublin, J.-J. 2016. A Palaeoproteomic evidence identifies archaic hominins associated with the Châtelperronian at the Grotte du Renne. *PNAS* 113(40),11162-11167.

Zilhão, J., Banks, W. E., d'Errico, F. and Gioia, P. 2015. Analysis of Site Formation and Assemblage Integrity Does Not Support Attribution of the Uluzzian to Modern Humans at Grotta del Cavallo. *PloS One* 10 (7), j.p.0131181.

Human exploitation of avifauna during the Italian Middle and Upper Paleolithic

Monica Gala, Ivana Fiore & Antonio Tagliacozzo[1]

Abstract

The regular and systematic exploitation of birds for subsistence purposes is considered to be a hallmark of behavioral modernity. Ethnographic data on recent hunter-gatherers suggest that in order to obtain large quantities of birds, advanced technologies (*i.e.*, snares, nets, bow and arrow) would have been required. The mastering of such technologies has been so far attributed exclusively to *Homo sapiens* and, in fact, to date only late Upper Paleolithic hunter-gatherers have been credited for capturing thousands of birds belonging to hundreds of different taxa at many sites in the Italian Peninsula such as Grotta Romanelli and Grotta del Santuario della Madonna. However, increasing evidences document human exploitation of birds already during the Lower and Middle Pleistocene as indicated by recent data from different areas of Europe. This work presents the results of the taphonomic study carried out on the bird bone assemblages from 10 Middle and Upper Paleolithic Italian sites (43,147 NISP). The aim is to evidence discriminating criteria for identifying anthropic traces related to the exploitation of birds as food. The most common human modifications detected on bird bones are those related to butchery: stone tool cut-marks, fresh bone breaks, peeling, crushing, wrench and, more rarely, notches or chop-marks. Burning traces are also very frequent.

This study shows that birds were exploited as a food source already since the Middle Paleolithic, although such exploitation was limited to a narrow range of species.

Keywords: Italy, *Homo neanderthalensis*, *Homo sapiens*, birds, taphonomy, subsistence strategies, diet.

---

1 Collaborator of Bioarchaeology Section of the National Museum of Prehistory and Ethnography "Luigi Pigorini", Polo Museale del Lazio. P.za G. Marconi 14, I-00144 Rome, Italy. E-mail: monarix@yahoo.it; iva_fiore@yahoo.it; antonio.tagliacozzo@beniculturali.it.

in: Borgia, V. and E. Cristiani (eds.) 2018: *Palaeolithic Italy. Advanced studies on early human adaptations in the Apennine peninsula*, Sidestone Press Academics (Leiden), pp. 183-218.

1. Introduction

Two main research questions remain unanswered and may benefit from a more in-depth study of bird bone assemblages from the Italian peninsula: when did bird hunting actually start? When does the exploitation of birds become a subsistence strategy? The aim is to investigate the following questions: did Neanderthals hunt birds? Did Neanderthals exploit birds as food? Were early Upper Paleolithic humans able to exploit birds intensively? At what stage did humans in the Italian peninsula start exploiting birds intensively?

In the Italian peninsula, some bird remains were found in association with stone tools and large mammal bones already in Lower Paleolithic sites (*e.g.*, Venosa Notarchirico) (Cassoli *et al.* 1999). Bird specimens become more abundant during the Middle-Upper Pleistocene, particularly in some sites of Latium such as Torre in Pietra (Cassoli 1978), Malagrotta (Cassoli *et al.* 1982), Casal de' Pazzi (Anzidei *et al.* 1984), and La Polledrara di Cecanibbio (Gala and Tagliacozzo in progress), where the remains of waterfowl (mainly ducks and geese) have been recovered. In the absence of detailed taphonomic studies, the relationship between bird bones and humans is still unclear, and their presence at these sites seems to be more likely linked to natural factors (water transport and subsequent accumulation) and to hunting or predation by carnivores or raptors. However, we cannot exclude that during the Lower and Middle Pleistocene, also in Italy human communities may have occasionally exploited carcasses of birds or captured some birds, as suggested by some anthropic traces on bird bones found at Sima Elefante (Huguet 2007), Gran Dolina TD10-1 and Bolomor Cave in Spain (Blasco and Fernández Peris 2009, 2012; Blasco *et al.*, 2013), Dursunlu in Turkey (Güleç *et al.* 1999), and Lazaret in France (Lumley *et al.* 2004; Roger 2004). Detailed studies carried out at Bolomor Cave provide evidence for a regular exploitation of birds by humans.

The current debate on changes in behavioral, cultural and subsistence strategies between the last *H. Neanderthalensis* and the first *H. sapiens* has recently benefited from new discoveries of in Italy, France, Germany, Spain, and Gibraltar. Direct evidence of Neanderthal bird exploitation comes from European Upper Pleistocene sites associated with Middle Paleolithic industries. Such evidence documents the exploitation of edible and non-edible avian products (Mourer-Chauviré 1975; Mourer-Chauviré com. pers. in Fiore *et al.* 2004; Soressi *et al.* 2008; Dibble *et al.* 2009; Gaudzinski-Windheuser and Niven 2009; Peresani *et al.* 2011; Finlayson *et al.* 2012; Morin and Laroulandie 2012; Blasco *et al.* 2014; 2016; Romandini *et al.* 2014, 2016; Radovčić *et al.* 2015; Fiore *et al.*2016; Laroulandie *et al.* 2016; Martínez Valle *et al.* 2016).

Outside Italy the exploitation of birds as food becomes progressively more common starting in the early Upper Paleolithic (Bochenski *et al.* 2009; Laroulandie 2016) and turns into a constant of human subsistence at late Upper Paleolithic (*e.g.*, Magdalenian) sites (Laroulandie 2003).

The use of long bones of large-sized birds (vultures, eagles, swans) to make ornamental objects (containers, beads, tubes) or flutes appears occasionally during the Chatelperronian and becomes well known in the archaeological record from the Aurignacian onwards (Buisson 1990; Conard *et al.* 2009). At the Gravettian site of Pavlov I (Bochenski *et al.* 2009) in the Czech Republic, human modified bones indicate that birds were used not only as food, but also as raw material for producing tools and decorations.

The aim of this work is to define the role of birds in the diet of Neanderthals and anatomically modern humans (AMH) in Italy comparing the bird bone assemblages from 10 sites of different periods in order to verify at what stage fast-moving birds became a regular component of human subsistence. Four sites are in Northern Italy, one in the Center and five in the South. The goal of the research is also to identify the products acquired by humans (skin, feathers, bones, entrails, meat, etc.) and to reconstruct carcass processing methods. Only direct evidence of human modification and exploitation on bird bones will be taken into account for this synthesis.

2. Methodology

Taxonomic determinations of species were based on comparisons with the osteological collections of the Bioarchaeology Section of the National Museum of Prehistory and Ethnography "Luigi Pigorini" and of the Italian Institute of Human Paleontology in Rome. The NISP (Number of Identified Specimens) of the identified bird bones has been considered in this work; the MNI (Minimum Number of Individuals) and MNE (Minimum Number of Elements) will be calculated only for two sites with long occupation sequences (Grotta di Fumane and Grotta di Castelcivita). These sites will be considered as a unit for each period. The bird bone surfaces have been analyzed with the aid of a stereomicroscope (Nikon SMZ 1000, 8-80X – Bioarcheology Lab., National Museum of Prehistory and Ethnography "Luigi Pigorini", Rome). The small size and thinness of bone walls make the bird bones more susceptible to fragmentation and makes the identification of some diagnostic butchery modifications (impact points, fracture edges, etc.) less easy. Furthermore, because of the small size of the birds, Paleolithic hunters adopted carcass processing strategies that were different from those employed with larger animals, for example often using directly the hands rather than cutting tools. Usually cut-marks on birds remains are rare; the *striae* are short, superficial and sometimes isolated, recognizable by their micromorphology (points of entry and exit of the tool, section type, presence of secondary *striae*) and position (functional to the treatment of the carcass). The location, orientation and depth of *striae* on the anatomical elements allow reconstructing the different stages of the butchery process: killing, skinning, dismembering, evisceration, disarticulation, and meat removal (Gala *et al.* 2009; Fiore *et al.* 2016). Particular marks document the use of bones, feathers and plumes for making tools or ornaments (Peresani *et al.* 2011; Romandini *et al.* 2016; Pedergnana and Blasco 2016). Such traces may be distinguished from those related to butchery on the basis of their occurrence on particular anatomical elements yielding small amounts of meat and of the position or orientation of cut-marks that are not functional to an usual butchery. An example is given by the distribution of cut-marks on the ulna, close to the tubercles for the removal of the primary feathers, and linked to the exploitation of these elements or parts of the wing. Intentional fracturing is not easily identifiable on small bones. Bones fractured in a fresh state (when the bone is still elastic) can be recognized by the morphology of fracture edges (Villa and Mahieu 1991; Peresani *et* *al.* 2011; Fiore *et al.* 2016). These can be linked to human activities only when they are associated with others of the above mentioned marks on the same element.

Butchering the carcasses of the preys only with the aid of hands leaves very specific and peculiar traces due to over-extension damages: peeling, crushing, notches and wrench (Lefèvre and Pasquet 1994; Laroulandie 2000; 2005; Laroulandie *et al.* 2008; Serjeantson 2009; Peresani *et al.* 2011; Laroulandie and Lefèvre 2014; Blasco *et al.* 2016). The process is to pull and twist the portion for dissecting and eventually eating it. Such actions can take place on raw as well as already cooked carcasses.

Disarticulation by traction and rotation often produces a localized and oriented detachment of small portions of the bone surface (peeling) corresponding to important muscular and tendon insertions (White 1992). Crushing on the olecranon fossa of the humerus is caused by the over-extension of the humerus – ulna articulation (Laroulandie *et al.* 2008). Wrench is the fracture of a portion of bone tissue from an articulation produced during disarticulation (Gourichon 1994).

Localized traces of burning on small game bones are interpreted as the result of the contact with fire of the bone portions not protected by meat (Cassoli and Tagliacozzo 1997a; Tagliacozzo and Fiore 1998; Fiore *et al.* 2004b; Medina *et al.* 2012). Its distribution on the anatomical elements provides important information about the butchery of the carcass before cooking.

Birds can be captured by other animals, and in some cases it is possible to recognize the traces left by carnivore teeth or by the beaks of raptors. Humans too may leave gnawing traces on bones that are different from those of carnivores for the particular morphology and the micro-features of the grooves: oval shape of the perforation, compressed surficial bone tissue, crenulated fracture edges (Laroulandie 2000; Landt 2007; Delaney-Rivera *et al.* 2009; Lloveras *et al.* 2009; Fiore *et al.* 2016). It is not easy to distinguish human gnawing on the bone (it varies according to the force applied, the type of tooth, the duration of mastication, the quantity of meat, etc.). Even in this case the combination of multiple traces on the same element (cut-marks, fresh bone fractures, localized burning), associated with holes of oval shape, crushing and crenulated margins, allow us to relate them to human mastication.

3. The Avian Assemblages

Ten Italian avian assemblages (total NISP 43,147) dated to the Middle and Upper Paleolithic will be analyzed in this study (Fig. 1). A summary of archaeological and archaeozoological data, the dating and references related to deposits, all located in caves or rock-shelters, is in table 1. Bird remains come from four northern Italian sites: Grotta Maggiore di S. Bernardino (Vicenza) – Middle Paleolithic (Cassoli and Tagliacozzo 1994a); Grotta di Fumane (Verona) – Middle and Upper Paleolithic (Cassoli and Tagliacozzo 1994b; Broglio *et al.* 2006); Riparo Dalmeri (Trento) – Upper Paleolithic (Tagliacozzo and Fiore 2009; Gala and Tagliacozzo 2010); Riparo Cogola (Trento) – Upper Paleolithic (Fiore and Tagliacozzo 2004; Gala, andTagliacozzo 2010). One site is in central Italy: Grotta di Pozzo (L'Aquila) – Upper Paleolithic (Mussi *et al.* 2008; Gala and Tagliacozzo 2010). The last five sites are in the South: Grotta di Roccia San Sebastiano (Caserta) – Middle and Upper Paleolithic (Ruiu *et al.* 2012); Grotta di Castelcivita (Salerno) – Middle

Figure 1. Location of the 10 Middle and Upper Paleolithic Italian sites.

and Upper Paleolithic (Cassoli and Tagliacozzo 1997b); Grotta Paglicci (Foggia) – Upper Paleolithic (Tagliacozzo and Gala 2004); Grotta Romanelli (Lecce) – Upper Paleolithic (Cassoli *et al.* 2003); Grotta del Santuario della Madonna (Cosenza) – Upper Paleolithic (Tagliacozzo and Gala 2002).

Many of the studies on birds from these sites were started by P.F. Cassoli who played a key role in identifying bird species and their ecological significance (Cassoli 1972; 1992; Cassoli and Tagliacozzo 1994a; 1994b; 1997a; 1997b; Cassoli *et al.* 2003).

The quantity of remains and the number of species are considerably variable: from 6 species identified at Grotta di Roccia San Sebastiano to over 32,000 remains and 109 species at Grotta Romanelli. The bird assemblage from Grotta Romanelli is exceptional within the Late Glacial European scenario also for the percentage of bird bones recov-

Site	m asl	Layer	Date BP *	Culture/Industry	Mammalia NISP	Mammalia Predominant species	Aves NISP	Aves Species	Sources
Grotta Maggiore di San Bernardino (VI)	135	VII-II	**VII:** 214,000-154,000 (ESR/U) **IV:** 108,000 (ESR/U) **II:** 38,000-33,000 (ESR/U)	Mousterian/Levallois	1,267	*Cervus elaphus, Capreolus capreolus* and *Rupicapra*	26	12	Cassoli and Tagliacozzo 1994a; Peresani 2001; Fiore *et al.* 2004; Picin *et al.* 2013
Grotta di Fumane (VR)	350	A13-A5	**A11:** 42,000±750-38,100±600 **A9:** 47,600-45,000 Cal / 42,750±700-36,450±400 **A6-5:** 44,200-42,240 Cal / 38,800±750-34,400±800	Mousterian/Discoid (A9); Levallois (A5-6)	>5,000	*Cervus elaphus* and *Capreolus capreolus*	1,098	47	Cassoli and Tagliacozzo 1994b; Higam *et al.* 2009; Peresani *et al.* 2011; Romandini *et al.* 2016; Fiore *et al.* 2016.
		A4-3	43,600-40,400 Cal / 37,828±430-29,233±350	Uluzzian	1,188	*Cervus elaphus* and *Capreolus capreolus*	271	25	Broglio *et al.* 2006; Higam *et al.* 2009; Romandini 2012; Tagliacozzo *et al.* 2013
		A2	41,230-39,250 Cal / 36,500±600-30,650±260	Aurignacian	1,111	*Capra ibex* and *Rupicapra rupicapra*	273	28	Gala and Tagliacozzo 2005; Cremaschi *et al.*2005; Gurioli *et al.* 2006
Grotta di Castelcivita (SA)	94	XIII-VII	42,700±900-39,100±1,300	Mousterian/Levallois	481	*Dama dama*	55	15	Cassoli and Tagliacozzo 1997b; Gambassini (ed.) 1997; Masini and Abbazzi 1997
		VI-IIIb	33,220±780-32,470±650	Uluzzian	278	*Cervus elaphus*	267	26	
		IIIa-I	32,930±720-31,950±650	Protoaurignacian / Dufour and small point	105	*Cervus elaphus*	115	19	
Grotta Paglicci (FG)	107	24	34,300+900-800; 29,300±600	Aurignacian	2,396	*Equus hydruntinus*	43	8	Boscato 2004; Palma di Cesnola 2004; Tagliacozzo and Gala 2004
		23-22	28,110±400-26,800±300	Early Gravettian		*Bos primigenius* and Capridae	1,206	29	
Grotta di Roccia San Sebastiano (CE)	?	c2; e; 1-6	c2: 23,660-22,770 cal / 19,570±210	Middle-Final Gravettian	1,718	*Bos primigenius* and *Cervus elaphus*	6	6	Belluomini *et al.* 2007; Ruiu *et al.* 2012
Riparo Dalmeri (TN)	1240	26b-c; 14	13,058-13,286 Cal / 11,260±100-10,800±110	Epigravettian	8,611	*Capra ibex*	80	8	Fiore and Tagliacozzo 2005a; Dalmeri *et al.* 2009; Tagliacozzo and Fiore 2009; Gala and Tagliacozzo 2010
Riparo Cogola (TN)	1070	19; 25; 18	12,891-11,179 Cal / 10,640±60-9,820±60	Epigravettian / Epigravettian -Sauveterrian	341	*Capra ibex*	13	3	Dalmeri 2004; Fiore and Tagliacozzo 2005b; Gala and Tagliacozzo 2010
Grotta di Pozzo (AQ)	720	PS7-1	15,500-14,000 Cal	Final Epigravettian	549	*Rupicapra pyrenaica ornata, Cervus elaphus*	33	6	Mussi *et al.* 2008, 2015
Grotta Romanelli (LE)	0	A-E	11,930±520-9,050±100	Final Epigravettian	19,879	*Cervus elaphus, Equus hydruntinus* and *Bos primigenius*	32,206	109	Alessi *et al.* 1966, 1967; Tagliacozzo and Gala 2002; Cassoli *et al.* 2003; Tagliacozzo 2003
Grotta del Santuario della Madonna (CS)	90	L (73-71; 65-48)	12,100±150-9,020±125	Final Epigravettian	19,748	*Sus scrofa, Cervus elaphus* and *Capreolus capreolus*	7,455	80	Alessi *et al.* 1967; Tagliacozzo and Gala 2002; Fiore *et al.* 2004; Gala and Tagliacozzo 2004; Gala and Tagliacozzo 2010
Total					**>62,672**		**43,147**	**157**	

*Table 1. Archaeological levels, chronology, industry, faunal data and summary sources from 10 Middle and Upper Paleolithic Italian sites. * Whenever possible calibrated ^{14}C dates have been reported, otherwise conventional ^{14}C dates are reported or ESR only for Grotta San Bernardino.*

ered compared to the mammal ones, with birds representing over 62% of the total faunal assemblage.

This paper analyzes only birds that have been surely identified to species (157), genus (104), family (38) and order (19) (Tables 2-8). Some bird orders are documented only at Grotta Romanelli and Grotta del Santuario della Madonna (Table 2): Gaviiformes (represented by two species of loons), Podicipediformes (3 species of grebes), Procellariiformes (2 species of shearwaters), Pelecaniformes (3 species of cormorants and pelicans) and Ciconiiformes (3 species of herons and bitterns).

The Cuculiformes were identified only at Riparo Dalmeri (2 remains of cuckoo), while Caprimulgiformes (1 specimen of nightjar) only at Grotta di Castelcivita (Aurignacian) (Table 7).

Galliformes and Passeriformes are represented in all levels of all sites (Tables 5 and 8). The gray partridge (*Perdix perdix*) among the Galliformes and the Yellow-billed Chough (*Pyrrhocorax graculus*) among the Passeriformes are dominant in term of number of remains and frequency of sites.

Among the species that were most frequently recovered at the ten sites analyzed here, besides the already cited *Perdix perdix* and *Pyrrhocorax graculus*, the quail (*Coturnix coturnix*) should also be mentioned; the remains of these three birds, however, are much less abundant than those of Gruiformes (bustards), Anseriformes (ducks and geese) and Columbiformes (pigeons) that are documented in a few sites, but by a

Taxa	San Bernarrdino	Fumane A13-A5	Castelcivita XIII-VII	Fumane A4-3	Castelcivita VI-IIIb	Fumane A2	Castelcivita IIIa-I	Paglicci 24	Paglicci 23-22	Roccia S. Sebastiano	Dalmeri	Cogola	Pozzo	Romanelli	Madonna	NISP	%NISP 43,147	Sites or layers
Gavia stellata														26	5	31	0.072	2
Gavia arctica														45	15	60	0.139	2
Total Gaviiformes														**71**	**20**	**91**	**0.211**	**2**
Calonectris diomedea															3	3	0.007	1
Puffinus sp.														1		1	0.002	1
Total Procellariiformes														**1**	**3**	**4**	**0.009**	**2**
Phalacrocorax carbo														62	4	66	0.153	2
Phalacrocorax aristotelis														5		5	0.012	1
Pelecanus crispus														1		1	0.002	1
Total Pelecaniformes														**68**	**4**	**72**	**0.167**	**2**
Botaurus stellaris															11	11	0.025	1
Nycticorax nycticorax														2		2	0.005	1
Ardea cinerea														1		1	0.002	1
Total Ciconiiformes														**3**	**11**	**14**	**0.032**	**2**
Tachybaptus ruficollis															12	12	0.028	1
Podiceps cristatus														15	13	28	0.065	2
Podiceps nigricollis														9	8	17	0.039	2
Total Podicipediformes														**24**	**33**	**57**	**0.132**	**2**

Table 2. NISP (Number of Identified Specimens) of Gaviiformes, Procellariiformes, Pelecaniformes, Ciconiiformes and Podicipediformes from 10 sites and 15 layers and percentage (calculated to relative total NISP).

Taxa	San Bernardino	Fumane A13-A5	Castelcivita XIII-VII	Fumane A4-3	Castelcivita VI-IIIb	Fumane A2	Castelcivita IIIa-I	Paglicci 24	Paglicci 23-22	Roccia S. Sebastiano	Dalmeri	Cogola	Pozzo	Romanelli	Madonna	NISP	%NISP 43,147	Sites or layers
Cygnus cygnus														16	18	34	0.079	2
Anser fabalis														1399	3	1402	3.249	2
Anser brachyrhynchus														16		16	0.037	1
Anser albifrons									1					3473	24	3498	8.107	3
Anser erythropus														29		29	0.067	1
Anser anser	1													86	3	90	0.209	3
Anser caerulescens														30		30	0.070	1
Branta leucopsis														144		144	0.334	1
Branta bernicla														1859		1859	4.309	1
Branta ruficollis														57		57	0.132	1
Tadorna tadorna														3	4	7	0.016	2
Anas penelope			1											241	5	247	0.572	3
Anas strepera			5				1							123	8	137	0.318	4
Anas crecca		1					3			1				32		37	0.086	4
Anas platyrhynchos	4			1	1			4	8				1	43	265	327	0.758	8
Anas acuta														28	38	66	0.153	2
Anas querquedula	2		1		13									2	3	21	0.049	5
Anas clypeata														9		9	0.021	1
Anas sp.		1						2				1	1			5	0.012	4
Netta rufina									1					7	16	24	0.056	3
Aythya ferina														46	88	134	0.311	2
Aythya nyroca					4				1					7	22	34	0.079	4
Aythya fuligula														3	76	79	0.183	2
Somateria mollissima															3	3	0.007	1
Clangula hyemalis														5		5	0.011	1
Melanitta fusca														7		7	0.016	1
Bucephala clangula														1	3	4	0.009	2
Mergellus albellus														2		2	0.005	1
Mergus serrator														1	7	8	0.019	2
Mergus merganser															7	7	0.016	1
Oxyura leucocephala														2		2	0.005	1
Total Anseriformes	**7**	**2**	**7**	**1**	**18**		**4**	**6**	**11**	**1**		**1**	**2**	**7671**	**593**	**8324**	**19.292**	**13**

Table 3. NISP (Number of Identified Specimens) of Anseriformes from 10 sites and 15 layers and percentage (calculated to relative total NISP).

Taxa	San Bernarrdino	Fumane A13-A5	Castelcivita XIII-VII	Fumane A4-3	Castelcivita VI-IIIb	Fumane A2	Castelcivita IIIa-I	Paglicci 24	Paglicci 23-22	Roccia S. Sebastiano	Dalmeri	Cogola	Pozzo	Romanelli	Madonna	NISP	%NISP 43,147	Sites or layers
Pernis apivorus															1	1	0.002	1
Haliaeetus albicilla														2	1	3	0.007	2
Gyps fulvus														11		11	0.025	1
cf. *Gypaetus barbatus*		2														2	0.005	1
Aegypius monachus		3							1					10	6	20	0.046	4
Circus aeruginosus														6	3	9	0.021	2
Circus cyaneus														2	22	24	0.056	2
Circus macrourus														2	4	6	0.014	2
Accipiter gentilis														4	9	13	0.030	2
Accipiter nisus															1	1	0.002	1
Buteo buteo	2						1								7	10	0,023	3
Buteo lagopus						1								2		3	0.007	2
Aquila clanga		1														1	0.002	1
Aquila heliaca														17		17	0.039	1
Aquila chrysaetos	1	1		1		2								66	71	142	0.329	6
Aquila sp.											2					2	0.005	1
Falco naumanni					1										3	4	0.009	2
Falco tinnunculus		20		4		5			4					80	3	116	0.289	6
Falco vespertinus		7				1								3		11	0.025	3
Falco subbuteo	1	6		2	6	4								21	3	43	0.100	7
Falco eleonorae														7		7	0.016	1
Falco peregrinus														15		15	0.035	1
Falco columbarius		1														1	0.002	1
F. vespertinus/columbarius		3														3	0.007	1
Falco sp.		3		1												4	0.009	2
Total Falconiformes	**4**	**47**		**8**	**7**	**13**	**1**		**5**		**2**			**248**	**134**	**469**	**1.087**	**10**
Tyto alba		2												3		5	0.012	2
Otus scops		2			1	2								1	1	7	0.016	5
Bubo bubo														2	11	13	0.030	2
Nyctea scandiaca														1		1	0.002	1
Athene noctua	1	1			1				4					20	13	40	0.093	6
Strix aluco		1		1	1		6								100	109	0.253	5
Strix sp.															25	25	0.058	1
Asio otus		19	5	7	7	12								10		60	0.139	6
Asio flammeus		3		4										166	2	175	0.406	4
Asio sp.		8		4												12	0.028	2
Aegolius funereus		5									1					6	0.014	2
Total Strigiformes	**1**	**41**	**5**	**16**	**10**	**14**	**6**		**4**		**1**			**203**	**152**	**453**	**1.050**	**11**

Table 4. NISP (Number of Identified Specimens) of raptors (Falconiformes and Strigiformes) from 10 sites and 15 layers and percentage (calculated to relative total NISP).

Taxa	San Bernardino	Fumane A13-A5	Castelcivita XIII-VII	Fumane A4-3	Castelcivita VI-IIIb	Fumane A2	Castelcivita IIIa-I	Paglicci 24	Paglicci 23-22	Roccia S. Sebastiano	Dalmeri	Cogola	Pozzo	Romanelli	Madonna	NISP	%NISP 43,147	Sites or layers
Lagopus lagopus		1														1	0.002	1
Lagopus muta		3		1		3					1				1	9	0.021	5
Lagopus sp.											11					11	0.025	1
Tetrao tetrix	4	99		56		48					13		16		1	237	0.549	7
Tetrao sp.		3														3	0.007	1
Tetraonidae ind.											12	2				14	0.032	2
Alectoris graeca	3	3	9	1	49		31		7					6	8	117	0.271	9
Alectoris rufa									5					3		8	0.019	2
Alectoris barbara									1							1	0.002	1
Alectoris sp.								2	9	1						12	0.028	3
Perdix perdix		3	3	4	89	2	19	2	65	1			1		19	208	0.482	11
Coturnix coturnix		13	1	2	7	5	2		1	1	10			16	6	64	0.146	11
Phasianidae ind.									1							1	0.002	1
Galliformes ind.		7							10			7				24	0.053	3
Total Galliformes	**7**	**132**	**13**	**64**	**145**	**58**	**52**	**4**	**99**	**3**	**47**	**9**	**17**	**25**	**35**	**710**	**1.646**	**15**
Rallus aquaticus		6		1		1									1	9	0.021	4
Porzana porzana				49												49	0.114	1
Crex crex		156			6	25	4		3					4	2	200	0.464	7
Gallinula chloropus		3				1								1	2	7	0.016	4
Fulica atra									1				1	28	273	303	0.702	4
Rallidae ind.		17									4					21	0.049	2
Grus virgo														2		2	0.005	1
Grus grus														56	30	86	0.199	2
Grus cf. *leucogeranus*														27		27	0.063	1
Tetrax tetrax									3					21979	685	22667	52.534	3
Otis tarda														556	25	581	1.347	2
Total Gruiformes		**182**		**50**	**6**	**27**	**4**		**7**		**4**		**1**	**22,653**	**1,018**	**23,952**	**55.513**	**10**

Table 5. NISP (Number of Identified Specimens) of Galliformes and Gruiformes from 10 sites and 15 layers and percentage (calculated to relative total NISP).

Taxa	San Bernarrdino	Fumane A13-A5	Castelcivita XIII-VII	Fumane A4-3	Castelcivita VI-IIIb	Fumane A2	Castelcivita IIIa-I	Paglicci 24	Paglicci 23-22	Roccia S. Sebastiano	Dalmeri	Cogola	Pozzo	Romanelli	Madonna	NISP	%NISP 43,147	Sites or layers
Recurvirostra avosetta		1														1	0.002	1
Burhinus oedicnemus					1									1		2	0.005	2
Charadrius morinellus									1					1		2	0.005	2
Pluvialis apricaria														6		6	0.014	1
Pluvialis squatarola							4							17		21	0.049	2
Vanellus vanellus		1												21		22	0.051	2
Philomachus pugnax					1									1		2	0.005	2
Gallinago media					1											1	0.002	1
Scolopax rusticola		3		1										1	8	13	0.030	4
Limosa limosa			2											1		3	0.007	2
Numenius phaeopus							1							111		112	0.260	2
Numenius arquata														1		1	0.002	1
Arenaria interpres					2											2	0.005	1
Chroicocephalus ridibundus					1		2									3	0.007	2
Larus canus															1	1	0.002	1
Larus argentatus														1		1	0.002	1
Larus marinus														3		3	0.007	1
Rissa tridactyla														1		1	0.002	1
Pinguinus impennis														14		14	0.032	1
Total Charadriiformes		**5**	**2**	**1**	**6**		**7**		**1**					**180**	**9**	**211**	**0.489**	**8**

Table 6. NISP (Number of Identified Specimens) of Charadriiformes from 10 sites and 15 layers and percentage (calculated to relative total NISP).

Taxa	San Bernarrdino	Fumane A13-A5	Castelcivita XIII-VII	Fumane A4-3	Castelcivita VI-IIIb	Fumane A2	Castelcivita IIIa-I	Paglicci 24	Paglicci 23-22	Roccia S. Sebastiano	Dalmeri	Cogola	Pozzo	Romanelli	Madonna	NISP	%NISP 43,147	Sites or layers
Syrrhaptes paradoxus									1							1	0.002	1
Pterocles orientalis														1	1	2	0.005	2
Pterocles alchata														10		10	0.023	1
Total Pteroclidiformes									**1**					**11**	**1**	**13**	**0.030**	**3**
Columba livia								3	213					98	4569	4883	11.317	4
Columba oenas			2		21		10							377	382	792	1.836	5
Columba livia/oenas		2							7							9	0.021	2
Columba palumbus		1							7						47	55	0.127	3
Streptopelia turtur														1	4	5	0.012	2
Columbiformes indet								1	6							7	0.016	2
Total Columbiformes		**3**	**2**		**21**		**10**	**4**	**233**					**476**	**5,002**	**5,751**	**13.329**	**8**
cf. *Cuculus canorus*											2					2	0.005	1
Total Cuculiformes											**2**					**2**	**0.005**	**1**
Caprimulgus europaeus							1									1	0.002	1
Total Caprimulgiformes							**1**									**1**	**0.002**	**1**
Apus apus														3		3	0.007	1
Apus melba	1									1						2	0.005	2
Total Apodiformes	**1**									**1**				**3**		**5**	**0.012**	**3**
Coracias garrulus					4										1	5	0.012	2
Total Coraciiformes					**4**										**1**	**5**	**0.012**	**2**
Picus viridis															5	5	0.012	1
Dendrocopos leucotos		3				2										5	0.012	2
Total Piciformes		**3**				**2**									**5**	**10**	**0.023**	**3**

Table 7. NISP (Number of Identified Specimens) of Pteroclidiformes, Columbiformes, Cuculiformes, Caprimulgiformes, Apodiformes, Coraciiformes, and Piciformes from 10 sites and 15 layers and percentage (calculated to relative total NISP).

Taxa	San Bernardino	Fumane A13-A5	Castelcivita XIII-VII	Fumane A4-3	Castelcivita VI-IIIb	Fumane A2	Castelcivita IIIa-I	Paglicci 24	Paglicci 23-22	Roccia S. Sebastiano	Dalmeri	Cogola	Pozzo	Romanelli	Madonna	NISP	%NISP 43,147	Sites or layers
Melanocorypha calandra															3	3	0.007	1
Galerida cristata														1		1	0.002	1
Lullula arborea						1										1	0.002	1
Eremophila alpestris									7							7	0.016	1
Alaudidae ind.									1							1	0.002	1
Ptyonoprogne rupestris		5	1	1	2	1	3		10					3	23	49	0.113	9
Hirundo rustica														1		1	0.002	1
Hirundo sp.									1							1	0.002	1
Hirundinidae ind.									1							1	0.002	1
Delichon urbicum			1				5									6	0.014	2
Zoothera dauma														1		1	0.002	1
Turdus merula			2												114	116	0.269	2
Turdus pilaris		4							2					4	23	33	0.076	4
Turdus iliacus		2			2	1								2	61	68	0.158	5
Turdus viscivorus		8	6		10	1	3		2					2	24	56	0.130	8
T. pilaris/viscivorus		1														1	0.002	1
Turdus sp.		1				3										4	0.009	2
Turdidae ind.											6					6	0.014	1
Oriolus oriolus		1													1	2	0.005	2
Garrulus glandarius		9				1									38	48	0.111	3
Pica pica		7		3		5			6					9		30	0.070	5
Nucifraga caryocatactes	1			1	6	3	1							1		13	0.030	6
Pyrrhocorax graculus	5	422	11	102	26	131	14	23	699	1			4	7	38	1483	3.437	13
Pyrrhocorax pyrrhocorax		1	5	1	4		4	3	52					13	6	89	0.206	9
Pyrrhocorax sp.		10														10	0.023	1
Corvus monedula		3		1		1								42	8	55	0.127	5
Corvus frugilegus														4	12	16	0.037	2
Corvus corone		2		1		5								17	37	62	0.144	5
Corvus corax		2				1								10	39	52	0.121	4
Corvus sp.		1														1	0.002	1
P. graculus/C. monedula		9														9	0.021	1
Corvidae ind.		27		4					42							73	0.169	3
Sturnus vulgaris														450		450	1.043	1
Montifringilla nivalis		2		1		3		2	2							10	0.023	5
Passeridae ind.									1							1	0.002	1
Fringilla coelebs															7	7	0.016	1
Carduelis chloris				1												1	0.002	1
Loxia curvirostra		1												1		2	0.005	2
Loxia pityopsittacus						2										2	0.005	1
Pinicola enucleator		1														1	0.002	1
Pyrrhula pyrrhula		3		1										1		5	0.012	3
Fringillidae indet									2							2	0.005	1
Plectrophenax nivalis									6							6	0.014	1
Emberiza citrinella									1							1	0.002	1
Emberizidae ind.									1							1	0.002	1
Passeriformes ind.		161		14				1	9		18	3	9			215	0.498	7
Total Passeriformes	**6**	**683**	**26**	**131**	**50**	**159**	**30**	**29**	**845**	**1**	**24**	**3**	**13**	**569**	**434**	**3,003**	**6.959**	**15**

Table 8. NISP (Number of Identified Specimens) of Passeriformes from 10 sites and 15 layers and percentage (calculated to relative total NISP).

	Grotta di Fumane									Grotta di Castelcivita								
	A13-A5			A4-3			A2-A1			XIII-VII			VI-IIIb			IIIa-I		
Taxa	NISP	MNI	NME	NISP	MNI	NME	NISP	MNI	NME	NISP	MNI	NME	NISP	MNI	NME	NISP	MNI	NME
Anas penelope										1	1	1						
Anas strepera										5	2	5				1	1	1
Anas crecca	1	1	1													3	3	3
Anas platyrhynchos				1	1	1							1	1	1			
Anas querquedula										1	1	1	13	4	13			
Anas sp.	1																	
Aythya nyroca													4	2	4			
cf. *Gypaetus barbatus*	2	2	2															
Aegypius monachus	3	2	3															
Buteo buteo																1	1	1
Buteo lagopus							1	1	1									
Aquila chrysaetos	1	1	1	1	1	1	2	1	2									
Aquila clanga	1	1	1															
Falco naumanni													1	1	1			
Falco tinnunculus	20	5	17	4	1	3	5	3	4									
Falco vespertinus	7	4	7				1	1	1									
Falco subbuteo	6	4	6	2	2	2	4	3	4				6	5	6			
Falco columbarius	1	1	1															
Falco vespertinus/columbarius	3																	
Falco sp.	3			1	1	1												
Lagopus lagopus	1	1	1															
Lagopus mutus	3	2	3	1	1	1	3	1	3									
Tetrao tetrix	99	15	85	56	7	48	48	8	42									
Tetrao sp.	3																	
Alectoris graeca	3	2	3	1	1	1				9	4	7	49	11	42	31	7	28
Perdix perdix	3	2	3	4	2	4	2	1	1	3	4	3	89	13	69	19	6	16
Coturnix coturnix	13	4	11	2	1	2	5	1	5	1	1	1	7	3	6	2	1	2
Galliformes ind.	7																	
Rallus aquaticus	6	3	6	1	1	1	1	1	1									
Crex crex	156	15	128	49	8	39	25	9	15				6	3	4	4	3	4
Gallinula chloropus	3	1	3				1	1	1									
Rallidae ind.	17																	
Recurvirostra avosetta	1	1	1															
Burhinus oedicnemus													1	1	1			
Pluvialis squatarola																4	2	4
Vanellus vanellus	1	1	1															
Philomachus pugnax													1	1	1			
Gallinago media													1	1	1			
Scolopax rusticola	3	1	3	1	1	1												
Limosa limosa										2	2	2						
Numenius phaeopus																1	1	1
Arenaria interpres													2	2	2			
Chroicocephalus ridibundus													1	1	1	2	2	2

Table 9. NISP (Number of Identified Specimens), MNE (Minimum Number of Elements) and MNI (Minimum Number of Individuals) of bird remains from Grotta di Fumane and Grotta di Castelcivita.

	Grotta di Fumane									Grotta di Castelcivita								
	A13-A5			A4-3			A2-A1			XIII-VII			VI-IIIb			IIIa-I		
Taxa	NISP	MNI	NME	NISP	MNI	NME	NISP	MNI	NME	NISP	MNI	NME	NISP	MNI	NME	NISP	MNI	NME
Columba oenas										2	1	2	21	8	17	10	5	8
Columba livia/oenas	2	1	2															
Columba palumbus	1	1	1															
Tyto alba	2	1	2															
Otus scops	2	1	2				2	1	2				1	1	1			
Athene noctua	1	1	1										1	1	1			
Strix aluco	1	1	1	1	1	1							1	1	1	6	5	6
Asio otus	19	3	19	7	4	7	12	4	12	5	2	5	7	5	6			
Asio flammeus	3	2	3	4	4	3												
Asio sp.	8			4														
Aegolius funereus	5	1	5															
Caprimulgus europaeus																1	1	1
Coracias garrulus													4	2	4			
Dendrocopos leucotos	3	2	2				2	1	2									
Lullula arborea							1	1	1									
Ptyonoprogne rupestris	5	2	5	1	1	1	1	1	1	1	1	1	2	2	2	3	2	3
Delichon urbicum										1	1	1				5	3	4
Turdus merula										2	1	2						
Turdus pilaris	4	1	4															
Turdus iliacus	2	1	2				1	1	1				2	1	2			
Turdus viscivorus	8	2	7				1	1	1	6	3	6	10	4	9	3	2	2
Turdus pilaris/viscivorus	1																	
Turdus sp.	1						3											
Oriolus oriolus	1	1	1															
Garrulus glandarius	9	2	8				1	1	1									
Pica pica	7	2	6	3	3	3	5	3	4									
Nucifraga caryocatactes				1	1	1	3	1	3				6	4	6	1	1	1
Pyrrhocorax graculus	422	28	337	102	8	73	131	12	74	11	5	10	26	7	23	14	6	12
Pyrrhocorax pyrrhocorax	1	1	1	1	1	1				5	2	5	4	3	4	4	3	4
Pyrrhocorax sp.	10																	
Corvus monedula	3	2	3	1	1	1	1	1	1									
Corvus corone	2	2	2	1	1	1	5	1	5									
Corvus corax	2	2	2				1	1	1									
Corvus sp.	1																	
P. graculus/C. monedula	9																	
Corvidae ind.	27			4														
Montifringilla nivalis	2	2	2	1	1	1	3	1	3									
Carduelis chloris				1	1	1												
Loxia curvirostra	1	1	1															
Loxia pityopsittacus							2	2	2									
Pinicola enucleator	1	1	1															
Pyrrhula pyrrhula	3	1	3	1	1	1												
Passeriformes ind.	161			14														
TOTAL	1,098	134	710	271	56	200	273	64	194	55	31	52	267	88	228	115	55	103

Table 9 (continued). NISP (Number of Identified Specimens), MNE (Minimum Number of Elements) and MNI (Minimum Number of Individuals) of bird remains from Grotta di Fumane and Grotta di Castelcivita.

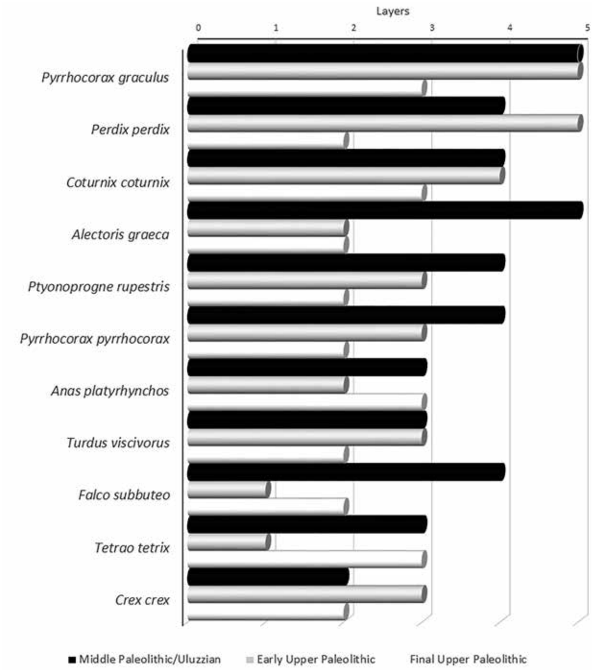


Figure 2. Percentages of the most abundant species at the 10 sites and 15 layers from Italian Middle Paleolithic/ Uluzzian, Early Upper Paleolithic and Final Upper Paleolithic.

large number of remains. Of the over 43,000 bones identified, more than half (55% of the total, or about 24,000) belongs to the order Gruiformes, and in particular to a single species, the Little Bustard (*Tetrax tetrax*), found only at three sites (Grotta Paglicci, Grotta Romanelli, and Grotta della Madonna), but represented at Grotta Romanelli by 21,979 remains. For two sites with long stratigraphic sequences (Grotta di Fumane and Grotta di Castelcivita) we also present data relating to the MNI and MNE. As shown in table 9, it is clear that the species with a greater number of remains are underrepresented in the number of individuals, whereas rare species are overrepresented.

Many of the 157 different species have been identified in the two above-mentioned sites and in the two sites with more bird bones (Grotta Romanelli and Grotta del Santuario della Madonna). Among the species that were more frequently recovered at these sites there are:

- Alpine chough (*Pyrrhocorax graculus*) at 8 sites (13 layers).
- Mallard (*Anas platyrhynchos*) and quail (*Coturnix coturnix*) at 7 sites (8 and 11 layers).
- Grey partridge (*Perdix perdix*), Partridge (*Alectoris graeca*), at 6 sites (11 and 9 layers).
- Black Grouse (*Tetrao tetrix*), Corncrake (*Crex crex*), Eurasian Hobby (*Falco subbuteo*), Eurasian Crag-Martin (*Hirundo rupestris*), Mistle Thrush (*Turdus viscivorus*) and Chough (*Pyrrhocorax pyrrhocorax*) at 5 sites (from 7 to 9 layers).

Besides, if we divide the long sequence sites into the various chronological and cultural levels Mousterian/Uluzzian, Early Upper Paleolithic (Aurignacian and Gravettian) and Final Upper Paleolithic (Epigravettian), we can observe some variations in the presence of the single species (Fig. 2), even though it is not possible to derive general indications. The main variations which can be noted are:

- *Pyrrhocorax graculus* is always present in the oldest and middle levels while it is absent at two Epigravettian sites;
- *Perdix perdix*, also present in almost all of the oldest and middle levels, has been identified only at two Epigravettian sites;
- *Alectoris graeca*, present in all oldest levels, is less represented in the entire Upper Paleolithic;
- None of the species considered is present in all the levels of the Final Upper Paleolithic;
- *Falco subbuteo* and *Tetrao tetrix,* well represented in the oldest and most recent levels, are present only at one site of the Early Upper Paleolithic.

However, these species are not represented by a large number of bone remains. Only 3.5% of the specimens are referable to *Pyrrhocorax graculus* and less than 1 % belongs to *Coturnix coturnix* and *Perdix perdix* (Tables 5 and 8).

As these avifaunal complexes differ in location, chronology, specific composition and quantity, it is not possible to draw paleoecological indications valid for the whole of the Italian peninsula, even though the study of avifauna has often contributed to providing paleoecological and environmental clues about a single deposit. Therefore, in this paper we limit our remarks only to the two sites with a long stratigraphic sequence that allow for chrono-environmental evaluations because of the quantity and quality of data.

At Grotta di Castelcivita in the Mousterian levels there is a higher presence of rocky habitat birds (choughs) and open habitat birds (*Alectoris graeca*) and a lower percentage of waterbirds (ducks) and wood and forest birds (*Asio otus* and thrushes), which is evidence of humid, cool-temperate climate. In the Uluzzian there is a first climate cooling and an increase in the steppe grasslands species (*Perdix perdix*) accompanied by an equivalent decrease in rock and aquatic species. In the successive levels of the Protoaurignacian steppe grasslands species are the majority. It is also interesting to note the fluctuations within this latter period: in the lamelle Dufour phase the prevalence of steppe grasslands species becomes more marked, rock species increase, the water and wood ones diminish, testifying to a colder and drier climate, which is also highlighted by the presence of two species nesting in arctic tundra, grey plover (*Pluvialis squatarola*) and whimbrel (*Numenius phoeopus*); in the phase of the Protoaurignacian small point there is an increase in wood and water species and the complete absence of rocky and alpine environment species (choughs), which reflects an evolution to a humid temperate climate.

The avifaunal assemblage at Grotta di Fumane from the Mousterian to the Aurignacian levels is dominated by 3 species dwelling in rocky environments (*Pyrrhocorax graculus*), alpine forest habitats (*Tetrao tetrix*) and grasslands in hilly and mountainous zones (*Crex crex*). However, evident modifications in the environment, indicating a climate cooling, are evidenced between the Mousterian and the Aurignacian where it is possible to observe an increase in choughs and black grouse (as to the latter even earlier, during the Uluzzian) and a decrease in *Crex crex*. These shifts to colder and drier climate conditions are corroborated by the presence in the Aurignacian levels of cold climate and nordic environment species such as rough-legged buzzard (*Buteo lagopus*), Snowy Owl (*Nyctea scandiaca*) and boreal owl (*Aegolius funereus*).

Despite the environmental difference that these two avian assemblages – ca 800km distant from one another – reflect, it is possible to note some analogies in the eco-environmental variations which also appear in macrofauna between the final phases of the Mousterian and the early phases of the Aurignacian with a progressive increase in alpine grassland and cold, dry steppe species (Cassoli and Tagliacozzo 1997b). In both deposits rock birds are well represented, especially the chough as well as galliformes, which at Fumane are those typical of an alpine environment (*Tetrao tetrix* and *Lagopus*) whereas at Castelcivita they are typical of steppe grassland (*Alectoris graeca* and *Perdix perdix*).

Unlike Grotta di Castelcivita, where some remains of Columbiformes have been found and used as indicators of a temperate climate, at Grotta di Fumane remains attributed to this order are virtually absent (NISP 3), while the clear prevalence of chough in the whole sequence confirms that the climate was colder than it is now during the entire occupation of the site Cassoli and Tagliacozzo 1994b).

Climatic-environmental considerations, instead, are not easily applicable to other sites where the coexistence of temperate, warm environment species with cold steppe environment ones occurs at the same stratigraphic levels. For example, at Grotta Romanelli we find the great auk (*Pinguinus impennis*) coexisting with the pin-tailed sandgrouse (*Pterocles alchata*) and black-bellied sandgrouse (*Pterocles orientalis*). Certainly these avian assemblages are mainly influenced by the processes leading to the formation of the archaelogical deposit. These processes are due to both anthropic action and, above all, to natural phenomena which caused sedimentary or erosion process that disturbed the orderly stratification of the soil.

4. Anthropic modifications

Human modification from the ten sites will be analyzed here (Table 10). All the references on the Late Glacial sites are already reported in another synthesis (Gala and Tagliacozzo 2010, tab. 1). The taphonomic study on the birds from Grotta San Bernardino, Grotta di Castelcivita and Grotta di Roccia San Sebastiano is still in progress, while new data from Grotta di Fumane is being published (Romandini *et al.* 2016; Fiore *et al.* 2016).

At San Bernardino (Gala and Tagliacozzo in progress) the ulna of a *Pyrrhocorax graculus* is partially burnt, while the coracoid of a teal (*Anas crecca*) is fragmented in the lower part according to a practice used in following periods, mainly during the Late Upper Paleolithic

Regarding the two sites with a long stratigraphic sequence, 13 bird species whose remains displayed human modifications have been identified at Grotta di Fumane (Peresani *et al.* 2011; Tagliacozzo *et al.* 2013), whereas human modified bones of only one bird species have been recovered so far at Grotta di Castelcivita (Gala and Tagliacozzo in progress).

At Grotta di Fumane, bird exploitation decreased from the Mousterian (13 species: Cinereous Vulture (*Aegypius monachus*), Lammergeier (*Gypaetus barbatus*), Golden

Site	Culture	N. Species	N. Species mod.	TOTAL NISP	Anthropic modifications: NISP Mod.	% NISP Mod.	Cutmark	Cutmark?	Peeling	Wrench	Crushing	Chop mark	Chop m./Use	Burned
San Bernardino	Mousterian	12	2	26	2	7.7					1			1
Fumane		47	16	1,098	51	4.6	26	11	21	4	4	5	1	
Fumane	Uluzzian	25	3	271	3	1.1	3							
Castelcivita		26	1	267	1	0.4					1			
Paglicci	Aurignacian	8	1	43	2	4.7	2							
Paglicci	Gravettian	29	6	1,206	20	1.7	20							
Roccia S.Sebastiano		6	1	6	1	16.7	1						-	
Dalmeri	Epigravettian	8	1	80	1	1.3	1							
Pozzo		6	1	33	1	3.0	1							
Romanelli		109	55	32,206	4,722	14.7	3,678		227			61		1,621
Madonna		80	13	7,455	296	4.0	75		34					187
Total 10 sites and 15 layers		157	81	43,147	5,100	11.8	3,807	11	282	4	6	66	1	1,809

Table 10. Species with human modifications (mod.) from the Mousterian to the Epigravettian. A single specimen may present more than one modifications.

Eagle (*Aquila chrysaetos*), Greater Spotted Eagle (*Aquila clanga*), Red-footed Falcon (*Falco vespertinus*), Merlin (*Falco columbarius*), *Tetrao tetrix, Crex crex,* Common Wood-Pigeon (*Columba palumbus*), Eurasian Magpie (*Pica pica*), *Pyrrhocorax graculus,* Carrion Crow (*Corvus cf. corone*), and a small Passeriformes) to the Uluzzian layers (3 species), as suggested by the presence of bones modified by human activities. So far no human modifications have been documented in Aurignacian layers (Gala and Tagliacozzo 2005). A wide range of bird species is recorded in the earliest Mousterian phase represented by unit A9. The discovery of a wing of a cough with burning, gnawing and traces of human handling, but without cut-marks, indicates that it was not always necessary to use lithic tools during disarticulation (Fiore *et al.* 2016; Romandini 2012). Other birds have been exploited as food *Tetrao tetrix* and *Crex crex*), but also for feathers and bone-working, as in the case of raptors. The latter practice is also documented in other Mousterian levels (Fiore *et al.* 2004 for the A12 level and Peresani *et al.* 2011).

In the Mousterian layers A5-A6 diurnal raptors, pigeon and corvids were exploited. Nevertheless, birds would have represented a small part of Neanderthal diet, considering also that some bird remains may derive from the activity of small carnivores. In the Uluzzian layer A3 human modifications have been observed on a few specimens. Cutmarks, wrench, impact points, and peeling suggest that *Tetrao tetrix*, *Aquila chrysaetos* and *Pyrrhocorax graculus* were disarticulated and defleshed.

At Grotta di Castelcivita a preliminary taphonomic analysis (work in progress) allowed to identify evidence of disarticulation (crushing) on a humerus of *Perdix perdix*, from the Uluzzian layer.

Evidences for the exploitation of birds as food are documented in the Aurignacian and early Gravettian layers of Grotta Paglicci (Tagliacozzo and Gala 2004) on 20 bones of grey partridge, rock dove and choughs. Cut-marks are also present on two diurnal raptor (*Aegypius monachus* and Eurasian Kestrel *Falco tinnunculus*).

The preliminary taphonomic analysis on the bird bones from Grotta di Roccia San Sebastiano allowed identifying disarticulation *striae* on a scapula of *Perdix perdix* (Ruiu *et al.* 2012).

In the Late Glacial sites of North and central Italy cut-marks are present on the humeri of Galliformes from Riparo Dalmeri and Grotta di Pozzo (Gala and Tagliacozzo 2010).

Except for Passeriformes, some birds that are not cave dwelling species, such as Anseriformes and Galliformes, come from Riparo Cogola, (Gala and Tagliacozzo 2010). They may have been introduced by predators, although no diagnostic evidence has been detected so far.

The taphonomic studies carried out on the samples from the Southern Italian caves of Grotta Romanelli (Cassoli and Tagliacozzo 1997a; Tagliacozzo and Gala 2000; Cassoli *et al.* 2003) and Grotta del Santuario della Madonna – focusing only on the remains of aquatic birds (Tagliacozzo and Gala 2002; Gala and Tagliacozzo 2004) – evidenced a systematic repetition, almost standardization, of human actions on the carcasses of many bird species. At Grotta Romanelli over 4,700 human modifications were detected, while at Grotta del Santuario della Madonna there were more than 300 (Table 10).

Hunting focused on the bird species that were more abundant in the surrounding environment and those that were more important from an alimentary point of view (ducks, geese, swans at both sites and little and great bustards at Grotta Romanelli).

Some of these actions produced very similar traces also on birds that do not have at present a particular alimentary interest, such as eagles, hawks, owls, little owls and Corvidae. The finding of bones of these latter species has been often interpreted as the result of animals hunted for their down, feathers or to obtain ornamental objects or tools from their bones.

The most frequent human modifications at these two sites are those related to butchery. These include mainly *striae* produced by lithic tools (Fig. 3) and fresh bone breaks, more rarely impact notches or chop-marks.

Chop-marks are often found on the bones of macromammals (Fiore *et al.* 2004 b), but are rare on bird bones. In the Late Glacial such traces have been identified only on some diaphyses of large-sized birds from Grotta Romanelli and Grotta del Santuario della Madonna (Gala and Tagliacozzo 2004; Gala *et al.* 2009).

Breaks and fractures produced during the dismemberment of the carcass are more common (Figures 4 and 5). In a few cases, and only on the humeri, some perforations produced during the disarticulation of these bones from the ulna by forced extension have been identified (Fig. 4).

Localized burning traces (Fig. 4 and 6), resulting from cooking on a fire or on coals with consequent burning of the bone parts not protected by meat, are very frequent

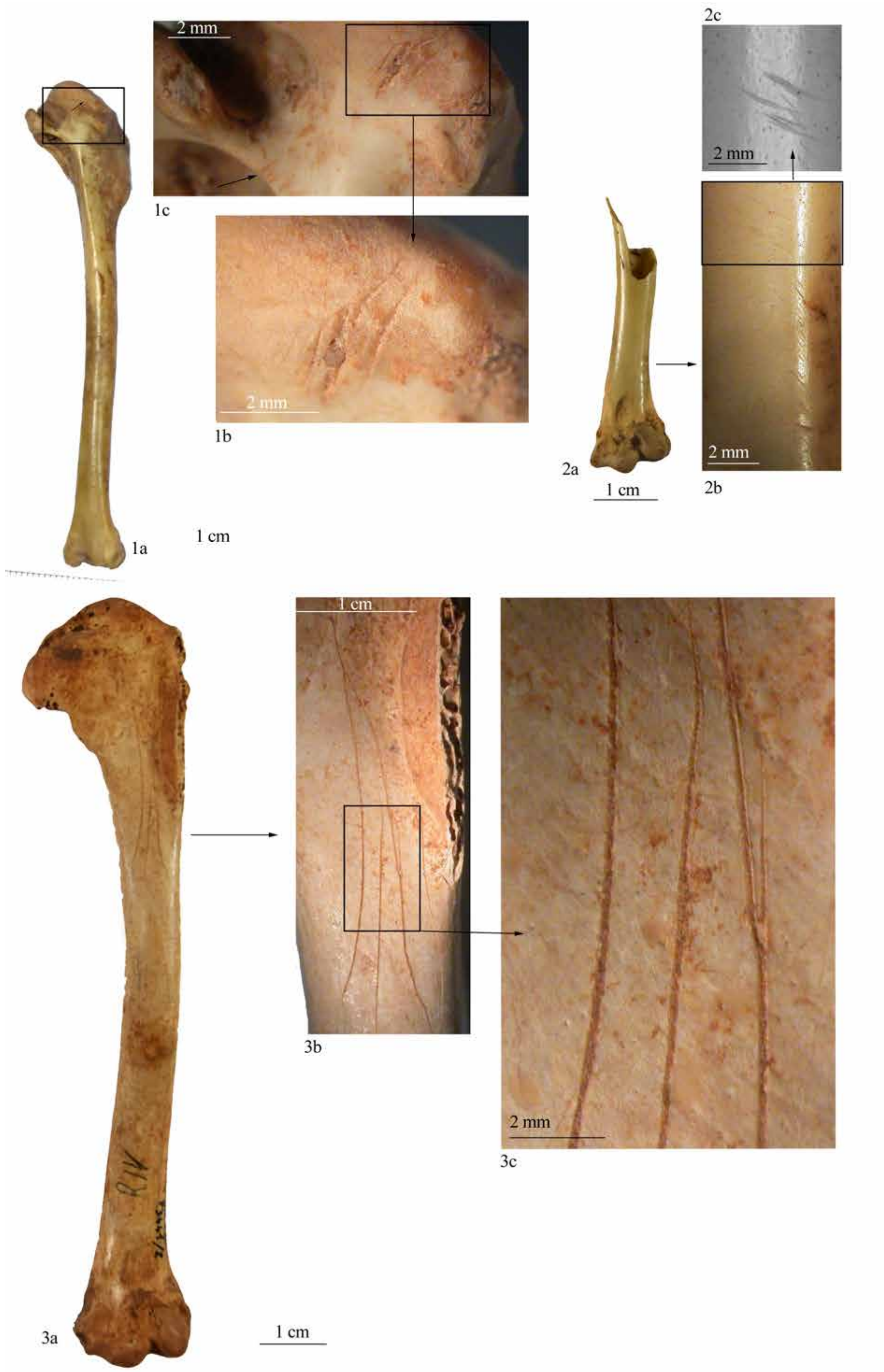


Figure 3. Examples of cut-marks on humeri: Fulica atra *from Grotta del Santuario della Madonna (1a-c), Tetraonidae from Riparo Dalmeri (2a-c) and* Branta leucopsis *from Grotta Romanelli (3a-c).*

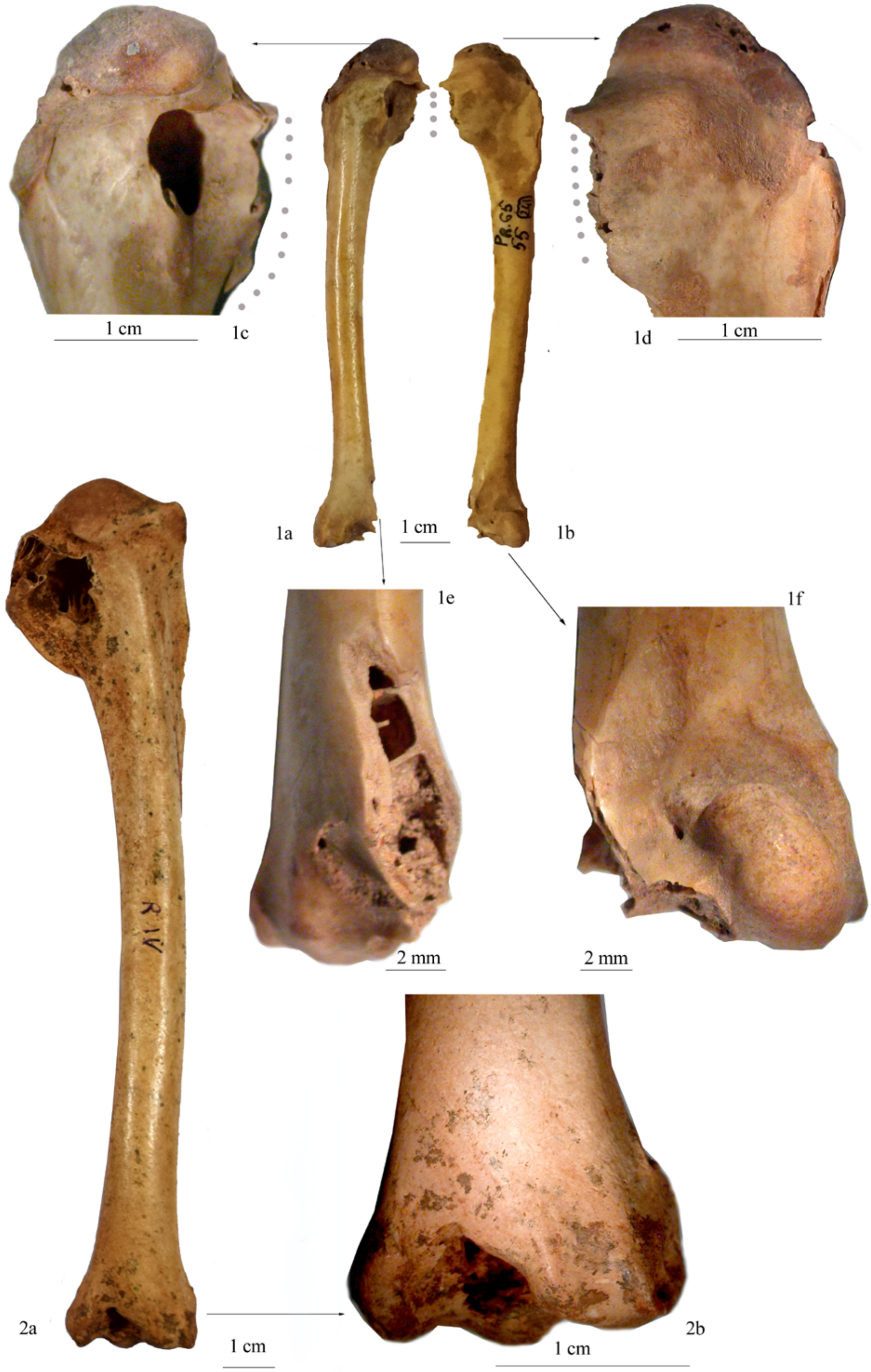


Figure 4. Examples of disarticulation marks on humerus. Anas platyrhynchos *from Grotta del Santuario della Madonna (1a caudal, 1b cranial): fracture on proximal end (1c-d with burning marks), crushing and medial wrench on distal part (1e-f).* Anser fabalis *from Grotta Romanelli (2): crushing and medial wrench on distal part (2a-b).*

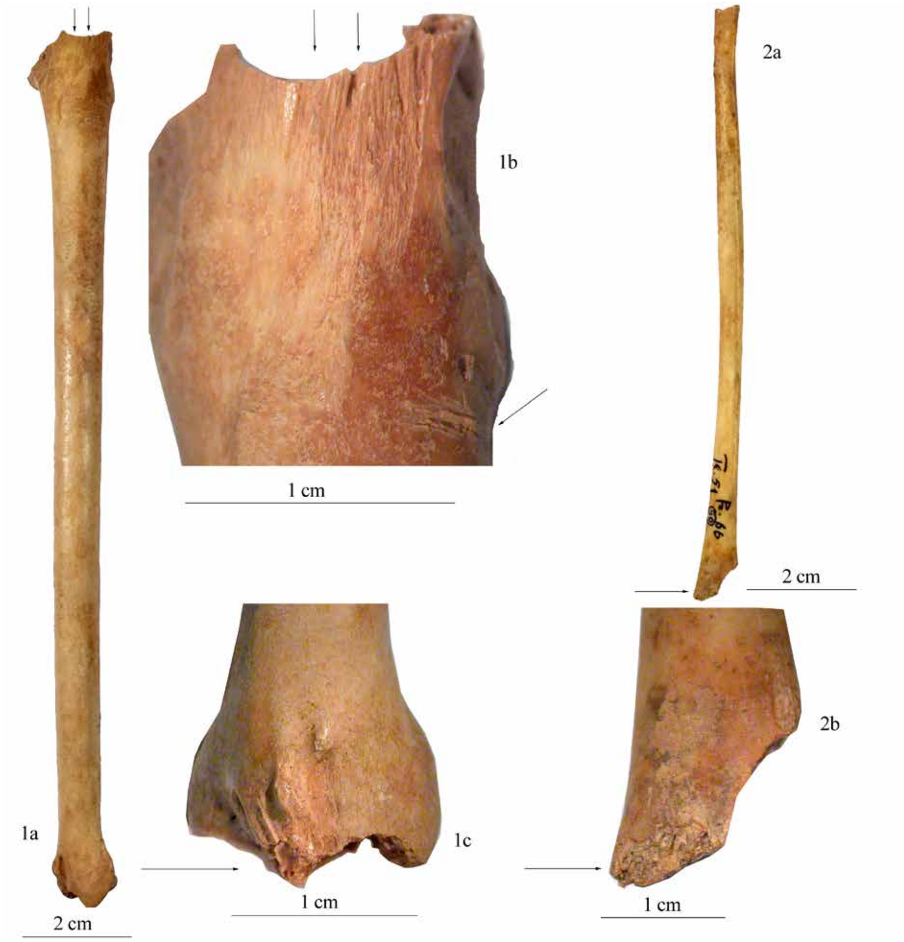


Figure 5. Examples of disarticulation marks: peeling on Anser fabalis *ulna from Grotta Romanelli (1a-c and* Gavia arctica *radius from Grotta del Santuario della Madonna (2a-b).*

(Cassoli and Tagliacozzo 1997a). Some modifications, which may be tentatively related to human gnawing, have been identified on some specimens, however a more detailed study on such traces is still in progress.

Birds were exploited both as a food source and to obtain raw material for tools and ornamental objects (feathers); such as the two modified bones belonging to cormorant and goose and possibly pigeon (Cassoli *et al.* 2003, 104 fig. 9.6).

In our research we found only one probable mark produced by a projectile point on a humerus of Great Bustard (*Otis tarda*) in the Late Upper Paleolithic levels of Grotta Romanelli.

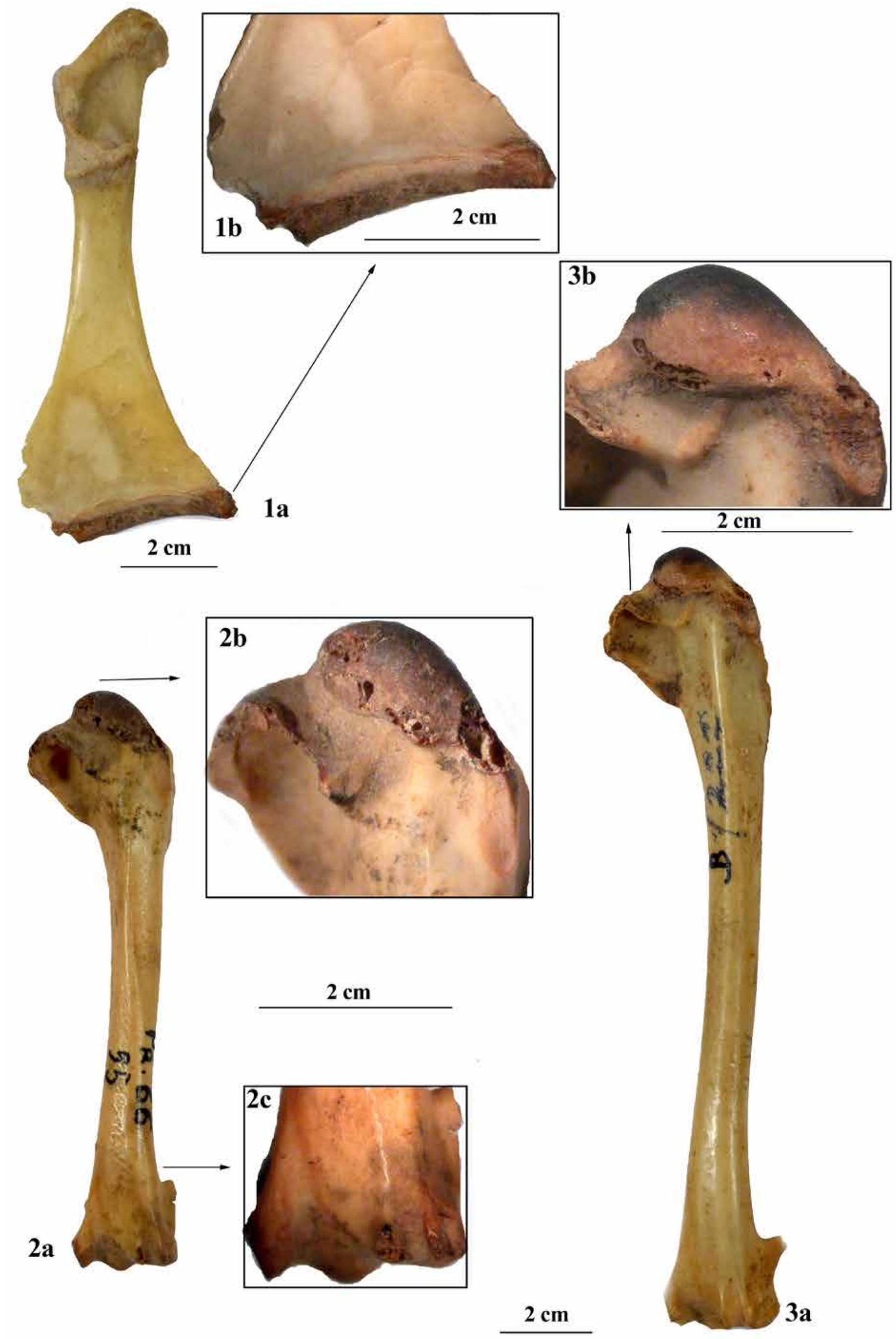


Figure 6. Examples of burning marks: Anas platyrhynchos *coracoid from Grotta del Santuario della Madonna (1a-b);* Scolopax rusticola *humerus (2a-c) and* Numenius phaeopus *humerus from Grotta Romanelli (3a-b).*

5. Discussion and conclusion

This study demonstrates that in Italy birds were exploited as a food source already since the Middle Paleolithic, although such exploitation was limited to a narrow range of species.

During the early Upper Paleolithic (Aurignacian and Gravettian) the use of birds for food purposes does not show a real increase in number of remains, species and sites involved. Birds represent only a small part of the diet of AMH. A dramatic change appears only in the late Upper Paleolithic when this practice seems to be widespread. During the Final Epigravettian the maximum exploitation of birds and an increase in the number of hunted species are documented, as indicated by the presence of bird orders, genera and species found only at Grotta Romanelli and Grotta del Santuario della Madonna (Tagliacozzo and Gala 2002). Only at this time we can talk about a specialized hunting focusing on specific species, as suggested by the cases of the little bustard at Grotta Romanelli and of the aquatic birds at Grotta del Santuario della Madonna. Hunting of these species was certainly favored by the ecological conditions around these two sites at the end of the Pleistocene (wide steppe plains in the first case, coastal environment with a large delta in the second one). The fact that hunting focused mainly on bird species related to the environment surrounding the site is a constant at all the examined sites (*e.g.*, chough, grouse, corncrake and large raptors in the peri-alpine environment of Fumane).

At all the sites considered here, there are many birds that usually do not live in or near caves but are of obvious interest as food source (especially Anseriformes, Galliformes, Gruiformes, and Charadriiformes); their remains may therefore be considered hunting products accumulated by humans, despite the absence of butchery marks. However, in the same deposits it is possible to find, numerous bones of birds that regularly frequent caves and probably died for natural causes (especially Columbiformes) or were introduced by raptors that used the walls of the caves as perches, and then rejected the remains within pellets (especially those of passerines, but not only). Some of these latter species have been, however, exploited by humans at least occasionally (*e.g.*, pigeons and crows at Grotta di Fumane, Grotta Paglicci, and Grotta Romanelli).

Galliformes and passerines are always present at all sites, but clearly their meat yield is different and, above all, not all passerines were exploited as food. In this regard, the use of corvids (crows, jackdaws and choughs) as food is noteworthy, clearly indicated by taphonomic evidence in all the periods investigated. We need to consider also that these birds were also exploited for other purposes, as evidenced by the occurrence of traces on the bone related to the acquisition of their feathers (Grotta di Fumane and Grotta Paglicci).

At 4 sites dated to different periods (Grotta di Fumane, Mousterian and Uluzzian; Grotta Paglicci, early Gravettian; Grotta Romanelli and Grotta del Santuario della Madonna, final Epigravettian), the presence among the hunted species of diurnal raptors, even of large size (vultures and eagles) is documented. Their exploitation as food (except for the little hawks), is not always certain, but the use of their feathers or bones at Grotta di Fumane during the Middle Paleolithic is unquestionable (Peresani *et al.* 2011).

It is not possible to identify the hunting tools (throwing spears, bow and arrow, traps, nets, etc.) on the basis of the data collected. During the Epigravettian the use of the bow is likely to have had a key role in the capture of some species of birds. A hole on a bustard humerus from Grotta Romanelli was probably produced by the impact with the pointed tip of a weapon. Different hypotheses have been suggested for the capture of Anseriformes using sticks or throwing stones, especially during the nesting period when they form interspecific groups of individuals in wetlands.

On the basis of metric data, some hypotheses on the capture season of Otididae have been suggested for Grotta Romanelli. These animals were probably mainly hunted in fall – winter, when they form large groups of males, females and young individuals, rather than in spring and summer when they are scattered over larger territories, solitary or in small groups (Gala *et al.* 2009).

Much more abundant are the evidence of carcass processing methods and of the products, mainly meat, but also skin, feathers, and bones that were exploited. The carcass treatment is in general similar in all periods considered (from skinning to cooking small portions), but with some differences related to the chronology, and, above all, to the species involved. In particular, the size of the animal influenced the disarticulation and dismemberment method (*e.g.*, using stone tools or not), as well as the whole butchering and cooking process.

Feather removal and skinning traces are evident on raptors and crows at Grotta di Fumane and Grotta Paglicci, on Anseriformes at Grotta del Santuario della Madonna and on Otididae at Grotta Romanelli. Traces of disarticulation made by stone tools are evident on the ends of some long bones of large birds, but sometimes, *striae* are also present on the bones of small birds (Grotta di Fumane, Grotta Paglicci, Grotta Romanelli and Grotta del Santuario della Madonna). It seems that the butchery and disarticulation processes made using stone tools involved always some anatomical portions, but not others or included them only occasionally. The dismemberment of the carcass could also have occurred simply using the hands, as indicated by peeling, crushing and wrench traces.

Few cases indicate the disarticulation of the skull or of the beak from the body (*striae* on a chough mandible at Grotta Paglicci and on a bustard quadratum at Grotta Romanelli). The separation of the sternum from the coracoid is documented several times (especially in the Late Glacial), but most of the traces can be referred to the disarticulation of humerus from the coracoid, scapula and furcula, possibly in order to obtain the wing (already since the Mousterian). Modifications produced during the disarticulation of humerus from the shoulder and of the tibiotarsus from the tarsometatarsus are also relatively frequent.

Traces indicating the use of hammers for disarticulation (presence of notches, grooves or chipping), are quite rare; these have been identified primarily on the fracture edges of large sized bird bones (large raptors at Grotta di Fumane and Grotta del Santuario della Madonna, bustard at Grotta Romanelli). In some cases the fracture margins indicate the breakage of bones still in anatomical connection by bending and torsion. The anatomical elements that were most often intentionally fractured are the coracoid and the furcula; this is certainly related to the acquisition of breast meat by forcedly stripping it from the sternum. The hypothesis of an intentional fracturing of the furcula is supported not only by the repetitiveness of the action, but also by the fact that the fractures are often associated with traces of peeling or cut-marks.

Traces of meat removal are present on the humerus and sternum of Otididae and, above all, on the sternum of Anseriformes at Grotta Romanelli and, more rarely, at Grotta del Santuario della Madonna. Sometimes, traces of defleshing are also found on small birds and could therefore indicate the acquisition of bone rather than meat. The presence of burnt areas on the ends of long bones, but not only, indicates that small anatomical portions were cooked in direct contact with coals (only the portions of bone not covered by meat show traces of burning). This practice is more evident during the Epigravettian than in the previous periods.

Only rarely traces of gnawing and punctures identified on birds bones may be surely related to human consumption. Sometimes it is difficult to discriminate carnivore gnawing traces and punctures from those produced by humans. For their particular morphology and the micro features of the furrows, some gnawing traces found on bird bones from Grotta di Fumane and Grotta Romanelli have been tentatively attributed to human chewing.

In a few other Italian sites birds bones with butchery marks or burning traces have been reported. Cut-marks are present on two humeri of a partridge and a snowy owl, in the Aurignacian level of Grotta del Fossellone (Monte Circeo, Latium) (Alhaique *et al.* 1998; Alhaique and Tagliacozzo 2000). Anseriformes were also exploited at Grotta di Ortucchio (Fucino Basin, Abruzzi), as documented by the presence of burning traces (Alhaique and Recchi 2001). Other burnt portions have been identified on partridge bones at Riparo Salvini (Terracina, Latium) (Cassoli and Guadagnoli 1987) and on those of several species at Grotta della Serratura (Wilkens, 1993). Hunting of Anseriformes, Galliformes and coot (*Fulica atra*) have been hypothesized at Grotta Continenza (Bevilacqua 1994).

Interesting paleoenvironmental features are evidenced by the presence of species that are now absent or rare in the Italian territory; this reflects both the climatic changes and the different morphologies of the territory surrounding the sites. The Willow Ptarmigan (*Lagopus lagopus*) found at Grotta di Fumane, the great Auk (*Pinguinus impennis*), the Siberian Crane (*Grus leucogeranus*), and the Snowy Owl (*Nyctea scandiaca*) recovered at Romanelli and the Black-bellied Sandgrouse (*Pterocles orientalis*) identified at Grotta del Santuario della Madonna are good examples of a changed environment.

Acknowledgements

We are very grateful to the conference organizers Emanuela Cristiani and Valentina Borgia

We thank Luca Bondioli director of the Bioarchaeology Section, National Prehistoric and Ethnographic Museum L. Pigorini, Claudia Minniti, Francesca Alhaique and Dora Anselmo for translation and revision of the English text. We are very thankful to Ruth Blasco and the anonymous reviewer for their comments and advice.

I.F., M.G., A.T. analyzed the data, wrote and edited the manuscript. Photo by I. Fiore.

References

Alessio, M., Bella, F., Bachechi, F., Cortesi, C. 1966. University of Rome, Carbon-14 Dates IV. *Radiocarbon* 8, 401-404.

Alessio, M., Bella, F., Bachechi, F., Cortesi, C. 1967. University of Rome, Carbon-14 Dates V. *Radiocarbon* 9, 354-357.

Alhaique, F., Biondi, S.V., Cassoli, P.F., Recchi, A. Tagliacozzo, A. 1998. Modification in the exploitation of animal resources between the Middle Paleolithic and the Aurignacian at Grotta del Fossellone (Monte Circeo, Italy). *Proceedings of the XIII UISPP Congress*. Forlí, 8-14 September 1996. Forlì: Abaco, 571-576.

Alhaique, F. and Tagliacozzo, A. 2000. L'interpretazione dei dati faunistici nella ricostruzione delle strategie di sussistenza nel Paleolitico medio: l'esempio del Lazio. *Atti del 2° Convegno Nazionale di Archeozoologia.* Asti, 14-16 November, 1997. Forlì: Abaco, 111-124.

Alhaique, F. and Recchi, A. 2001. La Grotta di Ortucchio e il Fucino alla fine del Paleolitico: analisi tafonomica e zooarcheologica delle mammalofaune e delle avifaune. *Il Fucino e le aree limitrofe nell'antichità: atti del 2° convegno di archeologia in ricordo di Antonio Mario Radmilli e Giuliano Cremonesi*. Museo di Preistoria, Celano-Paludi, 26-28 November, 1999. Avezzano, 56-69.

Anzidei, A.P., Bietti, A., Cassoli, P., Ruffo, M., Segre, A.G. 1984. Risultati preliminari dello scavo in un deposito pleistocenico in località Rebibbia-Casal de'Pazzi (Roma). *Atti XXIV Riunione Scientifica Istituto Italiano di Preistoria e Protostoria nel Lazio.* October, 1982, 131-139.

Belluomini, G., Calderoni, G., Collina, C., Fedi, M., Fiore, I., Gallotti, R., Garofalo, B., Pennacchioni, M., Piperno, M., Salvadei, L., Santangelo, N., Santo, A., Tagliacozzo, A. 2007. La Grotta di Roccia San Sebastiano (Mondragone, Caserta). *Atti della XL Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria*, Strategie di insediamento fra Lazio e Campania in età preistorica e protostorica. Roma, Napoli, Pompei, 30, 319-331.

Bevilacqua, R. 1994. La Grotta Continenza di Trasacco. I livelli mesolitici ed epigravettiani. *Rivista di scienze preistoriche* 46, 3-39.

Blasco, R. and Fernández Peris, J. 2009. Middle Pleistocene bird consumption at level XI of Bolomor Cave (Valencia, Spain). *Journal of Archaeological Science* 36, 2213-2223.

Blasco, R. and Fernández Peris, J. 2012. A uniquely broad spectrum diet during the Middle Pleistocene at Bolomor Cave (Valencia, Spain). *Quaternary International* 252, 16-31.

Blasco, R., Rosell, J., Peris, J.F., Arsuaga, J.L., de Castro, J.M.B., 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, 124-144.

Blasco, R., Finlayson, C., Rosell, J., Sánchez Marco, A., Finlayson, S., Finlayson, G., Negro, J.J., Giles Pacheco, F., Rodríguez Vidal, J. 2014. The earliest pigeon fanciers. *Scientific Reports* 4, 5971. DOI:10.1038/srep05971

Blasco, R., Rosell, J., Rufà A., Sánchez Marco, A., Finlayson C. 2016. Pigeons and choughs, a usual resource for the Neanderthals in Gibraltar, in: Ruth Blasco and Marco Peresani (eds.). Humankind and the avian world: Zooarchaeological evidence for inferring behavioural evolutionary signatures. *Quaternary International* 421, 62-77.

Bochenski, Z.M., Tomek, T., Wilczyński, J., Svoboda, J., Wertz, K. 2009. Fowling during the Gravettian: the avifauna of Pavlov I, the Czech Republic. *Journal of Archaeological Science* 36, 2655-2665.

Boscato, P. 2004. I macromammiferi dell'Aurignaziano e del Gravettiano antico di Grotta Paglicci, in: Palma di Cesnola A. (ed.). *Paglicci. L'Aurignaziano e il Gravettiano antico*. Foggia: Grenzi, 49-62.

Broglio, A., Tagliacozzo, A., De Stefani, M., Gurioli, F., Facciolo, A. 2006. Aurignacian dwelling structures, hunting strategies and seasonality in the Fumane Cave (Lessini Mountains), in: Anikovich, M.V., Platonova, N.I. (eds.). *Kostenki and the Early Upper Palaeolithic of Eurasia: General Trends, Local Developments*. Kostenki, 23-26 August 2004. Russian Academy of Sciences, Voronezh. Saint-Petersburg: Nestor-Historia, 263-268.

Buisson, D. 1990. Les flûtes paléolithiques d'Isturitz (Pyrénées-Atlantiques). *Bulletin de la Société préhistorique française* 87 (10-12), 420-433.

Cassoli, P.F. 1972. Lo pteroclide (Aves, Pteroclidae) fossile nei livelli del Paleolitico superiore e medio nel Pleistocene dell'Italia meridionale. *Quaternaria* XVI, 225-245.

Cassoli, P.F. 1978. L'avifauna pre-würmiana di Torre in Pietra in Torre in Pietra, Roma. *Quaternaria. Storia Naturale e Culturale del Quaternario Roma* 20, 429-440.

Cassoli, P.F. 1992. Avifauna del pleistocene superiore delle Arene Candide, Praia e Grotta Romanelli (Italia). *Quaternaria Nova* II, 239-246.

Cassoli, P.F., de Giuli, C., Radmilli, A.M., Segre, A.G. 1982. Giacimento del Paleolitico Inferiore a Malagrotta (Roma). *Atti XXIII Riunione Scientifica IIPU "Il Paleolitico Inferiore in Italia"* Firenze: Istituto Italiano di Paleontologia Umana, 531-549.

Cassoli, P.F., Di Stefano, G., Tagliacozzo, A. 1999. I vertebrati dei livelli superiori (A ed ALFA) della serie stratigrafica di Notarchirico, in: Piperno, M. (ed.), *Notarchirico. Un sito del Pleistocene medio-iniziale nel bacino di Venosa (Basilicata)*. Venosa: Osanna Ed, 361-438.

Cassoli, P.F., Gala, M., Tagliacozzo A. 2003. La caccia e l'utilizzo alimentare degli uccelli a Grotta Romanelli durante le fasi finali del Pleistocene, in: Fabbri, P.F, Ingravallo, E., Mangia, A. (eds.). *Grotta Romanelli nel centenario della sua scoperta 1900-2000.* Lecce: Congedo, 91-111.

Cassoli, P.F. and Guadagnoli, F. 1987. Le faune del Riparo Salvini: analisi preliminare, in: AAVV. (eds.). *Riparo Salvini a Terracina. Una stazione di cacciatori-raccoglitori del Paleolitico superiore*, Quasar: Roma, 43-48.

Cassoli, P.F. and Tagliacozzo, A. 1994a. I resti ossei di macromammiferi, uccelli e pesci della Grotta Maggiore di S. Bernardino sui Colli Berici (VI). Considerazioni paleoeconomiche, paleoecologiche e cronologiche. *Bullettino di Paletnologia Italiana*, 85/N.S./III, 1-71.

Cassoli, P.F. and Tagliacozzo, A. 1994b. Considerazioni paleontologiche, paleoecologiche e archeozoologiche sui macromammiferi e gli uccelli dei livelli del Pleistocene superiore del Riparo di Fumane (VR) scavi 1988-91. *Bollettino del Museo Civico di Storia Naturale di Verona*, 18 (1991), 349-445.

Cassoli, P.F. and Tagliacozzo, A. 1997a. Butchering and Cooking of Birds in the Palaeolithic Site of Grotta Romanelli (Italy). *International Journal of Osteoarchaeology* 7/4, 303-320.

Cassoli, P.F. and Tagliacozzo, A. 1997b. Avifauna e Ittiofauna di Grotta di Castelcivita: considerazioni ecologiche ed inquadramento crono-stratigrafico, in: Gambassini, P. (ed.). *Il Paleolitico di Castelcivita, culture e ambiente*. Materiae 5. Napoli: Electa, 60-74.

Conard, N.J., Malina, M., Münzel, S.C. 2009. New flutes document the earliest musical tradition in southwestern Germany. *Nature* 460, 737-740.

Cremaschi, M., Ferraro, F., Peresani, M., Tagliacozzo, A. 2005. La Grotta di Fumane: nuovi contributi su stratigrafia, cronologia, fauna a macromammiferi e industrie musteriane, in: Broglio, A. and Dalmeri, G. (Eds.), *Pitture paleolitiche nelle Prealpi Venete: Grotta di Fumane e Riparo Dalmeri*. Memorie Museo Civico Storia Naturale di Verona II serie, Sezione Scienze dell'Uomo 9, Preistoria Alpina, nr. speciale. Caselle di Sommacampagna: Cierre, 12-22.

Dalmeri, G. 2004. Studi sul riparo Cogola (Carbonare di Folgaria – Trento). Frequentazione umana e paleoambiente. *Preistoria Alpina*, 40, 91-98.

Dalmeri, G., Cusinato, A., Kompatscher, K., Kompatscher, M. H., Bassetti, M., Neri, S. 2009. The Ochre Painted Stones from the Riparo Dalmeri (Trento). Development of the Research on the Art and Rituality of the Epigravettian Site, in: Proceedings of the Hugo Obermaier Society 49th Annual Meeting in Trento (10-14 of April, 2007). *Preistoria Alpina* 44, 95-119.

Delaney-Rivera, C., Plummer, T.W., Hodgson, J.A., Forrest, F., Hertel, F., Oliver, J.S. 2009. Pits and pitfalls: taxonomic variability and patterning in tooth mark dimensions. *Journal of Archaeological Science* 36/11, 2597-2608.

Dibble, H.L., Berna, F., Goldberg, P., Mcpherron, S.P., Mentzer, S. 2009. A Preliminary Report on Pech de l'Azé IV, Layer 8 (Middle Paleolithic, France). *PaleoAnthropology* 2009, 182-219.

Finlayson, C., Brown, K., Blasco, R., Rosell, J., Negro, J.-J., Bortolotti, G.-R., Finlayson, G., Sánchez Marco, A., Giles Pacheco, F., Rodríguez Vidal, J., Carrión, J.-S., Fa, D.-A., Rodríguez Llanes, J.-M. 2012. Birds of a Feather: Neanderthal Exploitation of Raptors and Corvids. *PLoS ONE* 7/9, e45927. DOI:10.1371/journal.pone.0045927

Fiore, I. and Tagliacozzo, A. 2005a. Lo sfruttamento delle risorse animali nei siti di altura e di fondovalle nel Tardoglaciale dell'Italia nord-orientale, in: Malerba, G. and Visentini, P. (eds.). *Atti del 4° Convegno Nazionale di Archeozoologia*. Pordenone 13-15 november 2003. Quaderni del Museo Archeologico del Friuli Occidentale 6. Pordenone: Comune di Pordenone, Museo Archeologico, 97-109.

Fiore, I. and Tagliacozzo, A. 2005b. Riparo Cogola: il contesto paleoecologico e lo sfruttamento delle risorse animali tra Epigravettiano e Mesolitico antico. *Preistoria Alpina* (2004) 40, 159-186.

Fiore, I., Gala, M., Tagliacozzo, A. 2004a. Ecology and subsistence strategies in the eastern Italian Alps during the Middle Palaeolithic. *International Journal of Osteoarchaeology* 14/3-4, 273-286.

Fiore, I., Pino Urìa, B., Tagliacozzo, A. 2004b. L'exploitation des petits animaux au Paléolithique supérieur-Mésolithique en Italie: l'exemple de la Grotta del Santuario della Madonna a Praia a Mare (Cosenza, Italie), in: Brugal, J.P. and Desse, J. (eds.), *XXIVèmes Rencontres Internationales d'Archéologie et d'Histoire d'Antibes Petits animaux et sociétés humaines; du complément alimentaire aux ressources utilitaires*. Antibes, 23-25 october 2003. Antibes: APDCA, 417-430.

Fiore, I., Gala, M., Romandini, M., Cocca, E., Tagliacozzo, A., Peresani, M. 2016. From feathers to food: reconstructing the complete exploitation of avifaunal resources by Neanderthals at Grotta di Fumane, unit A9, in: Ruth Blasco and Marco Peresani (eds.). Humankind and the avian world: Zooarchaeological evidence for inferring behavioural evolutionary signatures. *Quaternary International* 421, 134-153.

Gala, M. and Tagliacozzo, A. 2004. L'exploitation des oiseaux pendant le Paléolithique supérieur et le Mésolithique a Grotta della Madonna di Praia a Mare (Calabre, Italie), in: Brugal, J.P. and Desse, J. (eds.), *XXIVèmes Rencontres Internationales d'Archéologie et d'Histoire d'Antibes. Petits animaux et sociétés humaines; du complément alimentaire aux ressources utilitaires*. Antibes, 23-25 october 2003. Antibes: APDCA, 173-177.

Gala, M. and Tagliacozzo, A. 2005. L'avifauna dei livelli aurignaziani di Grotta di Fumane (VR). Risultati preliminari dello studio tafonomico, in: Malerba, G. and Visentini, P. (eds.). *Atti del 4° Convegno Nazionale di Archeozoologia*. Pordenone 13-15 november 2003. Quaderni del Museo Archeologico del Friuli Occidentale 6. Pordenone: Comune di Pordenone, Museo Archeologico, 53-57.

Gala, M. and Tagliacozzo, A. 2010. The avifauna from Late Glacial archaeological sites in Italy: a tentative synthesis, in: Prummel, W., Zeiler, J.T., Brinkhuizen, D.C. (eds.). *Birds in Archaeology. Proceedings of the 6th Meeting of the ICAZ Bird Working Group in Groningen (23.8 – 27.8.2008)* Gronigen Archaeological Studies 12. Eelde the Netherlands: Barkhuis, 205-218.

Gala M., Fiore I., Tagliacozzo, A. 2009. The specialised hunting of Otididae (little Bustard and great Bustard) of the Upper Palaeolithic from the Romanelli Cave (Pouilles, Italy), in: Fontana, L., Chauvière, F.-X., Bridault, A. (eds.). *In Search of Total Animal Exploitation. Case Studies from the Upper Palaeolithic and Mesolithic. Proceedings of the XVth UISPP Congress, Lisbon, 4-9 September 2006, Session C61, vol. 42*. British Archaeological Reports (International Series) 2040, Oxford: Archaeopress, 113-134.

Gambassini, P. (ed.). Il Paleolitico di Castelcivita, culture e ambiente. Materiae 5. Napoli: Electa.

Gaudzinski-Windheuser, S. and Niven, L. 2009. Hominin subsistence patterns during the Middle and Late Paleolithic in northwestern Europe, in: Hublin, J-J, and Richards, M.P. (eds.). *The evolution of Hominin diets: Integrating Approaches to the Study of Palaeolithic Subsistence*. Dordrecht: Springer Netherlands, 99-111.

Gourichon, L. 1994. *Les Harfangs (Nyctea scandiaca L.) du gisement magdalénien du Morin (Gironde). Analyse taphonomique des restes d'un rapace nocturne chassé et exploité par les hommes préhistoriques*. DEA Thesis, Université Lumière-Lyon II, Lyon, France.

Guleç, E., Howell, C.F., White, T.D. 1999. Dursunlu – a new Lower Pleistocene faunal and artifact-bearing locality in southern Anatolia, in: Ullrich, H. (ed.). *Hominid Evolution – Lifestyles and Survival Strategies*. Gelsenkirchen/Schwelm: Archaea, 349-364.

Gurioli, F., Fiore, I., Tagliacozzo, A., Malerba, G., Giacobini, G., Broglio, A. 2006. I resti di Macromammiferi del livello aurignaziano A2 della Grotta di Fumane (VR): analisi delle strutture d'abitato S16, S17, S18, S19, S20, in: Malerba, G. and Visentini, P. (eds.). *Atti del 4° Convegno Nazionale di Archeozoologia*. Pordenone 13-15 november 2003. Quaderni del Museo Archeologico del Friuli Occidentale 6. Pordenone: Comune di Pordenone, Museo Archeologico, 35-42.

Higham, T. F. G., Brock, F., Peresani, M., Broglio, A., Wood, R., Douka, K. 2009. Problems with radiocarbon dating the Middle and Upper Palaeolithic transition in Italy. *Quaternary Science Reviews* 28, 1257-1267.

Huguet, R. 2007. *Primeras Ocupaciones Humanas En La Península Iberica: Paleoeconomía En La Sierra de Atapuerca (Burgos) y La Cuenca de Guadix-Baza (Granada) Durante El Pleistoceno Inferior*. PhD Thesis, Universitad Rovira i Virgili, Tarragona, Spain.

Landt, J.M. 2007. Tooth marks and human consumption: ethnoarchaeological mastication research among forages of the Central African Republic. *Journal of Archaeological Science* 34, 1629-1640.

Laroulandie, V. 2000. Taphonomie et archéozoologie des Oiseaux en grotte: applications aux sites Paléolithiques du Bois-Ragot (Vienne), de Combe Saunière (Dordogne) et de La Vache (Ariège). PhD Thesis, Université de Bordeaux I, France.

Laroulandie, V. 2003. Exploitation des Oiseaux au Magdalénien en France: Etat des lieux, in: Costamagno, S., Laroulandie, V. (eds.), *Mode de vie au Magdalénien: Apports de l'archéozoologie/Zooarchaeological insights into Magdalenian lifeways. Actes du colloque 6.4 du XIVe Congrés du l'UISPP, Liége, Belgique, 2-8 septembre 2001*. British Archaeological Reports 1144. Oxford: Archaeopress, 129-138.

Laroulandie,V. 2005. Anthropogenic versus non-anthropogenic bird bone assemblages: New criteria for their distinction, in: O'Connor, T. (ed.). *Biosphere to Lithosphere, New studies in vertebrate taphonomy. Processings of the 9th Conference of the International Council of Archaeozoology.* Durham 23-28 august 2002. Oxford: Oxbow Books, 25-30.

Laroulandie, V. 2016. Hunting fast-moving, low-turnover small game: The status of the snowy owl (Bubo scandiacus) in the Magdalenian, *Quaternary International* 414, 174-197.

Laroulandie, V. and Lefèvre, C. 2014. The use of avian resources by the forgotten slaves of Tromelin Island (Indian Ocean). *International Journal of Osteoarchaeology* 24, 407-416.

Laroulandie, V., Costamagno, S., Cochard, D., Mallye, J.-B., Beauval, C., Castel, J.-C., Ferrié, J.-G., Gourichon, L., Rendu, W. 2008. Quand désarticuler laisse des traces : le cas de l'hyper-extension du coude. *Annales de Paléontologie* 94/4, 287-302.

Laroulandie, V., Faivre, J.P., Gerbe, M., Mourre, V. 2016. Who brought the bird remains to the Middle Palaeolithic site of Les Fieux (Southwestern, France)? Direct evidence of a complex taphonomic story, in: Ruth Blasco and Marco Peresani (eds.). Humankind and the avian world: Zooarchaeological evidence for inferring behavioural evolutionary signatures. *Quaternary International* 421, 116-133.

Lefèvre, C. and Pasquet, E. 1994. Les modifications post-mortem chez les oiseaux: l'exemple de l'avifaune holocène de Patagonie australe. *Artefacts* 9, 217-229.

Lloveras, L., Moreno-Garcia, M., Nadal, J. 2009. Butchery, cooking and human consumption marks on rabbit (Oryctolagus cuniculus) bones: An experimental study. *Journal of Taphonomy* 7, 179-201.

Lumley, H., Echassoux, A., Bailon, S., Cauche, D., Marchi, M.-P., Desclaus, E., Guennouni, K., Lacombat, F., Roger, T., Valenci, V. 2004. *Le sol d'occupation acheuléen de l'unité archeostratigraphique UA 25 de la grotte du Lazaret (Nice, Alpes-Maritimes)*. Aix-en-Provence: Edisud.

Martínez Valle, R., Guillem, P.M., Villaverde, V. 2016. Bird consumption in the final stage of Cova Negra (Xátiva, Valencia, in: Ruth Blasco and Marco Peresani (eds.). Humankind and the avian world: Zooarchaeological evidence for inferring behavioural evolutionary signatures. *Quaternary International* 421, 85-102.

Masini, F. and Abbazzi, L. 1997. L'associazione di mammiferi della Grotta di Castelcivita, in: Gambassini, P. (ed.). *Il Paleolitico di Castelcivita, culture e ambiente*. Materiae 5. Napoli: Electa, 33-59.

Medina, M.E., Teta, P., Rivero, D. 2012. Burning damage and small-mammal human consumption in Quebrada del Real 1 (Cordoba, Argentina): an experimental approach. *Journal of Archaeological Science* 39/3, 737-743. DOI: 10.1016/j.jas.2011.11.006

Morin, E. and Laroulandie, V. 2012. Presumed symbolic use of diurnal raptors by Neanderthals. *PLoS ONE* 7/3, e32856.

Mourer-Chauviré, C. 1975. *Les oiseaux du Pléistocène moyen et supérieur de France*. Documents du Laboratoire de Géologie de la Faculté de Sciences de Lyon 64. Lyon.

Mussi, M., Cocca, E., D'angelo, E., Fiore, I., Melis, R., Russ, H. 2008. Tempi e modi del ripopolamento dell'Appennino centrale nel Tardiglaciale: nuove evidenze da Grotta di Pozzo (AQ), in: Mussi, M. (ed.). *Il Tardiglaciale in Italia – Lavori in corso*. British Archaeological Reports (International Series) 1859. Oxford: Archaeopress, 111-131.

Mussi, M., D'angelo, E., De Angelis, G., Gala, M., Russ, H., Tagliacozzo, A., Fiore, I. 2015. Piccole risorse alimentari tra Tardiglaciale e Olocene: il caso di Grotta di Pozzo (Aquila). *L Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria, Preistoria del Cibo,* Sessione 2, Roma, 7-8 ottobre 2015.

Palma di Cesnola, A. (Ed.) 2004. *Paglicci. L'Aurignaziano e il Gravettiano antico*. Foggia: Grenzi.

Pedergnana, A. and Blasco, R. 2016. Characterising the exploitation of avian resources: An experimental combination of lithic use-wear, residue and taphonomic analyses, in: Ruth Blasco and Marco Peresani (eds.). Humankind and the avian world: Zooarchaeological evidence for inferring behavioural evolutionary signatures. *Quaternary International* 421, 255-269.

Peresani, M. 2001. An overview of the Middle Palaeolithic settlement system in North-Eastern Italy. In: Conard NJ, editor. Settlement Dynamics of the Middle Palaeolithic and Middle Stone Age Tubingen: Tubingen Publications in Prehistory, Verlag,. 485-506.

Peresani, M., Fiore, I., Gala, M., Romandini, M., Tagliacozzo, A. 2011. Late Neanderthals e the intentional removal of feathers as evidenced from bird bone taphonomy at Fumane cave 44ky BP, Italy, *Proceedings of the National Academy of Sciences* 108/10, 3888-3893.

Picin, A., Peresani, M., Falguères, C., Gruppioni, G., Bahain, J-J. 2013. San Bernardino Cave (Italy) and the Appearance of Levallois Technology in Europe: Results of a Radiometric and Technological Reassessment. *PLoS ONE* 8(10): e76182. doi:10.1371/journal.pone.0076182.

Radovčić, D., Sršen, A.O., Radovčić, J., & Frayer, D.W. 2015. Evidence for Neanderthal jewelry: modified White-Tailed Eagle claws at Krapina. *PLoS ONE* 10/3, e0119802.

Roger, T. 2004. *L'avifaune du Pléistocène moyen et supérieur du bord de la Méditerranée européenne: Orgnac 3, Lazaret (France), Caverna delle Fate, Arma delle Manie (Italie), Kalamakia (Grèce), Karain E (Turquie). Paléontologie, Taphonomie et Paléoécologie*. PhD Thesis, Museum national d'histoire naturelle, Paris.

Romandini, M. 2012. *Analisi archeozoologica, tafonomica, paleontologica e spaziale dei livelli Uluzziani e tardo-Musteriani della Grotta di Fumane (VR). Variazioni e continuità strategico comportamentali umane in Italia Nord Orientale: i casi di Grotta del Col della Stria (VI) e Grotta del Rio Secco (PN)*. PhD Thesis, Università degli studi di Ferrara.

Romandini, M., Peresani, M., Laroulandie, V., Metz, L., Pastoors, A., Vaquero, M., Slimak, L. 2014. Convergent evidence of Eagle talons used by Late Neanderthals in Europe: a further assessment on symbolism. *PLoS One* 9 (7), e101278.

Romandini, M., Fiore, I., Gala, M., Cestari, M., Tagliacozzo, A., Guida, G., Peresani, M. 2016. Neanderthal scraping and manual handling of vulture wing bones: evidence from Fumane cave. Experimental activities and comparison, in: Ruth Blasco and Marco Peresani (eds.). Humankind and the avian world: Zooarchaeological evidence for inferring behavioural evolutionary signatures. *Quaternary International* 421, 154-172.

Ruiu, F.D., Fiore, I., Gala, M., Collina, C., Pennacchioni, M., Piperno, M., Calderoni, G., Tagliacozzo, A. 2012. The fauna from the Gravettian levels of Roccia San Sebastiano Cave (Mondragone, Caserta, Italy), in: Lefèvre, C. (ed.). *Proceedings of the General Session of the 11th International Council for Archaeozoology Conference*. British Archaeological Reports (International Series) 2354. Oxford: Archaeopress, 99-111.

Serjeantson, D. 2009. *Birds*. Cambridge Manuals in Archaeology. Cambridge: Cambridge University Press.

Soressi, M., Rendu, W., Texier, J.P., Daulny, L., d'Errico, F., Laroulandie, V., Maureille, B., Niclot, M., Tillier, A.M. 2008. Pech-del'Azé I (Dordogne, France): nouveau regard sur un gisement moustérien de tradition acheuléenne connu depuis le 19ème siècle, in: Jaubert, J., Bordes, J.G., Ortega, I., (eds.). *Les sociétés du Paléolithique* *dans un Grand Sud-Ouest de la France: nouveaux gisements, nouveaux résultats, nouvelles méthodes : Journées SPF, Université Bordeaux 1, Talence, 24-25 novembre 2006*. Société préhistorique Française, Mémoire XLVII, 95-132.

Tagliacozzo, A. 2003. Archeozoologia dei livelli dell'Epigravettiano finale di Grotta Romanelli (Castro, Lecce). Strategie di caccia ed economia di sussistenza. Grotta Romanelli nel centenario della sua scoperta (1900-2000), in: Fabbri, P.F, Ingravallo, E., Mangia, A. (eds.). *Grotta Romanelli nel centenario della sua scoperta 1900-2000*. Lecce: Congedo, 169-216.

Tagliacozzo, A. and Fiore, I. 1998. Butchering of small mammals in the Epigravettian levels of the Romanelli Cave (Apulia, Italy), in : Brugal, J.-P., Meignen, L., Patou-Mathis, M. (eds.), *Economie préhistorique : les comportements de subsistance au Paléolithique, XVIIIe rencontres internationales d'Archéologie et d'Histoire d'Antibes. Actes des rencontres.* Antibes 23-25 octobre 1997. Sophia-Antipolis: APDCA, 413-423.

Tagliacozzo, A. and Fiore, I. 2009. Hunting strategies in a mountain environment during the late Glacial in north eastern Italy. *Preistoria alpina* 44, 79-94.

Tagliacozzo, A. and Gala, M. 2000. Sfruttamento e macellazione degli Anseriformi nel giacimento dell'Epigravettiano finale di Grotta Romanelli (LE). *Atti del 2° Convegno Nazionale di Archeozoologia.* Asti, 14-16 Novembre, 1997. Forlì: Abaco, 151-166.

Tagliacozzo, A. and Gala, M. 2002. Exploitation of Anseriformes at two Upper Palaeolithic sites in Southern Italy: Grotta Romanelli (Lecce, Apulia) and Grotta del Santuario della Madonna di Praia a Mare (Cosenza, Calabria). *Acta Zoologica Cracoviensia* 45, 117-131.

Tagliacozzo, A. and Gala, M. 2004. L'avifauna dei livelli 24-22 (Aurignaziano e Gravettiano antico) di Grotta Paglicci: l'aspetto ambientale e quello economico, in: Palma di Cesnola A. (ed.). *Paglicci. L'Aurignaziano e il Gravettiano antico*. Foggia: Grenzi, 71-90.

Tagliacozzo, A., Romandini, M., Fiore, I., Gala, M., Peresani, M., 2013. Animal exploitation strategies during the Uluzzian at Grotta Fumane (Verona, Italy), in: Clark, J.L., Speth, J.D. (eds.). *Zooarchaeology and Modern Human Origins: Human Hunting Behavior during the Later Pleistocene*. Vertebrate Paleobiology and Paleoanthropology Series. Dordrecht: Springer, 129-150.

Villa, P. and Mahieu, E. 1991. Breakage patterns of human long bones. *Journal of Human Evolution* 21, 27-48.

Wilkens, B. 1993. L'Avifauna, in: Martini, F. (ed.). *Grotta della Serratura a marina di Camerota culture e ambienti dei complessi olocenici*. Montelupo: Garlatti e Razzai, 83-88.

White, T.D. 1992. *Prehistoric Cannibalism at Mancos 5M TURM-2346*. Princeton, NJ: Princeton University Press.

Lithic raw material circulation and settlement dynamics in the Upper Palaeolithic of the Venetian Prealps (NE Italy)

A key-role for palaeoclimatic and landscape changes across the LGM?

Stefano Bertola[1], *Federica Fontana*[1] *& Davide Visentin*[1,2]

Abstract

The Venetian Prealps preserve one of the richest archives relating to prehistoric human settlement in the Southern Alps. Our study focused on the lithic assemblages from some main Upper Palaeolithic sites of this area in order to investigate the raw materials procurement behavior of Modern Humans throughout time. Climate changes between MIS 3 and MIS 2 played an important role by affecting human settlement and life-styles. Modern Humans arrived in north-eastern Italy around 42 kyrs cal BP attesting an almost exclusive exploitation of regional lithic resources with few evidence (1%) of mid-distance procurement. In the Gravettian record, that is only preserved in the Lessini mountains and Berici hills, exploited cherts are exclusively local, with procurement distances never exceeding 40 km. A lack of data marks the period between ca. 28 and 24 kyrs cal BP while a sharp climatic and environmental change characterizes the LGM. During this period, Late Gravettian and Early Epigravettian assemblages are documented only in the eastern Berici hills and are represented by occasional hunting stands. Most of the exploited lithic raw materials come from the Umbria-Marches Apennines, attesting displacements of more than 250 km. Similar environmental con-

1 Università degli Studi di Ferrara, Dipartimento di Studi Umanistici – Sezione di Scienze Preistoriche e Antropologiche, Corso Ercole I d'Este 32, 44100 Ferrara, Italy. E-mail: bts@unife.it; federica.fontana@unife.it. Corresponding author: S. Bertola.

2 UMR 5608 TRACES, Université Toulouse Jean Jaurès, Maison de la Recherche, 5 allées A. Machado, 31058 Toulouse Cedex 9, France. E-mail: davide.visentin@unife.it.

in: Borgia, V. and E. Cristiani (eds.) 2018: *Palaeolithic Italy. Advanced studies on early human adaptations in the Apennine peninsula*, Sidestone Press Academics (Leiden), pp. 219-246.

ditions persisted until the early Lateglacial even if a climate improvement is attested since around 18.5 kyrs cal BP. At Riparo Tagliente a few Umbria-Marches Apennines cherts are still attested between ca. 17 and 15 kyrs cal BP, represented by retouched tools, a few cores and some maintenance and production blanks, within a lithic assemblage mostly realized on local (Lessini) cherts. Climate amelioration, followed by a rapid diffusion of forest environments across the Po plain is documented after 14.5 yrs cal BP. In connection with this widespread afforestation the importation of long distance Apennines cherts ceases and the sites of the Venetian area undergo a "regionalization" process marked by the exclusive exploitation of local resources.

Keywords: Upper Palaeolithic, North-eastern Italy, Venetian Prealps, Lithic raw materials, provisioning territories, Palaeoenvironmental changes.

1. Introduction

The Venetian Prealps are one of the areas in Italy where the Palaeolithic and Mesolithic record is best documented and they represent an interesting laboratory for the study of the earliest phases of human settlement in the country. The Prealps are very rich in good quality cherts belonging to the Upper Jurassic-Eocene interval. Different sectors with similar sedimentary sequences but very distinctive features were identified through geological prospection and analysis. A fine resolution characterization of the siliceous rocks exploited by Palaeolithic groups and their attribution to the relative geological formations was thus achieved through petrographic analysis.

In this paper we report results of a research carried out over more than 20 years by comparing the archaeological record of the main Upper Palaeolithic sites of this area in a diachronic perspective (Fig. 1). These are mostly located along the hills facing the Venetian plain in easily accessible positions. Their preservation was made possible by the low exposure to ice erosion and alluvial deposition (several meters thick in plain contexts). In particular, the attribution of the exploited lithotypes to the regional geological formations allowed reconstructing provisioning dynamics and mobility of human groups through time. Results were then compared to palaeoclimatic and palaeoenvironmental data on the evolution of the area.

2. Environmental setting

During the Upper Palaeolithic the geographic and environmental setting of the Southern Alps and adjacent Po-Adriatic plain were greatly influenced by glacial events (*e.g.* distribution of ice and land-cover, Adriatic Sea level). Generally climate was colder than nowadays. Models estimate the marine regression between -60 to -90 m during MIS 3 (Waelbroeck *et al.* 2002; Siddall *et al.* 2003; Siddall *et al.* 2008). Between 40 and 23 kyrs cal BP data indicate a partial afforestation (50-70% at Fimon lake, Berici) of the Venetian Prealps with isolated forests surrounded by steppe. In the central sector of the Po plain, models suggest the presence of diversified arid and semi-desertic environments dominated by steppe both during MIS 3 and MIS 2 (Pini *et al.* 2010). Throughout the LGM (23-19 kyrs cal BP, according to Mix *et al.* 2001) the Alps were largely covered by ice and therefore inaccessible. Only the Berici and the Euganei hills,

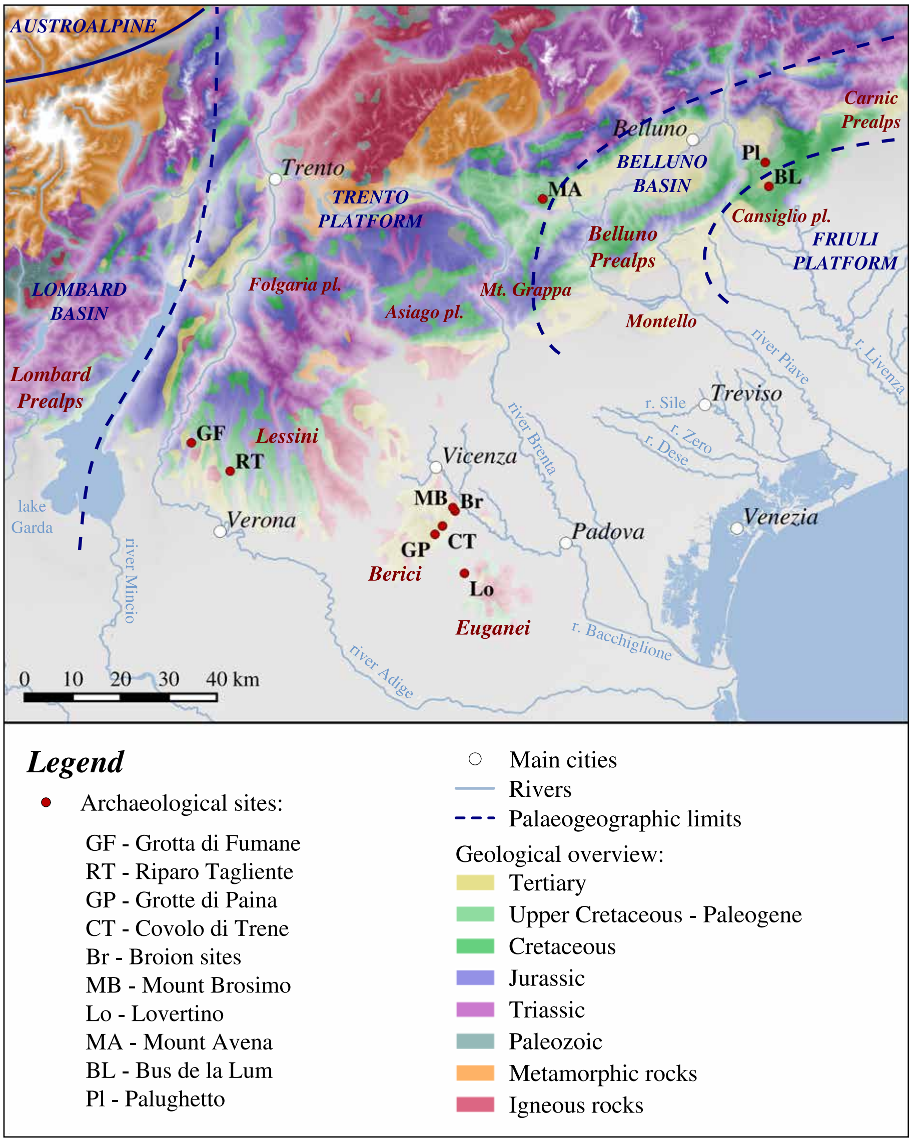


Figure 1. Location of the Upper Palaeolithic evidence with respect to the main current geographical and geological features. Blue lines indicate the main sedimentary basins (palaeogeography) affecting raw material characteristics. Raw data were provided by the Geoportale Nazionale (available at: http://www.pcn.minambiente.it).

rising isolated from the Venetian plain, were free of glaciers and constituted important ecological refugia (Kaltenrieder *et al.* 2009). The marine regression during the LGM is estimated between -120 and -135 m: the Adriatic sea coastline, interrupted by the palaeo-Po fan delta, was located between Pescara and Zadar (Suric and Juracic 2010; Maselli *et al.* 2011; 2014). A vast steppe-dominated alluvial plain stretched between the Southern Alps, the Northern Apennines and the Dalmatian coast. It was populated by herds of ungulates along with others mammals as testified by the findings of the

Settepolesini quarry (Bondeno, Ferrara), where the presence of *Bison* is attested up to 16,341-15,877 cal BP (13,400±70 BP; Gallini and Sala 2001; Sala 2007). *Bison priscus* was the most representative species attested in various spots along the Northern Apennines slope between Emilia and Marches (Sala 1987; Govoni 2003). About 19 kyrs cal BP a gradual and general climate amelioration began (Lambeck and Chappell 2001; Waelbroeck *et al.* 2002). In the Southern Alps, areas covered by ice started to reduce and the permafrost began melting. The sudden deglaciation caused slope instability (Casadoro *et al.* 1976) and river aggradation. Massive alluvial deposits organized in several adjacent megafans deposited in the Venetian-Friulian foreland (Fontana *et al.* 2008). The consequent sea level growth led to the progressive flooding of the Northern Adriatic plain and to a rapid shifting of the coastline towards the north. In the Venetian Prealps a steppe environment with reduced park tree forests prevailed until around 17 kyrs cal BP (Kaltenrieder *et al.* 2009). The arboreal species rate in the pollen series vary between 20 and 50% and the tree-line is estimated to be around 700-800 m a.s.l. (Ravazzi *et al.* 2004). The progressive warming brought about the establishment of the first rather closed forests in Northern Italy around 16 kyrs cal BP (Vescovi *et al.* 2007), but it was only with the beginning of the Bølling (ca. 14.5 kyrs cal BP) that a sharp increase in precipitations led to the complete afforestation of the Venetian-Po plain.

3. Geological overview and regional lithic resources

The Venetian Prealps constitute the junction between the Southern Alps and the Venetian plain. Slightly raised and not affected by a strong erosion, the bedrock in this area includes the most recent sedimentary sequences of the entire Southern Alps. Cherts are common both in neritic and pelagic marine series aged between the Upper Jurassic and Eocene (Fig. 2). As far as flaking is concerned, the best lithotypes correspond to the Biancone/Maiolica, Scaglia Variegata Alpina and Scaglia Rossa pelagic formations (Jurassic-Cretaceous), extensively outcropping in the whole area with thicknesses up to 400 metres. The sedimentological and petrographic features of these formations (and cherts) were influenced essentially by the palaeogeography of the substratum, while the current integrity of the chert blocks is often conditioned by tectonic faults, lithostatic decompression and thermoclastic stresses (the latter two increase at altitudes higher than 1000 m a.s.l.) (Bertola *et al.* 2007a).

3.1. Baldo and Lessini mountains (chert outcrops up to 1500 m)

The westernmost elevations include the Baldo and the Lessini, separated by the Adige valley (Fig. 1). In this area chert quality, abundance and variability has no equal in the entire Prealps. Cherts are included within the following Mesozoic and Cenozoic formations: Calcari Grigi (CG), Rosso Ammonitico (RA), Biancone (BI), Scaglia Variegata Alpina (SVA), Scaglia Rossa (SR) and Eocene limestones (EOC). Cherts differ by age, fossil content, texture, mineralogy, colour and mechanical properties (Bertola 2001; 2016). These formations, little disturbed by tectonics, constitute the bedrock of the gentle hills reaching the Venetian plain. In the Baldo chain the chert outcrops are mainly distributed on the eastern slope, towards the Adige Valley. In the Lessini the best outcrops are placed in the medium-lower reliefs, along the main valleys and the ridges separating them. Generally the most suitable chert blocks can be collected in the residual soils and karst wells.

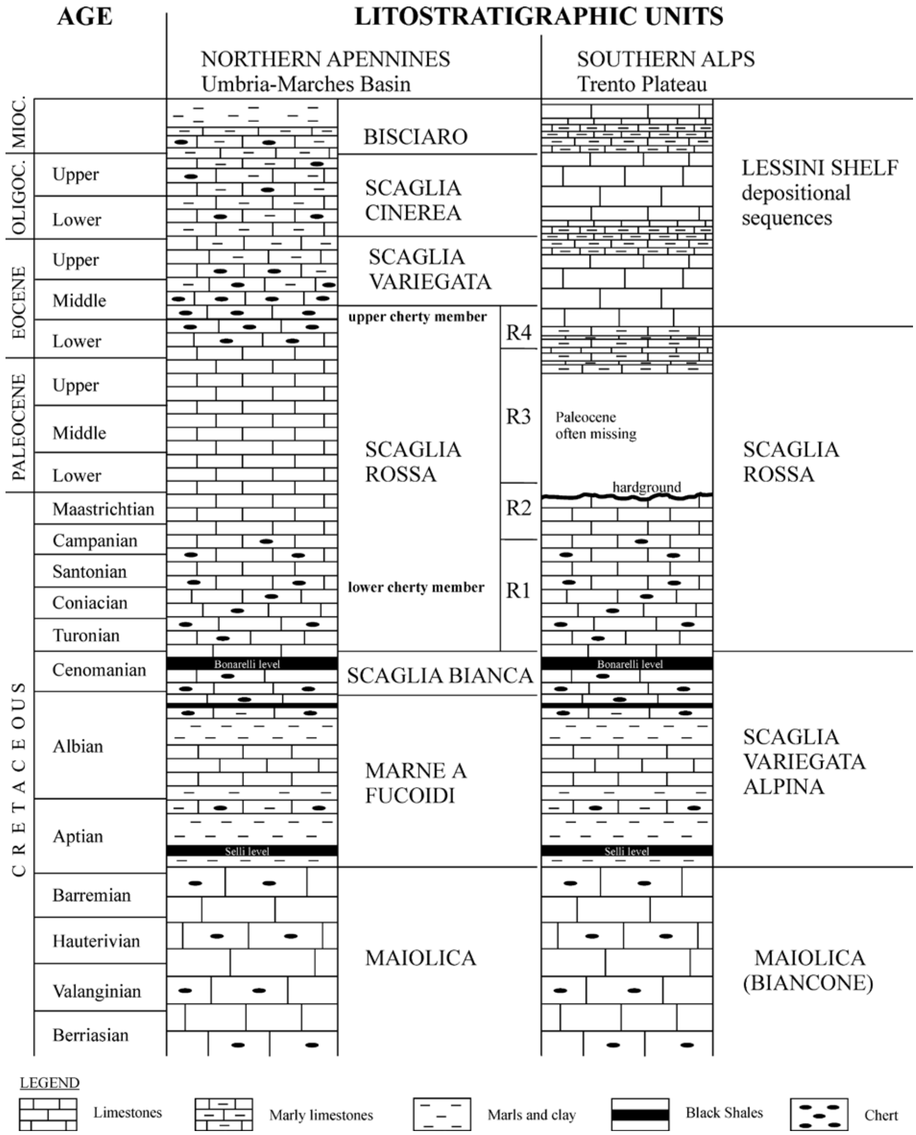


Figure 2. Comparison of the Umbria-Marches Basin and Southern Alps (Trento Plateau) schematic stratigraphic cherty series (after Bertola 2012, modified).

3.2. Berici-Euganei hills (chert outcrops up to 400 m)

About 10-30 km southeast of the Lessini, two hilly ranges, with different genesis and bedrock, emerge from the Venetian plain: the Berici and the Euganei (Fig. 1). The Berici are the extension of the Lessini, while the Euganei were generated by Eocene to Oligocene magmatic intrusions that raised and in some cases cut the Mesozoic and Cenozoic sedimentary sequences. The Berici are mainly formed by Cenozoic neritic limestones with sporadic cherts. In a restricted area at their eastern foothill the Upper Cretaceous cherty SR crops out. This formation is much more exposed in the Euganei and in the low hills interposed between the Berici and Euganei, where good lithotypes are very frequent. The underlying Middle Cretaceous – Upper Jurassic cherty SVA and BI outcrops are even more limited. The Berici-Euganei Scaglia Rossa cherts are much more abundant and diversified than the Baldo-Lessini ones and are in great part recognizable (Bertola 1996).

3.3. Folgaria-Asiago plateaus; Grappa massif (chert outcrops up to 1700 m)

Northeast of the Lessini, in a more internal position, are located the Folgaria and Asiago plateaus and the Grappa massif (Fig. 1), where the outcropping cherty series are discontinuous and incomplete (as a consequence of erosional processes activated by Alpine orogeny). BI is, by far, the most abundant formation with a considerable thickness (100-200 m) with respect to the Baldo-Lessini one (30-70 m) (Bertola and Cusinato 2004; Wierer and Bertola 2016). In the innermost sector of the area, tectonic processes, together with lithostatic decompression and thermoclastic stress, had a high impact on chert integrity. The best blocks can be collected within the residual soils of the plateaus (Peresani 1994; Bertola *et al.* 2007a).

3.4. Belluno Prealps (chert outcrops up to 1500 m)

From a palaeogeographic point of view, the Grappa massif constitutes the eastern limit (NE-SW oriented) of the Trento Plateau (which comprises all of the above described locations). Westwards the Belluno Basin is found (Fig. 1). In this area, since the Jurassic, the pelagic sequence was periodically influenced by re-sedimentation of neritic bioclastic sediments alimented by the edge of the Friuli Platform, which remained active until the end of the Cretaceous (Winterer and Bosellini 1981; Masetti and Bianchin 1987). In the very proximal areas these phenomena were so frequent that the formations are difficult to separate and have been grouped with the generic term of Soccher limestone (SOC) (Gnaccolini 1968). The alternation of micritic (pelagic) and coarser (resedimented) limestones strongly affected the distribution of cherts in these areas. The higher porosity of the coarser horizons favoured the penetration of silica rich fluids and the subsequent silicification. The BI reaches the greatest thickness (about 300 meters) but fine crystalline cherts can be found only in the areas furthest from the Friulian margin, close to the Grappa massif. The SR cherts, very frequent and of excellent quality, mostly belong to the Campanian-Maastrichtian range, when the bathymetric differences were definitively equalized. In isolated areas very close to the Friuli Platform (Alpago and Cansiglio), above and partly eteropically correlated to the SR, the Maastrichtian Col Indes (CI) and Scaglia Grigia (SG) formations deposited, both yielding medium to low quality cherts (Peresani and Bertola 2010; Visentin *et al.* 2016).

3.5. Molasse and Quaternary deposits

Cherts belonging to the above described formations have also been transported by marine (Molasse, Oligo-Miocene) and fluvial-glacial (Quaternary) processes. The Molasse conglomerate deposits are exposed and accessible exclusively around Vittorio Veneto and on the Montello (north of Treviso) (Fig. 1). Among cobbles transported from the dismantling formations to the north, cherts are also represented. They are intensively altered both by transport and pedogenesis and therefore scarcely suitable for knapping. The size of the exploitable blocks does not exceed 10 cm (Grandesso and Stefani 2008).

The high Venetian plain is crossed by detrital fans, which became very large after the LGM (megafan), alimented by the dismantling Alpine areas. In the investigated area the main megafans were the Piave, the Brenta and the Adige ones respectively alimented (in their last tract) by the Belluno, the Asiago-Grappa and the Baldo-Lessini Prealps. The detrital and pebbles cherts composition reflects their respective alimentation basins. Anyway they occur with low frequencies and their frequent diaclases limit the potential knapping suitability. Currently there is no evidence of exploitation of such deposits during the Upper Palaeolithic.

3.6. Extra-regional resources attested in the Venetian sites

Some extra-regional raw materials were imported from the Northern Apennines (Adriatic slope), where the Umbria-Marches Basin series crops out (Cresta and Deiana 1986; Alvarez and Montanari 1988; Centamore *et al.* 1989). This sedimentary bedrock is rich of good quality cherts with an even bigger variability than that of the Southern Alps sequence. Cherts are common in the following Jurassic-Miocene pelagic formations: Corniola (CO), Calcari Diasprigni (CD), Maiolica (MAI), Marne a Fucoidi (MF), Scaglia (SC) complex and Bisciaro (BIS) (Fig. 2 and 3). The best lithotypes in terms of abundance, size and quality are the MAI (Tithonian-Aptian) and SC (Bianca – SCB, Rosata – SCR, Variegata – SCV, Cinerea – SCC; Albian-Oligocene) formations. The SCR cherts (Lower Turonian-Middle Eocene) are the most characteristic of the Umbria-Marches region especially those included in Eocene layers (Bertola 2012).

4. Methods

Cherts are sedimentary rocks derived from the diagenesis of siliceous sediments, of which they often inherit textural features and paleontological content. They can, thus, be studied with a geological approach based on the identification and description of these features allowing the attribution to a specific formation or, even, a microfacies (Flügel 2010). The area between the Southern Alps and the Northern Apennines was intensively prospected during the last 20 years and cherts were sampled both in primary and secondary deposits. This large geological collection was used as a reference for comparison with archaeological assemblages. Chert artefacts were firstly attributed to the corresponding geological formation by detecting eventual diagnostic informations, *i.e.* differences in age, hue, morphology and size, structures, textural features, mineralogy, micropaleontology and rheology. The microfossils have been studied with the help of specific Atlas (Bolli *et al.* 1985; Premoli Silva and Sliter 2002;) and several publications dedicated to the area with illustrations, thin sections and drawings. A critical examination of these characteristics allowed the chrono-stratigraphic attribution of the samples thus supporting the identification of the geological formation of origin. Secondly the geographical distribution of the formations and their horizontal variability in relation to paleogeography were considered (Bosellini and Winterer 1975; Winterer and Bosellini 1981, for an overview). The features of the cherty formation may vary considerably both in time and space within a wide sedimentary basin. This is due to different factors including syn- and post-depositional processes. Such variability appears at different scales involving both small or vast areas. Mapping this variability

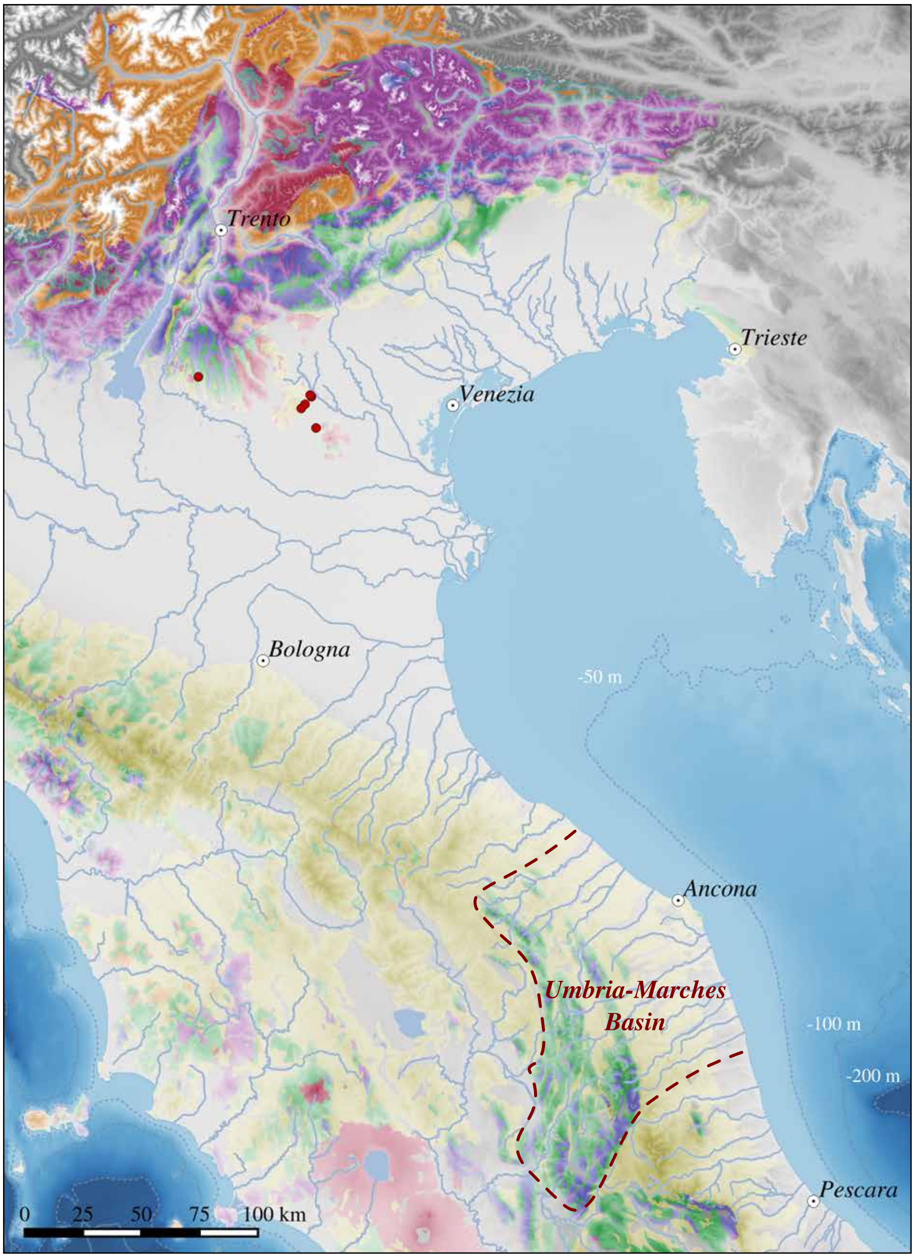


Figure 3. Current location of the deformed Umbria-Marches Basin, along the Adriatic slope of the Northern Apennines. Within the dashed line are included also slope deposits, river and stream beds where some of the cherts could have been collected. Red dots indicate the sites in the studied area that yielded artefacts made from Umbria-Marches cherts. For the legend of geological units refer to Fig.1. Raw data were provided by Geoportale Nazionale (available at: http://www.pcn.minambiente.it) and by EMODnet portal (available at: http://www.emodnet.eu).

is essential in order to formulate hypotheses related to the management (provisioning, mobility, exchanges) of lithic resources by prehistoric groups (Bertola 2016).

Further information can be deduced by analyzing the natural surfaces of archaeological artefacts which may indicate the origin of the blocks, *i.e.* whether they were collected from detritic covers, more or less far from the outcrops (blocks with sharp edges bearing traces of gravitational transport along the slopes), alluvial deposits (more or less pronounced roundness), soils or karst cavities (chemical dissolution of carbonates with no traces of transport; impregnation of residual red clay; Fe and Mn crusts).

5. Raw material exploitation in the Upper Palaeolithic

5.1. The Aurignacian record

The first cultural complex undoubtedly related to Modern Humans in Europe is the Protoaurignacian (Bertola *et al.* 2013; Broglio *et al.* in press). Its appearance in the Venetian Prealps is dated between 42 and 41 kyrs cal BP (Table 1). Most sites are located near the entrance of wide valleys, close to the adjacent plain, at altitudes generally lower than 400 m.

Lessini, Grotta Fumane, layers A2-D3. Situated in a tributary valley of Valpolicella, on the western Lessini (Fig. 1), this site is well-known for the extraordinary richness of the finds (Broglio and Dalmeri 2005). Protoaurignacian groups exploited almost exclusively the Lessini cherts (Table 2) selecting the most idoneous types (BI and SVA) for the production of blades and, in particular, of lamellar blanks destined to be transformed into *Dufour* bladelets. The presence of a small radiolarite (RAD) block coming from about 50 km westward (Lombard Basin) which was flaked on-site is also attested (Broglio *et al.* 2005).

Berici, Grotta Paina (Grottina Azzurra, layers 8-9). Grotta Paina is located in the steepy southeastern rocky slope of the Berici hills (Fig. 1). Layers 9 and 8, identified in a niche called "Grottina Azzurra", yielded a poor lithic assemblage attributed to the Protoaurignacian (Bartolomei *et al.* 1988). Exploited cherts mainly come from the Berici-Euganei area. SR was flaked on-site to produce lamellar blanks then transformed into *Dufour* bladelets and BI both for blade and bladelet production. The less exploited Lessini cherts are represented by bladelets belonging to two lithotypes of SVA.

Berici, Riparo Broion, layers 1f-1g. It is a rockshelter located on the eastern slope of the Berici hills, at the base of a south-facing rocky wall. In the Upper Palaeolithic series, Aurignacian levels are the richest. Besides lithic artefacts, among which splintered pieces are dominant, combustion structures and a few ornamental objects were recovered (De Stefani *et al.* 2005; Bertola *et al.* 2007b). Most recently the cultural attribution of these level was questioned and the lithic assemblages are currently under review (Peresani pers. com.). As for the nearby Grotta Paina, two provisioning areas were identified (Table 2). The Berici-Euganei cherts are the most represented (54%, short-distance procurement). The BI lithotypes were preferentially selected although being rarer than SVA and SR. BI cherts were flaked exclusively for blade and bladelet productions. Mid-distance provisioning in the Lessini is attested by BI lithotypes (gray to dark gray) which do not crop in the Berici-Euganei area. Other lithotypes belong to the SVA and to EOC formations. The assemblage suggests the exploitation of outcrops situated east of Valpantena (central – eastern Lessini).

Lessini, Riparo Tagliente, layer 25. Riparo Tagliente is located a few kilometres eastwards of Fumane, along the Valpantena (Fig. 1). Being the Protoaurignacian layer largely reworked it was only possible to carry out a preliminary qualitative assessment (Bartolomei *et al.* 1980). The raw material provisioning territory seems to be limited to the Lessini.

Belluno Prealps, Monte Avena. A site specialized in the extraction of local good quality SR cherts was identified north of Feltre, at 1450 m a.s.l. (Lanzinger and Cremaschi 1988) (Fig. 1). Radiometric datings are not available. Most artefacts are represented by flaking wastes while products are supposed to have been transported elsewhere. Exploited cherts have high qualitative standards. The altitudinal location of the site attests the presence of accessible and ice-free areas in the medium mountain during an indeterminate phase of MIS 3.

5.2. The Gravettian record

In the Venetian Prealps a Gravettian-Early Epigravettian reference sequence is still missing (Broglio *et al.* 2009). A few Gravettian assemblages were identified exclusively in the Lessini and Berici hills representing isolated ecological niches during a phase characterized by a progressive climate cooling.

Site	Layer	Lab. ID	Method	Material	Radiocarbon age	Cal. age BP (2σ)
Protoaurignacian						
Gr. Paina	9	UtC-2695	AMS	bone	38600 ± 1400	45725 – 40614
Gr. Paina	9	UtC 2042	AMS	bone	37900 ± 800	43496 – 40956
Gr. Fumane	A2R	LTL375A	AMS	charcoal	34312 ± 347	39737 – 38134
Gr. Fumane	A2 st. 19	Ly-1286 OxA	AMS	charcoal	32415 ± 1045	39335 – 34550
Gr. Fumane	A2 st. 19	GrA-16231	AMS	bone	33140 ± 460	38523 – 36249
Gr. Fumane	A2 st. 16	Ly-9920	conv.	charcoal	31300 ± 300	35874 – 34633
Gr. Fumane	A2 st. 14 base	OxA-6465	AMS	charcoal	31620 ± 500	36633 – 34573
Gr. Fumane	A2 st. 14 base	OxA-8053	AMS	charcoal	33640 ± 440	39011 – 36650
Gr. Fumane	A2 st. 14, liv. B2	Utc-2690	AMS	charcoal	34200 ± 900	40824 – 36464
Gr. Fumane	A2 st. 14, liv. B1	UtC-2689	AMS	charcoal	35400 ± 1100	42281 – 37810
Gr. Fumane	A2 st. 14, liv. A	UtC-2688	AMS	charcoal	36800 ± 1200	43420 – 39022
Gr. Fumane	A2 st. 14, top	OxA-8052	AMS	charcoal	34120 ± 460	39793 – 37277
Gr. Fumane	A2 st. 14, top	OxA-6566	AMS	charcoal	31900 ± 1100	38904 – 33997
Gr. Fumane	A2 st. 10	UtC-1774	AMS	charcoal	40000 ± 4000	… – 40034
Gr. Fumane	A2 st. 10	UtC-2051	AMS	charcoal	32800 ± 400	38225 – 36001
Gr. Fumane	A2 st. 9	UtC-2044	AMS	charcoal	31600 ± 400	36309 – 34734
Gr. Fumane	A2	UtC-2048	AMS	charcoal	36500 ± 600	42114 – 39954
Gr. Fumane	A2	OxA-8054	AMS	charcoal	33160 ± 400	38440 – 36353
Gr. Fumane	A2	OS-5871	AMS	marine shell	32700 ± 140	37146 – 36201
Gr. Fumane	A2	UtC-2047	AMS	charcoal	32100 ± 500	37541 – 34932

Table 1. Available radiocarbon datings for the studied sites and levels (after Broglio and Improta 1995; Broglio and Dalmeri 2005; De Stefani et al. 2005; Fontana et al. 2012; Peresani et al. 2000; Soubrier et al. 2016.). Radiocarbon dates were calibrated with OxCal 4.2, using the calibration curve IntCal13 (Reimer et al. 2013).

Gr. Fumane	A2	OS-5999	AMS	marine shell	32000 ± 90	36196 – 35615
Gr. Fumane	A2	OxA-11360	AMS	charcoal	31830 ± 260	36278 – 35132
Gr. Fumane	A2	OxA-11347	AMS	charcoal	30650 ± 260	35080 – 34089
Gr. Fumane	A1	UtC-2049	AMS	charcoal	31900 ± 500	37123 – 34737
Gr. Fumane	D6	OS-5872	AMS	marine shell	37100 ± 240	42048 – 41229
Gr. Fumane	D6	UtC-2046	AMS	charcoal	32300 ± 500	37870 – 35145
Gr. Fumane	D3ba st. 15, liv. A	OxA-8051	AMS	charcoal	32020 ± 340	36669 – 35126
Gr. Fumane	D3ba st. 15, liv. A	OxA-8050	AMS	charcoal	30320 ± 320	34882 – 33817
Gr. Fumane	D3b	UtC-2045	AMS	charcoal	32300 ± 400	37535 – 35310
Gr. Fumane	D3b	UtC-1775	AMS	charcoal	31700 ± 1200	39090 – 33740
Gr. Fumane	D1d base	UtC-2050	AMS	charcoal	30700 ± 400	35474 – 33963
Gr. Fumane	D1d base	LTL374A	AMS	charcoal	29828 ± 390	34695 – 33265
Gr. Fumane	D1d	OxA-11348	AMS	charcoal	31490 ± 250	35967 – 34839
Rip. del Broion	1g, st. 2	UtC-11790	AMS	charcoal	32100 ± 400	37062 – 35046
Rip. del Broion	1g, st. 3	UtC-12509	AMS	charcoal	31700 ± 400	36403 – 34791
Rip. del Broion	1g, st. 3	UtC-11791	AMS	bone	25980 ± 190	30744 – 29670
Rip. del Broion	1g	UtC-11792	AMS	charcoal	30480 ± 300	34986 – 33935
Rip. del Broion	1g-1f	LTL1637A	AMS	bone	30650 ± 300	35170 – 34035
Gravettian						
Gr. Fumane	D1e	R-2784	AMS	land snail	26890 ± 530	32070 – 29780
Gr. Broion	E	UtC-2693	AMS	bone	25250 ± 280	30150 – 28705
Gr. Broion	D	UtC-2694	AMS	bone	24700 ± 400	29656 – 27890
Rip. del Broion	1c	UtC-13321	AMS	charcoal	25860 ± 200	30657 – 29532
Rip. del Broion	1b	Utc-13320	AMS	charcoal	28460 ± 260	33220 – 31598
Rip. del Broion	1b alfa	UtC-10504	AMS	charcoal	27960 ± 300	32702 – 31216
Rip. del Broion	1b, st. 1	UtC-10506	AMS	charcoal	17830 ± 100	21890 – 21282
Gr. Paina	7	UtC-2697	AMS	bone	20200 ± 240	25040 – 23730
Early Epigravettian						
Gr. Paina	6	UtC-2696	AMS	bone	20120 ± 220	24875 – 23660
Gr. Paina	6	UtC-2043	AMS	bone	19430 ± 150	23810 – 22985
Gr. Trene	BII	UtC-2692	AMS	bone	18630 ± 150	22909 – 22174
Gr. Trene	BI	UtC-2691	AMS	bone	17640 ± 140	21761 – 20930
Late Epigravettian						
Rip. Tagliente	13a alpha	LTL4441A	AMS	bone	13986 ± 60	17219 – 16687
Rip. Tagliente	300	Lyon-10030	AMS	bone	13920 ± 80	17160 – 16555
Rip. Tagliente	15-16	R-605a	conv.	charcoal	13430 ± 180	16761 – 15660
Rip. Tagliente	15-16	R-605	conv.	charcoal	13330 ± 160	16537 – 15548
Rip. Tagliente	14	R-604	conv.	charcoal	12000 ± 400	15271 – 13095
Rip. Tagliente	352	OxA-29834	AMS	bone	13600 ± 60	16638 – 16179
Rip. Tagliente	13a	Lyon-10031	AMS	bone	13450 ± 70	16438 – 15941
Rip. Tagliente	13trincea	Lyon-10033	AMS	bone	13250 ± 80	16186 – 15684
Rip. Tagliente	10e (OL3)	OxA-3532	AMS	charcoal	13270 ± 170	16426 – 15371
Rip. Tagliente	13 burial	OxA-10672	AMS	human bone	13190 ± 90	16149 – 15532
Rip. Tagliente	10c (OL2)	OxA-3531	AMS	charcoal	13070 ± 170	16147 – 15176
Rip. Tagliente	419	Lyon-10034	AMS	bone	12430 ± 70	14966 – 14175
Rip. Tagliente	10a (OL1-II)	OxA-3530	AMS	charcoal	12650 ± 160	15537 – 14243
Rip. Tagliente	10-8	R-371	conv.	charcoal	12040 ± 170	14535 – 13472
Gr. Paina	5	UtC-2698	AMS	bone	10760 ± 100	12849 – 12432
Bus de la Lum	2	UtC-8912	AMS	charcoal	10430 ± 50	12530 – 12101

Table 1 (continued). Available radiocarbon datings for the studied sites and levels (after Broglio and Improta 1995; Broglio and Dalmeri 2005; De Stefani et al. 2005; Fontana et al. 2012; Peresani et al. 2000; Soubrier et al. 2016.). Radiocarbon dates were calibrated with OxCal 4.2, using the calibration curve IntCal13 (Reimer et al. 2013).

Assemblages	Lombard Prealps	Lessini					Berici/Euganei			Belluno Prealps					Umbria/Marches					Undet.	Total
	RAD	CG	BI	SVA	SR	EOC	BI	SVA	SR	SOC	BI	SVA	SR	CI+SG	CD	MAI	MF	SC	BIS		
1. Grotta di Paina, "G. Azzurra", L. 9-8				3			1		20												24
2. Grotta Fumane, L. A3-D3[a]	16	27	1,348	368	212	118														265	2,354
3. Riparo Broion, L. 1g-1f[a]			41	2		1	28	17	16											8	113
4. Grotta Fumane, L. D1d sup-D1f[a]			1																		1
5. Riparo Broion, L. 1e-1a[a]			21	4	2		40	24	31											19	141
6. Grotta del Broion, L. E-C			2	3	1	3	11	22	24											6	72
7. Buso Doppio del Broion L. 1			5			1	5		4									5		11	34
8. Grotta di Paina, "G. Azzurra", L. 7							3		3							1		16			23
9. Gr. di Paina, "Main Hall", L. 21-29																1		14		2	17
10. Buso Doppio del Broion L. Rim			6			1	14	11	1							1	3	5	1	6	46
11. Grotta di Paina, "Azzurra", L. 6				4					1							1	1	40			47
12. Gr. di Paina, "Main Hall", L. B,C																		18		31[b]	49
13. Covolo di Trene, L. B			3	1		1	6	8	5							3	1	5			33
14. Riparo Tagliente – internal series		1,568	29,692	4,425	692	51									3			48		896	37,375
15. Grotta di Paina, "G. Azzurra", L. 5			1	3			5	1	3											2	15
16. Bus de la Lum[c]										6	868	144	717	532						68	2,335
17. Palughetto[d]										1	14	1	28	24						1	69

a. Only retouched artefacts and cores were analysed;
[b] These artefacts belong to the Lessini and Berici/Euganei areas but specific lithologies were not determined;
[c] Only a sample of artefacts were analysed;
[d] Only cores and pre-cores were analysed.

Table 2. Composition of the lithic assemblages according to identified lithologies and relative provenance areas.

Lessini, Grotta Fumane (layer D1d sup). At Grotta Fumane, sporadic Gravettian findings were discovered in few horizons inside the detrital macro-unit D which definitively filled and closed the cave entrance. Radiometric datings are comprised between 33.5 (layer D1d) and 31 (layer D1e) kyrs cal BP (Table 1). This evidence was interpreted as resulting from occasional hunting camps. The most significant finding is represented by a backed point of a considerable size obtained from a local BI chert (Table 2) (Broglio 2002).

Berici, Grotta Broion (layers C-E). At Grotta Broion, a cave whose entrance is located a few meters from the homonymous rock-shelter (*cf. infra*), some meagre Gravettian lithic industries were identified in two different areas of the cave, the so-called "Sala Grande" and "Grottina delle Marmotte" (layers C-E) (Leonardi 1951; 1954; Broglio 1984). The assemblages include retouched tools and waste products deriving both from blade and bladelet productions. The Berici-Euganei cherts are largely predominant over the Lessini ones (Table 2). The close-by SR types were transported and flaked on the site while other varieties (SVA and BI) outcropping further from the site are represented only by flaked blanks and retouched tools. The few Lessini lithotypes (BI, SVA, EOC) are almost exclusively represented by blades, along with a few small flakes.

Berici, Riparo Broion (layers 1a-1e). The stratigraphic horizons lying over the Protoaurignacian ones (1f-1g) are most likely referable to the Gravettian although previously interpreted as a Gravettian-Epigravettian assemblage (De Stefani *et al.* 2005). The industry, characterized by small backed points, shows similarities with other Italian ancient Gravettian sequences such as that of Castelcivita (Campania, southern Italy) (A. Broglio pers. comm.). Generally, cherts were flaked elsewhere and mainly laminar blanks and retouched tools were imported. Exploited lithic raw materials can be ascribed to two main provisioning territories (Table 2). The Berici-Euganei lithotypes, represented by fine and high quality cherts idoneous for bladelet production, are the most represented raw materials. Among them the BI chert, outcropping in restricted areas of the Euganei, around 20 km far from the site, was preferentially collected. The Lessini cherts, whose quality is comparable or even higher, are mostly represented by BI lithotypes.

5.3. Late Gravettian and Early Epigravettian record

During MIS 2 the entire Southern Alps were almost depopulated. The only evidence dated to the Late Gravettian-Early Epigravettian so far discovered comes from a few hunting stands identified on the Berici hills.

Berici, Grotta Paina (Grottina Azzurra, layer 7). At Grotta Paina, layers 7 and 6 were attributed respectively to the Late Gravettian and Early Epigravettian (Bartolomei *et al.* 1988). Radiocarbon datings obtained for the two layers are very close (Table 1). The lithic assemblage of the older layer is composed of 23 artefacts, 17 of which are made on extra-regional cherts and 6 on local ones (Berici-Euganei). The former are represented by Umbria-Marches Apennine lithotypes, belonging to the Maiolica (MAI) and Scaglia Rosata (SCR) formations (Broglio *et al.* 2009) (Table 2), and are almost exclusively constituted by retouched artefacts (5 small backed points and 9 backed bladelets). The Berici-Euganei artefacts are all unretouched and include blade and bladelet fragments but also some flakes and small flakes attesting to on-site flaking activities.

Berici, Grotta Paina (Grottina Azzurra, layer 6). The lithic industry of the overlaying layer 6 includes 47 artefacts, among which some small backed points (2 entire and 6 fragments), shouldered points made on laminar blanks (1 entire and 10 fragments), 21 backed bladelets and 7 unmodified bladelet fragments. Lithic raw materials are almost entirely allochthonous (89.4%). They belong to the Scaglia Rosata (SCR, 40), Marne a Fucoidi (MF, 1) and Maiolica (MAI, 1) formations outcropping in the Umbria-Marches region (Broglio *et al.* 2009). Only one cortical flake and four backed fragments come respectively from the Berici-Euganei area (SR) and the Lessini mountains (SVA).

Berici, Grotta Paina, Sala Principale, layers B,C; 21-29. Similar data come from the bottom layers of Sala Principale and the intermediate area between the Sala Grande and the Grottina Azzurra (Leonardi *et al.* 1962; Bartolomei *et al.* 1988). Altogether the upper layers B-C (which are partly reworked) have yielded 49 artefacts coming from three different areas: Berici-Euganei, Lessini and Umbria-Marches Basin. Only the latter have been studied in detail. The industry is composed of armature fragments (11), small backed points (1 entire and 3 fragments) and shouldered points (3 fragments) (all made with SCR and comparable to the Grottina Azzurra series, layer 6). In this area the bottom layers (21-29) are strongly cemented and difficult to correlate with the close Grottina Azzurra series. They contain small backed points (1, SCR) armatures fragments (13, SCR; 1, MAI; 2, undetermined) but no shouldered points. The raw materials from which these diagnostic artefacts were obtained come from the Umbria-Marches Basin.

Berici, Covolo Trene, complex B. Covolo Trene is another cave located few hundreds meters northeast of Grotta Paina which yielded a lithic assemblage (33 artefacts) belonging to the Early Epigravettian (Leonardi *et al.* 1959; Broglio 1984). At least 9 artefacts were manufactured on Umbria-Marches cherts: 2 small backed points, 1 shouldered point, 1 retouched blade and 1 fragment, 2 backed fragments. The lithotypes belong to SCR (5), MF (1) and MAI (3). A bifacial foliate point possibly manufactured on a chert of the Lessini area (SVA) is also documented. All the other artefacts are unretouched and realized on raw materials coming from the Berici-Euganei (19) and Lessini (4) areas. Two radiocarbon datings are in accordance with the cultural attribution of the lithic assemblage to the early Epigravettian (Table 1).

Berici, Grotta Buso Doppio del Broion. Recent excavations (Romandini *et al.* 2015) conducted by the University of Ferrara in the narrow cavity of Buso Doppio del Broion, located between Grotta Broion and Riparo Broion allowed recovering a lithic industry partly comparable to those found in the Late Gravettian – Early Epigravettian layers of Grotta Paina and Covolo Trene (Broglio *et al.* 2009). The uppermost layers, likely referable to the Early Epigravettian, are unfortunately disturbed. An assemblage composed of 6 shouldered points (2 entire, 3 fragments and 1 probable pre-form), 3 small backed points (2 entire, 1 fragment), 3 backed fragments, 4 unretouched lamellar fragments and 1 unretouched blade comes from the Umbria-Marches Basin, showing a greater variability in comparison to the previously described sites. The attested lithotypes belong to the following formations: Bisciaro (BIS, 1), Scaglia Cinerea (SCC, 1), Scaglia Rosata (SCR, 9), Scaglia Bianca (SCB, 1), Marne a Fucoidi (MF, 3) and Maiolica (MAI, 2), covering an interval between the Miocene and Upper Jurassic. Other materials come from outcrops located at short-to-mid distances. The nearest outcrops (Berici-Euganei, 26 artefacts) are represented by both debitage (1 flakes core, 7 blades and fragments, 3 bladelets and fragments, 11 flakes, 1 rejuvenation flake) and retouched blanks (1 small backed point and 1 backed bladelet fragment), while the Lessini ones (7 artefacts) almost exclusively refer to retouched tools (1 small backed point and 3 fragments, 1 backed bladelet, 1 backed bladelet fragment and 1 *crested* bladelet). The bottom layer industry (Layer 1, total 20 artefacts) contains small backed points and other backed tools, without shouldered points. Raw materials still come from three areas. The Umbria-Marches Basin is represented by 1 backed point fragment (SCR), 1 backed bladelet fragment (SCR), 1 unretouched blade (SCR) and 2 bladelet fragments (1 SCR and 1 SCB); the Berici-Euganei by 4 backed point fragments, 1 unretouched blade, 3 bladelet fragments and 1 flake; the Lessini by 1 backed point fragment, 1 backed bladelet fragment, 2 unretouched bladelets and 1 flake.

Berici – Euganei, sporadic surface findings. Two other surface findings attest hunting activities during this time span. One shouldered point was identified on mount Brosimo (225 m a.s.l.) in the Berici area and one small backed point in the Euganei foothills (Lovertino, near Albettone). The chert provenance in the first case is uncertain while in the latter is local (SR).

5.4. Late Epigravettian record

Lessini, Riparo Tagliente. It is one of the most important Late Epigravettian sites of the Southern Alps dated to the first part of the Lateglacial (Fontana *et al.* 2009; 2012). The Epigravettian levels of the internal series (S.U. 13a, 13a alfa, 13a beta, 250, 299, 300, 300b, 301, 302, 307, 367 and 369), that belong to the most ancient phase of Late Glacial occupation in the site, are the only ones to have been extensively analysed up to the present day as far as raw material determination is concerned. Palaeobotanical and paleontological data indicate a dominating steppe environment in the surrounding of the site; the presence of the *Bison,* attested both among hunted fauna and in figurative art, is meaningful in this perspective (Bartolomei *et al.* 1982; Bertola *et al.* 2007a; Fontana *et al.* 2009). All Late Epigravettian levels are marked by a massive evidence of raw material processing activities, namely chert and ochre (*cf.* Fontana *et al.* this volume). The lithic assemblage is mostly made out of local raw materials (Arzarello *et al.* 2007; Fontana *et al.* 2009, 2015). All of the reduction sequence stages are attested. Recent researches also highlighted the presence of few implements on extra-regional cherts, from the same areas exploited during the Late Gravettian and the Early Epigravettian. Totally 48 artefacts on Umbria-Marches SCR and 3 on CD cherts were till now identified. The assemblage is composed of 13 retouched tools (among which 9 backed fragments, 1 burin, 1 endscraper, 1 truncated blade and 1 pointed piece), 35 unmodified blanks (including bladelets, flakes, semi-cortical blanks and maintenance elements) and 3 lamellar cores. Allochthonous Apennines cherts seem to disappear in the later levels (roughly corresponding with the Bølling chronozone) although more detailed researches on these assemblages are needed in order to definitely assess this trend.

Berici, Grotta Paina (Grottina Azzurra, layer 5). A meagre lithic assemblage dated to the Late Epigravettian was recovered in Grotta Paina (Bartolomei *et al.* 1988; Table 1). Most cherts come from the Berici-Euganei area and are represented by unretouched artefacts and armature fragments. Another group, coming from the Lessini, is represented by bladelet cores, armature fragments and retouched blades. A third set of retouched artefacts (5 armature fragments) coming from the Umbria-Marches Basin, most likely derives from an admixture with the bottom layer 6.

Cansiglio plateau, Palughetto. The Cansiglio Plateau is a calcareous promontory situated between the Venetian and the Carnian Prealps, at about 1,000 m a.s.l. Here numerous sites referable to the Lateglacial and Postglacial were discovered and excavated (Peresani 2009). The Palughetto Late Epigravettian settlement is located on a moraine surrounding a small basin, along the north-western edge of the plateau. Noteworthy is the presence of a chert cache associated to artefacts embedded in the lacustrine and peat sequence (Bertola *et al.* 1997; Di Anastasio *et al.* 2000; Peresani *et al.* 2011). The exploited lithic raw materials entirely belong to the Belluno Prealps. The best quality lithotypes were collected in the Southern slope of the Belluno Valley, about 25-35 km to the west, where fine crystalline good quality cherts crop out; a few lithotypes were probably collected along the eastern slope of the Grappa Massif (about 60 km to the west). The local cherts (Col Indes, Scaglia Grigia) where only sporadically used.

Cansiglio plateau, Bus de la Lum. The site is located on the eastern side of the central Piancansiglio plain, next to a deep karst pit (Peresani *et al.* 2000). Raw material provisioning system is similar to the one recorded at the Palughetto site. Most resources were collected about 25-35 km to the west. The very local cherts, outcropping on the Cansiglio plateau district and very common in the residual soils of the Piancansiglio, were used more frequently than at Palughetto but still in an opportunistic way and collected blocks were often tested and abandoned.

6. Discussion

Based on procurement distance, exploited raw materials from the analysed sites were grouped into three classes: short-, mid- and long-distance. The first group includes all the lithotypes outcropping less than 20 km as the crow flies from the examined sites, the middle one between 21 and 60 km and the latter between 200 and 300 km. Changes in raw material procurement strategies and circulation were thus schematized. By correlating these data with palaeoenvironmental, techno-typological and cultural variables, 4 major chronological phases were identified with respect to raw material circulation (Fig. 4).

The **first phase** corresponds to the interval between 43 and 28-27 kyrs cal BP, that is the time span included between the second part of MIS 3 and the beginning of MIS 2 (end of GI-3). It is a period characterized by a relatively rapid succession of Stadial and Interstadial stages. In the studied area open forests (50-70%) and steppe areas alternated (Pini *et al.* 2010). From a cultural viewpoint this phase corresponds to the beginning of the Upper Palaeolithic, testified by the diffusion of Protoaurignacian assemblages, and it also includes the first part of the Gravettian. The sequence of Grotta Fumane testifies that the first Protoaurignacian groups had already acquired a deep knowledge of the regional context, including the location of lithic outcrops and occurrences. Fine crystalline and homogeneous cherts were selected especially for the production of bladelets whereas coarser texture types, normally harder to knap but less affected by diaclases, were used only for blade production. At a general level the Aurignacian and the Gravettian sites show the exclusive exploitation of regional lithic resources. The sites located in the Lessini area (G. Fumane and R. Tagliente)

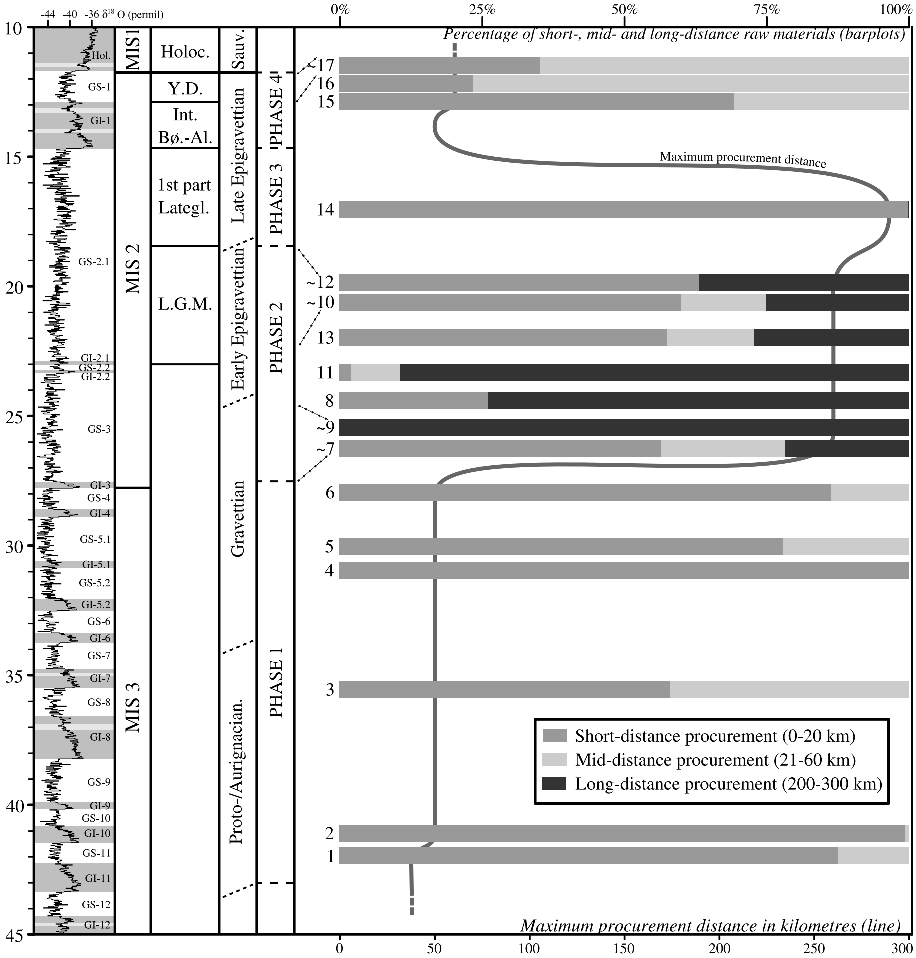


Figure 4. Periodization proposed for the Upper Palaeolithic of the Venetian Prealps on the base of exploited lithic raw materials and correlation with the palaeoclimatic and cultural phasing. Oxygen isotopic scale based on NGRIP data (Rasmussen et al. 2014); MIS subdivision based on Rasmussen et al. 2014; Late glacial subdivision as proposed by Ravazzi (2007); LGM lower limit according to Mix et al. 2001; sites were positioned according to radiocarbon datings; ~ indicates uncertain chronological attributions; numerical identifiers are explicated in table 2.

attest that lithotypes procured at short distances (less than 20 kilometres) were almost exclusively flaked. The collection of raw materials at mid-distances is documented only in the Aurignacian levels of Fumane (a single radiolarite block from the Lombard Prealps). On the other hand, the lithic assemblages of the sites in the Berici hills show the presence of raw materials belonging both to the Berici-Euganei (short-distance, 5-20 km) and the Lessini areas (mid-distance, 20-40 km) whose exploitation could be connected to the absence of lithic resources in the surrounding of the sites. Cherts imported from the Lessini area have a high quality and are represented both by blanks and retouched artefacts. There is no evidence of on-site flaking. Towards the end of this phase (Gravettian) a further contraction of mean provisioning territories can be surmised. The importation of Lombard raw materials in the Lessini area ceases and in the Berici area the percentage of Lessini cherts diminishes (from around 40% to 20% at Riparo Broion) (Table 2).

Phase 2 presumably started at the onset of MIS 2 (*sensu* Svensson *et al.* 2006). Considering the archaeological evidence the lower limit is estimated between 28 and 24 kyrs cal BP (the first radiocarbon dated evidence is that of Grotta di Paina, "G. Azzurra", L. 7). During this cold phase the maximum extent of glaciers in the Eastern Alps was reached (Monegato *et al.* 2007). In spite of the general climate worsening, moist air masses of Mediterranean origin feeding the Prealpine foreland and enhancing rainfall allowed open forests to persist (20-30%) close to the glacier front (Monegato *et al.* 2007; 2015; Pini *et al.* 2010). On the other hand being the lower sector of the Po-Adriatic plain partially active it is supposed to have been characterized by a patchy environment with steppe interspersed by semi-desertic and desertic areas. These wide open spaces favored a great mobility of human groups: the Venetian Prealps were occasionally frequented by hunting parties as testified by abandoned finished arrowheads (notably backed points and shouldered points), blades, bladelets and fragments. Game included bears (*Ursus spelaeus*), elks, red deers, roe deers and marmots (Bartolomei *et al.* 1988; Gurioli and Parere 2006; Romandini and Nannini 2012). These short-term settlements were so far identified exclusively in the Berici-Euganei area. From a cultural viewpoint the lithic assemblages were attributed to the Late Gravettian and Early Epigravettian, on the base of respectively the absence and the presence of shouldered points (Broglio *et al.* 2009) as attested in the only preserved continue stratigraphic sequence (Grotta Paina: layers 7 and 6). Since their discovery, these assemblages were correctly interpreted as hunting stands of groups coming from other areas (Broglio 1984; Bartolomei *et al.* 1988; Broglio and Improta 1995). As a matter of fact, all of the assemblages include, although with different percentages, Umbria-Marches cherts. Retouched artefacts (representing hunting weapons together with a few retouched blades) are almost exclusively composed of allochthonous lithotypes, along with some unmodified bladelets. As regards the possible geographic provenance of these raw materials within the Umbria-Marches Basin, the high variability of chert lithotypes attested (MAI, MF, SCB, SCR, SCC and BIS) provides an important hint. A dedicated prospection allowed delimiting the potential provenance area to the low hills situated between the Furlo and Chienti valleys, including the most external Apennine ridges and their slopes. Particularly favorable for provisioning is the sector located between Arcevia, Cupramontana and the Cingoli ridge (around 260 km far from the Berici) where all the mentioned lithotypes can be collected. Overall, the technological analysis of Umbria-Marches chert artefacts enables us to affirm that these blanks were imported as manufactured items and that not even retouching or resharpening took place on-site (Broglio *et al.* 2009). The interpretation of other artefacts made on short- and mid-distance raw materials from the same layers is more problematic. Although an opportunistic exploitation of local resources by the same groups that brought the allochthonous raw materials is currently the most reliable hypothesis, further factors should be considered such as post-depositional perturbation processes and/or the occurrence of multiple successive occupations by different groups. In this regard the different techno-typological composition of the two subsets is striking, the former consisting mostly of retouched artefacts along with a few bladelets and the latter being dominated by unretouched blanks (flakes, short blades, bladelets but also cortical and maintenance elements, debris and flake cores attesting on-site chert processing) together with some rare armature fragments. Shouldered points on local chert are not attested but for 2-3 doubtful pieces. Beyond this interpretative issue, it is important to remark that Late Gravettian and Early Epigravettian hunters moved in a radius of at least 260 km, crossing the Po plain, for hunting-related activities and carried with them finished tools and unmodified regular blanks.

The **third phase** sees a major change in the nature of contacts between the Venetian Prealps and the Umbria-Marches basin. Chronologically it corresponds to the "First part of the Lateglacial" as defined by Ravazzi *et al.* (2007) which spans between 19-18 kyrs cal BP and the beginning of the Bølling-Alleröd Interstadial (14.5 kyrs cal BP). During this phase environmental conditions are not supposed to have been much different than in the LGM. Nonetheless in the southeastern Alpine foreland the glacial ice-sheet had started to melt and the main valleys had become available for human settlement. The sole archaeological evidence of human peopling in the Venetian Prealps dated to this period is represented by the oldest levels of the Late Epigravettian series of Riparo Tagliente. Along with the impressive evidence of an intensive exploitation of local raw materials from the Lessini area, artefacts manufactured on Umbria-Marches cherts are present in these layers. During this phase not only hunting implements but also domestic tools and cores (and possibly pre-cores) are attested along with semi-cortical and maintenance blanks which document on-site exploitation of these exogenous cherts. The difference in the composition of the kits manufactured on these long-distance cherts with respect to the previous phase probably reflects a major change in the territorial organization of Late Epigravettian groups. The persistence of a connection between the two territories (the Lessini area and the Umbria-Marches Apennines) could either reflect the seasonal displacement of groups from the Marches to the Lessini area or the maintenance of social relationships between human groups settled in these two territories. Such mobility/exchange system could not only be motivated by hunting purposes and social behaviours but also by the exploitation and processing of the abundant mineral (*i.e.* chert and ochre) resources offered by the Lessini area. The alternative hypothesis that the rockshelter was settled by different groups needs further investigations and is, anyways, harder to be envisaged.

The following **Phase 4** characterizes the last part part of the Upper Palaeolithic, from the onset on the Bølling-Alleröd Interstadial (14.5 kyrs cal BP) to the end of the Pleistocene (11.6 kyrs cal BP). The beginning of the Lateglacial Interstadial marks a rapid environmental change that is reflected by the closure and extensive development of forested areas. The landscape afforestation could be one of the main causes that led to the progressive "regionalisation process" of the last Palaeolithic hunter-gatherer groups which determined the exploitation of raw materials exclusively available at mid- and short-distances (less than 60 km). Such a tendency is in continuity with current data on the Early Mesolithic settlement of Northern Italy showing the existence of distinct provisioning territories during the first part of the Holocene (Fontana and Visentin 2016; Visentin *et al.* 2016).

7. Conclusions

The Upper Palaeolithic record of the Venetian Prealps allowed a diachronic analysis of the changes in lithic raw material provisioning strategies over time to be attempted. It was thus possible to identify 4 main phases which appear to be correlated to the regional environmental evolution.

On one side the climate worsening recorded during MIS 2 made the Prealps an inhospitable area. On the other, it profoundly altered the ecosystems, triggering a major change in the mobility of human groups that resulted in an amplification of provisioning territories (> 250 km). In this period the Umbria-Marches cherts spread over a wide area across the Po-Adriatic plain spanning between the Venetian Prealps (Broglio *et al.* 2009) and the Istrian and Dalmatian coast (Vukosavljević and Perhoč 2017; E. Cancellieri, pers. comm.). Another direction of raw material displacements involving the Umbria-Marches cherts was in place since the Aurignacian involving two different routes running south and north of the Tuscan-Emilian Apennines up to Liguria and Provence (Fontana and Guerreschi 1996; Dini *et al.* 2006; Negrino and Starnini, 2006; 2010; Sozzi *et al.* 2008; Porraz *et al.* 2010; Bertola *et al.* 2013; Tomasso 2015; Broglio *et al.* in press).

The Venetian record indicates that, during the First part of the Lateglacial, the nature of this long-distance connection significantly changed. Afterwards, this mobility system came to an end with the climate amelioration corresponding to the onset of the Bølling-Alleröd Interstadial, that enhanced the establishment of a thick and close cover. The above presented modelisation does not match the reconstruction proposed by Tomasso (2015) for Provence and northwestern Italy both in its timing and modalities. The reasons for this discrepancy are possibly to be ascribed to the different geologic, geographic and palaeoenvironmental background of the two areas. If the Apennines played a role of junction between the Adriatic and Tyrrhenian coast, the Po plain acted as a paleoecological barrier: human groups carrying their lithic tools seem to have crossed the plain only during the colder phases when it was dominated by open and arid steppe environments. Marine ornamental shells, on the other hand, attest the permanence of long-distance contacts since the Aurignacian reflecting a different circulation pattern.

To conclude the diachronic analysis and reconstruction of lithic raw material provenance from same major sites of the Venetian area along with correlation to techno-typological data and the local environmental conditions allowed investigating and interpreting some of the major changes in provisioning systems throughout the Upper Palaeolithic. Moreover, the definition of a reference sequence for north-eastern Italy represents an important tool for the future development of researches aimed at the reconstruction of social networks and interactions during the Upper Palaeolithic in the neighboring areas.

Acknowledgements

Authors are particularly thankful to A. Broglio and M. Peresani that allowed including in this work the materials yielded by their excavations, as well as to B. Sala and C. Ravazzi for discussions regarding the palaeoecology of the ancient Po plain. We are also grateful to V. Borgia e E. Cristiani for inviting us to take part at the "Out of Italy" Conference in Cambridge as well as to the anonymous reviewers for their useful suggestions.

References

Alvarez, L.W. and Montanari, A. 1988. The Scaglia Limestone (Late Cretaceous – Oligocene) in the Northeast Apennines carbonate sequence: stratigraphic context and geological significance, in: Premoli Silva, I., Coccioni, R., Montanari, A. (eds.). *The Eocene – Oligocene boundary in the Marche – Umbria basin (Italy).* Ancona, Ind. Grafiche Aniballi, 13-29.

Arzarello, M., Bertola, S., Fontana, F., Guerreschi, A., Thun Hohenstein, U., Liagre, J., Peretto, C. and Rocci Ris, A. 2007. Aires d'approvisionnement en matières premières lithiques et en ressources alimentaires dans les niveaux moustériens et épigravettiens de l'Abri Tagliente (Verone, Italie): une dimension locale. Actes XV UISPP. Lisbona 2006. *Archaeopress,* 23, 161-169.

Bartolomei, G., Broglio, A., Corai, P., Cremaschi, M. 1980. Dépôt würmien à industrie protoaurignacienne à lamelles Dufour dans l'Abri Tagliente (Monts Lessini, Verona). *Actes Coll. Internat. L'Aurignacien et le Gravettien (Périgordien) dans leur cadre écologique.* Nitra, 37-51.

Bartolomei, G., Broglio, A., Cattani, L., Cremaschi, M., Guerreschi, A., Mantovani, E., Peretto, C., Sala, B. 1982. I depositi würmiani del Riparo Tagliente. *Annali dell'Università di Ferrara*, N.S., 15, III (4), 61-105.

Bartolomei, G., Broglio, A., Cattani, L., Cremaschi, M., Lanzinger, M., Leonardi P. 1988. Nuove ricerche nel deposito pleistocenico della Grotta di Paina sui Colli Berici (Vicenza). *Atti Ist. Veneto. SS. LL. AA.*, CXLVI, 111-160.

Bertola, S. 1996. *Studio petroarcheometrico delle selci preistoriche provenienti dalla Grotta di San Bernardino di Mossano (Colli Berici – Vicenza).* Unpublished Thesis (Geology), Ferrara University.

Bertola, S. 2001. *Contributo allo studio del comportamento dei primi gruppi di H. Sapiens diffusi in Europa. Sfruttamento della selce, produzione dei supporti lamellari, confezione delle armature litiche nel sito aurignaziano della Grotta di Fumane nei Monti Lessini (Verona)*, Unpublished Ph.D. thesis (Anthropology), Associated Universities Bologna, Ferrara and Parma.

Bertola, S. 2012. Approccio micropaleontologico discriminante per riconoscere la provenienza alpina o appenninica delle selci della Scaglia Rossa, *Bull. Musée Anthropologie Préhistorique Monaco*, 52, 17-27.

Bertola, S. 2016. Southern Alps (Trento plateau) and Northern Apennines cherts: ages and distribution. *Actes du Congress: Ressources lithiques, productions et transferts entre Alpes et Méditerranée, Nice 28-29 Mars 2013*, Paris, Publication de la Séances de la SPF, 55-75.

Bertola, S. and Cusinato, A. 2004. Le risorse litiche dell'Altopiano di Folgaria e il loro utilizzo a Riparo Cogola. *Preistoria Alpina*, 40, 107-123.

Bertola, S., Di Anastasio, G. and Peresani, M. 1997. Hoarding unworked flints within humid microenviroments. New evidence from the mesolithic of the Southern Alps. *Préhistoire Européenne*, 10, 173-185.

Bertola, S., Broglio, A., Cassoli, P.F., Cilli, C., Cusinato, A., Dalmeri, G., De Stefani, M., Fiore, I., Fontana, F., Giacobini, G., Guerreschi, A., Gurioli, F., Lemorini, C., Liagre, J., Malerba, G., Montoya, C., Peresani, M., Rocci Ris, A., Rossetti, P., Tagliacozzo, A. and Ziggiotti, S. 2007a. L'Epigravettiano recente nell'area prealpina e alpina orientale, in: F. Martini (ed.), *L'Italia tra 15.000 e 10.000 anni fa. Cosmopolitismo e regionalità nel Tardoglaciale,* Firenze, Atti della Tavola Rotonda 2005, Millenni – Studi di Archeologia preistorica, 39-94.

Bertola, S., Broglio, A., De Stefani, M., Gurioli, A. and Tagliacozzo, A. 2007b. Landscape exploitation at the beginning of Upper Palaeolithic: the example of Broion Shelter (Berici Hills, Vicenza). 49th Annual Meeting in Trento 10th – 14th of April 2007, unpublished poster.

Bertola, S., Broglio, A., Cristiani, E., De Stefani, M., Gurioli, F., Negrino, F., Romandini, M., Vanhaeren M. 2013. La diffusione del Primo Aurignaziano a sud dell'arco alpino, *Preistoria Alpina,* 47, 123-152.

Bolli, H. M., Saunders, J. B. and Perch-Nielsen K. 1985. Plankton Stratigraphy, vol. 1 Planktic foraminifera, calcareous nannofossils and calpionellids. Cambridge Earth Science Series, Cambridge University Press.

Bosellini, A. and Winterer, E. L. 1975. Pelagic limestone and radiolarite of the Tethian Mesozoic: a genetic model. *Geology*, 3, 279-282.

Broglio, A. 2002. Tracce di frequentazioni Gravettiana nei Lessini, in: A. Aspes (ed.) *Preistoria Veronese, contributi e aggiornamenti,* Memorie del Museo Civico di Storia Naturale di Verona, 2a serie, Sezione Scienze dell'Uomo, 5, 40.

Broglio, A. 1984. Il Paleolitico superiore (Aurignaziano, Gravettiano, Epigravettiano), in: A. Broglio (ed.), *Il Veneto nell'antichità – preistoria e protostoria*, Verona, Banca Popolare di Verona, I, 233-243.

Broglio, A. and Improta, S. 1995. Nuovi dati di cronologia assoluta del Paleolitico superiore e del Mesolitico del Veneto,del Trentino e del Friuli. *Atti Ist. Veneto SS. LL. AA.*, 103, 1-45.

Broglio, A. and Dalmeri, G. 2005 (eds.). *Pitture paleolitiche nelle Prealpi Venete.* Memorie del Museo Civico di Storia Naturale di Verona, 2a serie, Sezione Scienze dell'Uomo, 9. Preistoria Alpina: numero speciale.

Broglio, A., Bertola, S. and Negrino, F. in press, *The role of the Northern Adriatic region in the Protoaurignacian spread towards Mediterranean Europe*. Janusz Krzysztof Kozłowski's Jubilee Volume.

Broglio, A., Bertola, S., De Stefani, M., Marini, D., Lemorini, C. and Rossetti, P. 2005. La production lamellaire et les armatures lamellaires de l'Aurignacien ancien de la Grotte de Fumane (Monts Lessini, Vénétie), *ArchéoLogiques,* 1, 415-436.

Broglio, A., Bertola, S., De Stefani, M. and Gurioli, F. 2009. The shouldered points of the Early Epigravettian of the Berici Hills (Venetian Region – North Italy). Materials, Blanks, Typology, Exploitation, in: J.M. Burdukiewicz, K. Cyrek, P. Dyczek, K. Szymczak (eds.), *Understanding the Past, Papers offered to Stefan K. Kozlowski,* Warsaw, Center for Research on the Antiquity of Southeastern Europe, University of Warsaw, 59-68.

Casadoro, G., Castiglioni, G.B., Corona, E., Massari, F., Moretto, M.G., Paganelli, A., Terenzani, F., Toniello, V. 1976. Un deposito Tardowurmiano con tronchi subfossili alle Fornaci di Revine (Treviso). *Bollettino Comitato Glaciologico Italiano,* 24, 22-63.

Centamore, E. and Deiana, G. (eds.) 1986. *La geologia delle Marche.* Volume speciale in occasione del 73° Congresso della Società Geologica Italiana, Roma 30 settembre – 4 ottobre 1986, Studi Geologici Camerti.

Cresta, S., Monechi, S. and Parisi, G. 1989. *Mesozoic – Cenozoic Stratigraphy in the Umbria – Marche area.* Roma, Memorie descrittive della Carta Geologica d' Italia, 39, 1-185.

De Stefani, M., Gurioli, F. and Ziggiotti, S. 2005. Il Paleolitico superiore del Riparo del Broion nei Colli Berici (Vicenza), in: F. Martini (ed.), *Askategi – Miscellanea in memoria di Georges Laplace*, Rivista di Scienze Preistoriche, suppl. 1, 93-107.

Dini, M., Negrino, F., Tozzi, C., Ghiretti A. 2006. Strategie di approvvigionamento e circolazione delle materie prime silicee tra la valle del Serchio e il pedeappennino padano durante il Paleolitico superiore e il Mesolitico, *Atti XXXIX Riunione IIPP (Firenze 25-27 novembre 2004)*, Firenze, Istituto Italiano di Preistoria e Protostoria, Vol. 1, 230-240.

Fontana, A., Mozzi, P. and Bondesan, A. 2008. Alluvial megafans in the Venetian – Friulian Plain (north-eastern Italy): evidence of sedimentary and erosive phases during Late Pleistocene and Holocene. *Quaternary International,* 189 (1), 71-90.

Fontana, F. and Guerreschi A. 1996. Testimonianze del Paleolitico superiore, in: G. Nenzioni and F. Lenzi (eds.), *Lettere di pietra. I depositi pleistocenici: sedimenti, industrie e faune del margine appenninico bolognese*, Bologna, Editrice Compositori, 807-810.

Fontana, F. and Visentin, D. 2016. Between the Venetian Alps and the Emilian Apennines (Northern Italy): Highland vs. lowland occupation in the early Mesolithic. *Quaternary International,* 423, 266-278. doi:10.1016/j.quaint.2015.12.014

Fontana, F., Cilli, C., Cremona, M.G., Giacobini, G., Gurioli, F., Liagre, J., Malerba, G., Rocci Ris, A., Veronese, C. and Guerreschi, A. 2009. Recent data on the Late Epigravettian occupation at Riparo Tagliente, Monti Lessini (Grezzana, Verona): a multidisciplinary perspective. Proceedings of the 49th Hugo Obermeier Society Meeting, Trento, 10-14 Aprile 2007, *Preistoria Alpina,* 44, 51-59.

Fontana, F., Cremona, M.G., Falceri, L., Gajardo, A., Ndiaye, M., Neri, A., Visentin, D., Bertola, S. and Guerreschi, A. 2012. Lithic Technical Systems in the First Part of the Late Glacial at Riparo Tagliente (Stallavena Di Grezzana, Verona), XIX Congresso dell'Associazione Antropologica Italiana. 1961-2011: Cinquant'anni Di Congressi. Passato, Presente E Futuro Dell'antropologia. Torino, 21-24 Settembre 2011, *Journal of Biological Research*, LXXXIV, 1, 102-103.

Fontana, F., Guerreschi, A., Bertola, S., Cremona, M.G., Cavulli, F., Falceri, L., Gajardo, A., Montoya, C., Ndiaye, M. and Visentin, D. 2015. I livelli più antichi della serie epigravettiana "interna" di Riparo Tagliente: sfruttamento delle risorse litiche e sistemi tecnici, in: G. Leonardi and V. Tinè (eds.), *Atti della XLVIII Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria, Preistoria e Protostoria del Veneto*, Padova 5-9 novembre 2013, Istituto Italiano di Preistoria e Protostoria, 43-52.

Fontana, F., Falceri, L., Gajardo, A., Bertola, S., Cremona, M.G., Cavulli, F., Guerreschi, A. and Visentin, D., this volume, pp. 287-310. Re-colonising the Southern Alpine fringe: diachronic data on the use of sheltered space in the Late Epigravettian site of Riparo Tagliente (Verona, Italy).

Gallini, V. and Sala, B. 2001. Settepolesini di Bondeno (Ferrara – Eastern Po Valley): the first example of mammoth steppe in Italy, in: G. Cavarretta, P. Gioia, M. Mussi and M.R. Palombo (eds.), *The World of Elephants,* Proceedings of the Internat. Congress, Rome (16-20 October 2001), 272-275.

Gnaccolini, M. 1968. Sedimentologia del Calcare di Soccher nella regione compresa tra la valle del T. Vajont (Pordenone) e l'Alpago (Belluno). *Rivista Italiana di Paleontologia,* 74 (3), 829-864.

Govoni, L. 2003. La fauna wurmiana di Colle San Marco. Unpublished thesis (Natural Sciences), Ferrara University.

Grandesso, P. and Stefani, C. 2008. La successione miocenica, in: A. Zanferrari, F. Avigliano, P. Grandesso, G. Monegato, G. Paiero, M.E. Poli, C. Stefani (eds.), *Note illustrative della Carta Geologica d'Italia alla scala 1:50.000, foglio 065 Maniago*, Roma, ISPRA, Servizio Geologico d'Italia, 58-76.

Gurioli, F., Parere, V. and Sala, B. 2006. La fauna del Pleistocene Superiore nella Grotta di Paina (Colli Berici, Vicenza), in: AA.VV., *Atti del V Convegno Nazionale di Archeozoologia*, Rovereto, 27-32.

Kaltenrieder, P., Belis, C. A., Hofstetter, S., Ammann, B., Ravazzi, C., and Tinner, W. 2009. Environmental and climatic conditions at a potential Glacial refugial site of tree species near the Southern Alpine glaciers. New insights from multiproxy sedimentary studies at Lago della Costa (Euganean Hills, Northeastern Italy), *Quaternary Science Reviews*, 28, 2647-2662.

Lambeck, K. and Chappell, J. 2001. Sea level change through the Last Glacial Cycle, *Science*, 292, 679-686. doi: 10.1126/science.1059549

Lanzinger, M. and Cremaschi, M. 1988. Flint exploitation and production at Monte Avena in the Dolomitic region of the Eastern Alps: lithic industry, site pattern and paleoenvironmental context, in: H.L. Dibble and A. Montet-White (eds.), *Upper Pleistocene Prehistory in Western Eurasia*, Philadelphia, University of Pennsylavnia Museum of Ethnography and Archaeology Press, 125-137.

Leonardi, P. 1951. La Grotta del Broion nei Colli Berici (Vicenza). Nuova stazione preistorica con industria paleolitica gravettiana, *Rivista di Scienze Preistoriche*, 6, 141-150.

Leonardi, P. 1954. Nuove ricerche sulla stratigrafia e sulle industrie del Paleolitico superiore della Grotta del Broion nei Colli Berici (Vicenza), *Rivista di Scienze Preistoriche*, 9, 89-107.

Leonardi, P., Mancini, F. and Pasa, A. 1959. Il covolo fortificato di Trene nei Colli Berici orientali (Vicenza): stazione preistorica con industria gravettiana. *Bullettino di Paletnologia Italiana*, LXVII-LXVIII, 101-136.

Leonardi, P., Pasa, A., Broglio, A., Ronchetti G. 1962. La stazione preistorica del covolo di Paina nei Colli Berici (Vicenza). *Rivista di Scienze Preistoriche,* 17, 77-122.

Maselli, V., Hutton, E.W., Kettner, A.J., Syvitski, J.P.M., Trincardi, F. 2011. High-frequency sea level and sediment supply fluctuations during Termination I: an integrated sequence-stratigraphy and modeling approach from the Adriatic Sea (Central Mediterranean), *Marine Geology*, 287, 54-70.

Maselli, V., Trincardi, F., Asioli, A., Ceregato, A., Rizzetto, F., Taviani, M. 2014. Delta growth and river valleys: the influence of climate and sea level changes on the South Adriatic shelf (Mediterranean Sea). *Quaternary Science Review*, 99, 146-163.

Masetti, D. and Bianchin, G. 1987. Geologia del Gruppo dello Schiara (Dolomiti Bellunesi): Suo inquadramento nell'evoluzione giurassica del margine orientale della piattaforma di Trent, *Memorie di Scienze Geologiche*, 39, 187-212.

Mix, A.C., Bard, E. and Schneider, R. 2001. Environmental processes of the ice age: land, oceans, glaciers (EPILOG), *Quaternary Science Reviews,* 20, 627-657.

Monegato, G., Ravazzi, C., Donegana, M., Pini, R., Calderoni, G., Wick, L. 2007. Evidence of a two-fold glacial advance during the Last Glacial Maximum in the Tagliamento end moraine system (eastern Alps). *Quaternary Research,* 68, 284-302.

Monegato, G., Ravazzi, C., Culiberg, M., Pini, R., Bavec, M., Calderoni, G., Jež, J. and Perego, R. 2015. Sedimentary evolution and persistence of open forests between the south-eastern Alpine fringe and the Northern Dinarides during the Last Glacial Maximum, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 436, 23-40.

Negrino, F. and Starnini, E. 2006. Modelli di sfruttamento e circolazione delle materie prime per l'industria litica scheggiata tra Paleolitico inferiore ed Età del Rame in Liguria, in: *Materie prime e scambi nella preistoria italiana, Atti della XXXIX Riunione Scientifica IIPP (Firenze, 25-27 novembre 2004)*, Firenze, Istituto Italiano di Preistoria e Protostoria, Vol. 1, 283-298.

Negrino, F. and Starnini, E. 2010. Dinamiche di sfruttamento e circolazione delle materie prime silicee per l'industria litica scheggiata in Liguria tra Paleolitico inferiore ed Età del Rame, in: G. Odetti (ed.), *L'uomo e la terra ligure. La trasformazione e l'adeguamento delle popolazioni umane al territorio nel corso dei millenni,* Atti della tavola Rotonda (Genova 10-11 febbraio 2005), Genova, 21-34.

Peresani, M. 1994. Flint exploitation at epigravettian sites in the Asiago plateau (Venetian Prealps), *Preistoria Alpina*, 28/1, 193-205.

Peresani, M. 2009. Le frequentazioni del Cansiglio nel quadro del popolamento preistorico delle Alpi Italiane Orientali, in: M. Peresani and C. Ravazzi (eds.), *Le Foreste Dei Cacciatori Paleolitici. Ambiente e Popolamento Umano in Cansiglio tra Tardoglaciale e Postglaciale*, Supplemento al Bollettino della Società Naturalisti Silvia Zenari. Pordenone, 121-144.

Peresani, M. and Bertola, S. 2010. Approvvisionament des materiaux lithiques, ressources locales et economie du debitage dans le Sauveterrian: un exemple du Haut Plateau de Cansiglio (Alpes Orientales Italiennes), *Prehistoires Mediterraneennes*, 1, 87-99.

Peresani, M., Bertola, S., De Stefani, M. and Di Anastasio, G. 2000. Bus de la Lum and the Epigravettian occupation of the Venetian Pre-Alps during the Younger Dryas, *Rivista di Scienze Preistoriche,* L, 103-132.

Peresani, M., Astuti, P., Di Anastasio, G., Di Taranto, E., Duches, R., Masin, I. and Miolo, R. 2011. Gli insediamenti epigravettiani e la frequentazione mesolitica attorno al Palughetto sull'Altopiano del Cansiglio (Prealpi Venete). *Preistoria Alpina*, 45, 21-65.

Pini, R., Ravazzi, C. and Reimer, P.J. 2010. The vegetation and climate history of the last glacial cycle in a new pollen record from Lake Fimon (southern Alpine foreland, N-Italy). *Quaternary Science Review*, 29, 3115-3137.

Porraz, G., Simon, P. and Pasquini, A. 2010. Identité technique et comportements économiques des groupes proto-aurignaciens à la grotte de l'Observatoire (principauté de Monaco), *Gallia Préhistoire*, 52, 33-59.

Premoli Silva, I. and Sliter, W. 2002. Practical manual of cretaceous planktonic foraminifera, in Premoli Silva I. & Rettori R. (Eds.): International School of Planktonic Foraminifera, 1° course: Cretaceous, Perugia, 18 – 22 february 2002. Milano, Centro Stampa XBS.

Rasmussen, S.O., Bigler, M., Blockley, S.P., Blunier, T., Buchardt, S.L., Clausen, H.B., Cvijanovic, I., Dahl-Jensen, D., Johnsen, S.J., Fischer, H., Gkinis, V., Guillevic, M., Hoek, W.Z., Lowe, J.J., Pedro, J.B., Popp, T., Seierstad, I.K., Steffensen, J.P., Svensson, A.M., Vallelonga, P., Vinther, B.M., Walker, M.J.C., Wheatley, J.J. and Winstrup, M. 2014. A stratigraphic framework for abrupt climatic changes during the Last Glacial period based on three synchronized Greenland ice-core records: Refining and extending the INTIMATE event stratigraphy. *Quaternary Science Reviews,* 106, 14-28. doi:10.1016/j.quascirev.2014.09.007

Ravazzi, C., Orombelli, G., Tanzi, G. & CLIMEX group 2004. An outline of the flora and vegetation of Adriatic basin (northern Italy and eastern side of the Apennine) during the Last Glacial Maximum, in: F. Antonioli and G.B. Vai (eds.), *Litho-paleoenvironmental maps of Italy during the Last Two Climatic Extremes. Explanatory Notes,* 32nd International Geological Congress, Firenze: 15-20.

Ravazzi, C., Peresani, M., Pini, R. and Vescovi, E. 2007. Il Tardoglaciale nelle Alpi italiane e in Pianura Padana. Evoluzione stratigrafica, storia vegetazionale e del popolamento antropico, *Italian Journal of Quaternary Sciences,* 20(2), 163-184.

Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., Buck, C.E., Cheng, H., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Haflidason, H., Hajdas, I., Hatté, C., Heaton, T.J., Hoffmann, D.L., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., Manning, S.W., Niu, M., Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Staff, R.A., Turney, C.S.M. and van der Plicht, J. 2013. IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0-50,000 Years cal BP. *Radiocarbon,* 55, 1869-1887. doi:10.2458/azu_js_rc.55.16947

Romandini, M. and Nannini, N. 2012. Chasseurs épigravettiens dans le territoire de l'ours des cavernes: le cas du Covolo Fortificato di Trene (Colli Berici, Vicenza), *L'Anthropologie*, 116, 41-56.

Romandini, M., Bertola, S. and Nannini, N. 2015. Nuovi dati sul Paleolitico dei Colli Berici: risultati preliminari dello studio archeozoologico e delle materie prime litiche della Grotta del Buso Doppio del Broion (Lumignano, Longare, Vicenza), in: G. Leonardi and V. Tinè (eds.), *Atti della XLVIII Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria, Preistoria e Protostoria del Veneto*, Padova 5-9 novembre 2013, Istituto Italiano di Preistoria e Protostoria, 53-60.

Sala, B. 2007. Mammalofaune tardo glaciali dell'Italia continentale, in: F. Martini (ed.), *L'Italia tra 15.000 e 10.000 anni fa – Cosmopolitismo e regionalità nel Tardoglaciale,* Firenze, Atti della Tavola Rotonda 2005, Millenni – Studi di Archeologia preistorica, 21-38.

Siddall, M., Rohling, E.J.,, Almogi-Labin A., Hemleben, C., Meischner, D., Schmelzer, I., Smeed, D.A. 2003. Sea-level fluctuations during the last glacial cycle, *Nature* 423, 853-858. doi:10.1038/nature01690

Siddall, M., Rohling, E.J., Thompson, W.G., Waelbroeck, C. 2008. Marine isotope stage 3 sea level fluctuations: Data synthesis and new outlook, *Reviews of Geophysics*, 46, RG4003. doi:10.1029/2007RG000226.

Soubrier, J., Gower, G., Chen, K., Richards, S.M., Llamas, B., Mitchell, K.J., Ho, S.Y.W., Kosintsev, P., Lee, M.S.Y., Baryshnikov, G., Bollongino, R., Bover, P., Burger, J., Chivall, D., Crégut-Bonnoure, E., Decker, J.E., Doronichev, V.B., Douka, K., Fordham, D.A., Fontana, F., Fritz, C., Glimmerveen, J., Golovanova, L. V., Groves, C., Guerreschi, A., Haak, W., Higham, T., Hofman-Kamińska, E., Immel, A., Julien, M.-A., Krause, J., Krotova, O., Langbein, F., Larson, G., Rohrlach, A., Scheu, A., Schnabel, R.D., Taylor, J.F., Tokarska, M., Tosello, G., van der Plicht, J., van Loenen, A., Vigne, J.-D., Wooley, O., Orlando, L., Kowalczyk, R., Shapiro, B. and Cooper, A. 2016. Early cave art and ancient DNA record the origin of European bison, *Nature Communications,* 7, 13158. doi:10.1038/ncomms13158

Svensson, A.M., Andersen, K.K., Bigler, M., Clausen, H.B., Dahl-Jensen, D., Davies, S.M., Johnsen, S.J., Muscheler, R., Rasmussen, S.O., Röthlisberger, R., Peder Steffensen, J. and Vinther, B.M. 2006. The Greenland Ice Core Chronology 2005, 15-42 ka. Part 2: comparison to other records, *Quaternary Science Reviews,* 25, 3258-3267. doi:10.1016/j.quascirev.2006.08.003

Sozzi, M., Vannucci, M.L. and Vannucci, S. 2008. Siliceous raw materials. Mineralogical, petrographical and geochimical characterization and first results on sources, in: Aranguren, B. and Revedin, A. (eds.). *Un accampamento di 30.000 anni fa a Bilancino (Mugello, Firenze).* Firenze, Origines, 47-54.

Tomasso, A. 2015. Se déplacer moins ou se déplacer autrement ? Mutations des systèmes de mobilité et des stratégies d'approvisionnement à la fin du Paléolithique supérieur en Provence et en Italie, in: N. Naudinot, L. Meignen, D. Binder, G. Querré (eds.), *Les Systèmes de Mobilité de La Préhistoire Au Moyen Âge.* XXXVe Rencontres Internationales D'archéologie et D'histoire d'Antibes. Éditions APDCA, Antibes, 223-240.

Vescovi, E., Ravazzi, C., Arpenti, E., Finsinger, W., Pini, R., Valsecchi, V., Wick, L., Ammann, B. and Tinner, W. 2007. Interactions between climate and vegetation during the Late Glacial period as recorded by lake and mire sediment archives in Northern Italy and Southern Switzerland, *Quaternary Science Reviews*, 26, 1650-1669. doi:10.1016/j.quascirev.2007.03.005

Visentin, D., Bertola, S., Ziggiotti, S., Peresani, M. 2016. Going off the beaten path? The Casera Lissandri 17 site and the role of the Cansiglio plateau on human ecology during the Early Sauveterrian in North-eastern Italy. *Quaternary International*, 423, 213-229. doi:10.1016/j.quaint.2015.11.119

Vukosavljević, N. and Perhoč, Z. 2017. Lithic raw material procurement of the Late Epigravettian hunter-gatherers from Kopačina Cave (island of Brač, Dalmatia, Croatia), *Quaternary International,* 450, 164-185. doi:http://dx.doi.org/10.1016/j.quaint.2016.09.017

Waelbroeck, C., Labeyrie, L., Michel, E., Duplessy, J.C., McManus, J.F., Lambeck, K., Balbon E., Labracherie, M. 2002. Sea-level and deep water temperature changes derived from benthonic foraminifera isotopic records, *Quaternary Science Review,* 21, 295-305. doi:10.1016/S0277-3791(01)00101-9

Wierer, U. and Bertola, S. 2016. The Sauveterrian Chert Assemblage of Galgenbühel, Dos de la Forca (Adige Valley, South Tyrol, Italy): Procurement Areas, Reduction Sequences, Tool Making, in: *Actes du Congress: Ressources lithiques, productions et transferts entre Alpes et Méditerranée, Nice 28-29 Mars 2013,* Paris, Publication de la Séances de la SPF, 229-256.

Winterer, E.L. and Bosellini, A. 1981. Subsidence and sedimentation on Jurassic passive continental margin, southern Alps, Italy, *AAPG Bulletin*, 65, 394-421.

Laminar tools with sinuous profile from Grotta Continenza (Trasacco – AQ, Italy)

A specialized production from the Late Epigravettian levels

Marco Serradimigni[1]

Abstract

This article is about the study of the Final Epigravettian lithic assemblage coming from Continenza Cave in Fucino basin (Abruzzo – Italy). Through the study of this assemblage, a new category of tools, not included in the Laplace typological list, has been discovered. These artefacts, which have been named "Sinuous", have been divided into two primary types (Sin 1, 2). They have been classified according to their morphology, to their stepped retouch and, when possible, according to their function. The tools were covered by a very extended and thick patina, which has in most cases prevented the recognition of micro-wear. Therefore, it has been possible to analyse only five items. Based on these analyses, on the location of the cave (on a lakeside nowadays dry), and on the abundant fish remains present in the deposit, it was assumed that the use of these new tools (or at least part of them) was linked with the treatment of lake fishery resources (mainly *Salmo trutta*).

These items might in fact represent, even if partially, a consequence of the environmental changes that occurred from Final Epigravettian. In this period, in fact, Man could reach environments that were precluded to him because of the previous climatic/environment adversities linked with the last cold climatic period. Since the climatic change, the natural resources became more and more diversified, therefore also their lithic tools have been adapted to the new environment.

Keywords: Final Epigravettian, laminar tools, fish processing.

---

1 Via Carlo Cattaneo 124, 56125 Pisa. Email: serradi.marco@gmail.com.

in: Borgia, V. and E. Cristiani (eds.) 2018: *Palaeolithic Italy. Advanced studies on early human adaptations in the Apennine peninsula*, Sidestone Press Academics (Leiden), pp. 247-264.

1. The archaeological site

Grotta Continenza (Trasacco – AQ; Abruzzo, Italy) is a cave located on the southern side of the Fucino Basin (Fig. 1a, b). The Fucino Basin is a tectonic depression formerly occupied by a lake, whose level modified several times during the Late Pleistocene and Early Holocene (Giraudi 1989). The cave is located on the northern side of Mt. Labrone, at the base of a limestone cliff. It is situated at 710 m asl, *i.e.* 43 m above the present-day plain that corresponds approximately to the bottom of the old lake.

The external and main part of the cave is a rock-shelter about 20 m wide and 7-8 m deep, which develops into a cave which dimension is about 8x8 m. The cave partly develops also along a secondary fault approximately perpendicular to the cliff (Boschian 2001; Boschian and Ghislandi 2011; Giraudi 1991).

The mountain side around Grotta Continenza is characterised by steep sides (from 45° to sub-vertical) dissected by short valleys occupied by less steep colluvial fans (*sensu* Blikra and Nemec, 1998), dipping up to 45° and now partly stabilised by shrubs and subordinate wood vegetation (Boschian 2001).

Archaeological excavations started in 1978 (Grifoni *et al.* 2011; Serradimigni 2013) and were carried on until 2012 by the University of Pisa. These excavations put into light a 9 m thick sequence largely composed of coarse clastic limestone and/or anthropogenic sediments (Boschian 2001), spanning from the Late Upper Palaeolithic to the Neolithic. The sequence includes the almost unprecedented documentation of at least three cultural transitions (Fig. 1c):

- from LUP (Final Epigravettian, levels 48-30) to Early Mesolithic (Sauveterrian, levels 29-25);
- from Sauveterrian to Late Mesolithic (Castelnovian, level 24);
- from Castelnovian to Early Neolithic (Impressa pottery, levels 23-3).

On the surface are levels attributable to the Bronze Age and Roman period.

2. Materials and Methods

The typological classification of tools discovered in Grotta Continenza was carried out by following the Laplace typological list (Laplace 1964, 1966, 1968); *pièces écaillées* were classified according to the Cremilleux and Livache list (Cremilleux and Livache 1976). Sinuous tools have been identified during the PhD study and they were immediately isolated and separately classified outside of the "Laplacian categories".

The typometrical analysis was carried out following the different *criteria* proposed by Bagolini (Bagolini 1968, 1971), Guerreschi (Guerreschi 1975) and Laplace (Laplace 1968).

For fragmented blanks (which are the largest part of the laminar complex), width (whole for not retouched, reconstructed for tools) was the criterion to identifying blades, bladelets or micro/bladelets. Such limit is conventionally 12 mm for blades and bladelets (Bagolini 1968, 1971; Guerreschi 1975; Laplace 1968; Wierer 2012).

Technological study was carried out following the methodology introduced by several French scholars, including J. P. Tixier (Tixier, 1984), M. Gallet (Gallet 1998), J. Pelegrin (Pelegrin 1988, 2000), B. Valentin (Valentin 2000). About the study of

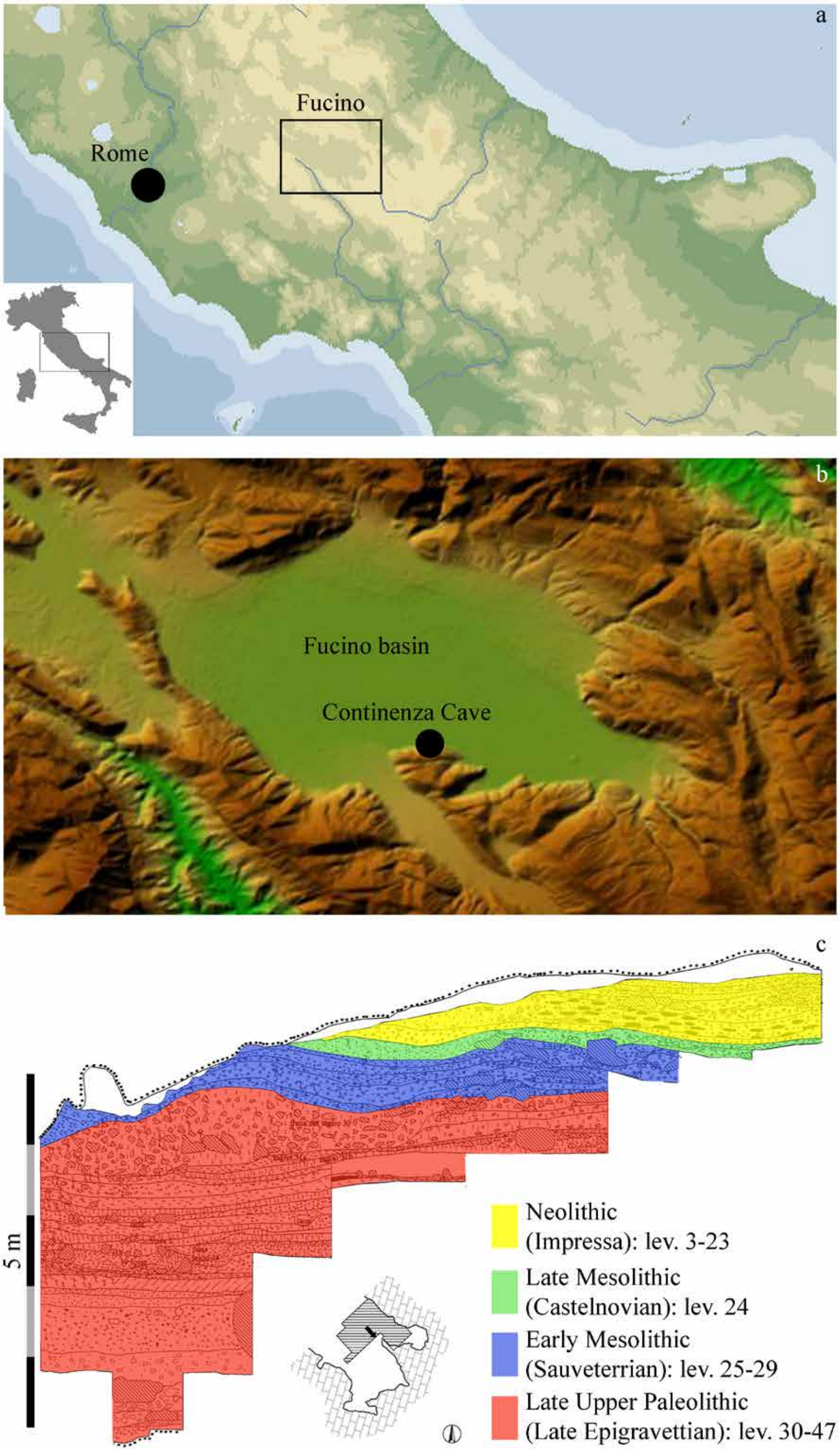


Figure 1. Location map. a: general location of Fucino Basin within Central Italy. b: Overview of the Fucino Lake basin with location of Grotta Continenza. c: stratigraphic profile E-W of Grotta Continenza, reporting level numbers and the main cultural phases.

M. Gallet (1998), which involves mostly Neolithic industries, some simplifications have been necessary on unnecessary characteristics in a study on a Palaeolithic complex.

Recognition of different types of percussion is mainly based on studies by J. Pelegrin (2000) and B. Valentin (2000). Percussion with soft stone was only recently identified as a separate technic (Pelegrin 2000; Valentin 2000; Tomasso 2014) and therefore its recognition is still to be completely defined. Uncertainties result from the variability of the gesture (position, size, strength), which contributes significantly to create the characteristic signs; these can then get confused and overlapped with those caused by the use of organic soft hammer. Characteristic signs of percussion with soft stone are the chipping angle (steeper than that produced by percussion with hard stone but less than organic hammer). Products are also more straight and less arched compared to those obtained with organic hammer; finally there is an intensive processing of the core frame.

Regarding raw material, I have used the few studies carried out in Abruzzo, mainly those of E. Danese (Danese 2003; Radi and Danese 2003) who identified flint categories used in the site and the probable outcrops exploited by the different communities settled in the Fucino basin. These studies were supported by intensive surveys in neighbouring areas to establish the existence of alternative flint deposits to those already known (Colombo *et al* 2011).

3. The lithic assemblage

In the Late Epigravettian levels, dated between 12937±50 BP (Lev. 45) and 9885±75 BP (Lev. 31) (Tab. 1), a very rich lithic assemblage was found. The amount of this assemblage is of 61.797 artifacts subdivided as follows:

- 28.795 chipped artifacts: blades, flakes and other technological recognizable categories; among these, 7.559 are tools (7.685 primary types), including blanks with only use-retouch;
- 32.650 flaking waste: which include all the finds, either whole or fragmentary, in which dimensional form (length + width) is less than 1 cm. Natural fragments are also included, even if their size is larger than 1 cm;
- 352 cores: all the different stages of the exploitation are present (tested block, starting-cores, pre-cores, cores, residues).

Based on the study of the above-mentioned lithic assemblage, the Late Epigravettian phase of Grotta Continenza has been divided into three parts:

EP 1 (Levels 44/41; approximately 13.000/11.500 BP): these older levels are related to a phase with many backed blades, backed points and short scrapers. The blade index is rather low, between 30 and 40% (Serradimigni 2013).

EP 2 (Levels 40/35; about 11500 BP): the lithic assemblage shows an increase of backed-tools, with the beginning of "backed-truncated blades" phase. Laminarity increases too (>50%) and long scrapers become substantially more than the short scrapers.

EP 3 (Levels 34/30; approximately 10.200/9.800 BP): after a chronological gap with EP2 lasting between 600 and 1400 years and which includes part of Dryas III (Serradimigni 2013), a "geometric phase" (segments, rare triangles) begins in levels close to the transition to Early Mesolithic (Sauveterrian). During this period, the microburin technique appears, Laminarity tends to decrease, though remaining high.

Through the study of the lithic assemblage of Late Epigravettian phase in Grotta Continenza (Serradimigni 2013), the author has identified tools with a particular morphology and a specific retouch. These tools seem not to belong to any canonical typological lists (Laplace 1964; 1966; 1968). Therefore they have been separately considered and classified.

Since their particular size and morphology, these tools could be included within the "special tools" typical of the Bertoniano Culture (*sensu* Radmilli – Radmilli 1954; 1983).

The Bertoniano Culture was identified for the first time by Prof. A. M. Radmilli during the excavations in the Campo delle Piane site (Montebello di Bertona – PE, Abruzzo) (Leopardi and Radmilli 1951/1952). Some peculiar features of lithic industries recur in the 35 "bertonian" sites identified in Abruzzo: rare microlithic tools, rare geometric tools, some rectangular tools, high laminarity, a different association of products compared to the one of other contemporary industries (Radmilli 1974, 1983; Tozzi 1977). Among retouched blades for the first time Radmilli describe "…*lame con due lati aventi accurato ritocco invadente con profilo sinuoso*…" (blades with two sides with an accurate invasive retouch and with a sinuous profile) (Radmilli 1983 p. 11).

Level	Laboratory	Date BP	Date Cal BC (2σ)	Material
31	Rome 1196	9885±75	9665-9235 (95,4%)	Charcoal
32	Rome 1195	9700±75	9294-9107 (57,1%) 9087-8832 (38,3%)	Charcoal
32	Rome 1194	9680±75	9281-9097 (49,7%) 9091-8826 (45,7%)	Charcoal
32	Rome 1197	9840±95	9693-9131 (92,6%) 8984-8930 (1,8%) 9753-9721 (1,0%)	Charcoal
32	Rome 557	10280±110	10486-9667 (93,2%) 10577-10514 (2,2%)	Charcoal
34	Rome 558	10230±110	10456-9647 (90,5%) 9612-9521 (3,4%) 9504-9457 (1,6%)	Charcoal
35	Rome 1198	11500±120	11610-11161 (95,4%)	Charcoal
37	Ly-10755	11830±110	12027-11487 (95,4%)	Charcoal
39	Lyon 1663 (OxA)	11725±65	11776-11490 (95,4%)	Charcoal
39	LTL 6188a	12353±60	12797-12152 (95,4%)	Charcoal
40	Ly-10754	11560±100	11631-11233 (95,4%)	Charcoal
41	Ly-10753	10760±140	11063-10446 (95,4%)	Charcoal
43	LTL 1249a	12381±60	12858-12175 (95,4%)	Charcoal
44	LTL 1250a	11983±80	12103-11651 (95,4%)	Charcoal
45	LTL 6187a	12937±50	13741-13306 (95,4%)	Charcoal

Table 1. Radiocarbon dates of the Late Epigravettian levels of Grotta Continenza.

The Fucino's lithic industries are, in fact, rather peculiar. Despite this, their importance is not enough to justify the identification of an independent culture ("Bertoniano") inside the mainstream Epigravettian culture (Serradimigni 2013).

4. Raw material

Flint raw material was introduced in Grotta Continenza as nodules/small nodules, less frequently as squared blocks. Pebbles are very rare (only 4 cases). In most cases, flint was recovered directly from outcrops in primary formation: cortex has a fresh look and is similar to that of nodules recovered in surveys on primary outcrops.

Pebbles come from a secondary supply source, probably from beds of torrents that have eroded the primary deposits leading downstream stone elements.

Squared blocks, coming from secondary deposits, have been collected from areas close to the main deposit. The angles of the blocks are not completely blunted by rolling, therefore it seems possible that the distance they traveled during the transportation was much lower than that of the pebbles.

The raw materials identified in Grotta Continenza have been classified according to 4 main categories selected according to macroscopic observation. A fifth group (Class E) includes all the cases where was impossible to track the comparison and provenance of the materials (Tab. 2).

Extensive sourcing surveys indicate that the raw material sources can be located within the "Maiolica" formation outcrops (white and grey flint), of the adjacent "Marne a Fucoidi", and of the "Scaglia Rossa Umbro-Marchigiana" (Danese 2003; Danese, Radi 2003).

The "Maiolica" flint is characterised by various shades of grey and white and is the most frequently exploited raw material (about 75%), whereas the "Marne a Fucoidi" grey-black flint and "Scaglia Rossa" fine reddish flint are less common (11% and 5% respectively), (Tab. 3).

Raw material class	Description
Class A (Maiolica)	White and gray flints with pink, blue, purple and yellowish variants
Class B (Scaglia rossa Umbro/Marchigiana)	Red or dark-beige flint
Class C (Marne a fucoidi)	Black or dark-gray vitreous and translucent flint
Class D	Other typologies
Class E	Indeterminable (altered by fire or other)

Table 2. Raw material classes identified in Grotta Continenza.

Cultural Phase	"Maiolica" (Num = %)	"Scaglia Rossa" (Num = %)	"Marne a Fucoidi" and others (Num = %)	Unidentified (Num = %)
EP3	6349 = 75.9%	324 = 3.9%	1053 = 12.6%	643 = 7.6%
EP2	12477 = 75.3%	834 = 5.1%	2305 = 13.9%	946 = 5.7%
EP1	2890 = 77.3%	212 = 5.7%	384 = 10.3%	252 = 6.7%

Table 3. Distribution of flint raw material per cultural phase.

The closest "Maiolica" outcrops are situated on Mount Genzana, about 30 km to the SE (Danese 2003), or alternatively on Mount Mentino, about 25 km to the west (Colombo *et al.* 2011). "Scaglia Rossa" outcrops are situated about 50 km to the north at high elevation in the Campo Imperatore area, close to the Gran Sasso Mountain; alternatively, they can be found much farer (about 80 km) to the north-east in the Montagna dei Fiori area. Other outcrops were mapped also in the Lazio region, about 70 km to the west, but the collected samples do not show the same characteristics of the Continenza assemblage (Colombo *et al.* 2011).

5. The Sinuous Tools

The 60 sinuous tools recognized in Grotta Continenza (29 complete, 31 fragmentary), represent the 0.79% of the whole retouched tools. They are widespread in both EP1, EP2 and EP3, with an intensification in the EP2 stage (38 elements) and a less consistent presence in EP1 (11) and EP3 (11).

This distribution is related to the different degrees of the human presence in the different levels (Serradimigni *et al.* 2016). They are more present in the central layers and rarefied at both ends of the Epigravettian sequence.

Sinuous tools are present only in the Late Epigravettian levels and they are absent in the Mesolithic and Neolithic phases.

The sinuous tools are not easily classifiable into any of the standard typological families *sensu* Laplace. They show particular morphological features which do not permit to insert them in the categories of long scrapers, points or denticulate tools.

The recurrent features of these objects are:

- S-form of the laminar blank. This peculiar form is already obtained in the *débitage* process. It is only partially modified/regularized later by retouching.
- Retouching-type (stepped retouch), partly justified by the thickness of the blade as well as the intended use of the finished tool.
- Size. Only blade longer than 5 cm.

According to shape variations, there are two different morphologies of sinuous tools: Sin 1 (36 elements) and the Sin 2 (18 elements). Furthermore, there are six findings that cannot be attributed with absolute certainty to any of the above categories.

Sin 1 (Fig. 2): 36 items in total, are mainly represented by retouched blades in which both edges have a marked "S" shape, obtained directly by *débitage* and/or modifying the edges by retouch. The sinuous morphology of these instruments suggests that they were used to scrape convex surfaces, perhaps during the fish processing operations. There is only a special case: a double point on a sinuous blank (Fig. 2a), characterized by backed retouch. Its morphology suggests its use as a hunting tool (or fishing tool, as a harpoon head) rather than as a descaler knife.

Sin 2 (Fig. 3): 18 elements in total; some specimens should be considered as a kind of large flint awls, with the functional part formed by the proximal portion, from which the bulb/butt part was removed. The distal part was maintained larger, to be used as a handle. They are characterized by a remarkable thickness and are less sinuous than Sin1. Among Sin 2, at least two different way of use are associated to the same

Figure 2. Sinuous Tools (Sin 1).

shape (see below: Functional analysis): some tools have use-wear traces in the proximal area, so they were used as an awl/puncher, other tools have the use-wear traces on the long concave and retouched edge.

On some of these artifacts there are remains of a dark substance (these residues are also present on some backed point); this do not seem belonging to the deposit, but to some substance used as a natural glue (tar or bitumen). For example, tool 19568 (Sin 1 from Level 44; Fig. 6b) has remains of a dark substance associated with ocher residues. Ocher is often used as "degreaser" mixed with natural glues (Wadley 2005; Serradimigni and Colombo 2015).

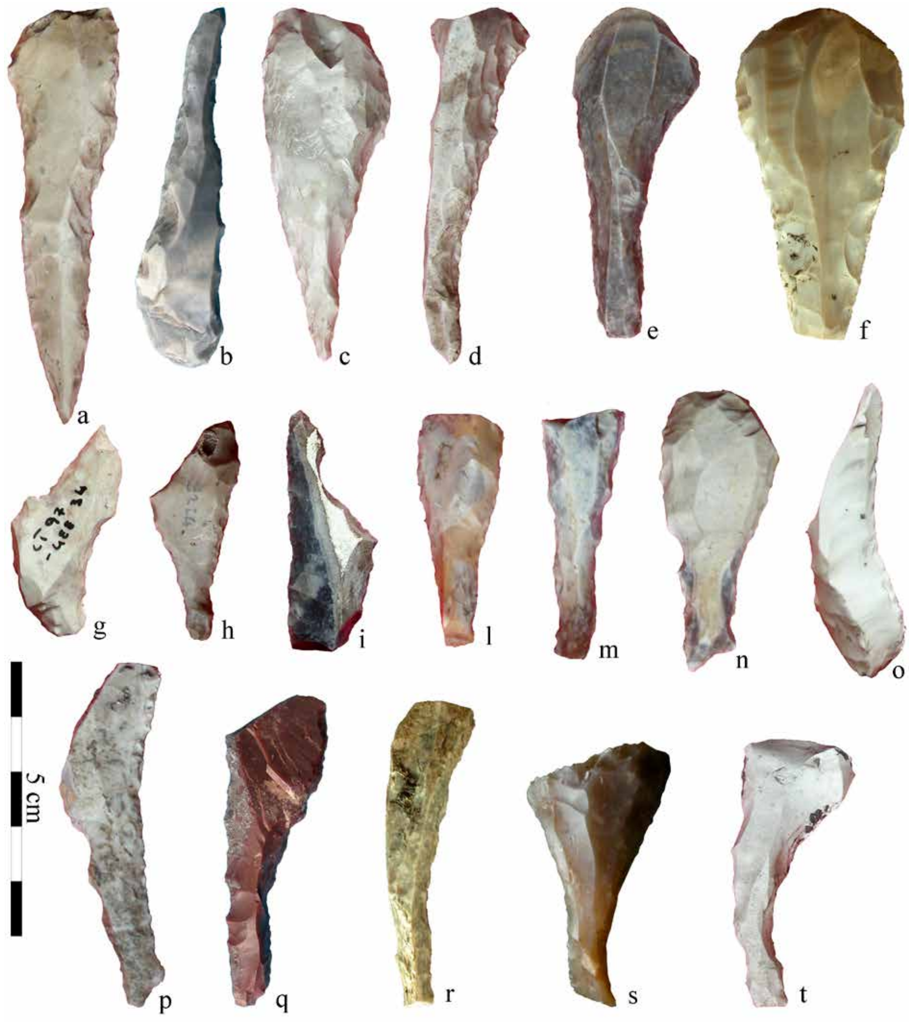


Figure 3. Sinuous Tools (Sin 2).

5.1. Technological analysis

Four *châines opératoires* for blade/bladelet and flake production can be identified: two of these aims at producing blades/bladelets by progressive reduction of medium-size (10-20 cm) (Fig. 4a) or small-size (less than 10 cm) (Fig. 4b) flint blocks; one exploits core-flakes, for bladelets production (Fig. 4c); the last one, is expedient and aims at producing flakes by small discoid cores. Blades/bladelets size is standardised by post-flaking modification of the length by blank fracturing, and of the width by retouch (Serradimigni 2011).

The technological analysis on sinuous tools is based only on the observation of laminar products and not on the study of cores. Many cores have been abandoned to the state of residual cores or when sinuous laminar products have already been chipped. There are not cores which have been abandoned at an early stage of exploitation that can actually witness sinuous negative traces.

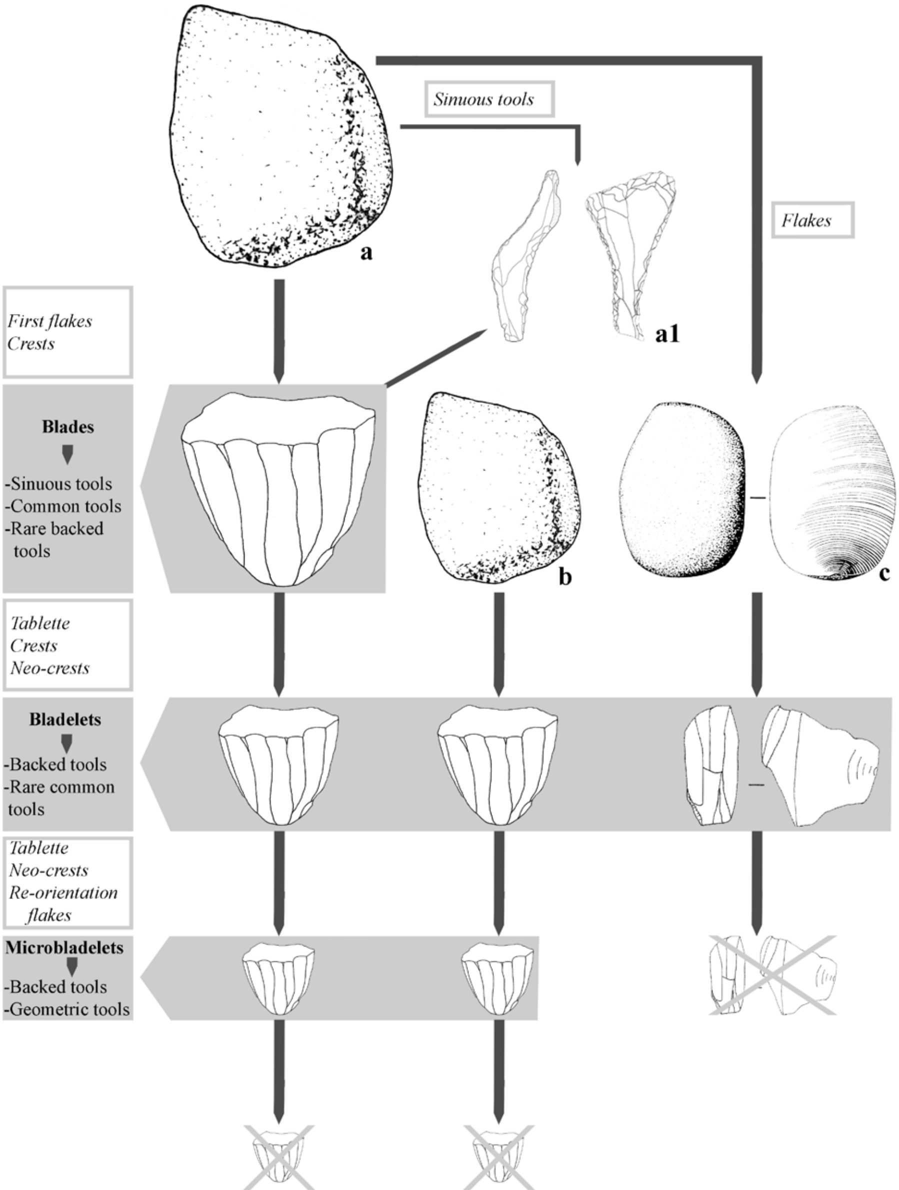


Figure 4. Chaines opératoires of laminar blank production.

Sinuous tools are made on blades that go far beyond the dimensional blade blank average normally discovered in the lithic assemblage of Grotta Continenza. The average length is 5.9 cm, with the longest item is up to 9.3 cm.

Sinuous tools are always full *débitage* elements, obtained in an initial stage (Fig. 4a1) of the *châine opératoire* that leads to blade, bladelets and micro-bladelets production (Fig. 4a) through the progressive reduction of core volume. Tools made on corticate blades are frequent. They should be considered as elements of full-production, and not as management products.

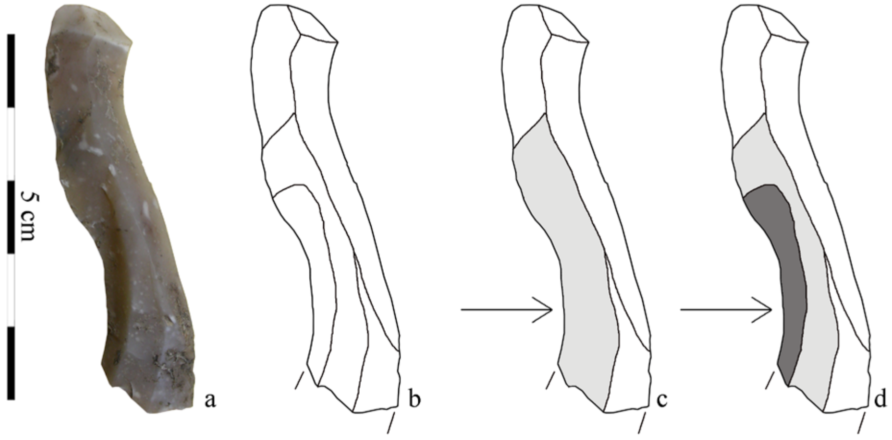


Figure 5. Fragmentary not retouched sinuous blade, probably for making a sinuous tool. a-b: blade (photo and draw). c: the first flake-negative. d: the second flake-negative.

In order to detach the sinuous tools from the core, it has been used only direct percussion, with both hard and soft hammer (Pelegrin 1988; 2000; Valentin 2000; Arzarello *et al.* 2011; Tomasso 2014). Organic direct percussion does not seem to have been used, even if this method characterizes much of the remaining lithic complex (Serradimigni 2013).

The production of the sinuous blanks is linked to the purpose of obtaining blades with a particular morphology:

Sin 1: blank was chipped in order to have a blade with S-form edges, which could be partially modified by retouch emphasizing or reducing the sinuosity.

Sin 2: production was aimed to chip blanks with two special feature:

- a wide plunging distal part, probably often used as a handle.
- a narrow proximal part, which in some cases was the functional portion of the tool (see below: Functional analysis).

The only sinuous not retouched element is fragmented (Fig. 5 – preserved lenght 5,4 cm). On its dorsal surface traces that indicate how the guide-rib could have been obtained are observable: the median-left proximal portion is affected by two negatives detachments (due to the distal part of flakes) (Fig. 5c, d) orthogonal to the direction of the blade. This flake seems to have the function of producing the necessary curvature in that portion of the blank.

In summary, it can be assumed that a secondary production dedicated (Fig. 4a1) to these particular tools (Fig. 2, 3, 6) was realized in early stages of the main *chaine opératoire* (Fig. 4a):

- Sin 1: they were produced by making cores from which it was possible to detach blades with a sinuous profile; unfortunately up to now these cores are not present within the lithic collection because their exploitation continued (there are only core-residues).

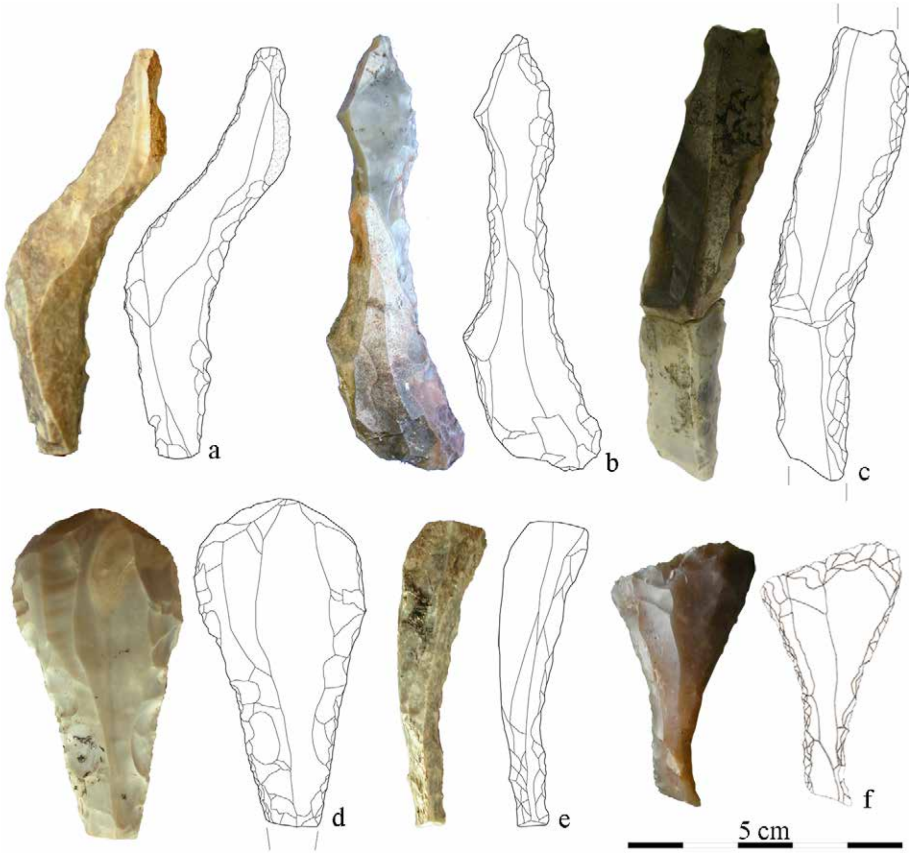


Figure 6. Examples and drawings of the two types of Sinuous tools: a, b, c. Sin 1; d, e, f. Sin 2.

- Sin 2: the goal of this production was obtaining plunging blades with the distal portion used as a handle. Also in this case no cores abandoned at this stage of exploitation are presents.

Another hypothesis is that these particular laminar blanks were introduced into the cave as already finished tools. This could explain why there are not elements of their *châine opératoire*.

5.2. Functional analysis

Most of the tools found in the paleolithic sequence of Grotta Continenza have a very thick patina that has made impossible the micro-traces investigation. For this reason only 5 pieces (Fig. 7) were analyzed under a microscope.

Sin 1: 3 tools have been analyzed:

N. 8633 (Tg. 38) (Fig. 7c, d, e): the blank is fragmentary, but the tool could be considered entire because the apical fracture is recovered and modified by retouch. There are polished areas on both concave and on the extremely sharp edges of the tool. Ventral and deep micro-scars affect the whole right edge and the apex of the left side.

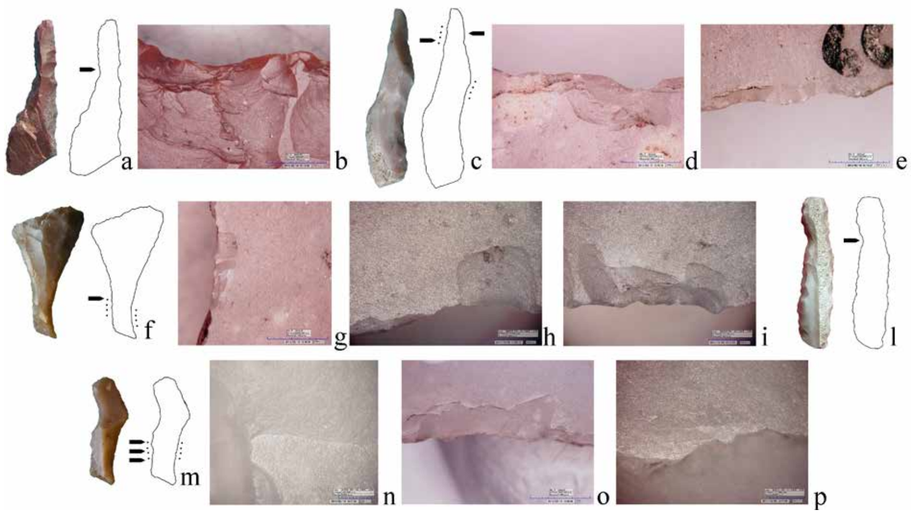


Figure 7. Continenza Cave. a, c, f, l, m. Pieces that were observed under the microscope for the functional analyses; b, d, e, g, h, i, n, o, p. Images of the detail of micro-traces on the margins of the instruments (microscope photos, Dr. Valentina Borgia).

N. 5169 (Tg. 37) (Fig. 7m, n, o, p): the tool is intact, but made on a fragmentary blank because the apical fracture has been recovered by retouch and has evident use-wear. The edges, very sharp, have polished areas and micro fractures along the less accentuated concavity and in the outer part of the opposite dent. In this case, the polished area is above a wider detachment and could be interpreted as the trace left by a handle; there are also some micro-scars.

N. 19948 (Tg. 36) (Fig. 7h, i, l): macro-wear are included within the more evident retouched dent; it involves a "bottleneck" (*étranglement*) of the blade.

Sin 2: 2 tools were analyzed:
N. 18861 (Tg. 43) (Fig. 7f, g): the tool is has both edges retouched and sharp; many micro-fractures and polished areas are visible on it.

N. 12615 (Tg. 39) (Fig. 7a, b): the tool is fractured at both ends and presents concretions covering any micro-traces. On the concave part of the piece there are very deep macro-traces visible even by naked eye and not compatible with the use on fish. These are attributable to an intense work on a hard material, so that the margin in that area is very rounded.

Despite the small quantity of the analyzed elements, functional analysis can provide interesting ideas:

1. As already verified by both typological and technological analysis, there are at least two groups of tools. Some were used as sinuous knives or scrapers (wear is on side

edges), others are blades that have use-wear traces on one end, which is often very rounded and with fractures retouched again.

2. All sinuous tools have in common at least one curved side with very sharp and slightly denticulate edges, which is the functional part in all the 5 analyzed samples. This recess is always obtained (or feature by) with a stepped retouch.

6. Discussion

The unusual shape of sinuous tools, their recurrent retouch type and the study of use-wear traces (although it is still preliminary), lead to hypothesize their use for specialized works carried out within the cave.

In this perspective, it would be interesting to determine if sinuous tools were tools with a particular form, but used in common actions (leather or wood working, cutting plants, etc..), or if this morphology was requested to carry out specific activities that were not made with other traditional tools. Without a more consistent traceological data, the answer to this question is unfortunately lacking.

The second hypothesis seems however the most plausible, especially considering the not common form of these tools and the particular environment near Grotta Continenza (linked to the exploitation of the lake/torrential resources). The abundance of fish faunal remains in all the Epigravettian levels and the use-wear analysis do not contradict this hypothesis.

Archaeological comparisons are present only in the territory of the Fucino basin and surrounding areas, especially in the area occupied by human communities who frequented Grotta Continenza. These tools are often present, although in rather limited number, inside the lithic complexes recovered in contemporary contexts. In Grotta Achille Graziani (Radmilli 1955), Grotta Maritza (Grifoni and Radmilli 1964) and Grotta/Riparo di Venere (Radi 1983) the authors describe some sinuous blades very similar to those from Grotta Continenza. In particular, two items unearthed at Grotta Maritza and Grotta Achille Graziani are almost identical to sinuous tools of Grotta Continenza. They have identical morphology, dimension and type of retouch (Fig. 8a-f).

No specific ethnographic comparisons have been found, therefore analogies with modern tools have been searched. This research has identified in current descaler knives the closest object to sinuous tools (Fig. 8g). The "S" silhouette is common to both modern and Epigravettian tools. It was such sinuosity that pushed to consider the above-mentioned hypothesis. This specific morphology is well adapted to "work" along the silhouette of the animal's body.

Sinuousity with denticulate margins is, also in the modern tools, a requested characteristic in knives used to clean fish, especially associated to a point for the extraction of entrails.

Some traces found on Sin 2 tools would be compatible with their use on fish, but never in an exclusive way. Some of these instruments, in fact, have macro-chippings on the ventral surface that indicate an alternative use on harder materials such as wood.

In short, the sinuosity of these tools can be functional in different activities, both on soft and harder materials such as wood. The work on hard material could be the

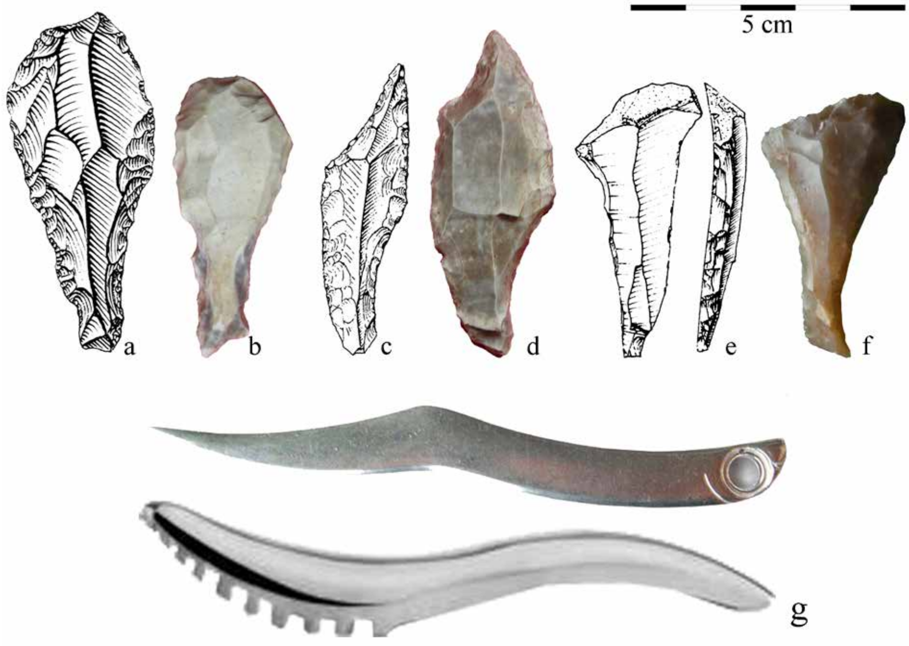


Figure 8. Comparison between some examples of Sinuous tools found in Grotta Continenza and in other caves of the Fucino basin and neighbouring territories. b, d, f. Grotta Continenza; a. Grotta Maritza; c. Grotta Achille Graziani; e. Grotta/Riparo di Venere. Images of modern fish scalers (from the web) (g).

cause of the macro-traces found on the tool number 12615. The polished areas and other micro-traces, however, are compatible with the machining of soft organic material, including fish and meat in general.

7. Conclusions

Regardless of the interpretation of use for these particular objects, it is evident that their production is not the result of random and sporadic episodes within the lithic Epigravettian complex of Grotta Continenza and in the neighboring sites. On the contrary, their presence is the result of the desire to create objects with a particular shape, probably intended for specific activities.

Production of specialized tools such as sinuous tools falls entirely in the context of rapid and sudden changes that characterize the end of Late Glacial in Italy. With the expansion of available resources, these specialized tools well fit within a range of modifications and specializations that also involve lithic complexes.

Also in the Late epigravettian lithic complex of Grotta Continenza, the increased frequency of geometric tools and the overall microlithisation of backed tools (Serradimigni 2013) could be directly linked to these changes, both climate (transition Younger Dryas/Preboreal) (Serradimigni and Boschian 2015) and in the spectrum of the available fauna.

Biomass of ungulates decreased, equides disappeared and bovids became rare (Tozzi 1999); at the same time, predation of medium-small size animals increased. There was an increase of small mammals and birds hunting (in Fucino there was a big increase in ducks presence) (Tozzi 1999; Cremonesi 1969; Grifoni and Radmilli 1965; Wilkens 1991), fishing (*Salmo trutta*), landsnails exploitation (*Helix ligata*) and plants gathering.

Big lithic tools were no longer needed for hunting, but in this context of general microlithisation in the Fucino area we see the emergence of the sinuous tools, which conversely are of a big size.

Despite often the presence of a point (mostly in Sin1), their use seems not directly tied to hunting but rather to some other specific activities.

The location of the site along the perimeter of the ancient Fucino Lake and the presence of abundant fish remains in Epigravettian levels (almost exclusively *Salmo trutta*, a torrential species) (Wilkens 1991; Nutini 2007) lead us to hypothesize an at least partial use of these tools in exploitation of freshwater resources.

Acknowledgements

I would like to thank Dr. Valentina Borgia for his valuable contribution on use-wear traces and Prof. Renata Grifoni for entrusting me, now so long ago, the study of lithic complex from Grotta Continenza.

I want also to thank Prof. Carlo Tozzi, Prof. Annamaria Ronchitelli, Dr. Marta Colombo, and Dr. Fabio Negrino, for their helpful advice about this still little known finds.

References

Arzarello, M., Fontana, F., Peresani, M. 2011. *Manuale di tecnologia litica preistorica. Concetti, metodi e tecniche*, Carocci editore, Roma.

Bagolini, B. 1968. *Ricerche sulle dimensioni dei manufatti litici preistorici non ritoccati*, Annali dell'Università di Ferrara (Nuova Serie), Sezione XV – Paleontologia umana e paletnologia, I, N° 10, 195-219.

Bagolini, B. 1971. *Ricerche sulla tipometria litica dei complessi epipaleolitici della Valle dell'Adige*, Preistoria Alpina, 7, 243-276.

Blikra, L. H., Nemec, W. 1998. Postglacial colluvium in western Norway: depositional processes, facies and palaeoclimatic record. *Sedimentology*, 45, 909-959.

Boschian, G. 2001. Breve nota sui depositi di riempimento della Grotta Continenza di Trasacco (Conca del Fucino, Italia centrale), in: Grossi, G., Irti, U., Malandra, C. (Ed.). *Atti del II convegno di Archeologia "Il Fucino e le aree limitrofe nell'antichità"*, Celano – Paludi, 33-37.

Boschian, G., Ghislandi, S. 2011. Nuovi dati geoarcheologici sulle grotte Continenza e Maritza, in: Irti, U. (Ed.). *Atti del III convegno di Archeologia "Il Fucino e le aree limitrofe nell'antichità"*, Avezzano, 40-54.

Colombo, M., Pepe, M., Serradimigni, M., Usala, M. 2011. Dati e test sperimentali sulle materie litiche silicee provenienti dai territori limitrofi al bacino del Fucino, in: Irti, U. (Ed.). *Atti del III convegno di Archeologia "Il Fucino e le aree limitrofe nell'antichità"*, Avezzano, 581-583.

Cremilleux, H., Livache, M. 1976. *Pour le classement des piéces écailées*, Dialektiké, Cahiers de Typologie Analytique, Université de PAU, Institut Universitaire de Recherche Scientifique, 1-13.

Cremonesi, G. 1969. Contributo alla conoscenza della preistoria del Fucino: la Grotta di Ortucchio e la Grotta La Punta, *Rivista di Scienze Preistoriche*, 23, 145-203.

Danese, E. 2003. Approvvigionamento della selce nei settori marsicano e aquilano dell'Abruzzo. Dati preliminari, *Atti della XXXVI Riunione Scientifica Istituto Italiano di Preistoria e Protostoria*, 605-609.

Gallet, M. 1998. *Pour une technologie des débitages laminaires préhistorique*, Dossier de documentation archéologique, 19, CNRS Editions.

Giraudi, C. 1989. Lake levels and climate for the last 30'000 years in the Fucino area (Abruzzo, Central Italy). A review. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 70, 249-260.

Giraudi, C. 1991. Evoluzione geologica della piana del Fucino (Abruzzo) negli ultimi 30.000 anni, in: Irti, U., Grossi, G., Pagani, V. (Ed.), *Atti del I convegno di Archeologia "Il Fucino e le aree limitrofe nell'antichità"*, 17-44.

Grifoni, R., Radmilli, A. M. 1965. La Grotta Maritza e il Fucino prima dell' età romana, *Rivista di Scienze Preistoriche*, 19, 55-127.

Grifoni Cremonesi, R., Serradimigni, M., Usala, M. 2011. Le campagne di scavo dal 2001 al 2009 nella Grotta Continenza di Trasacco. Livelli dell'Epigravettiano finale, Mesolitico e Neolitico antico, in: Irti, U. (Ed.), *Atti del III convegno di Archeologia "Il Fucino e le aree limitrofe nell'antichità",* 27-37.

Guerreschi, A. 1975. *L'epigravettiano di Piancavallo (Pordenone)*, Preistoria Alpina, 11, 255-293.

Laplace, G. 1964. Essai de typologie systématique, *Annali dell'Università di Ferrara*, XV/1, suppl. II, 22-71.

Laplace, G. 1966. *Recherches sur l'origine et l'évolution des complexes leptolithiqes*, Ecole Française de Rome, 4, Paris.

Laplace, G. 1968. Recherches de typologie analythique, *Origini*, II, 7-64.

Leopardi, G., Radmilli, A. M. 1951-52. Giacimento preistorico all'aperto di Campo delle Piane (Pescara), *Bullettino di Paletnologia Italiana*, VIII, 89-92.

Nutini, S. 2007. *Studio archeozoologico del materiale osteologico animale proveniente dai livelli epigravettiani (tagli 31-40) della Grotta Continenza (Trasacco-L'Aquila)*, Unpublished Degree Thesis, University of Pisa.

Pelegrin, J. 1988. *Sur une recherche technique expérimentale des techniques de débitage laminaire, Archéologie Expérimentale*, Tome 2-La Terre, Archéologie Aujourd'hui, Paris éd. Errance, 118-128.

Pelegrin, J. 2000. Les techniques de débitage laminaire au Tardiglaciaire: critères de diagnose et quelques réflexions, *L'Europe centrale et septentrionale au Tardiglaciaire, Table ronde de Nemours, Memoires du Musée de Préhistoire d'Ile de France*, 73-86.

Radi, G. 1983. L'industria bertoniana del Riparo di Venere (L'Aquila), *Atti della Società Toscana di Scienze Naturali*, A/LXXXIX, 189-207.

Radmilli, A. M. 1954. Una nuova facies del Paleolitico italiano presente in Abruzzo, *Bullettino di Paletnologia Italiana*, IX/64, 73-105.

Radmilli, A. M. 1955. Il paleolitico superiore nella Grotta Achille Graziani (Parco Nazionale d'Abruzzo), *Atti della Società Toscana di Scienze Naturali*, A/LXII (II), 479-495.

Radmilli, A. M., 1974. *Popoli e Civiltà dell'Italia antica*, Vol. 1.

Radmilli, A. M. 1983. Ricerche sul Bertoniano cultura dell'Epigravettiano italiano. Località Campo delle Piane, *Archeoclub di Pescara*, 1, 46.

Serradimigni, M. 2011. Il complesso litico dei livelli più antichi dell'Epigravettiano finale di Grotta Continenza (Trasacco – AQ): supporti/strumenti standardizzati e fratture intenzionali tra le lame e le punte a dorso, *Quaderni di Archeologia dell'Abruzzo*, 1, 3-8.

Serradimigni, M. 2013. *L'industria litica dei livelli epigravettiani di Grotta Continenza (Trasacco, AQ): studio, revisione e inquadramento nell'ambito delle coeve industrie dell'Italia adriatica centro-meridionale*, PhD Thesis, University of Siena.

Serradimigni, M., Boschian, G. 2015. The Upper Palaeolithic-Mesolithic transition in Continenza Cave (Abruzzo-Italy) in the framework of contemporary cultures in central and southern Italy, *Book of Abstracts of "Prehistoric hunter-gatherers and farmers in the adriatic and neighbouring regions"*, ISBN 978-953-7276-38-6, 70.

Serradimigni, M., Colombo, M. 2015. Ocra rossa tra funzionalità e simbolismo: il caso del complesso litico dell'Epigravettiano finale di Grotta Continenza (Trasacco – AQ), *Atti della Società Toscana di Scienze Naturali,* A/CXXII, 85-95.

Tixier, J. P. 1984 *Préhistoire de la pierre taillée, 2 : économie du débitage laminaire*, III Table ronde de technologie lithique, Meudon-Bellevue, octobre 1982.

Serradimigni, M., Colombo, M., Grifoni, R. 2016. Grotta Continenza (Trasacco – AQ): uso funerario e uso abitativo della cavità dal Paleolitico Superiore all'Età dei Metalli, *Atti del IV Convegno di Archeologia "Il Fucino e le aree limitrofe nell'antichità"*, Avezzano, 49-57.

Tomasso, A. 2014. *Territoires, systèmes de mobilité et systèmes de production. La fin du Paléolithique supérieur dans l'arc liguro – provençal*, PhD Thesis, University of Nice Sophia-Antipolis – UFR Lettres, Sciences Humaines et Sociales, and University of Pisa.

Tozzi, C. 1977. *Il passaggio dal Paleolitico al Neolitico sul versante adriatico della penisola italiana. Aspetti economici e culturali*, Abruzzo Rivista dell'Istituto di Studi Abruzzesi, anno XV, n° 1-2-3, 59-81.

Tozzi, C. 1999. L'alimentazione dei mesolitici in Italia, *Actes des Vlle Rencontres culturelles interdisciplinaires de l'Alta Rocca*, 63-66.

Valentin, B. 2000. L'usage des percuteurs en pierre tendre pour le débitage des lames. Circonstances de quelques innovations au cours du Tardiglaciaire dans le Bassin parisien, in: Pion, G. (Ed.), *Le Paléolithique Supérieur récent: nouvelles données sur le peuplement et l'environnement, Actes de la Table Ronde de Cambery*, 253-260.

Wadley, L. 2005. Putting ochre to the test: replication studies of adhesives that may have been used for hafting tools in the Middle Stone Age, *Journal of Human Evolution*, 49, 587-601.

Wilkens, B. 1991. Resti faunistici ed economia preistorica nel Bacino del Fucino, in: Irti, U., Grossi, G., Pagani, V. (Ed.), *Atti del I Convegno di Archeologia "Il Fucino e le aree limitrofe nell' antichità"*, 147-153.

An overview of early Epigravettian techno-economic behavior in northern and western Adriatic area

Emanuele Cancellieri[1]

Abstract

The aim of the paper is to provide an overview, mostly focused on lithic technology, of the human occupation of the northern and western Adriatic areas at the end of the Last Glacial Maximum (ca. 24,000- 20,000 calBP). Is then advanced a point of view on the role, in the early Epigravettian hunter-gatherers settlement system, of the once exposed Great Adriatic Plain, suggesting that while the areas around the plain attracted specialized activities, the plain itself probably acted as residential area. The progressive reduction of the plain by the end of the LGM is paralleled by the southward diffusion of early Epigravettian assemblages within archaeological contexts increasingly consistent with palimpsests of diversified activities. This is interpreted as a reorganization of Epigravettian settlement systems due to geographical and paleoenvironmental modifications.

Keywords: Last Glacial Maximum, Great Adriatic Plain, techno-economic behaviour, hunter-gatherers land use.

1. Introduction

This paper attempts at reviewing the evidence from early Epigravettian sites distributed along the western Adriatic basin, from Istria peninsula in northern Croatia to Salento peninsula in southern Italy. The main goal is to investigate the subject of the human

1 Dipartimento di Scienze dell'Antichità, Sapienza Università di Roma, via dei Volsci 122, 00185, Rome, Italy. E-mail: emanuele.cancellieri@uniroma1.it.

in: Borgia, V. and E. Cristiani (eds.) 2018: *Palaeolithic Italy. Advanced studies on early human adaptations in the Apennine peninsula*, Sidestone Press Academics (Leiden), pp. 265-286.

occupation of the area at about the end of the Last Glacial Maximum (ca. 24,000-20,000 calBP) contributing this way to the debate about the role of the then exposed Great Adriatic Plain within early Epigravettian hunter-gatherers settlement system(s). In doing this, a synthesis of available data about the considered time span and geographic range is first provided focusing on selected areas bordering the western and northern sides of the Adriatic sea (Fig. 1): the Istria peninsula in northern Croatia, the Berici Hills in Veneto region, the Central Apennine in Marche and Abruzzi regions, the Gargano promontory, the Murge and the Salento peninsula in Apulia. The overview integrates a survey of published data with the results of the analyses carried out by the author on early Epigravettian assemblages from the Italian sites of Fosso Mergaoni, Madonna dell'Ospedale, Grotta di Pozzo and Fondo Focone (Fig. 1). Fosso Mergaoni will also serve here as case-study, and accordingly it will be the object of a more detailed description (§3.3.1).

The analysis of the archaeological record adopted a techno-economic approach which combined analysis of the reduction sequence (Pelegrin *et al.* 1988) and the assessment of raw materials and flaking products economy (Perles 1991), in order to gain a wide and complete idea of the procurement, circulation and consumption of lithic raw materials and flaking products within the different study areas. If assuming that major differences in the systemic organization of hunter-gatherer societies can have an important and predictable impact on the formation of sites archaeological record (Binford 1980; Bietti 1986; Shott 1986), analyzing the spatial heterogeneity of cultural data from a wide and diversified geographical range like the one considered here allows to better understand how human communities interacted with each other and with the environment in the framework of specific settlement systems, and also to catch the relationships between cultural patterns and ecological processes.

In this perspective, comprehensive techno-economic analyses represent a powerful means to investigate site function, mobility and land use, in a framework of multi-scope territorial-oriented research (*e.g.* Burke 2006) where the shift from site to region allows to uncover spatial relations within and between sites, and between sites and key elements of the landscape (*e.g.* the distribution of raw materials), that are, series of natural constraints within which the variability of human behaviour can be analyzed (Kuhn 2004).

2. Framework

The last glacial cycle in Europe was marked by extensive and pronounced climatic variability particularly in correspondence of the Last Glacial Maximum. During this time period, characterized by the maximum expansion of the glacial icecap in Scandinavia and northern Europe and generally cold, arid climatic conditions in northwest Europe, the amount of ice in the glaciers and in the continental ice sheets reached its maximum, which corresponded to an abrupt drop in sea level of up to about -120 m (Shackleton *et al.* 1984). Vast areas of the continental shelves were then exposed, causing the rivers to change their course and to flow into the sea far from their present-day estuaries (Lambeck *et al.* 2002; Lambeck and Chappell 2001; Shackleton *et al.* 1984; Antonioli *et al.* 2004; Lambeck and Purcell 2005; Correggiari *et al.* 1997).

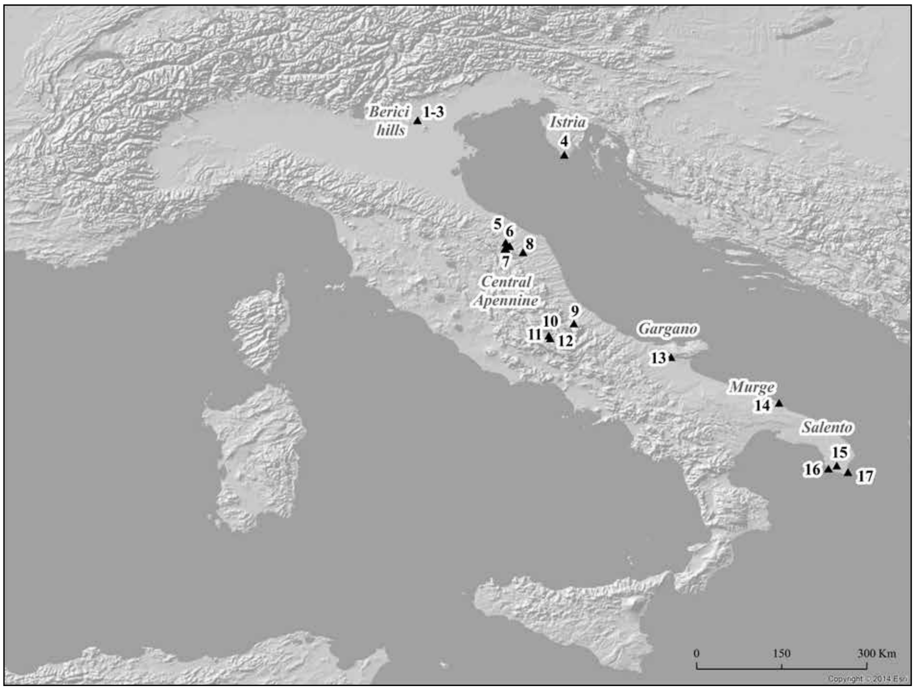


Figure 1. Map of sites mentioned in the text: 1, Grotta di Paina; 2, Grotta di Trene; 3, Riparo del Broion; 4, Šandalja II; 5, Ponte di Pietra; 6, Fosso Mergaoni; 7, Madonna dell'Ospedale; 8, Grotta di Frasassi; 9, Grotta S. Angelo; 10, Grotta Tronci; 11, Riparo Maurizio; 12, Grotta di Pozzo; 13, Grotta Paglicci; 14, Grotta delle Mura; 15, Taurisano; 16, Fondo Focone; 17, Cipolliane C.

The geography of the western Mediterranean was different from that of today because of dramatic sea lowering. Corsica and Sardinia, for example, formed a single island, while the Elba island was part of a coastal plain connected to the continent. East of Spain and between the Pyrenees and Maritime Alps there were wide coastal plains. Conversely, the shape of the central and southern Tyrrhenian coast was similar to the current ones because of its steepness. North-east of Tunisia and north of Libya there was a coastal plain over 200 km wide (Shackleton *et al.* 1984; Lubell 2001).

The northern fringe of the Adriatic basin underwent dramatic changes that profoundly altered its extension. A wide coastal plain occupied in fact the northern half of the current basin, which was crossed by rivers supplied by the water from the alpine glaciers and from the Apennine chain. At the same time, the eastern sector, the current Dalmatian coast, was characterized by the presence of steep hills over the plain (Shackleton *et al.* 1984; Antonioli *et al.* 2004).

The LGM archaeological record features a few sites and shows large gaps in many areas, interpreted as the result of the abandonment of the northern regions and of the contraction of human presence in southern *refugia* (Djindjian *et al.* 1999; Straus 1991a, b; Bailey and Gamble 1990; Kozlowski 2005). While western Europe saw the onset of the Solutrean, characterized by very typical bifacial projectile points, southern and eastern Europe witnessed the development of the Early Epigravettian, mostly characterized by shouldered projectile points. Differently from the Solutrean, which is considered an innovative technocomplex, the Epigravettian is tied to the Gravettian tradition (Djindjian *et al.* 1999; Broglio and Kozlowski 1987; Broglio 1997; Otte 1990; Peresani 2006). According to Banks *et al.* (2008), although "Epigravettians" could have adapted to territories west of those they actually occupied, this did not occur because of eco-cultural conditioning. Their need to maintain strong links – also linguistic ones – within the borders of well-defined geographic barriers, supposedly prevented "Epigravettians" from expanding beyond the Alps and the Pyrenees (Banks *et al.* 2008).

The earliest evidences of the spread of the early Epigravettian in the Balkans are in Istria (Šandalja, ca. 24,000 calBP), Slovenia (Ovca Jama, ca. 23,000 cal BP) and western Greece (Kastritsa, ca. 24.000 cal BP) while the youngest in Slovenia, Bosnia, southern Bulgary and eastern Greece (Montet-White and Kozlowski 1983; Kozlowski 2008; Montet-White 1996; Mihailovic and Mihailovic 2007). It has been suggested that the first appearance of the technocomplexes with shouldered points in the Balkans should be identified with the occupation of the area as a *refugium* by late Gravettian groups coming from the middle Danube region (Kozlowski 2008). Furthermore, the origin of the shouldered points of this region is linked, on a morpho-stylistic basis, to some eastern types, like the Kostienky and Willendorf ones (Kozlowski, 2008, 1999).

The early Epigravettian in peninsular Italy chronologically spans between ca. 24,000 and 19,000 calBP (ca. 20,000 – 16,000 uncalBP), and is traditionally subdivided into three phases: the «initial phase», the «foliates phase» and the «shouldered points phase» (Palma di Cesnola 1993; Mussi 1990; Bietti 1990; Mussi 2001; Broglio 1997; Bietti 1997; Palma di Cesnola and Bietti 1983; Bartolomei *et al.* 1979; Gioia *et al.* 2003), the latter being the best known and more precisely defined. It extends mainly along the Adriatic side of the peninsula, where it shows a chronological gap of about 4,000 radiocarbon years between the northern and the southern sites, suggesting that this technocomplex spread from north to south (Peresani 2006). Although more sparsely distributed, crucial evidence of early Epigravettian occupation is equally present along the Tyrrenian side of the peninsula. These are the cases of the Caverna delle Arene Candide in Ligury (*e.g.* Bietti 1994), Grotta delle Settecannelle in Latium (*e.g.* Ucelli Gnesutta *et al.* 2006) or Grotta del Romito in Calabria (*e.g.* Martini and Lo Vetro 2005).

3. Regional overview

3.1. Istria peninsula (Croatia)

The cave site of Šandalja II is set close to the town of Pula (Croatia), at the very southern end of Istria. It rises to about 70 m.a.s.l., overlooking the current coastal strip. The cave is entirely filled with more than 8 m thick Pleistocene deposits (Montet-White, 1996). The stratigraphy identified by the Malez excavations (1962 to 1989), includes eight layers, from layer H at the base to layer A at the top. The early Epigravettian is separated from the late Epigravettian by a long hiatus due to erosive events that probably removed the sediments of the earlier part of the Late Glacial. The layer attributed to the early Epigravettian is the C 'base', dated to 20750±400 uncalPB (24822 ± 612 calBP) (Karavanić *et al.*, 2013). The top of the same layer was dated to the Late Glacial (Montet-White 1996; Jankovic *et al.* 2012; Karavanic 2003).

The faunal assemblages (Miracle, 2007), composed of species of different biomes and abundant enough to meet the needs of a wide spectrum of carnivores, suggest that the Great Adriatic Plain was a highly productive environment for both large herbivores and predators, including humans.

The lithic industry has been the object of a re-analysis and thorough publication by Karavanić *et al.* (2013). The assemblage is composed of more than 600 artefacts: ca. 80% is made of by-products and unretouched pieces, and the rest by tools and armatures. The presence of cortical flakes and other materials issued from different phases of the reduction sequence suggests that at least part of the production occurred in situ. Blades, generally flaked by soft hammer direct percussion, firmly outnumber bladelets. Tools include mostly «simple» end-scrapers and side-scrapers; armatures are mainly represented by backed bladelets and microlithic backed points. Unfortunately, shouldered points have uncertain stratigraphic provenance, but it is highly likely that they belong to the early Epigravettian (Karavanić *et al.* 2013).

The lithic raw materials include both local lithotypes and exogenous materials. The procurement area is principally identified around the southern end of the Istria peninsula, where it was probably possible to recover flint pebbles transported by the Isonzo River from the alpine and pre-alpine formations (Zupanic, 1975, Karavanic, 2003). The presence of artefacts made of red and pinkish flints, very similar to the Scaglia Rossa flints present in the Lessini Mountains and the Apennine, indicates medium to long range movements (Cancellieri 2015).

3.2. Berici hills (Veneto region)

The Berici Hills are a calcareous relief emerging from the plain south of the city of Vicenza. They are about 25 by 20 km wide, and are separated by the Lessini Mountains by a narrow plain. The early Epigravettian sites are all located along the eastern side of the relief (Leonardi and Broglio 1962) at elevations between 150 and 350 m.a.s.l., within the caves and shelters of Grotta di Paina, Grotta di Trene and Riparo del Broion. Radiocarbon dates frame the occupation between ca. 24,000 and 21,500 cal BP (Broglio 1997; De Stefani *et al.* 2005). The cultural evidence was probably the result of a complex settlement system which possibly included also sites on the plain to the south, currently buried under massive alluvial deposits and out of reach (Mussi and Peresani 2004).

Lithic industries are dominated by armatures. The shouldered points are very similar in typology, blank types and size to those from the Croatian and Slovenian sites (Broglio 1997). At the Broion shelter, the presence of armatures with impact scars and the rarity of flaking activity indicate short-term occupations possibly during hunting expeditions (Broglio *et al.* 2009). Technological and functional analyses carried out on the shouldered points of Grotta di Paina clarified some aspects of the manufacture of these projectiles (Broglio *et al.* 1993), highlighting in particular the predetermination criteria adopted for the production of suitable laminar blanks, and demonstrating the actual function as projectiles of these armatures thanks to identification of impact scars.

Further analyses on the material from Grotta di Paina also identified the existence of wide transapennine networks after the recognition of an almost exclusive use of flint procured from central Apennine formations, some 400 km to the south (Broglio *et al.* 2009).

3.3. Marche Apennine

During the end of the LGM, and until at least the onset of the Late Glacial interstadial (Broglio *et al.* 2005; Peresani *et al.* 2005; Peresani and Silvestrini 2007), the Epigravettian occupation of the Marche Apennine seems to stop along the Apennine eastern ridge. The archaeological evidence indicates the presence of almost only open-air sites devoted to extractive and productive activities that probably took place during short visits. An exception to this pattern is represented by the finding of mobiliar art -the so-called «offering Venus»-within the karstic complex of Grotta di Frasassi (Coltorti *et al.* 2012). Unfortunately it has been found in surface at the base of a scarp at the entrance of the cave. Stratigraphical setting of the nearby sequence and the stylistic traits suggest nevertheless a preliminary attribution to the Gravettian/early Epigravettian sphere.

The open-air sites of Ponte di Pietra, Fosso Mergaoni and Madonna dell'Ospedale are all located close to streams and rivers, near rather wide-open areas and

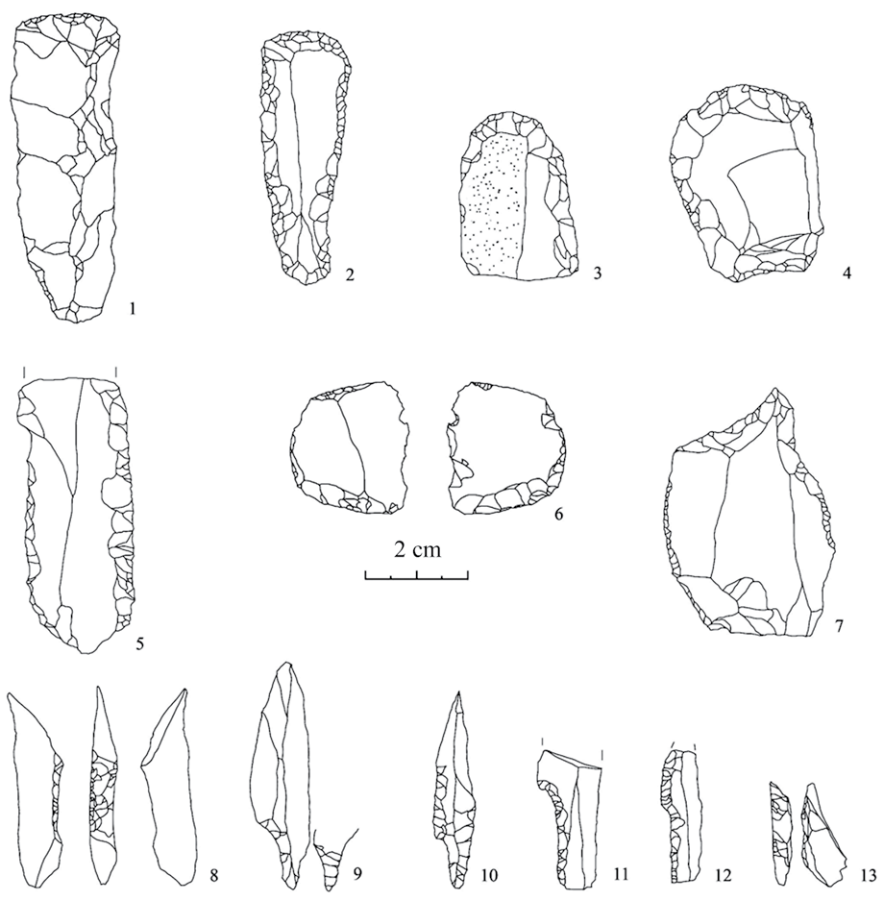


Figure 2. Lithic artefacts from Madonna dell'Ospedale. 1-4: end-scrapers; 5: retouched blade; 6: basally thinned flake by bifacial foliate retouch; 7: beck; 8; backed bladelet with piquant-trièdre; 9-12; shouldered armatures; 13: Krukowsky microburin (Modified after Silvestrini et al 2008).

set at the end of gorges. Radiocarbon dates put the first two sites between ca. 24,000 and 21,000 cal BP (Broglio 1997; Silvestrini *et al.*, 2005). The chronological attribution of the third site is based on the presence of shouldered points (Fig. 2), which could place the assemblage within a period ranging from ca. 24,000 to 19,000 cal BP (Silvestrini *et al.*, 2008).

Ponte di Pietra, dated to 23,822 ± 604 and 22,171 ± 777 cal BP (Lollini *et al.*, 2005, Broglio and Lollini, 1981, Broglio *et al.*, 2005), is close to the village of Arcevia, in the province of Ancona, along the course of the Misa River. Its sedimentary succession includes an eolic unit superimposed to gravel deposits. The archaeological evidence is represented by thousands of flint artefacts distributed through several clusters, rare faunal remains and combustion areas. Lithic industry includes macrolithic laminar products. Large size is also characteristic of the retouched tools, which mainly include burins, end-scrapers and points. Armatures include frequent *gravette* and *microgravette* as well as backed truncated bladelets. The analysis of selected clusters of lithic artefacts, the refittings, and their technological composition, led to conclude that frequent workshop activities were carried out at the site, with subsequent withdrawal and transport of the predetermined artefacts within the site or elsewhere (Lollini *et al.* 2005).

The site of Madonna dell'Ospedale is located along the Gingoli ridge. The cultural evidence was collected from an archaeological layer partially destroyed in the 80's by quarry activities. While the majority of the artefacts was collected in the disturbed sediment, a small part of them was recovered during the excavation of a test trench in 1984 (Silvestrini 1984). The lithic assemblage indicates a massive production of highly standardized blades and bladelets. The low number of tools and the absence of faunal remains suggest that the site was rather specialized and devoted to the production of blanks and hunting weapons and, probably, to their maintenance (Silvestrini *et al.* 2008).

3.3.1. Fosso Mergaoni

The early Epigravettian open-air site of Fosso Mergaoni is located outside the Natural Park of Frasassi and Rossa Gorges (Parco Naturale Gola della Rossa e Frasassi) (Fig. 1), an area that attracted human groups at different periods during the late upper Palaeolithic (Broglio *et al.* 2005). The site lies at an altitude of ca. 180 m.a.s.l at the end of a narrow gorge cut by the Esino River. To the west and the south it is framed by peaks of about 900 m.a.s.l. with rocky abrupt slopes facing the river. The landscape to the north and east is smoother because of the presence of lower reliefs and the beginning of the hilly belt and alluvial plain extending towards the Adriatic sea.

The site was discovered in the early 1980s after its partial destruction by quarry activities (Silvestrini and Pignocchi, 1987) that exposed upper Pleistocene layers belonging to a series of slope deposits and alluvial terraces (Silvestrini *et al.* 2005). The LGM sediments are gravels produced by gelifraction within a local conoid formed by diffuse streaming episodes. Sandy and silty layers of alluvial origin containing early Epigravettian lithic industries are intercalated within the gravels (Silvestrini *et al.* 2005).

The lithic assemblage is made of more than 60 units of lithic raw material (RMU), coherent groups of flaked elements coming from as many flint blocks. Local flint sources show great variability in availability and suitability. The territorial distribution of the flint outcrops, and their nature (*e.g.* slope debris or stream beds) determines a series of diversified environments of procurement, where different amounts of flint blocks of varying quality and size can be found. The raw materials introduced and processed at the site mostly come from local Tertiary formations, less from Jurassic ones. The best represented are Tertiary flints of the Scaglia Variegata formation, which are present in the form large nodules and slabs of multicolor flint (*e.g.* black, pale blue, red).

Flint procurement was strictly local within a very few kilometers from the site and mainly focused on stream beds and debris deposits close to primary outcrops.

A small amount of lithic raw material was introduced at the site in its raw state, without any presumable intention of storage. Large amounts of undifferentiated flakes suggest that shaping interventions were recurrent traits of the flaking activities. Blanks production is well represented by quite a large number of laminar supports that broadly fall into three dimensional categories: bladelets, blades and large blades. Mega blades also exist, but they seem not to be the outcome of standardized production processes. Laminar production was for the most part performed by soft organic hammer direct percussion. Another significant segment of the reduction sequences is represented by management interventions, mostly aimed at the restoration of the striking platforms.

Cores are poorly represented: nine cores, mainly blade cores, represent the total number of artefacts belonging to this category, which is somewhat striking if compared to the number of RMU identified. This discrepancy, together with the important incidence of intermediate phases of the reduction sequence, suggests that flint blocks were introduced partially pre-worked and they were carried somewhere else after some production/management cycles. This hypothesis is further supported by the paucity of totally cortical flakes. From a dimensional and technological point of view, blade and bladelet cores seem to belong to continuous reduction processes and it can be argued that the selection of the raw materials was primarily oriented towards large blocks suitable for the production of blades and large blades.

The retouched blanks include both common tools and armatures. Tools, which account for the majority of retouched blanks, are dominated by retouched blades and side-scrapers. Truncated backed bladelets constitute the majority of armatures. A large part of the tools are made on undifferentiated and management flakes or on regular laminar products, both cortical and non-cortical. Interestingly, pointed blades (Fig. 4, right), very peculiar tools of the assemblage, are almost always made on very regular non-cortical blades. Armatures are made on non-cortical regular bladelets.

A functional analysis (Ziggiotti 2007) emphasized the very low incidence of artefacts active edges and consequently a limited use of them. At the same time, it revealed a spectrum of activities mainly related to the transformation of animal and vegetal resources rather than to their procurement.

The spatial distribution of the archaeological remains reveals a series of concentrations of sub-circular shape, with irregular contours and inner areas characterized by higher density (Fig. 3). More than 200 refittings/conjoins *e.g.* (Fig. 4, left) suggest quite a good preservation of the spatial distribution, and a primary deposition of the archaeological content. Refittings occur at a rate of about 31%.

The settlement choices of the Epigravettians who occupied the site can be related to the access to resources that its position allowed. As revealed by the territorial distribution of flint outcrops, low altitude locations near stream beds and slope bases generally contain large flint blocks, and it is quite clear that the lithic

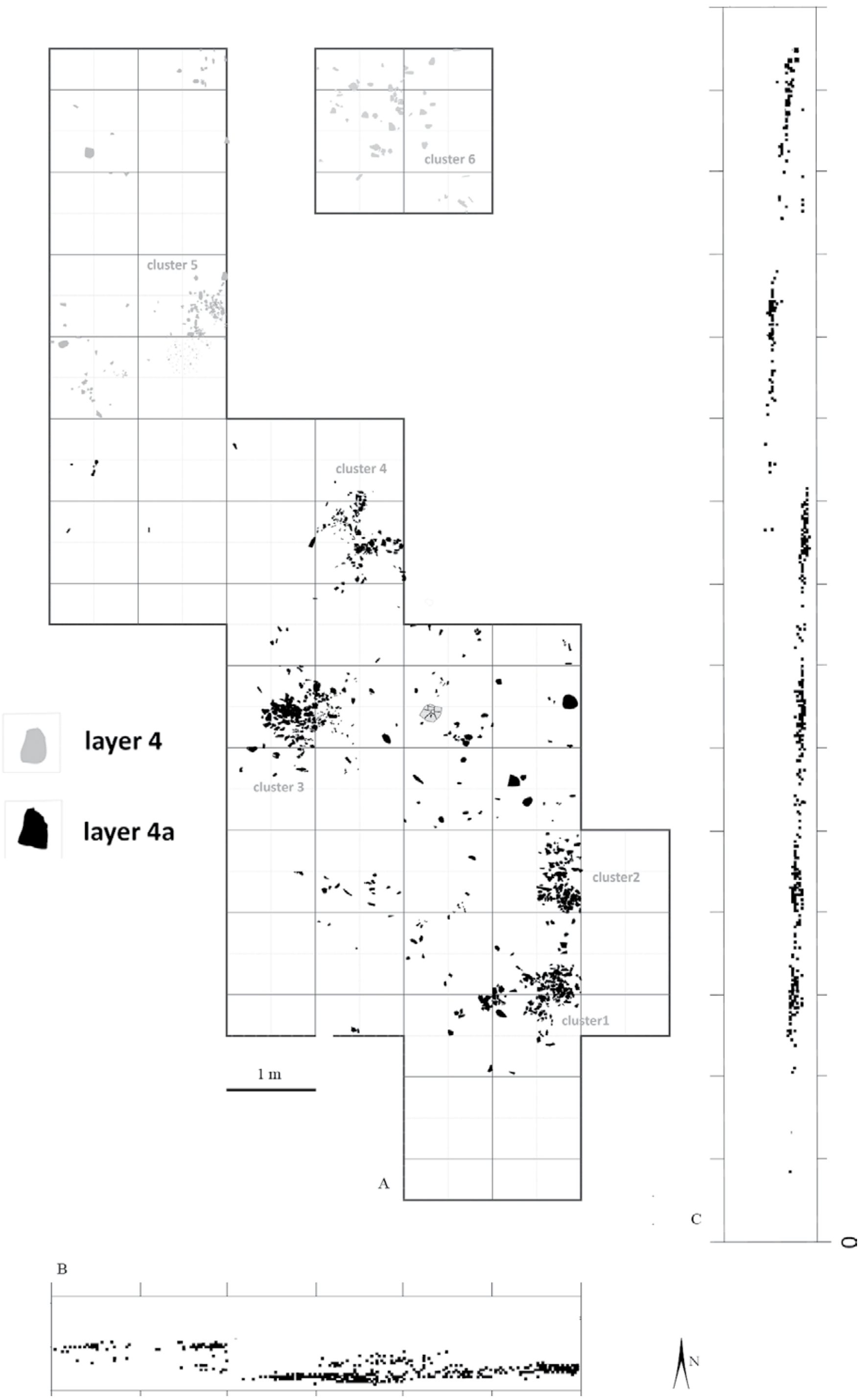


Figure 3. Map of the excavated surface at the site of Fosso Mergaoni. The clusters of artefacts referable to discrete workshop areas are well identifiable through the area. A: horizontal distribution; B: East-West vertical distribution; C: North-South vertical distribution; black: layer 4a; gray: layer 4. Scale bar 1 m. (Modified after Cancellieri 2015).

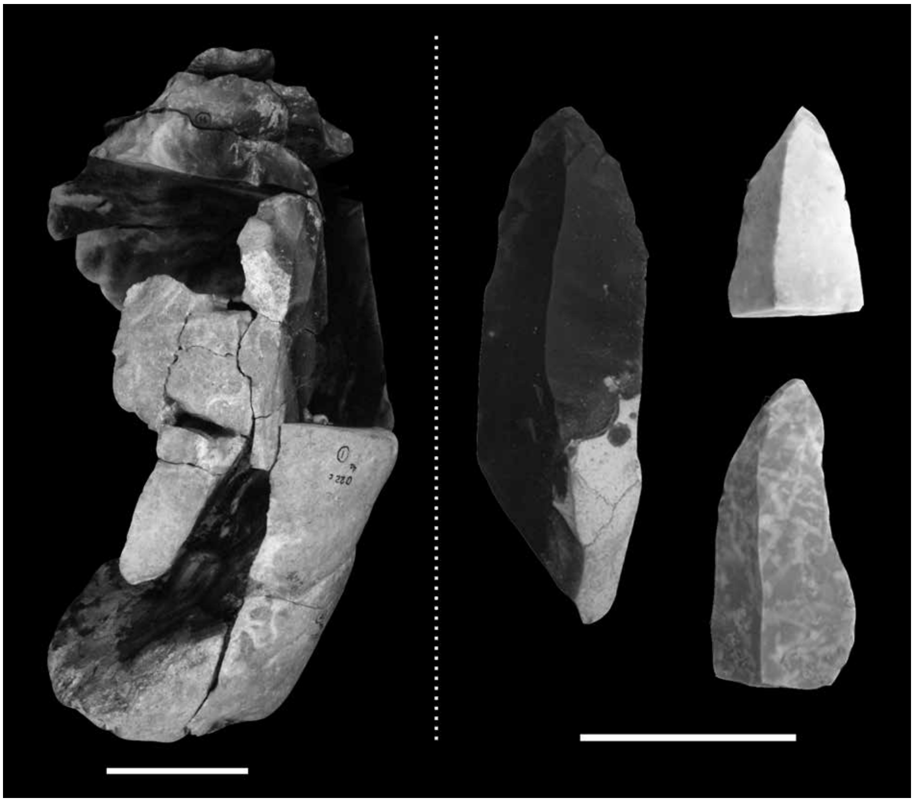


Figure 4. Fosso Mergaoni. Left: refitting of lithic artefacts produced by the reduction of a large flint pebble. Right: pointed blades. Scale bars 5 cm. (Modified after Cancellieri 2015).

resources of the areas immediately surrounding the site fit the technological needs of the human groups.

The site should be interpreted primarily as a workshop area. The identification of ephemeral combustion areas, together with the limited series of activities detected by the functional analyses, speak to the occurrence of some activities that possibly paralleled those of flint processing.

It can be argued that the site was frequented for short periods of time, during special task expeditions, by groups of hunter-gatherers whose residential camps could have been located to the east, over the Apennine foothills. The recovery of some retouched blanks made of flint varieties which do not find comparisons with any among the identified RMUs– in other words, introduced as readymade tools– suggests that people arrived at the site already equipped.

Finally, the presence of two occupation layers suggests that the place was known and that frequentation was repeated through time. Even if the extent of chronological separation between the two occupation events is not possible to establish, it suggests a repeated activity, carried out for the same reasons in the same place, probably during cyclical expeditions of resource acquisition.

3.4. Abruzzi Apennine

One of the best investigated areas in the Abruzzi region is the Fucino basin. Here, the absence of archaeological evidence around 24,000 calBP could be related to the presence of a lake at about 700 m.a.s.l. and the presence of glaciers up to 1.500 m.a.s.l. (Mt. Velino and Mt. Vulture). Fluvio-lacustrine layers at the base of the Palaeolithic sequences of the area formed in this period, and is arguable that the Fucino did not allow prolonged human settlement (Mussi *et al.* 2008).

An early resettlement of the Apennine took place soon after the maximum of the LGM (Mussi and Peresani 2004). Between ca. 21,000 and 19,000 calBP, in fact, the return of more temperate conditions, the slight lowering of lake level and the 100-200 m recession of the glaciers allowed human occupation of a series of caves and shelters for hunting purposes, like Grotta di Pozzo, Grotta Tronci and Riparo Maurizio (Agostini *et al.* 2008; Mussi *et al.* 2008; Giraudi 1989; Giraudi and Frezzotti 1997; Mussi *et al.* 2012).

Agostini *et al.* (2008) propose a model of the exploitation of the area on the basis of the zooarchaeological record of Grotta Tronci and Riparo Maurizio. Faunal evidence attest to the predation of large animals, in particular horse and *Equus Hydruntinus*, typical of flat open environments (Wilkens 1991; Alhaique and Recchi 2003). Cervids are also present, as are auroch and ibex (Phoca-Cosmetatu 2004), respectively typical of wooded environments and mid-high mountain open areas. Fishing, marsh bird hunting and mollusk harvesting are represented by little zooarchaeological evidence, despite the presence of low water and marshy environments within a few kilometers from the sites. The hypothetical distribution of the habitats of the recognized species has been considered in the light of a gradient map of the area, where particular attention is given to the distinction between flat areas, reliefs and slopes. According to the authors, the whole spectrum of resources exploited by the Epigravettian hunters of Grotta Tronci and Riparo Maurizio was available within a radius of 10 kilometers from the sites, where open flat areas, shore belts, mountain slopes and river valleys are all present.

The technological organization of the Epigravettian hunters who frequented the area can be partially traced in the archaeological record of the lower levels of Grotta di Pozzo. Data about the lithic industry suggest the frequentation of the cave for hunting purposes (Cancellieri 2015; Mussi *et al.* 2012). Hunters probably reached the site partially equipped with an almost ready-made tool kit, to be maintained by means of the substitution of broken armatures with new ones, possibly produced at the site from pre-formed blanks or extracted from partially exploited cores (Cancellieri 2015; Mussi *et al.* 2012).

Grotta Sant'Angelo is located at approximately about 700 m asl, on the Maiella Mountain, and it represents the only evidence of human occupation of the area during the LGM. The site sequence includes a thin layer with the remains of two hearths dated to ca. 24.500 calBP (20,530 ± 100 BP, Beta-203484) and a scatter of lithic artefacts (Ruggeri and Whallon 2010). The lithic industry is dominated by waste products and armatures, and indicates that the site was briefly but cyclically occupied for logistic activities mostly focused on lithic raw materials procurement.

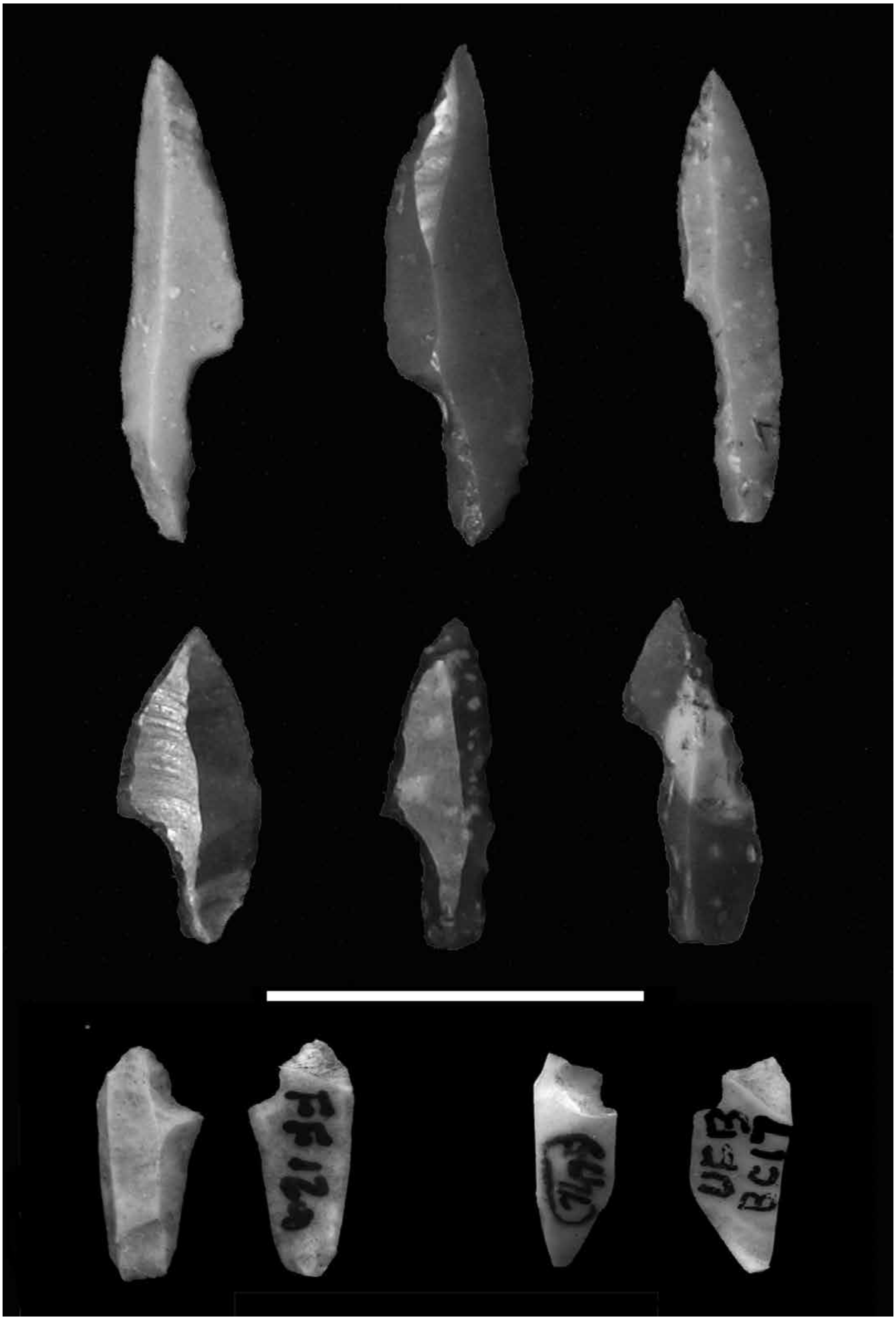


Figure 5. Fondo Focone "Trench B". Top: microlithic shouldered points; bottom: microburins.

3.5. Gargano promontory, Murge, Salento pensinsula (Apulia region)

The quantity and importance of palaeoenvironmental and cultural data gathered from sites in Apulia gave to this region a preeminent place for the study of Italian and European upper Palaeolithic (*e.g.* Palma di Cesnola 1993; Bietti 1990; Djindjian *et al.* 1999; Mussi 2001). In particular Grotta Paglicci, located on the Gargano promontory, is a classic reference site (Palma di Cesnola 1993; Palma di Cesnola and Bietti 1983; Palma di Cesnola 2004). The rich evidence related to the early Epigravettian, which is bracketed between ca. 23.000 e 18.000 cal BP (Palma di Cesnola 2004,1993) and the human occupation during the LGM make the site a key archive to understand the role of the southern fringes of the Great Adriatic Plain.

Grotta delle Mura, located in the Murge, in central Apulia, keeps the evidence of early Epigravettian occupation at ca. 19.000 calBP (Calattini and Marconi 2003). Lithic industry is small-sized, which links it to coeval industries of more southern Apulian sites. Raw materials come presumably from the Gargano (Calattini and Marconi 2003).

In the Salento peninsula, sites related to this time span are Cipolliane-Riparo C, Taurisano and Fondo Focone. At Cipolliane, the analyses carried out by P. Gambassini (1970) showed in example that burins are extremely small sized and, in the most part, they are core-like and very much exploited. Cores, which rarely exceed 20 mm in length, can be ordered along a sequence ending with the *pièce esquillées*, which are to be considered cores being reduced by the bipolar technique on anvil.

At Taurisano, dated to ca. 19.000 calBP (Bietti 1979), tools like end-scrapers are mostly made on small flakes (*e.g.* of the unguiform type), as are burins, which are often over exhausted and core-like. Again, as at Cipolliane, *pièce esquillées* are a major component, signaling in this way the careful exploitation of raw materials by means of technological expedients aimed at maximizing the production. Armatures are very abundant and feature an high incidence of microlithic shouldered points.

The site of Fondo Focone " Trench B" was investigated in 1974 by members of the IsIPU (Segre Naldini and Biddittu, 1992). In the absence of absolute dating, and after comparisons with Taurisano and Cipolliane C, its chronological position is estimated at the end of the LGM (Bietti and Cancellieri 2007; Cancellieri, 2017). The site testifies to a palimpsest of diversified activities, whose material traces overlap each other eventually hiding the presence of special purpose areas through time. The raw materials are represented for more than 95% by flint, which is totally exogenous, probably from Gargano, likely procured as a result of logistic movements. A greater degree of reduction / rejuvenation of tools on blade rather than on flake suggests technological choices aimed at the " maintainability " of the tool kit. The techno-typological analysis indicates mostly lamellar reduction chains. The percussion on anvil is widely used at the end of the reduction sequences as an expedient to maximize productivity. Tools and armatures include scrapers, burins, retouched blades, microlithic shouldered points (Fig. 5, top), backed points, backed truncated bladelets and rare triangles. The microburin technique is attested on a considerable sample of artefacts (Fig. 5, bottom).

4. Discussion

The reconstruction of the main environmental features of the Great Adriatic Plain and their relationships with human activity has produced contrasting scholarly positions (Miracle 2007; Shackleton *et al.*, 1984; Mussi 2001; Bailey and Gamble 1990; Mussi 1990). The major theme of the debate is centered around the possibility that this geographic feature represented (or not) a link between the sides of the Adriatic, for example by holding seasonal aggregation of bands and an area of resources procurement. This view was criticized by scholars who instead see the Great Adriatic Plain as an avoided territory because of adverse climatic and environmental conditions and because of paucity of resources.

A renewed view of the role that the Great Adriatic Plain could have played for the Late Upper Palaeolithic human groups of the surrounding areas was proposed by Miracle (2007). With the maximum lowering of the sea and climatic worsening during the LGM, the principal and more stable settlement may have been the plain, which was a highly productive environment for both animals and humans, and which could have worked as a refugium. In particular, the LGM human/carnivore occupation trend at Šandalja II provides evidence that the cave was alternating peripheral or central in the settlement choices.

This interpretation is further supported by the local settlement system patterns recognizable in the areas that once bordered the Great Adriatic Plain, especially the northernmost ones. The central Apennines, the Berici Hills, the Istria peninsula – and the nearby Slovenian karst, whose early Epigravettian sites are also interpreted as short occupation campsites (Montet-White 1996) – are all regions that attest to specialized activities carried out by task-oriented groups that frequented the sites in occasion of resource acquisition movements.

A number of suggestions proposed by different scholars point to a network linking the Epigravettian populations on both sides of the northern Adriatic (*e.g.* Djindjian *et al.* 1999; Peresani 2006; Koslowski and Otte 1997) and an increasing east-west mobility of human groups, shifting between valley systems along paths of resource procurement (Montet-White 1994, 1996). Close similarities can be established between series of projectile points from the Venetian, Slovenian and Croatian sites, in particular regarding the morphology of blanks and typology (Broglio 1994, 1997; Montet-White and Kozlowski 1983). As Broglio (1994) suggested, the shouldered points from Grotta di Paina, Šandalja II and Ovca Jama could in fact indicate a common techno-typological background.

The hypothesized existence of a large-scale network of contacts between hunting bands and high mobility within the study area is definitely confirmed by tracing the provenance of lithic raw materials. As mentioned, in the early Epigravettian of both Grotta di Paina i (Broglio *et al.* 2009) and Šandalja II (Cancellieri 2015), there is evidence for the introduction of flint artefacts made on materials imported from the Umbria-Marche basin. This raises questions about the procurement of such "exotic" resources. The archaeological evidence from the Marche Apennine could shed some light on the subject: it indicates that provisioning was not embedded within a broad strategy of resource acquisition; instead it was the outcome of specialized, planned activities (Cancellieri 2015). As exemplified by the evidence collected at Fosso Mergaoni, lithic sets define the existence of workshops including shaping flakes, cores, laminar products and different by-products resulting from the production of large blades, blades and bladelets from flint blocks collected close to the site. Technological composition, rare retouched implements, and the spatial patterning indicate that specialized tasks were carried out, probably within a settlement system related to the lithic resources of the fluvial basin (Silvestrini *et al.* 2005; Cancellieri 2015).

Another question addresses the possible routes followed by LGM hunter gatherers to reach the flint outcrops. One possibility would be to draw straight paths between the procurement areas and the archaeological sites, but this would imply movements between specialized sites, or, in other words, between non-residential sites. Instead, it is more likely that exogenous flint artefacts probably reached sites after at least a two-step transport, the first from the procurement area to the residential area, and the second from the residential area to hunting camps. This is in part supported, at least at Paina, by the fact that exogenous flints are exclusively represented by ready-made armatures, which indicates that the production process was entirely carried out somewhere else (Broglio *et al.* 2009). Further, on the basis of the reconstructed paleogeographic features, the rivers that originate from the Apennine crossed the plain toward its centre. Therefore it is arguable that part of the exogenous flint recovered in the assemblages of Šandalja and Paina could have been procured from the fluviatile deposits accumulated along the river courses. However, this possibility should be investigated further.

The series of considerations proposed here paint an overall picture of the northern Adriatic basin around 24,000 and 21,000 calBP as an area where logistically mobile human groups, sharing a single cultural identity, built an archaeological landscape made of a number of distinct areas for special purpose activities. This landscape included what should be regarded as a broad residential settlement area, the Great Adriatic Plain, which probably also constituted a node for cyclical aggregation and cultural transmission (Miracle 2007). It was surrounded by series of provisioning areas, destinations of short-duration specialized expeditions.

The Late Glacial interstadial climatic change, together with the progressive flooding of the Plain, led human groups to intensely occupy the more interior mountainous regions (Miracle,2007). It is probable that the onset of such a shift occurred at the very end of the LGM, when it is observable a progressive diffusion toward the south of the peninsula of early Epigravettian assemblages with shouldered points (Palma di Cesnola and Bietti 1983; Bartolomei *et al.* 1979; Bietti, 1990). In the southernmost end of Italy, in the Salento peninsula, these assemblages can be found until about 19,000 calBP (Bietti 1979; Gambassini, 1970). It should be noted that shouldered armatures from these sites often figure within lithic sets with almost complete reduction sequences and large inventories of both tools and armatures (Alhaique and Bietti, 2008) which include innovative elements like the microburin technique (Bietti and Cancellieri 2007; Cancellieri, 2017), suggesting a relative "residentialization" and, accordingly, a progressive change in the settlement system pattern. From this perspective, the data from the Fucino basin, in the Abruzzi region, fits well within the observed pattern, possibly signaling the beginning of the change observable in the settlement system pattern of the last phases of the early Epigravettian.

5. Concluding remarks

Reasoning about the settlement system around the submerged Great Adriatic Plain poses some problems, especially if the Plain plays a primary role in the framework within which interpretation is built. The evidence from the territories all around the supposed borders of the Great Adriatic Plain provide bases to infer local patterns of land use, which at the same time (and by nature) form an incomplete picture.

On a larger scale a coarser speculative level has to be adopted, based on correspondingly coarser assumptions. This is particularly useful here, where a specific settlement system pattern around (and on) an area currently not investigable is under consideration. These methodological and scientific constraints are mitigated by observing that these conclusions are aimed at explaining and providing a coherent framework for what is currently observable, rather than for what is definitely out of reach. In this perspective, information coming from the northern fringe of the current Adriatic basin is considered the proxy-data produced by a wider subsistence-settlement system which comprised a physiographic element that, in any event, is no longer investigable.

Acknowledgements

I would like to thank Valentina Borgia and Emanuela Cristiani for having invited me to contribute a paper to the “Out of Italy” conference (Cambridge, May 2015). I also thank two anonymous reviewers for their valuable comments and suggestions. Part of the data and results presented in this paper are the outcome of the research that I have conducted at both the Sapienza-University of Rome (MA) and the University of Ferrara (PhD). Research at the University of Ferrara was directed by prof. Marco Peresani, which I warmly aknowledge, and was supported by a three-year scholarship provided by the same University.

References

Agostini, S., Iacopini, A., Masserotti, M.V., Barsocchi, S.,Porsia, C.D., 2008. Applicazione delle tecnologie GIS per la ricostruzione della presenza umana nella Preistoria del Fucino (Abruzzo). *Preistoria Alpina,* 43, 101-115.

Alhaique, F., Bietti, A., 2008. Il livello di conoscenza sulle strategie di sussistenza e i modelli di insediamento nel Tardiglaciale italiano: un bilancio dopo più di 15 anni. *In:* Mussi, M. (ed.) *Il Tardiglaciale in Italia: lavori in corso.* B.A.R. International Series 1859, 21-34.

Alhaique, F., Recchi, A., 2003. Sfruttamento delle risorse faunistiche durante le fasi più antiche dell’occupazione nel Fucino. *Atti XXXVI Riunione Scientifica I.I.P.P*, 53-64.

Antonioli, F., Lambeck, K., Amorosi, A., Belluomini, G., Correggiari, A., Devoti, S., Demuro, S., Monaco, C., Marocco, R., Pagliarulo, R., Orru’, P., Silenzi, S., 2004. Sea Level at 8 and 22 ka cal BP on Italian coastline. *In:* Antonioli, F. & Vai, G. B. (eds.) *Litho-Palaeoenvironmental Maps of Italy during the last two Climatic Extremes, Explanatory Notes.* Museo Geologico Giovanni Capellini, Bologna., 4-7.

Bailey, G., Gamble, C., 1990. The Balkans at 18.000 BP: the view from Epirus. *In:* Soffer, O. & Gamble, C. (eds.) *The world at 18.000 BP.* London: Unwin Hyman Ltd, 148-167.

Banks, W.E., D'errico, F., Peterson, A.T., Vanhaeren, M., Kageyama, M., Sepulchre, P., Ramstein, G., Jost, A., Lunt, D., 2008. Human ecological niches and ranges during the LGM in Europe derived from an application of eco-cultural niche modeling. *Journal of Archaeological Science,* 35, 481-491.

Bartolomei, G., Broglio, A., Palma Di Cesnola, A., 1979. Chronostratigraphie et écologie de l'Epigravettien en Italie. *In:* De Sonneville-Bordes, D. (ed.) *La fin des temps glaciaires en Europe.* Paris: CNRS, 297-324.

Bietti, A., 1979. Le gisement paléolithique supérieur de Taurisano (Lecce, Italie) et sa position chronologique et culturelle dans l'Epigravettien italien. *In:* De Sonneville-Bordes, D. (ed.) *La fin des temps glaciaires en Europe.* 333-344.

Bietti, A., 1986. Problemi di metodologia nello studio antropologico delle società di cacciatori e raccoglitori preistorici. *Dialoghi Di Archeologia,* 1, 9-26.

Bietti, A., 1990. The Late Upper Paleolithic in Italy: An Overview. *Journal of World Prehistory,* 4 95-155.

Bietti, A., 1994. A re-examination of the lithic industries of the P layers (1940-42 excavations) of the Arene Candide Cave (Savona, Italy). Discussion and general conclusions. *Quaternaria Nova,* IV, 341-370.

Bietti, A., 1997. Considérations sur la définition de l'Epigravettien ancien en Italie. *In:* Fullola, J.M. & Soler, J.M. (eds.) *El mon mediterrani deprés del Pleniglacial (18.000-12.000 BP).* Girona: Museu d'Arqueologia de Catalunya, 131-146.

Bietti, A., Cancellieri, E., 2007. New data from the Late Upper Paleolithic site of Fondo Focone (Ugento, Southern Apulia, Italy): the litihic industry of the B Trench. *In:* Whallon, R. (ed.) *Late Paleolitihic Environments and Cultural Relations around the Adriatic (Session C17).* B.A.R. International series 1716, 1-14.

Binford, L.R., 1980. Willow smoke and dogs tails: hunter-gatherer settlement systems and archaeological site formation. *American Antiquity,* 45, 4-20.

Broglio, A. 1994., Il Paleolitico superiore del Friuli-Venezia Giulia. Considerazioni sul popolamento umano nel territorio tra Penisola Italiana e Penisola Balcanica. *Atti della XXIX riunione scientifica dell' IIPP*, 37-56.

Broglio, A. 1997., Considérations sur l'Epigravettien italique. *In:* Fullola, J.M. & Soler, J.M. (eds.) *El mon mediterrani deprés del Pleniglacial (18.000-12.000 BP).* Girona: Museu d'Arqueologia de Catalunya, 147-57.

Broglio, A., Bertola, S., De Stefani, M., Gurioli, F., 2009. The shouldered points of the early Epigravettian of the Berici Hills (Venetian region – North of Italy).Materials, blanks, typology, exploitation. *In:* Burdukiewicz, J.M., Cyrek, K., Dyczek, P. & Szymczak, K. (eds.) *Understanding the past.Papers offered to Stefan K. Kozlowski.* Warszaw, Pologne: Center for Research on the Antiquity of Southeastern Europe, University of Warsaw, 59-68.

Broglio, A., Chelidonio, G., Longo, L., 1993. Analyse morphologique et fonctionnelle des pointes à cran de l'Épigravettien ancien. *In:* Anderson, P.C., Beyries, S., Otte, M. & Plisson, H. (eds.) *Traces et fonction: les gestes retrouvés.* ERAUL, 31-39.

Broglio, A., Coltorti, M., Peresani, M., Silvestrini, M., 2005. Il Paleolitico delle Marche. *Atti della XXXVIII Riunione Scientifica IIPP*, 25-51.

Broglio, A., Kozlowski, J., 1987. *Il Paleolitico. Uomo, ambiente e culture,* Milano, Jaca Book.

Broglio, A., Lollini, D. 1981. I ritrovamenti marchigiani del Paleolitico superiore e del Mesolitico. *Atti del I Convegno sui Beni Culturali e Ambientali delle Marche*, 27-61.

Burke, A., 2006. Introduction to the special issue: "Multidisciplinary approaches to the study of site function and settlement dynamics in prehistory". *Journal of Anthropological Archaeology,* 25, 403-407.

Calattini, M., Marconi, E., 2003. L'Epigravettiano antico di Grotta delle Mura (Ba). Nota preliminare. *In:* Gravina, A. (ed.) *23°Convegno Nazionale sulla Preistoria – Protostoria – Storia della Daunia, San Severo 23 – 24 novembre 2002.* San Severo: Archeoclub d'Italia, 27-32.

Cancellieri, E., 2015. *Over the Hills and Far Away: Last Glacial Maximum Lithic Technology Around the Great Adriatic Plain,* Oxford, Archaeopress.

Cancellieri, E., 2017. Il sito di Fondo Focone-Trincea B (Ugento, Lecce) nel contesto dell'Epigravettiano antico dell'Italia peninsulare orientale, in: Radina, F. (Ed.), *Preistoria e Protostoria della Puglia, Istituto Italiano di Preistoria e Protostoria*, Firenze, pp. 79-86.

Coltorti, M., Lemorini, C., Peresani, M., Polzinetti, S., Pieruccini, P., Silvestrini, M., Zampetti, D., 2012. La « Vénus offrant » de Frasassi (Italie centrale): un nouveau type de statuette paléolithique. *In:* Clottes, J. (ed.) *L'art pléistocène dans le monde / Pleistocene art of the world / Arte pleistoceno en el mundo, Actes du Congrès IFRAO, Tarascon-sur-Ariège, septembre 2010, Symposium «Art mobilier pléistocène».* Tarascon-sur-Ariège: Société Préhistorique Ariège-Pyrénées, 1275-1289.

Correggiari, A., Roveri, M.,Trincardi, F. 1997. Late Pleistocene and Holocene evolution of the North Adriatic Sea. *Il Quaternario,* 9, 697-704.

De Stefani, M., Gurioli, F., Ziggiotti, S., 2005. Il Paleolitico superiore del Riparo del Broion nei Colli Berici (Vicenza). *Rivista di Scienze Preistoriche,* Supplemento I, 93-108.

Djindjian, F., Koslowski, J., Otte, M., 1999. *Le paléolithique supérieur en Europe,* Paris, Armand Colin.

Gambassini, P., 1970. Risultati della campagna di scavi 1964 nel riparo C delle Cipolliane (Lecce). *Rivista di Scienze Preistoriche,* XXV, 1, 127-181.

Gioia, P., Mussi, M., Zampetti, D., 2003. L'Epigravettien italien et la chronologie au Carbone 14. *In:* Widemann, F. & Taborin, Y. (eds.) *Chronologies géophysique et archéologiques du Paléolitihique supérieur.* Bari: Edipuglia, 247-253.

Giraudi, C., 1989. Lake levels and climate for the last 30,000 years in the Fucino area (Abruzzo-central Italy): a review. *Palaeogeography, Palaeoclimatology, Palaeoecology,* 70, 249-260.

Giraudi, C., Frezzotti, M., 1997. Late Pleistocene Glacial Events in the Central Apennines, Italy. *Quaternary research,* 48, 280-29.

Jankovic, I., Ahern, J.C.M., Karavanic, I., Stockton, T., Smith, F.H., 2012. Epigravettian Human Remains and Artifacts from Šandalja II, Istria, Croatia. *PaleoAnthropology,* 2012, 87-122.

Karavanic, I., 2003. L'industrie aurignacienne de la grotte de Šandalja II (Istrie, Croatie) dans le contexte de la région de l'Est de l'Adriatique. *L'anthropologie,* 107, 577-602.

Karavanić, I., Vukosaljević, N., Šošić Klindžić, R., Kurtanjek, D., Zupanič, J., 2013. The lithic and bone industries of the Epigravettian layers from Šandalja II near Pula. *Vjesnik za arheologiju i povijest dalmatinsku,* 106, 7-73.

Koslowski, J., Otte, M., 1997. Transformations culturelles en Méditerranée septentrionale à la fin de l'époque glaciaire en relation aux modifications paléo-climatiques. *In:* Fullola, N. & Soler, J. M. (eds.) *El mon mediterrani deprés del Pleniglacial (18.000-12.000 BP).* Girona: Museu d'Arqueologia de Catalunya, 23-28.

Kozlowski, J., 1999. Gravettian/Epigravettian sequences in the Balkans: environment, technologies, hunting strategies and raw material procurement. *In:* Bailey, G., Adam, E., Panagopoulou, E., Perles, C. & Zachos, K. (eds.) *The Palaeolithic Archaeology of Greece and adjacent areas.* Athens, 319-329.

Kozlowski, J., 2005. Paléolitihique supérieur et Mésolithique en Méditerranée: cadre culturel. *L'anthropologie,* 109, 520-540.

Kozlowski, J., 2008. End of the Aurignacian and the beginning of the Gravettian in the Balkans. *In:* Darlas, A. & Mihailovic, D. (eds.) *The Paleolitihic of the Balkans.* BAR International Series 1819, 3-14.

Kuhn, S.L., 2004. Upper Paleolithic raw material economies at Üçagizli cave, Turkey. *Journal of Anthropological Archaeology,* 23, 431-448.

Lambeck, K., Chappell, J., 2001. Sea Level Change through the Last Glacial Cycle. *Science, New Series,* 292, 679-686.

Lambeck, K., Purcell, A., 2005. Sea-level change in the Mediterranean Sea since the LGM: model predictions for tectonically stable areas. *Quaternary Science Reviews,* 24, 1969-1988.

Lambeck, K., Yokoyama, Y., Purcell, A., 2002. Into and out of the Last Glacial Maximum: sea-level change during Oxygen Isotope Stages 3 and 2. *Quaternary Science Reviews,* 21, 343-360.

Leonardi, P., Broglio, A., 1962. Le Paléolithique del la Vénétie. *Annali dell'università degli studi di Ferrara,* Suppl.1.

Lollini, D., Silvestrini, M., Broglio, A., Coltorti, M.,De Stefani, M., 2005. Ponte di Pietra, sito all'aperto del Gravettiano finale. I risultati degli scavi 1987-89. *Atti della XXXVIII Riunione Scientifica IIPP*, 81-91.

Lubell, D., 2001. Late Pleistocene-Early Holocene Maghreb. *In:* Peregrine, P. N. & Ember, M. (eds.) *Encyclopedia of Prehistory, Volume 1: Africa.* New York: Kluwer Academic/Plenum Publishers, 129-149.

Martini, F. and Lo Vetro, D. 2005., Il passaggio Gravettiano-Epigravettiano a Grotta del Romito (Scavi 2003-2004). Prime osservazioni. *Rivista di Scienze Preistoriche,* Supplemento I, 151-175.

Mihailovic, B. and Mihailovic, D., 2007. Considérations sur le Gravettien et l'Epigravettien ancient des Balkans de l'ouest. *Paleo,* 19, 115-128.

Miracle, P., 2007. The Late Glacial 'Great Adriatic Plain': 'Garden of Eden' or 'No Man's Land' during the Epipalaeolithic? A view from Istria (Croatia). *In:* Whallon, R. (ed.) *Late Paleolitihic Environments and Cultural Relations around the Adriatic (Session C17).* B.A.R. International series 1716, 41-51.

Montet-White, A., 1994. Alternative Interpretations of the Late Upper Paleolithic in Central Europe. *Annual Review of Anthropology,* 23, 483-508.

Montet-White, A., 1996. *Le Paléolithique en ancienne Yougaslavie,* Grenoble, Jérome Millon.

Montet-White, A., Kozlowski, J., 1983. Les industries à pointes à dos dans les balkans. *Rivista di Scienze Preistoriche,* 38,1-2.

Mussi, M., 1990. Continuity and change in Italy at the Last Glacial Maximum. *In:* Soffer, O. & Gamble, C. (eds.) *The World at 18.000 BP.* London: Unwyn Hyman Ltd, 126-147.

Mussi, M., 2001. *Earliest Italy: An Overview of the Italian Paleolithic and Mesolithic*, New York: Kluwer Academic.

Mussi, M., Cancellieri, E., D'angelo, E., Fiore, I., Melis, R.T., Russ, H.,Salvadei, L., 2012. Ricerche a Grotta di Pozzo (AQ): 1992-2009. *In:* Grossi, G., Irti, U. & Malandra, C. (eds.) *Atti del III Convegno di Archeologia "Il Fucino e le aree limitrofe nell'antichità", Avezzano 13-15 novembre 2009.* Avezzano: Archeoclub d'Italia – Sezione della Marsica, 92-106.

Mussi, M., Cocca, E., D'angelo, Fiore, I., R.T., M., Russ, H., 2008. Tempi e modi del ripopolamento dell'Appennino centrale nel Tardiglaciale: nuove evidenze daGrotta di Pozzo (AQ). *In:* Mussi, M. (ed.) *Il Tardiglaciale in Italia: lavori in corso.* B.A.R. International Series 1859, 111-132.

Mussi, M. and Peresani, M., 2004. The peopling of northern and central Italy at the LGM. *In:* Antonioli, F. & Vai, G. B. (eds.) *Litho-Palaeoenvironmental Maps of Italy during the last two Climatic Extremes, Explanatory Notes.* Bologna: Museo Geologico Giovanni Capellini, 59-60.

Otte, M., 1990. The northwestern European plain around 18,000 BP. *In:* Soffer, O. & Gamble, C. (eds.) *The world at 18.000 BP.* London: Unwin Hyman, 54-68.

Palma Di Cesnola, A., 1993. *Il Paleolitico Superiore in Italia. Introduzione allo studio.,* Firenze, Garlatti e Razzai.

Palma Di Cesnola, A. 2004. La sequenza stratigrafica della grotta. *In:* Palma Di Cesnola, A. (ed.) *Paglicci. L'Aurignaziano e il Gravettiano antico.* Foggia: Claudio Geronzi Editore, 21-26.

Palma Di Cesnola, A., Bietti, A., Le Gravettien et l'Epigravettien ancien en Italie. *In:* Palma Di Cesnola, A., ed. Actes du colloque international "La position taxonomique et chronologique des industries a pointes a dos autour de la Mediterranee europeenne", Siena, 3-6 novembre 1983. IN Rivista di Scienze Preistoriche, 1983. 181-228.

Pelegrin, J., Karlin, C.,Bodu, P., 1988. "Chaînes opératoires": un outil pour le préhistorien. *Technologie préhistorique. Notes et Monographies Techniques, Editions du CNRS, Paris,* 25, 55-62.

Peresani, M. 2006. Cultures et traditions du Paléolithique supérieur dans les régions nord-méditerranéennes. In*:* Sanchidrianan Torti, J. L., Marquez Alcantara, A. M., Fullola, J. M. & Pericot (eds.) *La Cuenca Mediterránea durante el Paleolítico Superior (38.000-10.000 años).* Nerja: Fundación Cueva de Nerja,, 408-429.

Peresani, M. and Silvestrini, M., 2007. Lo stato delle ricerche sull'Epigravettiano Recente delle Marche. Ambiente, territorio, sistema insediativo. *In:* Martini, F. (ed.) *L'Italia tra 15.000 e 10.000 anni fa. Cosmopolitismo e regionalità nel Tardoglaciale.* Firenze: Museo Fiorentino di Preistoria Paolo Graziosi, 129-134.

Peresani, M., Silvestrini, M., Gardin, S., 2005. Baracche, un site Epigravettien récent dans la Dorsale de Cingoli, Marches. *Rivista di Scienze Preistoriche,* Suppl.1, 201-211.

Perles, C., 1991. Economie des matières premières et économie du débitage: deux conceptions opposées ? *25 ans d'études technologiques en préhistoire: bilan et perspectives.* Juan-les-Pins: APDCA, 34-45.

Phoca-Cosmetatu, N., 2004. A zooarchaelogical reassessment of the habitat and ecology of the Ibex (*Capra ibex*). *In:* Lauwerier, R. C. G. M. & Plug, I. (eds.) *The future from the past. Archaeozoology in wildlife conservation and heritage management.* Oxford: Oxbow Books, 64-78.

Ruggeri, D., Whallon, R., 2010. Sant'Angelo Cave – a Gravettian hunting and raw material procurement site in the Maiella mountains, Abruzzo (Italy). *Human Evolution,* 25, 67-82.

Segre Naldini, E., Biddittu, I., 1992. Rinvenimenti di arte mobiliare paleolitica ad Ugento (Lecce). *Atti della XXVIII Riunione Scientifica dell'Istituo Italiano di Preistoria e Protostoria, L'arte in Italia dal Paleolitico all'età del Bronzo.* Firenze: Istituto Italiano di Preistoria e Protostoria, 341-345.

Shackleton, J.C., Van Andel, T.H., Runnels, C.N., 1984. Coastal Paleogeography of the Central and Western Mediterranean during the Last 125,000 Years and Its Archaeological Implications. *Journal of Field Archaeology,* 11, 307-314.

Shott, M., 1986. Technological Organization and Settlement Mobility: An Ethnographic Examination. *Journal of Anthropological Research,* 42, 15-51.

Silvestrini, M., 1984. Rio di Cingoli (Prov. di Macerata). *Rivista di Scienze Preistoriche, notiziario,* XXXIX, 345.

Silvestrini, M., Cancellieri, E., Peresani, M., 2008., Madonna dell'Ospedale, un sito Epigravettiano antico al margine dell'Appennino marchigiano: osservazioni sulla produzione litica. *In:* Mussi, M. (ed.) *Il Tardiglaciale in Italia: lavori in corso.* B.A.R. International Series 1859, 81-102.

Silvestrini, M., Ferrari, S., Peresani, M., 2005. La produzione laminare nella tradizione gravettiana: le officine litiche di Fosso Mergaoni (Valle dell'Esino). *Atti della XXXVIII Riunione Scientifica IIPP*, 93-102.

Silvestrini, M., Pignocchi, G., 1987. Giacimento del Paleolitico superiore di Fosso Mergaoni presso Serra S.Quirico (Ancona). *le Marche. Archeologia, storia, territorio.* Istituto Regionale per la Pre-Protostoria nelle Marche, Arcevia-Sassoferrato, 1-21.

Straus, L.G., 1991a. Human Geography of the Late Upper Paleolithic in Western Europe: Present State of the Question. *Journal of Anthropological Research,* 47, 259-278.

Straus, L.G., 1991b. Southwestern Europe at the Last Glacial Maximum. *Current Anthropology,* 32, 189-199.

Ucelli Gnesutta, P., Boschian, G., Cantoro, G., Castiglioni, E., Dini, M., Maspero, A., Petrinelli Pannocchia, C., Rottoli, M., 2006. I livelli epigravettiani della Grotta delle Settecannelle (Viterbo). *Rivista di Scienze Preistoriche,* 56, 127-183.

Wilkens, B., 1991. Resti faunistici ed economia preistorica nel bacino del Fucino. *In:* Irti, U., Grossi, G. & Pagani, V. (eds.) *Atti del I Convegno di Archeologia "Il Fucino e le aree limitrofe nell'antichità".* Archeoclub d'Italia, sezione della Marsica, 147-153.

Ziggiotti, S., 2007. Il contributo dell'analisi funzionale alla ricostruzione del sito epigravettiano di Fosso Mergaoni (Ancona). Primi risultati emersi dallo studio di un campione di manufatti. *Rivista di Scienze Preistoriche,* 57, 83-90.

Zupanic, J., 1975. Petrografske karakteristike paleolitskih artefakata iz Sandalje II kod Pule I porijeklo kamene sirovine za njihovu izradbu. *Rad Jugoslavenske akademije znanosti i umjetnosti,* 383(18), 267-275.

Re-colonising the Southern Alpine fringe

Diachronic data on the use of sheltered space in the Late Epigravettian site of Riparo Tagliente (Verona, Italy)

Federica Fontana[1], *Laura Falceri*[2], *Alessia Gajardo*[1], *Stefano Bertola*[1], *Maria Giovanna Cremona*[1], *Fabio Cavulli*[3], *Antonio Guerreschi*[1] *&* *Davide Visentin*[1]

Abstract

This paper focuses on the use of space by Late Epigravettian groups in the Italian peninsula through the analysis of data from the site of Riparo Tagliente, which has yielded the earliest evidence of re-occupation of the Southern Alpine fringe after the end of the LGM. Previous works had underlined the presence of a persistent pattern in the differential use of the outer area of the site – mostly characterized by secondary refuse accumulations – compared to the sheltered area- dedicated to domestic activities undertaken around hearths. Here a "site-structural" approach has been applied to the abundant evidence of the sheltered area, where an articulated stratigraphic series documenting the first occupation phases in the site – disturbed at the top by an artificial "cut" carried out in historical times – was excavated starting from the late '70s of the last century. Radiocarbon dating of this series indicates a chronological span between 17,219 and 15,940 years cal BP and locates these occupations in the first part of the Late Glacial (GS-2.1a).

1 Università degli Studi di Ferrara, Dipartimento di Studi Umanistici, Corso Ercole I d'Este 32, 44121 Ferrara, Italy.

2 Universidad Politécnica Salesiana, Campus El Giron, Avenida 12 de Octubre 2422 y Wilson, Quito, Ecuador.

3 Università degli Studi di Trento, Dipartimento di Lettere e Filosofia, Laboratorio "B. Bagolini", via Tommaso Gar 14, 38122 Trento, Italy.

in: Borgia, V. and E. Cristiani (eds.) 2018: *Palaeolithic Italy. Advanced studies on early human adaptations in the Apennine peninsula*, Sidestone Press Academics (Leiden), pp. 287-310.

Four phases have thus been recognized, which have then been grouped into two main macro-phases, each of which includes thick habitation soils, hearth-pits and cumulative features (formed by the amassing of different categories of residues). A large sunken "dwelling structural complex" was also identified and attributed to the most recent macro-phase. The two macro-phases record an important change in the organisation of domestic space over time, testified by the displacement of hearth-pits, the different intensity in their use and the variations in the frequencies of the typologies of lithic artefacts. Such modifications could be related to the different social identity of the groups that occupied the site over time or to changes in the duration and/or aims of the occupations possibly connected to settlement dynamics on a wider scale.

Keywords: Lessini Mountains, rock-shelter, spatial organisation, palimpsests, dwelling structures.

1. Introduction

Studies focused on intra-site spatial organisation are of crucial importance in archaeology, as they contribute to improving our understanding of the social and economic organization of human groups. Another value is recognized in their capacity to be a mirror of the symbolic perception of spaces by past communities. Nonetheless, for the Palaeolithic and Mesolithic periods, our knowledge on this aspect remains rather weak and, since the time of Leroi-Gourhan and Brézillon's (1966, 1972) first works at the famous Magdalenian site of Pincevent, in most cases limited to open-air settlements (for instance: Adouze 1987; Adouze and Enloe 1997; Cavulli 2008; Martinez-Moreno and Mora 2011; Pigeot 2004; Visentin and Fontana 2016). In contrast, cave and rock-shelters, which in several areas represent the majority of known deposits, have only rarely been explored from this viewpoint, with case-studies possibly more frequently applied to Middle than to Upper Palaeolithic contexts in search for similarities and divergences of behaviours between *Homo neanderthalensis* and Anatomically Modern Humans (Mellars 1995; Galanidou 1997a; Vaquero and Pastò 2001; Ontanon 2003; Utrilla *et al.* 2003). As previously observed, this emphasis on open-air sites seems mostly to be related to the assumption that the identification of the so-called "*structures latentes*" ("an organisation of the findings – which is detectable – in an indirect way and rarely on the field") in opposition to "*structures évidentes*" ("a meaningful assemblage of remains that represent something – which is – directly interpretable") (Leroi-Gourhan 1984: 266) is strictly dependent on the presence of contexts created by the synchronic deposition of materials, a condition that happens more frequently at open-air locations. By contrast, caves and rock-shelters are more often characterized by repeated occupations determining the deposition of layers corresponding to palimpsests derived from multiple and superimposed settlement phases and frequently featuring a high degree of taphonomic disturbance. This allows us to assume, as far as intra-site spatial aspects are concerned, that we have a better knowledge of single occupied short-term camps than of settlements occupied either repeatedly, and therefore comprising an unknown number of settlement episodes, or for longer periods of time.

By the way, long ago scholars started to explore and discuss the potentiality of cave and rock-shelters for the reconstruction of prehistoric groups' settlement dynamics.

After F. Bordes' reflections (1975) on the notion of "*sol d'habitat*" in the late 1980s Taborin (1987) proposed a distinction between "palimpsest of activities" and "palimpsest of occupations", where only the former can compromise the possibility to obtain data on the spatial use of settlement areas. In the following years, while Meignen (1993) assumed that analysing patterns of activities in caves and rock-shelters is a false problem since the spatial constraints imposed by the dimensions and disposal of such sites enforce broadly similar patterns in the use of space across time, Galanidou (1997a, 1997b, 1998, 2000) approached the problem by applying a methodology based on the study of overall spatial patterns offered by the association of "evident" ("hearth and other habitation features") and "latent" structures ("robust patterns in the distribution of cultural materials") (Galanidou 1997b, 275). Namely, this author defined such an approach as "site-structural", opposing it to the "reconstructionist" one based on the identification of activity areas in "high-resolution" deposits which, however, may also be subjected to problems of interpretation (Galanidou 1997b, 275). From a methodological viewpoint, parameters such as the type and arrangement of habitation features in a camp, the patterns of refuse disposal, the spacing of activities and the rules about re-using single features, are considered as basic elements for the identification of "redundant patterns" to be compared through time and space. Based on the assumption derived from the ethnographic literature that "each culture has its own set of rules and meanings regarding space" (Galanidou 1998, 5) the dissimilarities observed in the dimension of time are considered to reflect the different social identity of the groups, while those observed at a regional scale are supposed to mirror both the specific function of sites and the social composition of occupying parties. Lately, Bailey and Galanidou (2009, 236), supporting the idea that palimpsests rather than being seen as a problem "should be accepted for what they are", have further explored the issue of re-using pre-existing remains and stressed the importance of the symbolic value of the organisation of space among human communities.

In this paper we will focus on the use of space by Late Palaeolithic groups in the Italian peninsula through the analysis of data from the Late Epigravettian sequence of Riparo Tagliente, which represents one of the main rock-shelter deposits of the Alpine region. Thanks to extensive investigations carried out in the Northern sector of this site, which corresponds in its whole to less than half of the total occupied surface of the site, we have been able to apply a "site-structural" analysis. Particularly the sheltered area is examined in detail, while data from the outer zone is considered for comparison. Riparo Tagliente is the first site so far documented for which we have an evidence of settlement in the south-eastern Alpine region after the end of the LGM. Therefore, analysis of the organisation of domestic space in relation to the activities carried out by Late Epigravettian groups, has a particular interest even for its contribution to the reconstruction of the modalities of re-colonisation of this area, interfacing with results obtained from other studies applied to this site and in general to the whole region (see also Bertola *et al.* 2018). Furthermore, this site allows a diachronic survey of the organisation of space, given the presence of a stratigraphic sequence spanning some thousands of years.

Riparo Tagliente has been the object of studies focused on the structure of space since the late 1970s, when extensive excavations led to the identification of well-preserved dwelling structures (Guerreschi 1983; Bartolomei *et al.* 1984; Peretto *et al.*

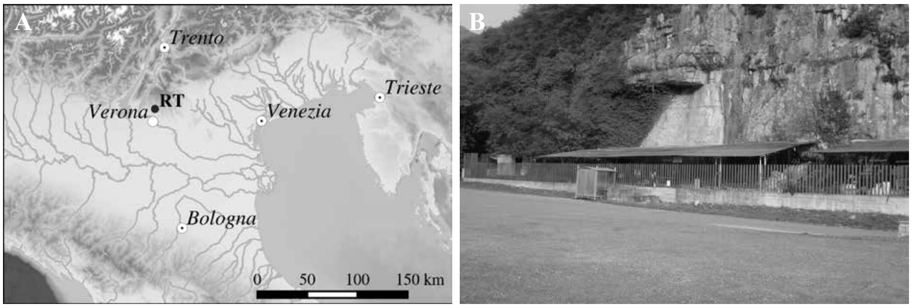


Figure 1. Location of Riparo Tagliente in North-eastern Italy (A), a general view of the site (B) and of the stratigraphic sequence. Dashed line indicates the erosion surface separating the Late Epigravettian sequence from the Mousterian and Aurignacian one.

2004). Nevertheless such studies remained substantially descriptive and did not consider the diachronic dimension of these occupations.

Our study followed two main steps respectively consisting in: a) reconstructing the different phases of occupations by identifying and analysing the record collected over around 30 years of investigations; b) comparing data on the organisation of space in the different phases, in relation to the available radiometric dates, in order to define patterns of continuity and discontinuity over time. Lastly, since no other evidence is currently available in the same region for the time span examined, which could allow locating Riparo Tagliente in the larger-scale settlement system, some preliminary comparisons are attempted with sites attributed to more recent phases of the Late Epigravettian, located in different areas of the Italian peninsula.

2. The Epigravettian occupation of Riparo Tagliente

Riparo Tagliente (Stallavena di Grezzana, Verona) is located on the left slope of Valpantena, one of the main valleys of the Lessini pre-Alpine complex.

The wide rock-shelter opens at the base of Monte Tregnago under a bank of oolitic limestones at an altitude of 250 m a.s.l. After its discovery in 1958 by Francesco Tagliente, archaeological investigations were carried out by Museo Civico di Storia Naturale of Verona from 1962 to 1964. These were resumed in 1967 by the University of Ferrara and are still ongoing. Until the mid-seventies, research focused on the excavation of a long trench running orthogonally to the rock wall and of a smaller trench located in the most internal area (southern sector). The latter led to the identification of a Mousterian sequence and of a late Epigravettian burial, while the first one brought

Figure 2. Panoramic view of the Northern sector with the transversal trench.

to light a stratigraphic sequence about 4.60 metres thick (Bartolomei *et al.* 1974, 1982, 1984; Bertola *et al.* 2007; Gazzoni *et al.* 2013). This sequence can be divided into two main units separated by an alluvial erosion surface: the lower one is attributed to the early and middle Würm and contains Mousterian and Aurignacian assemblages, while the upper one dates back to the Late Glacial and is culturally associated with the Late Epigravettian. At the end of the 1970s, fieldworks in the Late Epigravettian series were extended to the whole Northern sector of the site, over a total surface of around 45 sqm, with the aim of acquiring spatial data on the occupation of the site.

The Late Epigravettian series shows an irregular thickness being thinner and more compact in the area protected by the overhang of the shelter and thicker in the external one. Here the river erosive surface forms a slope which is covered by a sequence of deeply anthropized layers. In this outer zone deposits are constituted by a loess matrix mixed to a coarse breccia that appears denser in the lowermost levels (layers 18-15) and decreases in the uppermost ones. Starting from level 14, pollen analyses indicate the transition from a steppe environment with cold and arid climate conditions to a more temperate one, characterized by wooded grassland with conifers and deciduous trees. Taking into account the rich faunal assemblage in the lower part of the deposit (17-14), the prevailing species are represented by the ibex and the marmot. From layer 13 up to layer 5, temperate species increase, particularly red deer, which becomes dominant starting from layers 12 to 10. A similar situation is recorded by the malacofaunal and microfaunal assemblages (Bartolomei *et al.* 1982, 1984; Fontana *et al.* 2009; Berto *et al.* 2018). In the inner area only the bottom portion of the sequence is preserved, due to removal of the upper one during the Medieval age. This thinner sequence corresponds roughly to layers 13 to 15/18 in the outer zone but a more precise correlation is under elaboration.

Considering the whole northern sector, a constant opposition in the use of the sheltered and outer area of the site was observed (Peretto *et al.* 2004; Fontana *et al.* 2009). Whereas the first was dedicated to domestic and manufacturing activities that were carried out around hearth-places, the second one was devoted to the accumulation of debris of different categories, especially chert wastes within and around some large limestone boulders just outside the sheltered area and bone remains associated to chert knapping waste in the outermost zone. Such accumulations – containing very little sediment – seem the result of both cleaning practises of the internal zone (secondary refuse areas) (Fontana *et al.* 2008; Liagre 2005) and short-term tasks carried out on-site (short knapping sequences and occasional butchering of parts of the animal carcasses etc.) (Cremona and Fontana 2007; Cilli *et al.* 2000; Fontana *et al.* 2009). In this work we will attempt to define the different phases of occupation documented in the sheltered area and to analyse their spatial patterns and variability through time.

3. Methodology

The reconstruction of the articulated stratigraphic sequence in the area protected by the overhang of the shelter has implied a long and complex work of revision of past field documentation starting from the late '70s of last century. Since that time, the system of Stratigraphic Units (hereafter just units or SU) (Harris 1979) was adopted, but the Harris matrix was not compiled during the excavation campaigns and the phasing process was not carried out. Although stratigraphic profiles at regular distances of one meter and stratigraphic unit plans were drawn, and the Stratigraphic Unit forms redacted, the reconstruction of the stratigraphic sequence revealed to be a problematic task as it was done *a posteriori*. All of the plans and profiles were digitalised into a GIS system (QGIS, http://www.qgis.org). When the plans of the SUs were missing (or incomplete), the limits of the SUs were reconstructed on the base of the presence/absence of artefacts with respect to the reference grid system.

The identified SUs were classified into three main categories:

- "habitation soils" or occupation layers representing the result of repeated occupations and long-lasting processes that determined the formation of palimpsests in connection to reduced natural deposition and intense anthropic activity;

- "sunken" dwelling features, along with their diversified sedimentological fillings: hearth-pits that were mostly filled with ashy sediments and characterized by the presence of burned elements (mostly pebbles, faunal remains and chert artefacts, charcoal fragments being extremely rare), some small depressions interpreted as post-holes on the base of their shape and dimensions and one large depression interpreted as the base of a hut (SU 13a);

- "cumulative features" composed of different materials, usually with one prevailing category (chert debris, pebbles, ashes, etc.) and reflecting rather rapid processes of discharge (dumping).

Through the analysis of the whole field documentation the limits of the different layers were defined along with their respective stratigraphical relations and the phases of occupation reconstructed by associating the different ”habitation soils” to the respective negative and positive (“cumulative”) features.

4. Results

4.1. Reconstruction of settlement phases in the sheltered area

The digitalisation of the topographic documentation and its cross checking with the information contained in the SU forms (concerning the stratigraphic relationships among the different SUs) allowed the identification of four occupation phases, each one including several stratigraphic units. These were ordered from the most ancient one (Fig. 3-6). The internal area is delimited by a series of limestone boulders fallen just outside the drip-line. The chronology of this event is uncertain (the excavation is still ongoing) although it is thought to shortly precede the deposition of the first Epigravettian layers (phase I).

The sheltered area is characterized by thick and homogeneous occupation layers (“habitation soils”) interrupted by sunken features, mostly hearths-pits. Cumulative features, on the other hand, are mostly found in the transitional zone between the inner and the outer area.

The first and second phases share one thick habitation soil (SU 13a beta) and one large fireplace (SU 250). The most ancient Epigravettian layers of the inner stratigraphic series, which lie directly on the Mousterian sequence, belong to **phase 1** (Fig. 3). These correspond to occupation layers SUs 13a beta, 302, 303, 304 and 307 and hearths-pits SUs 250, 264, 266 e 310 and their fillings. SU 250 is an “*en cuvette*” hearth – reaching a depth of 20 cm – excavated in the Mousterian layers and reused repeatedly over time. It presents an irregular shape due to continuous filling and reuse. Its matrix was almost exclusively composed of ash and silt and contained some clasts and pebbles deeply altered by fire. Hearths corresponding to SUs 264 and 266 are to be considered as one single entity. Their content was similar to SU 250. These two structures and SU 310 have been so far only partially identified and excavated. Hearth-pit SU 250 appears partially covered by a habitation soil named SU 302: this indicates that only the central part of SU 250 remained in use during the deposition of SU 302. SU 13a beta (variable thickness 4-20 cm), SU 303 and 307 were similar in composition, being composed of a reddish silty-clayey matrix, somewhat rich in clasts, and characterized by the presence of spots of dark grey ashy sediment. They are considered as part of the same habitation soil. SUs 302 and 304, both composed of light grayish silty sediments and containing a percentage of ash and horizontally disposed clasts, are still under investigation and represent parts of another occupation soil. The presence of distinct habitation soils, one overlying the other, could indicate the occurrence of relatively long periods of abandonment of the site between the different occupations.

During **phase 2** the formation of SU 13a beta in the innermost area of the shelter continues, indicating a persistency of occupation (Fig. 4). Meanwhile, hearth SU 250 is partially covered by a new soil (SU 301, *i.e.* silty-clay matrix of a reddish colour containing clasts and with grey spots of sediments rich in ash) which develops above SUs

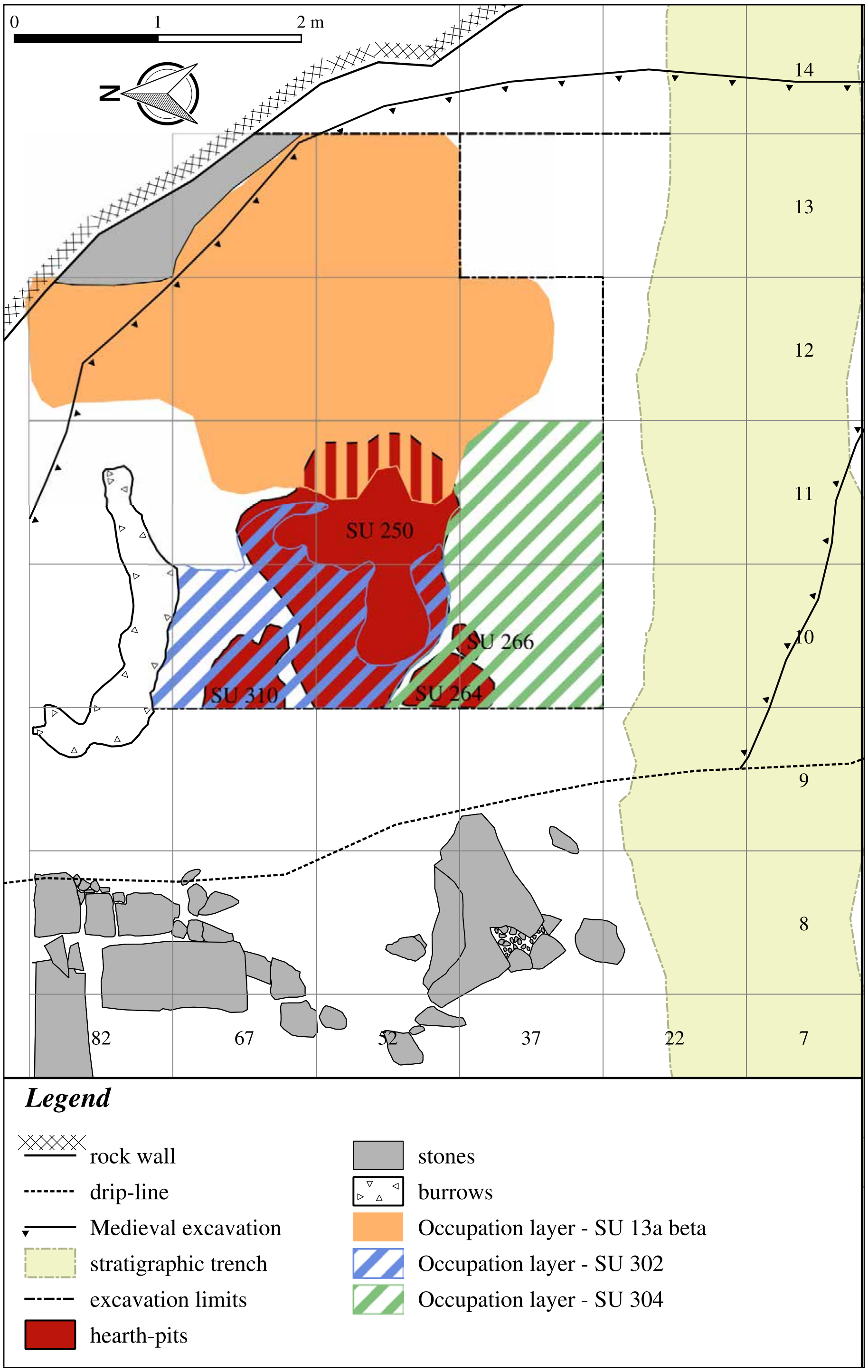


Figure 3. Map of the stratigraphic units identified for phase 1.

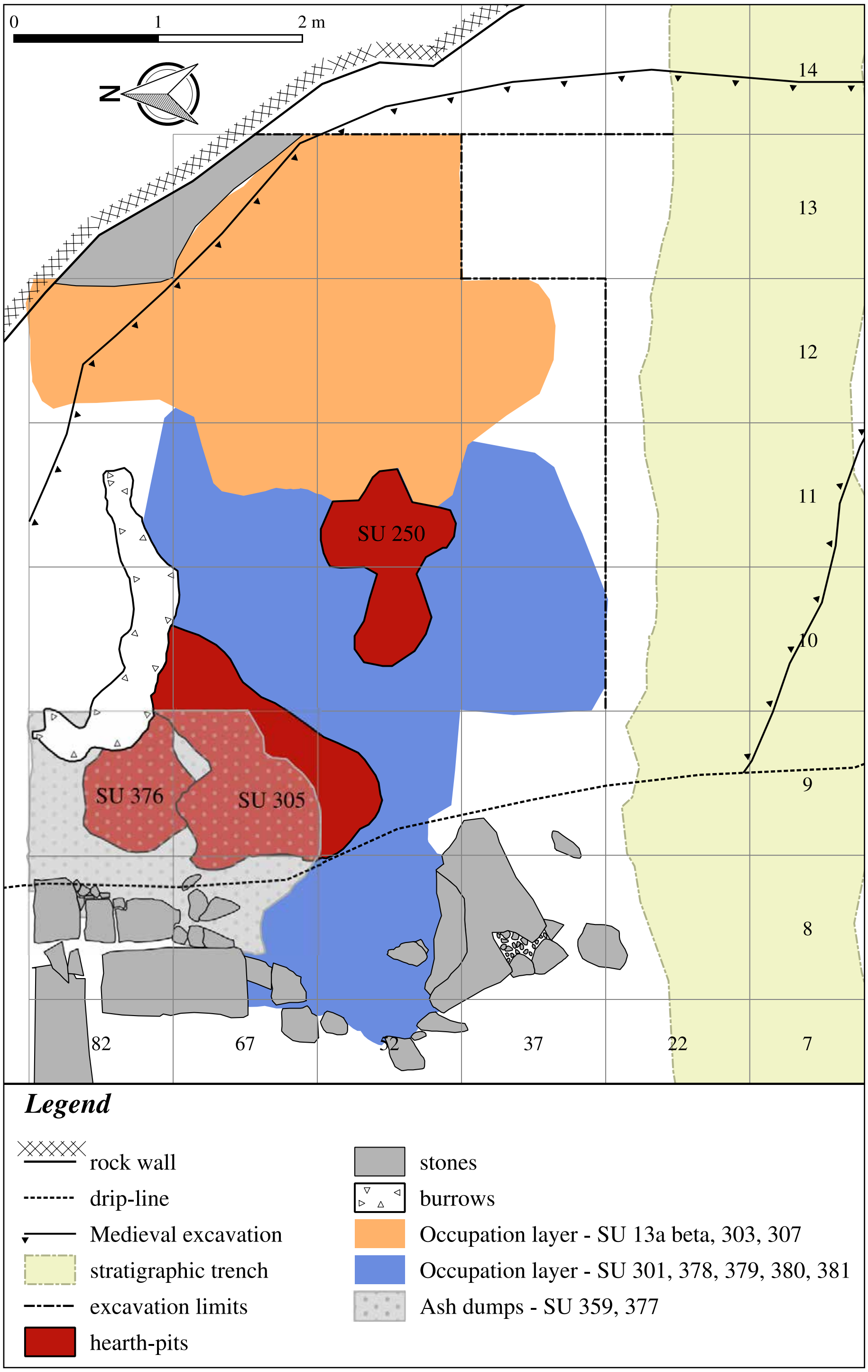


Figure 4. Map of the stratigraphic units identified for phase 2.

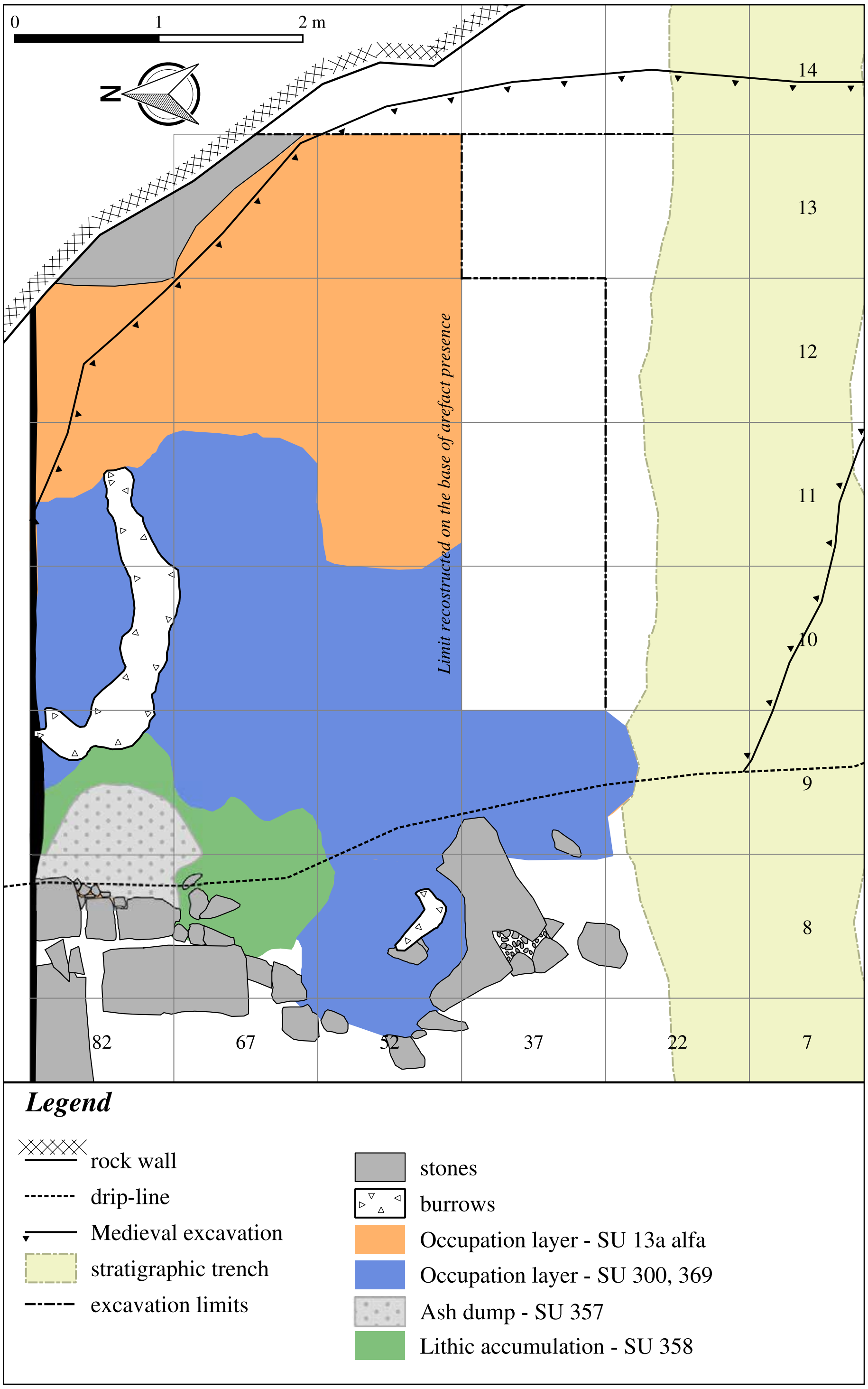


Figure 5. Map of the stratigraphic units identified for phase 3.

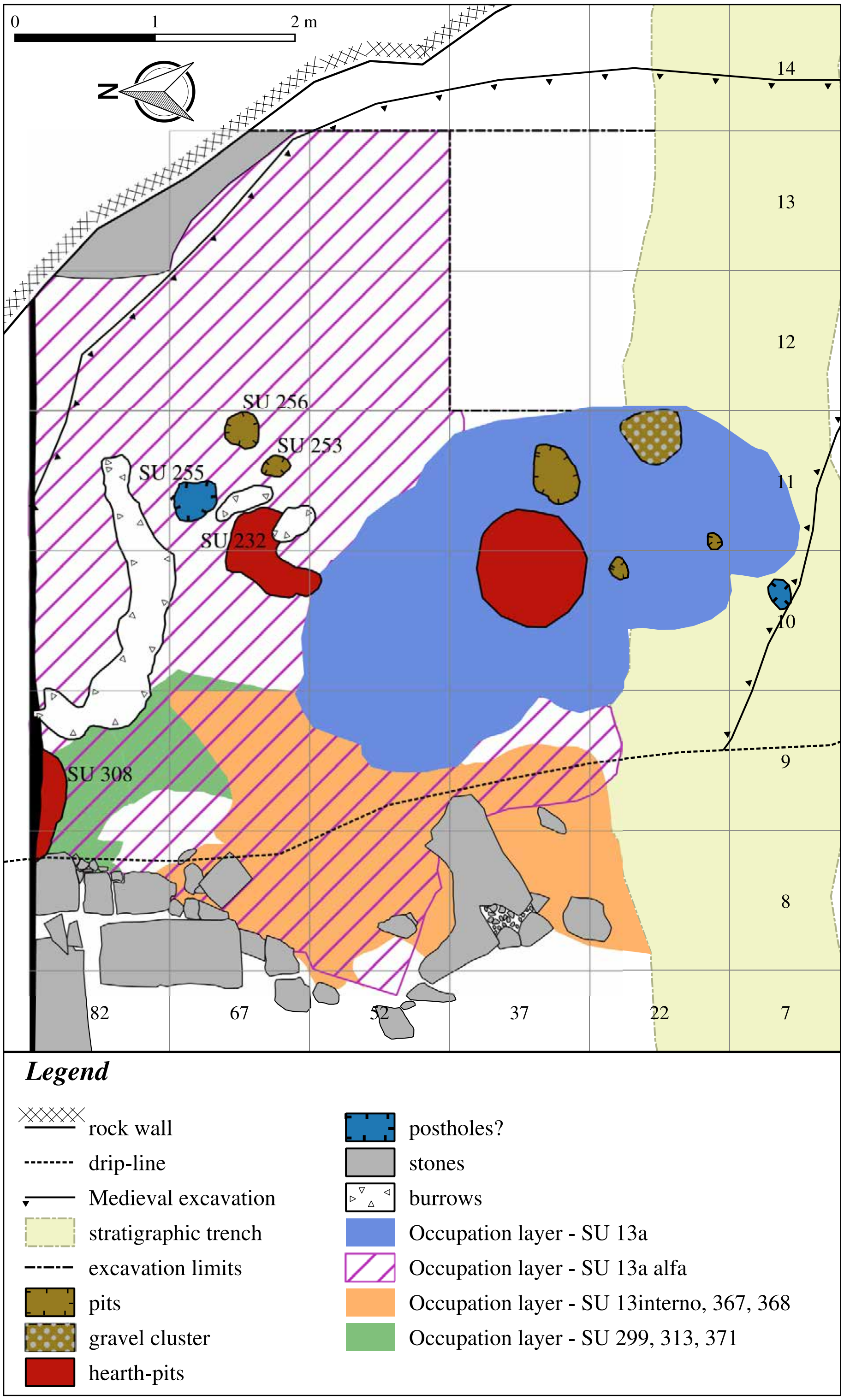


Figure 6. Map of the stratigraphic units identified for phase 4.

302 and 304. Two further combustion structures were in function during this phase (SUs 376 and 305 which are currently under excavation). Both are shallow depressions filled with a fine sediment rich in ashes and including the presence of clasts, sometimes altered by fire. These two structures are covered by two heaps of ashes dumped next to the collapsed boulders (SUs 359 and 377). Between the drip-line and the collapsed blocks other portions of habitation soils (SUs 378, 379, 380, 381) which can be considered as parts of SU 301, were identified. The fabric in these layers is rather chaotic and the deposition of calcite is important in correspondence to the drip-line.

Phases 3 and 4 share another thick (10 to 20 cm) occupation layer (SU 13a alfa) and display a persistence of occupation from one to the other. In **phase 3** a new occupation layer named SU 300 (which includes SU 369) develops in the outwards portion of the sheltered area (Fig. 5). It is a compact, reddish-grey silty layer rich in ashes and clasts. At the same time SU 13a alfa starts to grow in the innermost zone. It is composed of a compact, greyish-brown, silty matrix, with local variations due to the presence of ashes and containing a very rich archaeological record. Following the deposition of SU 300 along the drip-line zone and against the collapsed boulders, two new layers develop (SUs 357 and 358). They are respectively represented by an ash dump with stones and an accumulation of lithic wastes in a scarce silty matrix of an orangish-brown colour with some bone remains and stones.

During **phase 4** the formation of SU 13a alpha continues, extending over most of the sheltered area for a total surface of 18 m^2 and reaching 15-20 cm of thickness (Fig. 6). Two different series of layers precede its formation. The former is represented by SUs 299, 313 and 371, three thin layers – 2 to 4 cm thick – composed of a loose silty sediment rich in ashes, which are associated to SU 308, a hearth partially emerging from the Northern section; the latter by SUs 13 "interno", 367 and 368, all layers dominated by a silty-ashy matrix with colours varying from brownish grey and reddish grey. Moreover SU 13a alpha is interrupted by a series of small depressions (SUs 232, 253, 255, 256): one has been interpreted as a small hearth (SU 232), while for SU 255 the hypothesis of a post-hole has been advanced; two others (SUs 253 and 256) have an unknown origin. The last layer attributed to this phase is SU 13a, a few metres-wide hollow, delimited by an escarpment with a scalloped shape excavated into SU 13a alfa that contained an incoherent filling mostly composed of a dark greyish silty matrix (with the presence of lighter reddish spots) and rare clasts. It included a hearth-pit, sub-circular in shape, with pebbles at the bottom and showing evident traces of heating, and a heap of small pebbles. A small depression pit located at its external limit was interpreted as a post-hole (Bartolomei *et al.* 1984; Guerreschi 1983). Such association of features was inferred to correspond to "a dwelling structural complex". It also represents the last event recorded inside the rock-shelter, partially cut at the top by a digging carried out in historical times. As said before, such activity has led to the destruction of the uppermost part of the Epigravettian sequence in this sector.

4.2. Definition of the macro-phases and their archaeological content

In this work the study of the spatial distribution of archaeological remains in the different phases, which is still in progress due to the high quantity of recovered findings, will not be presented. However, some data on the frequency of the major categories of ar-

Represented pecies	Macro-phase 1	Macro-phase 2
Capra ibex	44 37,9%	363 35,9%
Capreolus capreolus	23 19,8%	96 9,5%
Cervus elaphus	19 16,4%	187 18,5%
Marmota marmota	30 25,9%	365 36,1%
Total	116 100%	1011 100%

Table 1. Riparo Tagliente, Northern sector, Epigravettian series – Distribution of the main faunal species (NR) in the two macro-phases identified in the sheltered area.

Composition of the lithic assemblage	Macro-phase 1	Macro-phase 2
blanks	8,983 4.28%	19,806 15.78%
retouched blanks	403 0.19%	2,120 1.69%
cores	66 0.03%	256 0.2 %
bladelets < 2 cm	1,722 0.82%	1,299 1.03%
flakes < 3 cm	2,531 1.21%	1,113 0.89%
thermally altered p.	53,853 25.68%	33,059 26.33%
débris < 1 cm	106,058 50.57%	42,669 33.99%
débris > 1 cm	36,312 17.22%	25,220 20.09%
Totale	209,928 100%	125,542 100%

Table 2. Riparo Tagliente, Northern sector, Epigravettian series – Composition of lithic assemblages in the two macro-phases identified in the sheltered area.

chaeological items recovered are here reported. Although not being definitive, they offer an idea of the richness of these layers and of the relative quantities of remains. As the two main occupation layers – 13a alfa and 13a beta – are shared respectively by the first two and the second two phases, these were grouped into two macro-phases (macro-phase 1 which includes phases 1 and 2 and macro-phase 2 with phases 3 and 4).

All of the area was characterized by the presence of considerable amounts of different categories of finds. The most represented categories (macro-faunal remains, lithic assemblages and ochre residues) show a marked difference between the two macro-phases, with a higher density in the second macro-phase. The distribution of the main faunal species, according to the number of determined remains, indicates a dominance of open environments (ibex and marmot) over wooded ones (roe deer and red deer) (Tab. 1). This distribution is in accordance with the faunal composition of the most ancient Epigravettian layers of the stratigraphic trench (Bartolomei et al 1982; Rocci Ris 2006). The analysis of seasonality shows an occupation spanning from the beginning of the spring season to the end of autumn (Rocci Ris 2006).

The lithic assemblages are extremely abundant, totalling over 200,000 items for Macro-phase 1 and over 120,000 for Macro-phase 2 (Tab. 2), although it should be underlined that the counting of undetermined pieces belonging to macro-phase 2 is still in progress and therefore under-estimated (Fontana *et al.* 2015). Raw materials employed are almost totally composed of cherts outcropping in the Lessini area, although the presence of some items (mostly retouched tools but also debitage by-products and cores) obtained from cherts of the Umbria-Marches Apennine area, has recently been identified (Bertola *et al.* 2018). The presence of cores and of considerable quantities of by-products and debris indicates that knapping was carried out on-site. The high number of retouched blanks, including formal tools and armatures, attests that both domestic activities and the preparation and replacement of armatures on the shafts were undertaken in this area.

Ochre is represented by a very large number of residues with prevailing dimensions lower than 20 mm, amounting to a total of almost 10,000 fragments in Macro-phase 1 and over 15,000 in Macro-phase 2, mostly characterized by angular edges. There is a clear dominance of red samples obtained from the calcination of yellow types, which were in great part collected from geological deposits of the Lessini area, within a distance of approximately 20 km from the archaeological site (Fontana *et al.* 2009; Cavallo *et al.* 2017a, 2017b; Sardelli 2015).

Besides these dominating categories of finds in this inner area, also a rich collection of tools from hard animal materials, as well as several ornamental elements made from marine shells and red deer atrophic teeth, were recovered. These items, such as chert retouched tools and armatures, only occasionally are present in the outer area. This marked difference clearly defines a different pattern in the use of the two zones.

4.3. Chronology of settlement phases

Seven radiocarbon dates were carried out at the CEDAD of Lecce, the Centre de Datation par le RadioCarbone de l'Université Lyon 1 and Oxford Radiocarbon Accelerator Unit some of which are unpublished while others have recently been published (Tab. 3) (Fontana *et al.* 2015; Soubrier *et al.* 2016). These dates are compared to previous measurements from the trench area, the so-called "Officine litiche" (layers 10a, c, e) and the burial (Tab. 4). The six new dates were performed on samples coming from the outer area of the site (SUs 13 *trincea*, 419 and 352) and the inner one (SUs 13a, 13a alpha, 300 and 13a beta) respectively. As far as the inner series is concerned, dating of US 13a (16438-15941 cal BP) is the youngest in accordance with the stratigraphical reconstruction. Dating of SUs 13a alfa (17219-16687 cal BP) and 300 (17160-16555 cal BP) are older and overlap significantly (although they have different standard deviations), which confirms the reconstruction of macro-phase 2, suggesting that the two SUs deposited during the same period. According to these dates an important temporal gap seems to separate the deposition of SUs 13a alfa and 300 from that of SU 13a. This would imply that SUs 13a alfa and SU 13a belong to different phases of occupation. By the way, so far these have been considered as part of the same phase (phase 4, *i.e.* macro-phase 2), since we cannot exclude that SU 13a alpha continued to form also at the time of the deposition of SU 13a. Such reconstruction should be confirmed or denied by further dating. Unfortunately the dating of SU 13a beta has given a result older than 45000 BP, therefore attributable to the Mousterian occupation. This is not surprising, as Mousterian layers directly underlie layer 13a beta and some Mousterian lithic artefacts were found in this layer. Their presence is mostly due to the excavation activity by Epigravettian groups (*e.g.* the digging of hearth-pits) more than to natural post-depositional processes. Therefore, so far, we do not have any elements to verify the chronological relationship between macro-phases 1 and 2. By the way in their whole the radiocarbon dates obtained from the layers of macro-phase 2

S.U.	Q.	Lab/sample	BP	Cal BP	Cal BC	Sampled material
419	Ext. area Q. 80/8	Lyon-10034 (SacA 32399)	12.430±70	14966-14175	13016-12225	Coxal bone, *Cervus elaphus*
352*	Ext. area Q. 53/3	OxA-29834	13.600±60	16638-16179	14688-14229	Bone, *Bison* cladex
13 trincea	Ext. area Q. 37/8	Lyon-10033 (SacA 32398)	13.250±80	16186-15684	14236-13734	Metacarpal bone, *Capra ibex*
13a	Int. area Q. 39/7	Lyon-10031 (SacA 32396)	13450±70	16438-15941	14488-13991	Metatarsal bone, *Cervus elaphus*
300	Int. area Q. 54/3	Lyon-10030 (SacA32395)	13.920±80	17160-16555	15210-14605	Femur, *Capra ibex*
13a alpha**	Int. area Q. 72/5	LTL4441A (Cedad)	13.986±60	17219-16687	15269-14737	Bone, *Cervus elaphus*
13abeta**	Int. area Q. 57/4	Lyon-10032 (SacA 32397)	> 45.000	--------	------	Tibia, *Cervus elaphus*

*Table 3. Riparo Tagliente, Northern sector, Epigravettian series – Recently performed radiocarbon dates (Calibration 2sigma; OxCal 4.2.3) of layers from the internal (sheltered) and external area (**Fontana et al. 2015; *Soubrier et al. 2016).*

S.U.	Q.	Lab/sample	BP	Cal BP	Cal BC	Sampled material
10-8	trench	R-371	12.040±170	14535-13472	12585-11522	charcoal
10a (OL1II)	NS – Ext. area	OxA-3530	12.650±160	15537-14243	13587-12293	Bone: *Cervus elaphus*
10c (OL 2)	NS – Ext. area	OxA-3531	13.070±170	16147-15176	14197-13226	Bone: *Cervus elaphus*
Burial	SS – Int. area	OxA-0672	13.190±90	16149-15532	14199-13582	Human bone
10e (OL 3)	NS – Ext. area	OxA-3532	13.270±170	16426-15371	14476-13421	Bone: *Cervus elaphus*
14	*trench*	*R-604*	*12.000±400*	*15271-13095*	*13321-11145*	charcoal
15-16	trench	R-605	13.330±160	16537-15548	14587-13598	charcoal
15-16	trench	R-605a	13.430±180	16761-15660	14811-13710	charcoal

Table 4. Riparo Tagliente, Northern sector, Epigravettian series – Elderly performed radiocarbon dates (Calibration 2 sigma; OxCal 4.2.3) from the trench area, the burial (Southern sector) and Northern sector, outer area.

confirm that this inner sequence deposited during the first occupation period in the site, corresponding to the latest part of the Ancient Dryas (GS2.1a) (Rasmussen *et al.* 2014). Lastly, the dates available for the external area attest, on one hand, a close chronology to the sequence of the inner area (SUs 352 and 13 trincea) and, on the other hand (SU 419), a more recent age, which corresponds to the beginning of the Lateglacial interstadial occupation phase, not attested inwards.

5. Discussion

The study of the spatial organisation in the sheltered area of Riparo Tagliente allowed the identification of four main phases of occupation, which were grouped into two main macro-phases, each of which including a series of thick occupation layers, hearth-pits and cumulative features (formed by the amassing of different categories of residues) (Fig. 7).

The earliest macro-phase (the field investigation of which is still in progress) is characterized by the presence of some occupation soils and hearth-pits, one of which attests several phases of reuse through time. A wide ash accumulation layer is located in correspondence to the drip-line. The second macro-phase differs in the disposition of hearth-pits and occupation soils. Two of the three attested hearth-pits, are smaller than those of macro-phase 1 and do not show any evidence of reuse over time, while the latter has been only partially explored. Accumulation layers (dumps of ashes

Figure 7. Picture taken during fieldworks showing the "dwelling structure complex" named SU 13a delimited by an escarpment (the left side) (phase 4) and the hearth-pit named SU 250 (at the centre) (phases 1 and 2).

and lithics), on the other hand, are still located in correspondence with the drip-line. Additionally, a large sunken "dwelling structural complex" was attributed to this phase. Similar structures are very rare in the Palaeolithic archaeological record, especially as regards cave and rock-shelters, although frequently attested by ethnographic accounts, where such artificial depressions are referred to as "domestic units", where single groups sleep around hearths (Galanidou 2000: 250, 265). According to available radiocarbon dating, it is possible that this feature corresponds to an even later occupation phase, although further chronological data are needed in order to confirm this hypothesis.

To summarize, the two macro-phases record an important change in the organisation of domestic space testified by the displacement of hearth-pits and by the different intensity in their use. Actually, the high presence of ashes in the sediments composing the second macro-phase allows the inference that combustion structures did not have a minor role with respect to the previous phase, but were probably located elsewhere. Occupation layers, as attested by the archaeological findings, correspond to multi-purpose areas. In both macro-phases, activities appear to be clustered around the hearths and include flaking, preparation and repairing of arrows and ochre processing, as well as other domestic activities. We expect that ongoing functional studies on the lithic assemblages will enable us to better define such activities and their possible connections to dwelling structures. On the other hand, when comparing the inner to the outer area, a persisting difference in the pattern of use is attested, the former being dedicated to domestic activities and the latter to the discard of wastes and specialised, short-term processing activities (Fontana *et al.* 2008, 2009; Peretto *et al.* 2004).

The possibility to draw comparisons with other Late Epigravettian sites in the Italian peninsula is rather limited, due to the low number of deposits explored over sufficiently wide surfaces and with published data. For most of these sites, data on the diachronic organisation are not available, and, at the same time, spatial details for all of them are limited to the areas protected by the overhang of the shelter. The main evidence comes from three sites respectively situated in Northern (Riparo Dalmeri), Central (Grotta Continenza) and Southern Italy (Grotta del Romito). The site of Riparo Dalmeri is the closest one, being located on the Asiago Plateau at an altitude of 1,240 m a.s.l., but its occupation belongs to a later Epigravettian period than that attested by the sequence of Riparo Tagliente. Two main occupation layers are documented, which attest the use of the same area of the shelter for a few hundred years during the Allerød interstadial. The occupation is preceded by a phase of preparation, which includes the ritual disposition on the soil of ochre painted slabs with animal and anthropomorphic representations, along with stone alignments, pits, hearths and post-holes. Although an exhaustive report on this site is not available yet, authors support a "semi-permanent" occupation of the site, with the retrieval and reuse of the same area at different times (Dalmeri *et al.* 2002). At Grotta Continenza (Peretto *et al.* 2004), located around the ancient Fucino basin, in the central Apennines (Abruzzo), the Epigravettian layers are characterized by several burning pits of oval or circular shape which are filled or lined with stones and delimited by flint knapping areas, or by zones with burnt soil remains and accumulation of food waste (mostly fish remains). So far, spatial analyses carried out on one of these layers (layer 32) allowed the identification of two different areas: the inner one, facing the hearth, was devoted to the preparation and consumption of food, while the outer one shows several elements linked to flint knapping. Lastly, Riparo Romito, located in Northern Calabria, on the Southern Apennines, seems to represent only one part of the inhabited area of the site, which probably continued inside the homonymous cave (Martini *et al.* 2012). Underneath the sheltered area a series of pits, filled with artefacts of different categories and containing some "exceptional" items, were identified and given a ritual explanation.

Data from the three sites allow carrying out only some general considerations with respect to the evidence brought to light at Riparo Tagliente. On one hand, the repeated location of hearths in areas protected by the rock-shelter overhangs and their central role as catalysts of domestic activities appear as common features to all situations, as also observed from ethnographic studies and other geographic contexts of Palaeo-Mesolithic hunter-gatherers (*e.g.* Dalmeri *et al.* 2002, Galanidou 1997b, 2000, Vaquero and Pasto 2001); on the other, each considered site shares some specific aspects with Riparo Tagliente, *i.e.* the occurrence of possible post-holes is only attested at Dalmeri and Tagliente which could indicate the presence of mobile structures (tents? huts?) in these sites while a similar pattern in the location of knapping debris – which were scattered in an area far away from hearths – is a common feature with Grotta Continenza. Lastly another aspect is the connection of the domestic areas of these sites to elements that reflect a symbolic dimension. From this viewpoint there is no evidence of "ritual structures" at Riparo Tagliente similar to those brought to light at Riparo Dalmeri and Grotta Romito, but the presence, in the inner area, of several objects that refer to a ritual sphere, such as engraved pebbles and bones with figurative representations of animals and geometric lines, which were in most cases found out of context, has been highlighted.

6. Conclusions

This study has focused on the organisation of space during the Late Epigravettian occupation of Riparo Tagliente. Despite the very high density of the findings, the extensive exploration of the northern sector, over a surface of around 45 sqm including both the sheltered and external area, allowed the structural organisation of the site to be investigated and recognized. Previous works had underlined the presence of a persistent pattern in the differential use of the outer area of the shelter, characterized by secondary refuse accumulations (lithic waste products, chert cores, bone remains) and, to a lesser extent, by short-term practises carried out on-site with respect to the sheltered area dedicated to domestic activities undertaken around hearths (Fontana *et al.* 2009).

In this paper we have focused on the diachronic structure of space in the inner area, which has led to highlight a main transformation through time (differences between macro-phase 1 and macro-phase 2), especially concerning the arrangement of hearth-pits and dwelling-structures. Evidence for this change is supported also by the composition of the lithic assemblages of retouched artefacts (Fontana *et al.* 2015) that could reflect a different organisation of the activities, although this aspect still awaits to be better investigated in the future through functional analyses.

We are thus induced to reflect on the reasons that may have brought about such modifications. Actually, the evidence recovered in the sheltered area attests an intense occupation of Riparo Tagliente since the first Late Epigravettian settlement phase, with an emphasis on processing of the rich lithic, mineral and biological resources offered by the Lessini area. Moreover, the variety and abundance of finds in all the layers indicates an excellent knowledge of this territory, which was exploited from the valley-bottoms to the top of the plateau (i.e ibex hunting on the valley slopes and chert nodules collection within the highland soil deposits) and including the surrounding valleys (i.e ochre extraction from the area of Ponte di Veja along the ridge connecting Valpantena to Valpolicella) (Bertola *et al.* 2007; Bietti *et al.* 2004; Cavallo *et al.* 2017a, 2017b; Cusinato *et al.* 2003; Fontana *et al.* 2009). Such occupations occurred on a seasonal basis, especially during the period of the year between early spring and late autumn, by groups whose mobility remains unknown. Nonetheless, the presence of few artefacts and cores manufactured on cherts of the Northern Adriatic Apennines (Umbria-Marche basin) among the wide quantity of items and discarded elements obtained on local raw materials, seems to imply the persistence of contacts with this area over time with no apparent and substantial difference between the two macro-phases (Bertola *et al.* 2018).

We must therefore conclude that available data do not allow the support of any definite hypothesis for the interpretation of the patterns highlighted, namely the consistent transformations of the structural organisation of the site between the two macro-phases identified. This could depend, either on the different social identity of the groups that occupied the site overtime, or on changes in the duration and/or the aim of occupations in relation to settlement dynamics on a wider scale.

Lastly, this study constitutes clear evidence that caves and rock-shelters, besides being important archives for the diachronic definition of past cultural changes, also yield a great potentiality for understanding the use of domestic spaces, thus bringing a substantial contribution to the reconstruction of economic, social and symbolic behaviours of prehistoric groups.

Acknowledgements

Authors would like to thank the Municipality of Grezzana (Verona) for the financial support of field research in the site. The work has been coordinated by FF, who has also written the Introduction and Discussion parts while LF has elaborated the phase maps with the support of FC and DV. All the Authors have discussed stratigraphical data; SB has worked on the aspects of provenance of lithic raw materials while AGa, MGC, LF and DV have analysed the lithic assemblages with the support of FF. A special thanks to Owen Alexander Higgings for proofreading the text.

References

Adouze, F. and Enloe, J.G. 1997. High resolution archaeology at Verberie: limits and interpretations. *World Archaeology* 29 (2), pp. 195-207.

Adouze, F. 1987. Des modèles et des faits: les modèles de A. Leroi-Gourhan et de L. Binford confrontés aux résultats récents. *Bulletin de la Société Préhistorique Française* 84, pp. 243-252

Bailey, G. and Galanidou, N. 2009. Caves, palimpsests and dwelling spaces: examples from the Upper Palaeolithic of south-east Europe. *World Archaeology* 41 (2), pp. 215- 241.

Bartolomei, G., Broglio, A., Guerreschi, A., Leonardi, P., Peretto, C. and Sala, B. 1974. Una sepoltura epigravettiana nel deposito pleistocenico del Riparo Tagliente in Valpantena (Verona). *Rivista di Scienze Preistoriche* 29 (1), pp. 101-152.

Bartolomei, G., Broglio, A., Cattani, L., Cremaschi, M., Guerreschi, A., Mantovani, E., Peretto, C. and Sala, B. 1982. I depositi würmiani del Riparo Tagliente. *Annali dell'Università di Ferrara*, N.S., sez. 15, III (4), pp. 61-105.

Bartolomei, G., Broglio, A., Cattani, L., Cremaschi, M., Guerreschi, A., Leonardi, P. and Peretto C. 1984. Paleolitico e Mesolitico. In Aspes, A. ed. *Il Veneto nell'antichità. Preistoria e Protostoria* 2, Banca Popolare di Verona, pp. 167-319.

Berto, C., Luzi, E., Montanari Canini, G., Guerreschi, A., Fontana, F, 2018. Climate and landscape in Italy during Late Epigravettian. The Late Glacial small mammal sequence of Riparo Tagliente (Stallavena di Grezzana, Verona, Italy). Quaternary Science Review, 184, pp. 132-142.

Bertola, S., Broglio, A., Cassoli, P., Cilli, C., Cusinato, A., Dalmeri, G., De Stefani, M., Fiore, I., Fontana, F., Giacobini, G., Guerreschi, A., Gurioli, F., Lemorini, C., Liagr,e J., Malerba, G., Montoya, C., Peresani, M., Rocci Ris, A., Rossetti, P., Tagliacozzo, A. and Ziggiotti S. 2007. L'Epigravettiano recente nell'area prealpina e alpina orientale. In: Martini, F. ed. *L'Italia tra 15.000 e 10.000 anni fa.*

Cosmopolitismo e regionalità nel Tardoglaciale. Atti della Tavola Rotonda (Firenze 18 novembre 2005). Museo Fiorentino di Preistoria "Paolo Graziosi", Firenze, Millenni, Studi di Archeologia Preistorica, 5, pp. 39-94.

Bietti, A., Boschian, G., Mirocle Crisci, G., Danese, E., De Francesco, A. M., Dini, M., Fontana, F., Giampietri, A., Grifoni, R., Guerreschi, A., Liagre, J., Negrino, F., Radi, G., Tozzi, C. and Tykot, R. 2004. Inorganic raw materials economy and provenance of chipped industry in some stone age sites of Northern and Central Italy. *Collegium Anthropologicum*, 28,1, pp. 41-54.

Broglio A., Bertola S., De Stefani M., Gurioli F., 2009: "The shouldered points of the Early Epigravettian of the Berici Hills (Venetian Region – North Italy). Materials, Blanks, Typology, Exploitation". In: Burdukiewicz J. M., Cyrek K., Dyczek P., Szymczak K. (Eds): Understanding the Past, Papers offered to Stefan K. Kozlowski. Center for Research on the Antiquity of Southeastern Europe, University of Warsaw, Warsaw, pp. 59-68.

Bertola, S., Fontana, F. and Visentin, D. 2018. Lithic raw material circulation and settlement dynamics in the Upper Palaeolithic of the Venetian Prealps (NE Italy). A key-role of paleoclimatic and landscape changes across LGM? In: Borgia, V. and Cristiani, E. (Eds.): Palaeolithic Italy. Advanced studies on early human adaptations in the Apennine peninsula. Sidestone Press, Leiden, pp. 219-246.

Bordes, F. 1975. Sur la notion de sol d'habitat en préhistoire paléolithique. *Bulletin de la Société préhistorique française* 72 (5), pp. 139-144.

Cavallo, G., Fontana, F., Gonzato, F., Guerreschi, A., Riccardi, M.P., Sardelli, G. and Zorzin, R. 2017a. Sourcing and processing of ochre during the late upper Palaeolithic at Tagliente rock-shelter (NE Italy) based on conventional X-ray powder diffraction analysis. Archaeological and Anthropological Sciences, 9 (5), pp. 763-775.

Cavallo, G., Fontana, F., Gonzato, F., Peresani, M., Riccardi, M.P and Zorzin, R. 2017b. Textural, microstructural, and compositional characteristics of Fe-based geomaterials and Upper Palaeolithic ochre in the Lessini Mountains, NE Italy: Implications for provenance studies" for publication in Geoarchaeology. Geoarcheology, 32 (4), pp. 437-455.

Cavulli, F. 2008. L'analisi della distribuzione spaziale. In Aranguren, B. and Revedin, A. eds. *Un accampamento di 30.000 anni fa a Bilancino (Mugello, Firenze)*, Origines, Firenze, pp. 183-229.

Cilli, C. and Guerreschi, A. 2000. Studio archeozoologico e tafonomico di un'area di concentrazione di reperti faunistici di età epigravettiana (Riparo Tagliente, Verona). Atti del *2° Convegno Nazionale di Archeozoologia*, Asti, 14-16 novembre 1997. Forlì, ABACO, pp. 141-149.

Cremona, M.G. and Fontana, F. 2007. Analisi tecno-economica di una concentrazione di scarti litici (US 411) dai livelli epigravettiani di Riparo Tagliente (Stallavena di Grezzana, Verona). In: Thun Hohenstein, U. ed. Atti del I Convegno Nazionale degli Studenti di Antropologia, Preistoria e Protostoria, Ferrara, 8-10 Maggio 2004, *Annali dell'Università di Ferrara*, Volume Speciale, pp. 59-62.

Cusinato, A., Dalmeri, G., Fontana, F., Guerreschi, A. and Peresani, M. 2003. Il versante meridionale delle Alpi durante il Tardiglaciale e l'Olocene antico: mobilità, sfruttamento delle risorse e modalità insediative degli ultimi cacciatori-raccoglitori. *Preistoria Alpina*, 39, pp. 129-142.

Dalmeri, G., Bassetti, M., Cusinato, A., Kompatscher, K., Hrozny Kompatscher, M. and Lanzinger, M. 2002. Le pietre dipinte del sito epigravettiano di Riparo Dalmeri. Campagna di ricerche 2001. *Preistoria Alpina* 38, pp. 3-34.

Fontana, F., Cilli, C., Cremona, M. G., Giacobini, G., Gurioli, F., Liagre, J., Malerba, G., Rocci Ris, A., Veronese, C. and Guerreschi, A. 2009. Recent data on the Late Epigravettian occupation at Riparo Tagliente, Monti Lessini (Grezzana, Verona): a multidisciplinary perspective. Proceedings of the 49th Hugo Obermeier Society Meeting, Trento, 10-14 Aprile 2007, *Preistoria Alpina* 44, pp. 51-59.

Fontana, F., Guerreschi, A., Bertola, S., Bonci, F., Cilli, C., Liagre, J., Longo, L., Pizziolo, G., Thun Hohenstein, U. 2008. The first occupation of the Southern Alps in the Late Glacial at Riparo Tagliente (Verona, Italy). Detecting the organisation of living-floors through a G.I.S. integrated analysis of technological, functional, palaeoeconomic and spatial attributes. In: Grimaldi, S. and Perrin, T. eds. *Mountain environments in prehistoric Europe: settlement and mobility strategies from Palaeolithic to the early Bronze age*. Proceedings of the XV U.I.S.P.P. Congress, Lisbon, 3-9 September 2006, B.A.R. International Series, 26, Oxford, Archaeopress, pp. 71-79.

Fontana, F., Guerreschi, A., Bertola, S., Cremona, M.G., Cavulli, F., Falceri, L., Gajardo, A., Montoya, C., Ndyaie, M. and Visentin, D. 2015. I livelli più antichi della serie epigravettiana "interna" di Riparo Tagliente: sfruttamento delle risorse litiche e sistemi tecnici. In: Leonardi, G. and Tinè, V. eds. Atti della XLVIII Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria, *Preistoria e Protostoria del Veneto*, Padova 5-9 novembre 2013, Istituto Italiano di Preistoria e Protostoria, pp. 43-52.

Galanidou, N. 1997a. *Home is where the hearth is. The spatial organisation of the Upper Palaeolithic rock-shelter occupations at Klithi and Kastritsa in Northwest Greece*. BAR International S687

Galanidou, N. 1997b. The spatial organisation of Klithi. In: Bailey, G. ed. *Klithi: Palaeolithic settlement and Quaternary landscapes in northwest Greece.* McDonald Institute for Archaeological Research, pp. 275-304.

Galanidou, N. 1998. Uses of ethnography in modelling Palaeolithic settlement: the past, the present and the future. Préhistoire Européenne, 13, 1998, p. 195-204.

Galanidou, N. 2000. Patterns in Caves: Foragers, Horticulturists, and the Use of Space. *Journal of Anthropological Archaeology* 19, pp. 243-275.

Gazzoni, V., Goude, G., Herrscher, E., Guerreschi, A., Antonioli, F. and Fontana, F. 2013. Late Upper Palaeolithic human diet: first stable isotope evidence from Riparo Tagliente (Verona, Italy*). Bulletin et mémoires de la Société d'Anthropologie de Paris* 25 (1), pp.103-117.

Guerreschi, A. 1983. Structures d'habitat épigravettiennes dans l'Abri Tagliente (Vérone) et dans la grotte du Prete (Ancone-Italie). In : Berke, H., Hahn, J. and Kind C.J. eds. Upper *Paleolithic settlement patterns in Europe*, Reisensburg/Gunzburg, *Archaeologica Venatoria*, 6, 59-67.

Harris, E.C., 1979. *Principles of archaeological stratigraphy*. London, Academic Press.

Leroi-Gourhan, A. and Brézillon, M. 1966. L'habitation magdalénienne n° 1 de Pincevent près Monterau (Seine-et-Marne). *Gallia Préhistoire,* 9 (2), pp. 263-385.

Leroi-Gourhan, A. and Brézillon, M. 1972. Fouilles de Pincevent. Essai d'analyse ethnographique d'un habitat magdalenien (la section 36). CNRS, Paris, *Gallia Préhistoire,* VII Supplément.

Leroi-Gourhan, A. 1984. Réflexion terminologique sur "structure". In: Berke, H., Hahn, J. and Kind, C. J. eds, Jungpaläolithische Siedlungsstrukturen in Europa, Reisensburg/Günzburg 8-16 mai 1983, Urgeschichtliche Materialhefte, 6, Verlag Archaeologia Venatoria, Tübingen, p. 266.

Liagre, J. 2005. Gestion de l'activité de taille et de l'espace domestique au Tardiglaciaire en Italie nord orientale. Analyse des « Officine Litiche » de l'abri Tagliente (Vénétie). PhD thesis, Université Aix-Marseille I.

Martini, F., Lo Vetro, D., Di Giuseppe, Z., Baglioni, L., Colonese, A. C., Lemorini, C., Mazzucco, N. and Trenti, F. 2012. Strutture e sottostrutture del Paleolitico superiore di Grotta del Romito tra funzionalità e simbolismo. *Rivista di Scienze Preistoriche* LXII, pp. 33-66.

Mellars, P., 1995. *The Neanderthal Legacy: An Archaeological Perspective from Western Europe*. Princeton University Press.

Martinez-Moreno, J. and Mora, R. 2011. Spatial organisation at Font del Ros, a Mesolithic settlement in the South-eastern Pyrenees. In: Gaudzinski-Windheuser, S., Sensburg, O. J. M., Street, M., Turner, E., eds. Site-internal spatial organisation of hunter-gatherer societies: case studies from European Palaeolithic and Mesolithic. Römisch-Germanisches Zentralmuseum Forschungsinstitut für Vor- und Frühgeschichte, erlag des Römisch-Germanischen Zentralmuseums, Mainz, pp. 213-231.

Meignen, L. 1993. *L'abri des Canalettes. Un habitat moustérien sur les grands Causse (Nant, Aveyron). Fouilles 1980-1986*. Paris, Monographie du CRA, Editions du CNRS.

Ontañon P. R. 2003. Sols et structures d'habitat du Paléolithique supérieur, nouvelles données depuis les Cantabres: La Galerie inférieure de La Garma (Cantabria, Espagne). *L'Anthropologie*, 107 (3), pp. 333-363.

Peretto, C., Biagi, P., Boschian, G., Broglio, A., De Stefani, M., Fasani, L., Fontana, F., Grifoni, R., Guerreschi, A., Iacopini, A., Minelli, A., Pala, R., Peresani, M., Radi, G., Ronchitelli, A., Sarti, L., Thun Hohenstein, U. and Tozzi C. 2004. Living-floors and structures from the lower Palaeolithic to the Bronze age in Italy. *Collegium Anthropologicum* 28 (1) pp. 63-88.

Pigeot, N. (Ed.) 2004. Les derniers Magdaléniens d'Étiolles. Perspectives culturelles et paléohistoriques (l'unité d'habitation Q31). CNRS, Paris, *Gallia Préhistoire*, XXXVII supplément, 351 p.

Rasmussen, S.O., Bigler, M., Blockley, S.P., Blunier, T., Buchardt, S.L., Clausen, H.B., Cvijanovic, I., Dahl-Jensen, D., Johnsen, S.J., Fischer, H., Gkinis, V., Guillevic, M., Hoek, W.Z., Lowe, J.J., Pedro, J.B., Popp, T., Seierstad, I.K., Steffensen, J.P., Svensson, A.M., Vallelonga, P., Vinther, B.M., Walker, M.J.C., Wheatley, J.J., Winstrup, M., 2014. A stratigraphic framework for abrupt climatic changes during the Last Glacial period based on three synchronized Greenland ice-core records: Refining and extending the INTIMATE event stratigraphy. *Quaternary Science Reviews* 106, 14-28. doi:10.1016/j.quascirev.2014.09.007

Rocci Ris, A. 2006. *I macromammiferi di Riparo Tagliente. Archeozoologia e tafonomia dei livelli epigravettiani*. PhD thesis, Dipartimento di Anatomia, Farmacologia e medicina Legale, Università degli Studi di Torino.

Sardelli, G. 2015. *L'ocra dei livelli epigravettiani di Riparo Tagliente (Grezzana, Verona): caratterizzazione, distribuzione e ipotesi di utilizzo*. Unpublished BA dissertation, University of Ferrara.

Soubrier, J., Gower, G., Chen, K., Richards, S.M., Llamas, B., Mitchell, K.J., Ho, S.Y.W., Kosintsev, P., Lee, M.S.Y., Baryshnikov, G., Bollongino, R., Bover, P., Burger, J., Chivall, D., Crégut-Bonnoure, E., Decker, J.E., Doronichev, V.B., Douka, K., Fordham, D.A., Fontana, F., Fritz, C., Glimmerveen, J., Golovanova, L. V., Groves, C., Guerreschi, A., Haak, W., Higham, T., Hofman-Kamińska, E., Immel, A., Julien, M.-A., Krause, J., Krotova, O., Langbein, F., Larson, G., Rohrlach, A., Scheu, A., Schnabel, R.D., Taylor, J.F., Tokarska, M., Tosello, G., van der Plicht, J., van Loenen, A., Vigne, J.-D., Wooley, O., Orlando, L., Kowalczyk, R., Shapiro, B., Cooper, A., 2016. Early cave art and ancient DNA record the origin of European bison. *Nature Communications* 7, 13158. doi:10.1038/ncomms13158

Taborin, Y. 1987. Une certaine lecture des sols d'habitation. *Bulletin de la Société Préhistorique Française* 84 (10-12), pp. 353-357.

Utrilla, P., Mazo, C. and Domingo, R. 2003. Les structures d'habitat de l'occupation magdalénienne de la Grotte d'Abauntz (Navarre, Espagne). L'organisation de l'espace. In : Vasil'ev, S. A., Soffer, O. and Kozlowski, J. eds. *Perceived Landscapes and Built Environments. The cultural geography of Late Paleolithic Eurasia*. BAR International Series, 1122, pp.25-37.

Vaquero, M. and Pasto, I. 2001. The Definition of Spatial Units in Middle Palaeolithic Sites: The Hearth-Related Assemblages. *Journal of Archaeological Science* 28, pp. 1209-1220.

Visentin, D. and Fontana, F. 2016. The Sauveterrian of the Emilian Po plain: intra-site spatial organization face to face. *Quaternary International*, 423, pp- 58-72.

Epigravettian osseous technology from the eastern Alpine region of Italy

The case of Riparo Dalmeri (Trentino)

E. Cristiani[1]

Abstract

The article focuses on the repertoire of osseous artefacts from the Epigravettian site of Riparo Dalmeri (Asiago Plateau), which yielded one of the richest Late Palaeolithic assemblage of organic tools recovered in the Italian Peninsula. The author discusses how the analysis of operational sequences, technological know-how and skills related to osseous artefacts' production, use, recycling and discard can help shedding light on daily life activities as well as social dynamics within the Late Epigravettian community in the eastern Alpine region.

Keywords: Bone and antler technology, Late Epigravettian, Alpine region, site specialization, technological variability, social practice.

1. Introduction

At the end of the Pleistocene, a general amelioration of the climatic conditions determined the retreat of the main glaciers from the Alpine valleys of Italy (between ca. 25,000 and 18,000 years cal BP, Ravazzi 2003) and set favorable environment for the Epigravettian human re-colonization of the mountains ecosystems.

A dataset of more than 40 radiometric dates from the most important sites located in the area between the Giulie Prealps and the Adige Valley establishes the chronology of the Epigravettian peopling of the eastern Alpine region (Broglio *et al.* 2005: 40).

1 *Sapienza University of Rome.* Corresponding author: Tel. +39 3288651381. Email addresses emanuela.cristiani@uniroma1.it (E. Cristiani).

in: Borgia, V. and E. Cristiani (eds.) 2018: *Palaeolithic Italy. Advanced studies on early human adaptations in the Apennine peninsula*, Sidestone Press Academics (Leiden), pp. 311-334.

The first testimony of human occupation comes from Riparo Tagliente located in the Lessini Mountains, which is dated by the Oldest Dryas (ca. 16,500 years cal BP) (Bisi *et al.* 1983; Bartolomei *et al.* 1985; Fontana *et al.* 2002). Mid and high altitudes of the Prealps and southern Dolomites were reached only by the Late Glacial Interstadial Bølling/Allerød (ca. 14,000 years cal BP) as documented at Ripari Villabruna and Grotta del Clusantin (500 m a.s.l. and 520 m a.s.l. respectively) and later, at the end of the Lateglacial, during the Allerød (ca. 13,450 years cal BP) as testified by the site of Val Lastari and Riparo Dalmeri in the Asiago-Sette Comuni Plateau (1060 m a.s.l. and 1240 m a.s.l. respectively; Broglio *et al.* 2005; Dalmeri *et al.* 2001).

The reconstruction of the Epigravettian settlement strategies in the Alps has mostly been "lithic" oriented through the analysis of raw material procurement and circulation, the reconstruction of the operational schemes related to tools production, as well as the interpretation of the artefacts' function. On the other hand, little work has been done in characterizing techno-functional attributes of osseous industries and their role in the modalities of landscape exploitation as well as subsistence choices characterising the re-colonization of the Alpine environment by Epigravettian groups. This lack of knowledge is significant if one considers that Eastern Alpine Epigravettian bone and antler tools constitute the richest and morphologically various repertoires of Italy. Furthermore, their association to both daily life and funerary contexts would imply an adaptive as well as a social and symbolic significance of osseous technology for the Alpine Epigravettian groups.

So far, most of the Upper Palaeolithic collections of Italian osseous tools come from Epigravettian sites in the eastern Alpine region (Cilli and Gurioli 2007). The majority of these artefacts have been found in caves located in valleys bottoms of the regions of Veneto and Trentino – at Riparo Tagliente (in the Lessini Mountains – Cilli 2002, Cilli *et al.* 2006), Ripari di Villabruna (in Val Cismon – Aimar *et al.* 1992, Cilli 2002), Grotta E di Veia (in the Lessini Mountains – Broglio *et al.* 2006), Grotte Verdi di Pradis (in Clauzetto – Gurioli 2004) – and Friuli – at Riparo Biarzo (in the Natisone valley – Guerreschi 1996). In Trentino, few fragmented bone artefacts have also been discovered at the high-altitude site of Riparo La Cogola (in Folgaria Plateau – Fiore and Tagliacozzo 2004). In the Alpine region, bone and antler artefacts are mainly composed by formal tools (entire or fragmentary) while blanks and manufacturing waste are also documentd (*e.g.* at Riparo La Cogola – Fiore and Tagliacozzo 2004 – and Riparo Biarzo – Guerreschi 1996). Curated points and awls are the most numerous tools while little evidence is available for artefacts such as punches or chisels, which have been found at Grotta E, Ripari di Villabruna, Riparo Tagliente and Riparo Dalmeri. Interestingly, osseous tools have also been discovered in association to a funerary context at Ripari di Villabruna (Aimar *et al.* 1994).

With the aim of understanding how human groups engaged with hard animal tissues in order to create and use tools, organic artefacts from Riparo Dalmeri, one of the most important and well-documented Late Epigravettin sites in the Eastern Alpine region, have been analysed. The results of the study outline flexibility in the technological behaviour related to osseous tools' production as well as high specialization in the functional destination of organic artefacts, according to what is already known about the strategies of occupation of the Alpine territories at the end of the Pleistocene.

2. Site background

Riparo Dalmeri is located at about 1240 m a.s.l. onto the head of a small periglacial valley, a tributary of the deep canyon of the Valsugana (Trentino), crossed by the River Brenta (Fig.1, a,b). Since 1991, stratigraphic excavations have revealed a series of anthropic levels related to two main Late Epigravettian dwelling phases (Fig.1, c). The first (Stratigraphic Units 65 and 15a) represents the earliest human occupation of the site, which is characterized by the presence of hearths, a dwelling structure and rich anthropogenic components such as lithic industry, faunal and charcoal remains. An extraordinary amount of 267 stones showing red ochre depictions with zoomorphic and anthropomorphic motifs, hands, signs, colour associated to engravings, bas-relief colour, uniform-colour related to one or more surfaces and also composite figures on both sides of the stones (Fig. 2) come from the earliest levels of the occupation of the site (SU 65) whereas few others laid abandoned in the inner part of the shelter on top of a cryoclastic breccia (SU15a). Most of the stones were located with the decorated side facing down on a fan-shaped area of ca. 30 m^2 and more than 4 m wide oriented east-west towards the rock-wall (Dalmeri *et al.* 2009). Another interesting discovery made just outside of the rock-shelter relates to two pits, which were filled up with ibex horn cores and sealed by one of the painted stones. This early phase of occupation of the site is defined by three dates that gave ranges from 13,400 to 12,900 cal BP (Dalmeri *et al.* 2005).

The second series of anthropic horizons- dwelling surfaces 26c and 26b – revealed the presence of hearths and a possible subcircular feature interpreted as a hut. These layers were also associated with an abundant knapped stone industry, osseous tools and faunal remains. No painted stones have been found so far in these stratigraphically later units. Levels 14/26b and 26c have chronologically placed from 13,300 to 12,900 cal BP in accordance with the techno-typological features of the lithic industry typical of the Late Epigravettian. The dates coming from these stratigraphically separated horizons are statistically indistinguishable when calibrated and may suggest a relatively confined period of occupation at this site before its final abandonment.

Alpine prairie with little presence of wooded areas of pines and larches were developed in the vicinity of the site as indicated by the palaeo-environmental analysis (Broglio and Dalmeri 2005; Bertola *et al.* 2007). The shelter was extensively exploited during summer and autumn for hunting *Capra ibex*. In particular, the archaeozoological analysis suggests that bones and teeth from this ungulate represent about 90% of the determinable faunal remains (Cassoli *et al.* 1999). Other animals such as deer, roebuck and chamois and more sporadically bear and badger were also hunted and butchered (Cassoli *et al.* 1999; Albertini and Tagliacozzo 2004; Fiore and Tagliacozzo 2005). The representation of the anatomic elements of ibex, the analysis of the butchering marks and of the percussion flakes show that the carcasses were processed inside the shelter, which was periodically cleaned of the largest fragments. The faunal analyses also underline the role of bird hunting (Fiore and Tagliacozzo 2005) whereas the importance of fishing is demonstrated by barbel and chub and less frequently trout, grayling and pike remains (Albertini and Tagliacozzo 2004). The latter data suggest that the territory exploited by the hunters inhabiting Riparo Dalmeri included not only the Alpine prairies of the plateau at 1200-1350 m a.s.l. and the conifer forests at

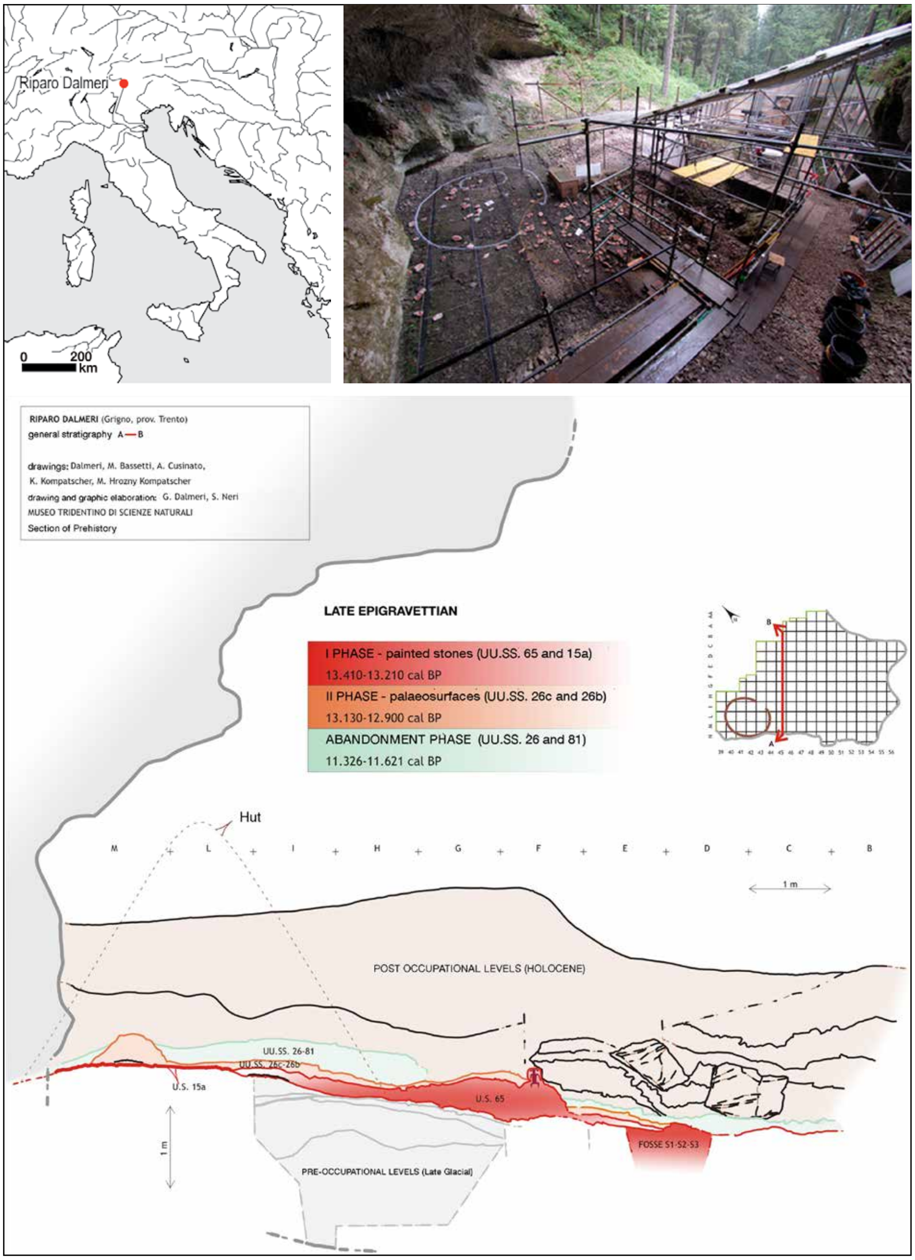


Figure 1. a. Map of Italy and location of Riparo Dalmeri. b. The site; c. Stratigraphy.

slightly lower level, but that it also extended as far as the valley bottom of the River Brenta at the altitude of about 200 m a.s.l.

Technological and typological features of the lithic tools are very similar to other lithic assemblages coming from Epigravettian sites dated to the Bølling and Allerød temperate interstadials situated in north Italy (Montoya 2008). Functional study of both knapped and non-knapped stone tools has revealed that the site was a specialized location for carrying our seasonal activities related to hunting, butchering, hide

Figure 2. Sample of painted stones from the first phase of occupation of Riparo Dalmeri.

treatment and stone and ochre working (Lemorini *et al.* 2005; Cristiani 2008). The presence of specific functional areas related to hide treatment inside the shelter has also been suggested on the basis of the analysis of the spatial distribution of use-wear traces (Lemorini et al. 2005).

3. Materials and method

Osseous artefacts from Riparo Dalmeri have been analysed in order to reconstruct the sequence of gestures related to their production, use, recycle and discard. In particular, the assemblage of bone and antler objects has undergone a morphological and techno-functional study by means of naked eyes and low/high magnification analyses. Technological and functional interpretations on the archaeological osseous assemblage from Riparo Dalmeri have been based on experimental data. An experimental reference collection composed of several bone and antler artefacts created using various techniques (*e.g.* direct and indirect percussion, longitudinal grooving, abrasion, etc.) and used in different activities (*e.g.* working hide, sewing leather, cutting meat, splitting wood, flint knapping, game hunting, etc.) has been used for the techno-functional analysis. Such collection was started in 2008 with the aim of evaluating the microscopic appearance of technological and use-wear traces on osseous materials using low and high-power microscopic approaches. Since then the collection was implemented with new experiments that were specifically performed for understanding operational sequences and osseous tools' function at Riparo Dalmeri.

Osseous specimens have directly been analysed without the use of resina replicas. Artefacts have firstly been categorized on the basis of the morphology of the active part (*e.g.* pointed, edged and smoothed) and their metrical information. As for the morphological definitions, we referred to the Committee of Nomenclature of Prehistoric Bone Industry (Camps-Fabrer *et al.* 1988, 1990, 1998; Ramseyer *et al.* 2004).

Technological and use-wear traces on archaeological artefacts have been identified by naked eye and subsequently through a stereoscopic microscope Leica MZ12.5 (magnification range from 10x to 100x) and an incident light metallurgical microscope Leica DC2500 (magnification range from 50x to 200x). The interpretation of the technological and use-wear traces on the archaeological artefacts has been based on: 1) results of experimental activities (modern bone and antler artefacts have been produced using different techniques such as longitudinal engraving, direct and indirect percussion, scraping and abrasion. Osseous tools used for hide, grasses and wild siliceous plants, bark, stone- and ochre-processing have been used for the interpretation of the use-wear traces); 2) criteria defined in the literature (for the technological interpretations: Newcomer 1977, d'Errico *et al.* 1984, Campana 1989, Averbouh and Provenzano 1999, Averbouh and Christensen 2003, David 2004; for the study of the use-wear traces: Maigrot 1997, Christidou 1999, Christidou and Legrand 2005, Legrand and Sidéra 2007; for the study of impact traces and Petillon 2006, Petillon 2008).

Morphometric descriptions have involved the use of several variables. The measurements of the tools included the length, width and thickness of the objects. Invasiveness and symmetry of the distal and proximal parts of the tools (*e.g.* of the pointed ends or the bases of the points) have also been recorded. For each pointed artefact width and thickness have also been measured at 5 and 15 mm from the functional tips, at the mesial part of the tools as well as at locations situated at 10 and 20 mm from the base of the curated points (Petillon 2006). Sections of distal, mesial and proximal parts of points have been measured, whereas anatomical provenance and animal species have been recorded for identifying special criteria in the blank selection of each artefact. The manufacturing technique, the presence of use-wear traces and re-use modifications, their development, location and distribution on the tool, the presence of impact fractures and their type have been recorded.

4. The osseous industry

The Late Epigravettian osseous industry from Riparo Dalmeri is composed by 56 bone and antler tools objects (Figg.3-4; Table 1). Of these, a total of 17 artefacts come from the earliest occupational levels of the site, which are related to the painted stones production (SU 65) whereas 38 objects belong to the latest ones (SUs 26 B and C) and 1 comes from an unclear stratigraphic position between the two main occupations.

Most of the osseous tools are in an exceptional state of preservation. Taphonomic alterations are mainly due to roots agency although their development has not prevented technological and functional analyses from being carried out.

The assemblage is mostly characterised by pointed tools, and smoothed artefacts. Tools with a diffuse active part are also documented to a less extend. A total of 3 manufacturing wastes are also documented.

Pointed artefacts are the most numerous (N=39) and have been categorized into awls (N=17) (Fig.4, n. 4,6-8,15,16,18), well-finished symmetric points (N=13) (Fig. 3, n.7-9,11,12; Fig.4, n. 1-3,5,10-14), slightly worked asymmetrical points (N=5) (Fig.3, n. 13-15; Fig.4, n.17), and needles (N=4) (Fig.3, n. 19) on the basis of their morpho-metrical, typological and functional attributes. In particular, well-finished points are characterized by symmetrical distal parts and totally shaped surfaces. Most of the points are entire or with little fragments missing (N=8) whereas a little number is half preserved (N=3) or fragmentary (N=2). The length of the entire points ranges from 199 to 67 mm according to the progressive reshaping of the tip whereas the width of the artefacts is constant despite the reduction of the original length of the points as a consequence of the point

	Well-finished points	Slightly worked asymm. points	Awls	Needles	Spatulas	Scrapers	Punches	Recycled tools	Manufacture waste	Total
SU65	3	2	4		4	1	1	2		17
26b	5	3	8	2	4				3	25
26c	4		5	2		1	1			13
Unknown provenance	1									1
Total	13	5	17	4	8	2	2	2	3	56

Table 1. Osseous tools from Riparo Dalmeri and their stratigraphic provenance.

Table 2. Weight of the entire well-finished points expressed in grams and stratigraphic provenance.

Stratigraphic provenance	Weight
SU65	6
26B	8,7
26B	4,5
26B	4,2
26B	3,8
26C	4,3
26C	11,2

resharpening and ranges between 8 and 9 mm. The elongation and flattening indexes (L/l, l/th) are between 22.1 and 9.6 the first and between 1.5 and 1.3 the second. The weight, calculated on the entire points only, ranges from 2.14 g and 11.2 g (Table 2).

Well-finished points are characterized by standardized section shapes: (i) circular at the distal end, (ii) convex-flat dorsal/ventral at the mesial part, (iii) oval at the base. In particular, the proximal ends are tapered and characterized by have convergent edges thinned on the sides as well as on the superior and inferior surfaces (Fig.9).

Awls are mostly characterized by asymmetrical pointed tips (N=6) while needles are represented by 4 completely worked artefacts with symmetrical points, total invasiveness of the worked surfaces, circular sections which becomes narrower towards the tip (for a morphological definition of needle see Stordeur 1977: 10).

The category of edged tools is mainly represented by expedient bone scrapers (N=2) and among the smoothed tools entire and fragmentary bone spatulas (N=8) are documented (Fig.3, n. 3,16; Fig.4, n. 22, 23, 26). Tools with a diffuse active part are represented by antler punches (N=2) while pointed tools which have been recycled after a functional breakage are also documented (N=2).

5. The technological analysis

Osseous artefacts from Riparo Dalmeri have mainly been worked out from *Cervus elaphus* metapodials and antler as well as from *Capra ibex* long bones (femurs, tibias, ulna). In particular, *Capra ibex* constitutes about the 90% of the fauna found at Riparo Dalmeri, whereas *Cervus elaphus* remains represent only a small quantity of the hunted

Figure 3. Repertoire of osseous artefacts and technological waste from various stratigraphic units (from 1-10: SUs 15a, 65, 26d and 26e; 11-19: SUs 22, 24-26, 26a, 28). The bar is 3 cm.

animals (Fiore *et al.* 2001). The recovery of 3 manufacturing wastes at the site attests that operational sequences related to the production of antler and bone tools was carried out in situ (Fig.3, n.1,2; Fig.4, n.9).

Red deer metapodials and antler were mainly selected in order to produce well-finished points and long fine bone spatulas. Technological traces identified on well-finished points on red deer metapodials indicate that longitudinal grooving and indirect percussion techniques were used to produce these tools (Fig.5, a,b; Fig.6, a-d). For manufacturing antler points only longitudinal grooving was used (Fig.5, c,d). Both

Figure 4. Repertoire of osseous artefacts and technological waste from various stratigraphic units (from 1-10: SUs 26c-83-62-47and 26e; 11-26: SUs 26b-14-41-4a). The bar is 3 cm.

longitudinal grooving and indirect percussion have been aimed at extracting long regular blanks, later finished by covering flint scraping. In particular, technological traces left by longitudinal grooving consist in straight striated surfaces (Fig.6, b,d) while the indirect percussion can be characterized by the presence of regular impact cones localized all along the ventral surface of the blank/tool (Fig.6, a). The "waving" appearance

Figure 5. Manufacturing waste and technological traces. a,b. Waste of manufacture on metacarpal bone documenting the use of indirect percussion for the production of more regular blanks from ibex long bones (a: the scale 3 cm; b: the scale is 1 cm) ; c,d. Antler tine documenting traces of longitudinal grooving aimed at extracting long regular blanks for points production (c: the scale 3 cm; d: the scale 1 mm); e and f. Waste of manufacture on red deer metapodial with indirect percussion marks (e: the scale 3 cm; f: the scale 1 cm).

characterising one completely worked point has been produced by scarping out the notches left by indirect percussion (Fig.6, e).

Asymmetrical points have been produced on flakes of ibex long bones slightly modified through longitudinal scraping on their distal parts. In one case, regular impact cones localized all along the ventral surface of the blank suggest the use of indirect percussion as extraction technique (Fig. 3, n.13-15; Fig.4, n. 17). This technique was used on ibex metapodial bones, as documented by a manufacturing waste (Fig. 4, n. 9) and a bevel-end tool on a splinter (Fig.4, n. 24).

A different technological strategy was associated to the production of more expedient tools on ibex long bones such as awls and scrapers. In particular, irregular helicoidal flakes produced during the butchering activity were selected for producing expedient tools and roughly modified on their active part through marginal flint scraping or retouch (Fig.7, a).

Punches tools have been produced on long antler tines, which were cut from the beam through indirect percussion and subsequent flexion (Fig.3, n. 10). This tech-

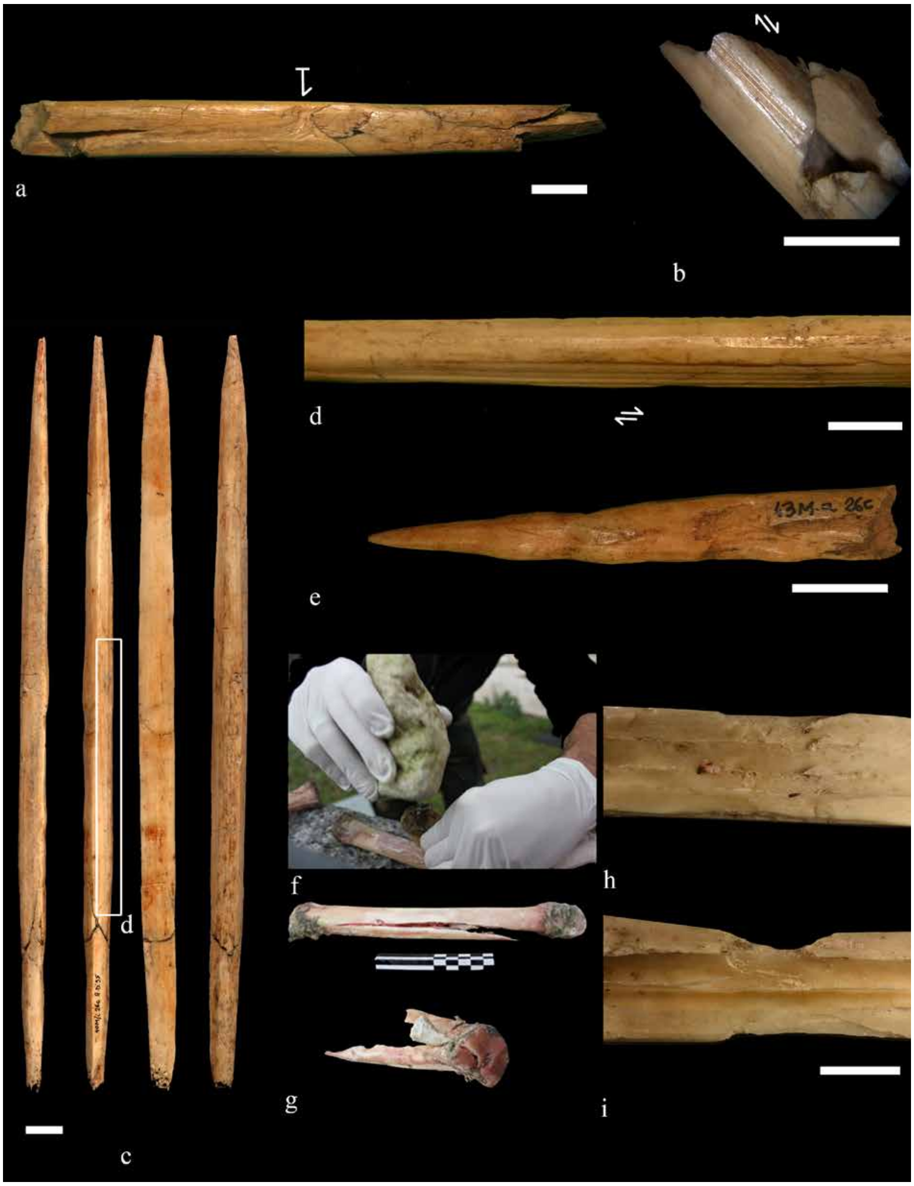


Figure 6. Manufacturing phases and technological traces associated to the production of osseous well-finished points. a. Long regular blank extracted from red deer metapodial. The arrow shows cones produced by indirect percussion. b. Fragment of regular bone blank with long striations produced by longitudinal grooving; c,d. Well-finished point (c) with traces of longitudinal grooving visible on the mesial part (d); e. Distal part of a point with "waving" appearance produced by scraping out the notches left by indirect percussion. f. Experimenting indirect percussion on red deer metapodial. g. Regular blanks produced by longitudinal grooving and indirect percussion. h.i. Notches left by the indirect percussion. The bar is 1cm.

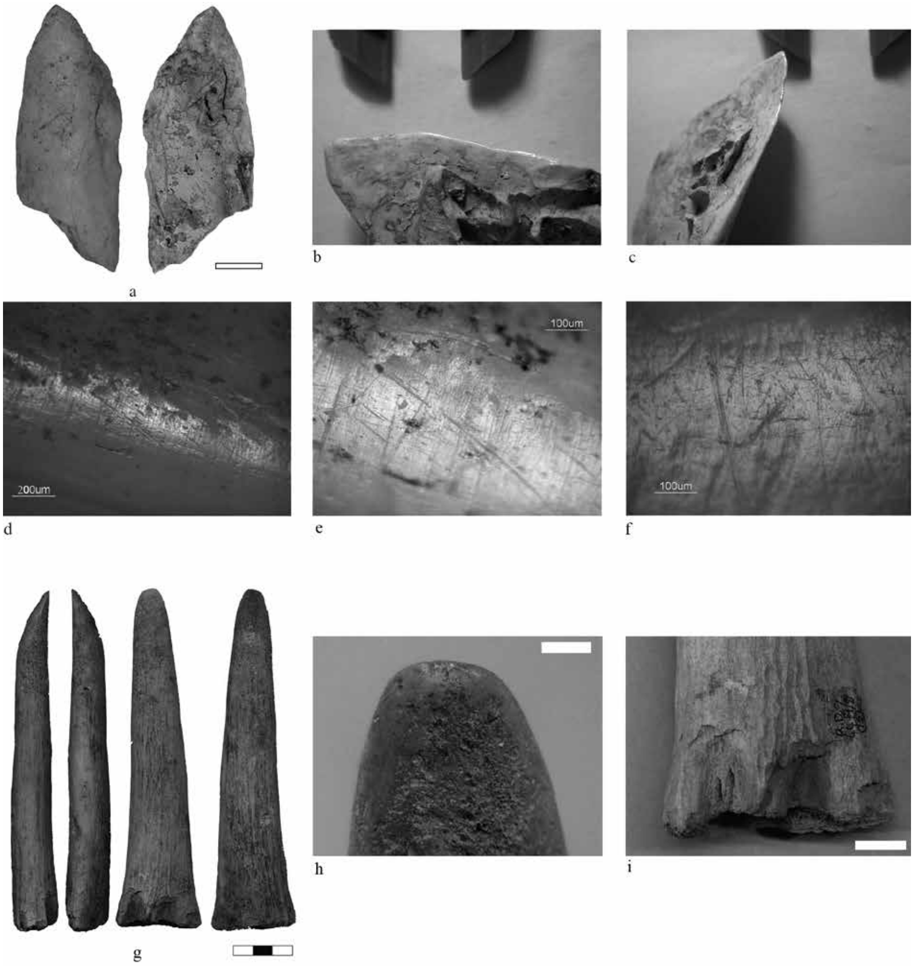


Figure 7. Use modifications on osseous tools. a. Retouched bone flake used as a hide scraper. The bar is 1 cm; b,c. Close-up on the edge of the retouched flake used as a hide scraper. The calliper indicates 1 cm; d-f. Micro use-wear traces produced by hide scraping; g. Antler tine used as punch. The bar is 1 cm; h. Deep grooves produced by contact with flint. The bar is 1cm; i. Stepped removals located on the proximal end of the antler tine and produced by using the object as an intermediate piece. The bar is 1cm.

nique left overlapping chopping marks and wide retouches with hinge terminations all around the proximal end of the tools.

6. Use-wear analysis

In order to evaluate whether the different operational sequences individuated so far could have reflected a differential use of the artefacts by the groups who inhabited Riparo Dalmeri, a specific analysis of the use-wear traces has been undertaken.

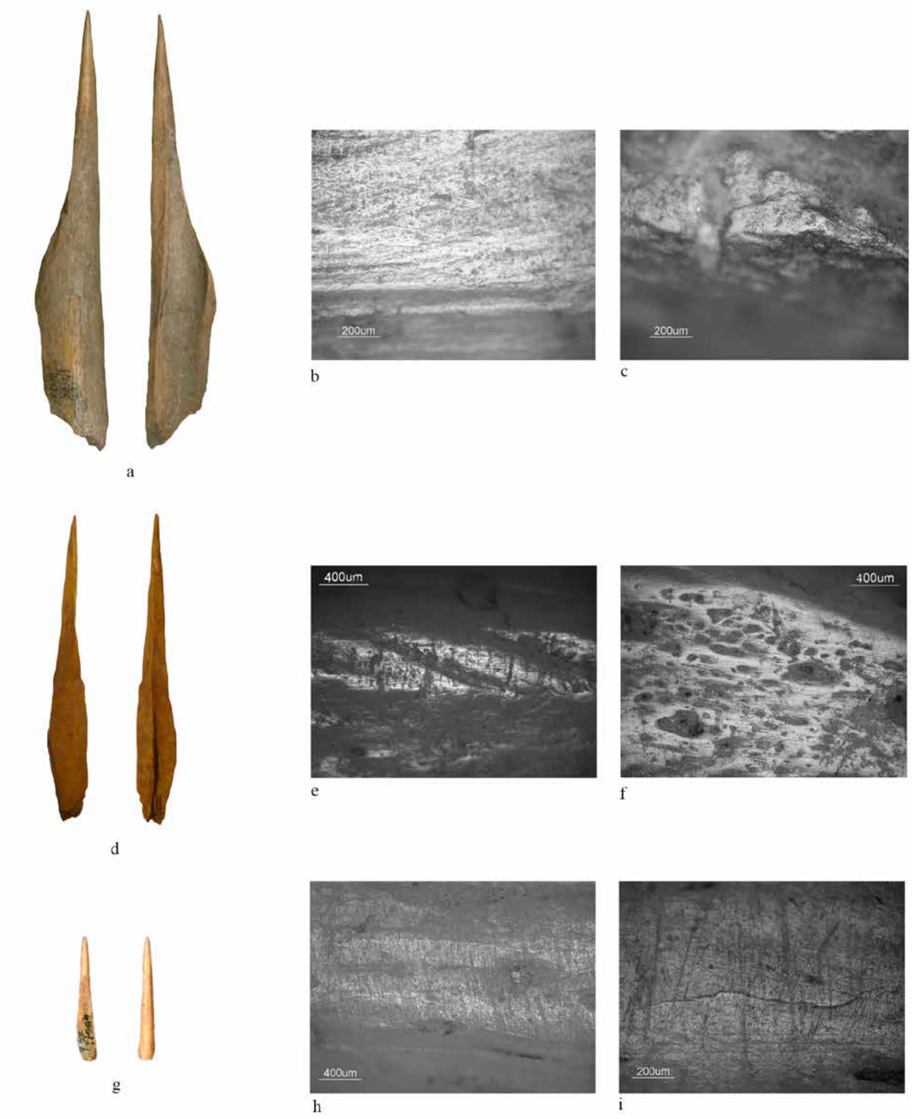


Figure 8. Use-wear traces on archaeological awls. a. Awl on ibex long bone flake; b,c. Use-wear traces characterized by depression, striations and micro-topography suggesting the awl was used for longitudinal perforation of ochred hide; d. Awl on ibex long bone flake; e,f. Use-wear traces suggesting a longitudinal and transversal perforation of hide; g. Distal part of an awl; h,i. Use-wear traces with deep rough bottomed striations suggesting the tools was used in transversal perforation of hide.

6.1. Awls

Awls have been used to cut holes on fresh, humid and dry hides sometime treated with ochre both by rotation as well as indirect percussion (Fig.8). The first action produced intense rounding of the tips whereas the second is characterized by flattened tips, use-retouches and compression traces on the proximal part. Overall, the use-wear observed at high magnification is characterized by a grainy appearance as well as by

Figure 9. Projectile point length reduction due to intensive use. The bar is 1 cm.

rounded and smoothed surface elevations (Fig.8). Rough-bottomed striations and non-linear depressions and micro-pits are numerous (Fig.8, b,h,i).

6.2. Needles

Needles show the same macro-traces pattern characterized by hinge fractures on the proximal ends and rounded tips. Use-wear traces observed at high magnification are well preserved and characterized by a covering distribution, striations, non-linear depressions and micro-pits typical of dry hide working.

6.3. Points

Well-finished points

The functional fractures are localized mainly on the mesial part of the points (Fig.10) and have been classified as (i) single hinge and (ii) double hinge (*i.e.* two hinge and opposed fractures). Micro-traces related to the hafting system are distributed on the mesial, proximal parts and on the bases of the points (Fig.11). On the mesial part, traces are developed on the inferior surface and on the convexity of the upper surface as well as on the lateral sides (Fig. 11, a,b); on the proximal part, the traces are less developed and characterized by short and deep striations and little rounding; on the bases, rounding, flattening, striations and non-linear depressions are developed the most (Fig. 11, c,d). Sometime, reshaping marks are located in correspondence with the limit of the hafting traces, suggesting that the process could have been carried out when the points were still inserted on the shaft. Typology, morphology and location of the macro-traces identified on the points from Riparo Dalmeri suggest they were produced by impacts (Tyzzer 1936; Arndt & Newcomer 1986; Bergman 1987; Stodiek 1993; Pétillon 2000).

Asymmetrical points

Overall, asymmetrical points are characterized by hafting traces located on the mesial, proximal and basal part of the tools, similarly to the well-finished points described above. No functional fractures or developed use-wear traces have been identified on slightly worked asymmetrical points.

6.4. Spatulas

Use modifications on the bone spatulas are characterized by distal and lateral edges rounding, fine as well as deep rough bottomed striations obliquely and transversally oriented as regard to the distal end of the tools. At high magnification, the functional traces resemble the ones identified on some experimental used for processing hide coloured with ochre.

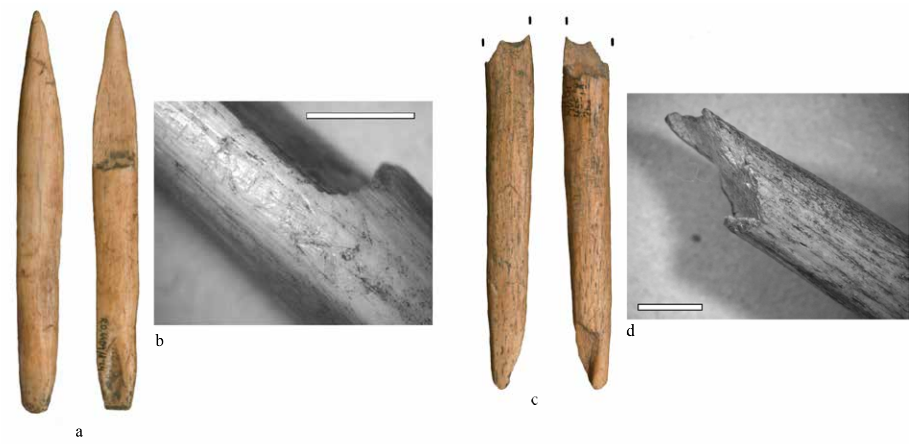


Figure 10. Impact fractures on two well-finished points. The bar is 1 cm.

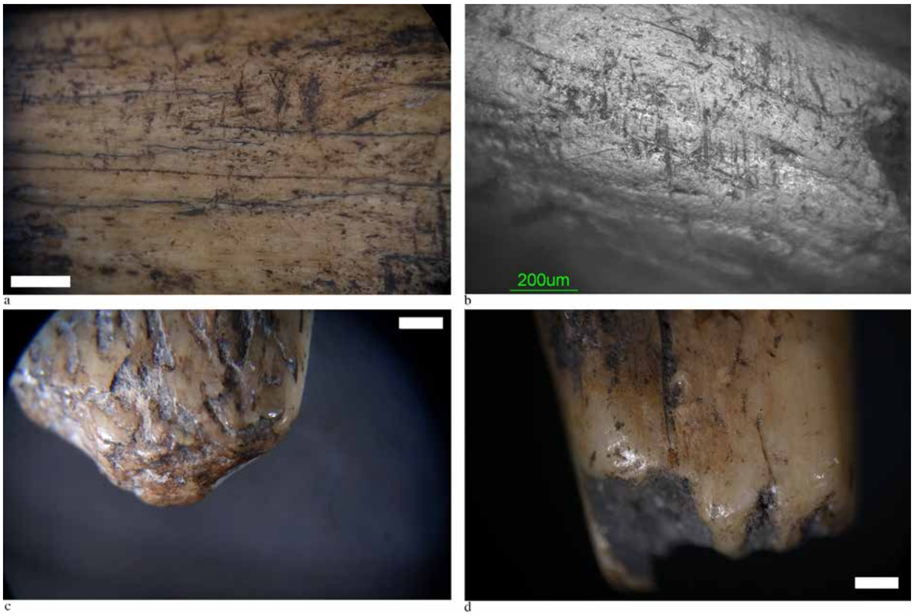


Figure 11. Functional modifications on projectile points: a. Crushing and developed rounding and of the tip of a bone point. The bar is 1mm; b. Hafting striations observed on the mesial part of an antler point. The bar is 1mm; c,d. Developed rounding and flattening of the proximal end of one antler (c) and one bone (d) projectile points. The bar is 1mm.

6.5. Scrapers

The two expedient scrapers created starting from simple butchery flakes extracted from ibex long bones (Fig. 4, n. 24, 25) have been used without any further technological amelioration to scrape hide (Fig. 7, a-f).

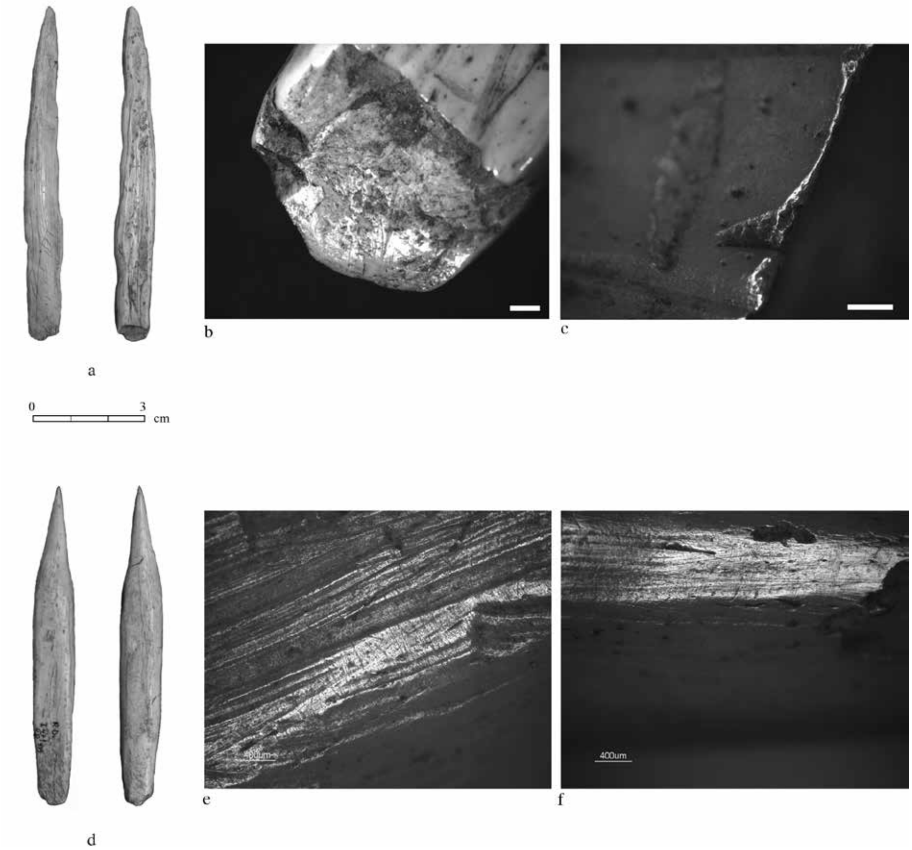


Figure 12. Recycled points. a. Points with hinge fracture on the proximal part; b. Rounding, polishing and striations located on the use fracture and associated with a recycle of the point for ochred hide scraping; c. Rounding of the fracture outline. The bar is 1mm; d. Projectile points recycled as an awl; e. Polish, depressions and deep transversal striations typical of hide perforation activity; f. Experimental use-wear traces produced after perforating ochred hide.

6.6. Punches

This category comprehends 2 almost entire antler tines characterized by single and double invasive oblique surfaces, respectively, and produced after their use. The first tool shows clear deep flint striations on its distal part, big stepped ended detachment and flattened spots along the proximal end suggesting its use as punch in flint knapping (Fig. 7: h-i). The second tool is characterized by little use-retouches on the distal part which can be compared to similar modifications experimentally produced after hard material processing (*e.g.* stone or wood).

6.7. Recycled tools

Two curated points from the earliest dwelling levels (US65) have been re-used as awls for hide piercing after a fracture episode. The proximal part of one of these points has also been used for softening hide (Fig.12, a-d).

7. Discussion

Alpine region yielded some of the richest and morphologically various ensembles of osseous tools of Italy. Unfortunately, many aspects of osseous technology, such as the way tools have been produced and used, stay for the most part unknown (Cilli and Gurioli 2005). In this regard, the techno-functional study carried out on the Epigravettian osseous artefacts from Riparo Dalmeri is particularly significant, considering the richness of the assemblage and its extraordinary state of preservation.

The results of the analysis performed on osseous implements from Riparo Dalmeri indicate hard animal tissues such as antler and bone were used for producing both "hunting" and "domestic" technology (Tartar et al 2006), the first represented by projectile implements while the second composed of awls, scrapers and spatulas. Microscopic traces developed on those tools reveal different sets of technological choices were put forward for producing and using "hunting" and "domestic" equipment. This is particularly evident within the category of the pointed tools, the most abundant recovered at the site. Well-finished bone and antler points, in particular, show use-wear traces suggesting their use as projectile implements while their technological features indicate higher techno-functional anticipation in comparison to awls (cfr. Tartar *et al.* 2006). Those points were produced in situ through longitudinal grooving technique, with or without indirect percussion. The presence of highly reshaped as well as recycled items further testimonies the curation associated to such implements, which were transported, used and eventually transformed into functionally different tools (awls). On the other side, "domestic" awls exhibit low techno-functional anticipation as they were expediently made out from alimentary bone waste and used for hide working tasks only, with no evidence of tool maintaining. Well-finished points would have been transformed into hide perforators only when dismissed from hunting activities.

A variability in the technical effort invested in the production of "hunting" vs "domestic" equipment could effectively be explained in functional terms by focusing on the ability of selecting the most suitable technique for addressing the specific needs at hand (cfr. Tartar *et al.* 2006 for a discussion of technological investment in hunting vs domestic equipment during the Aurignacian and Duches *et al.* 2017 for a discussion about technological flexibility with regards to projectile equipment at Riparo Dalmeri). Thus, differently from the awls used for perforating hide, projectile points needed an important technical investment due to the specific functional requirements inherent to the way such armatures were used. At Riparo Dalmeri, the investment in maintaining constant width, mesial thickness and profile of well-finished points even after reshaping, hints at a possible functional necessity to preserve a correct fit between those armatures and the shaft they were inserted in. Such need required the investment of specific technical effort in order to produce regular bone and antler blanks, which was mastered and anticipated by using longitudinal grooving and indirect percussion. Evidently, no anticipation would be functionally required for sharpening hide perforators or scrapers.

At Riparo Dalmeri, a similar technological behaviour has been recognised also in relation to the production of projectile stone equipment (Duches *et al.* 2017). In particular the normalization of specific morpho-technological parameters of backed and truncated lithic implements, such as the width, has been considered a response to the functional constraints inherent to their use with a bow-arrow system (Duches *et al.*2017), the existence of which has been hypothesized by many scholars already during the Epipaleolithic (Cattelain 1994, 1997; Hays and Surmely 2005; Valentin 2008). Similarly, the normalization of morpho-technical features, such as the width, in well-finished osseous points, might suggest the possibility that such points were fixed in arrow shafts with constant section.

Additional support to the hypothesis of the use of well-finished osseous points in a bow-arrow system at Riparo Dalmeri comes from contemporary archery. In particular, traditional bow producers consider projectiles points with a mesial thickness up to 1cm, thus comparable to that characterising osseous well-finished points from the site, as arrow points (Brizzi 2002). Also the weight of the entire or almost entire symmetric osseous points from Riparo Dalmeri, which oscillates between 2.4 g and 11.2 g, would support an interpretation of those artefacts as arrow points as contemporary hunters using traditional bow recommend points between 6g and 9 g of weight for targeting medium-large sized ungulates (Comstock 1990; Dalmeri, Grimaldi 2002). Experimental studies have also tested the efficacy of points with a weight up to 15 g in bow hunting (Brizzi 2002).

Functional analysis has emphasized the use of antler tools in flint knapping. Remarkably, the use of pressure technique was assumed for the retouch of backed pieces at Riparo Dalmeri, especially during the first occupation phase, on the basis of the experimental data (Duches *et al.* 2017). Functional data also shed light on the key role of "domestic" bone implements in leather processing, softening and sewing. Noteworthy, use-wear traces on bone awls, needles, scrapers, and spatulas show the extensive utilisation of ochre in such activities, probably for colouring purposes. Ochre residues associated to traces of suspension have also been identified on some ornaments (Fig. 13, a-c) recovered at the site and on the mesial parts of well-finished points (Fig. 13, d,e). According to this data, the use of red coloured strings might have represented a cultural trait during the Epigravettian (Cristiani 2009). Functional analysis carried out on other categories of artefacts such as knapped stones and macro-lithic tools provides additional evidence of the importance of domestic equipment in hide and ochre processing at Riparo Dalmeri, and offer a picture of site as a key location for carrying out seasonal tasks, which might have involved the participation of a large part of the group (Lemorini *et al.* 2005; Cristiani *et al.* 2012). Although we will never know whether hunting and domestic technologies were, actually, the expression of different social agencies, data unequivocally indicate that during summer children frequented Riparo Dalmeri together with the adult hunters, allowing us to suppose the contemporaneous presence of women/mothers together with them. Perhaps, their presence also explicates the recovery of ornamental gears such as a red deer canine and various shell beads (Cristiani 2008). The presence of the entire group at the seasonal camp is further suggested on the basis of the recovery of 5 deciduous human teeth. In the wider Alpine region, a occupational strategy involving the mobility of the entire group is also documented at the very beginning of the Holocene, at the Early Mesolithic high altitude sites of Plan de Frea (Angelucci *et al.* 1999), Lago delle Buse (Dalmeri & Lanzinger 1989, 1992) and Colbricon 1 (Bagolini & Dalmeri 1987), where deciduous teeth have been discovered.

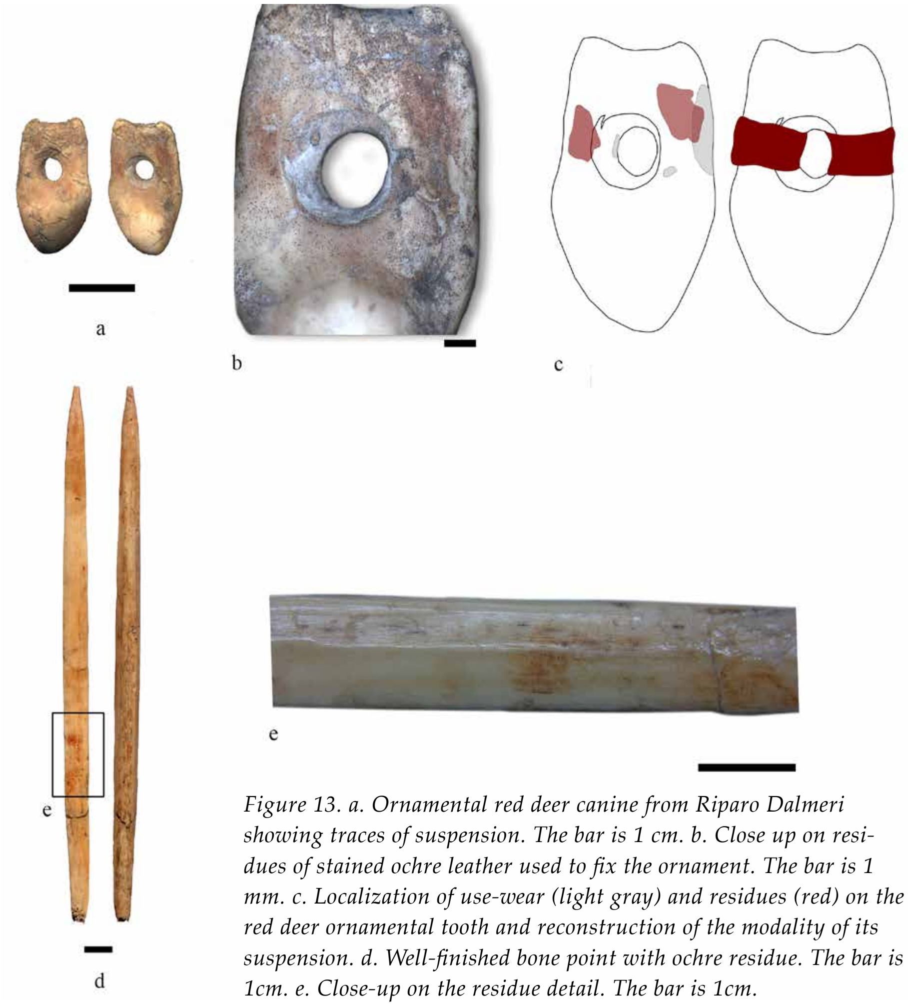


Figure 13. a. Ornamental red deer canine from Riparo Dalmeri showing traces of suspension. The bar is 1 cm. b. Close up on residues of stained ochre leather used to fix the ornament. The bar is 1 mm. c. Localization of use-wear (light gray) and residues (red) on the red deer ornamental tooth and reconstruction of the modality of its suspension. d. Well-finished bone point with ochre residue. The bar is 1cm. e. Close-up on the residue detail. The bar is 1cm.

8. Conclusions

In this article, the author discusses the role of the osseous technology from the Epigravettian phases of inoccupation of Riparo Dalmeri in hunter-gather strategies of re-colonization of the eastern Alpine areas during the Late Glacial interstadials.

The results shed light on a still very poorly known aspect of Italian Epigravettian lifeway, *i.e.* the ways Lateglacial human groups of Italy engaged with animal matter in order to produce technological equipment.

A different technological investment related to the production and the use of "hunting" vs "domestic" equipment, has been identified and explained in the light of the specific functional constraints inherent to the way the two different kits were used. A similar interpretation was also provided by other authors with regards to the Aurignacian (Tartar *et al.* 2006). At Riparo Dalmeri, functional data underline the involvement of osseous tools in specialized activities such as game hunting and hide processing, and echo the conclusions put forward by the analysis of other archaeological evidence, such as faunal remains, knapped and non-knapped stone tools. Overall the results confirm the key role of high altitude locations, such as Riparo Dalmeri, for performing seasonal tasks at the end of the Lateglacial in the Eastern Alpine region of Italy (Lemorini *et al.* 2005; Fiore e Tagliacozzo 2008; Cristiani *et al.* 2012).

Acknowledgements

I want to express my gratitude to Stefano Neri who gave me access to bone tools distribution maps at Riparo Dalmeri and Isabella Caricola who helped me with the reference section. Also, I am grateful to Dušan Borić who provided much needed help with the previous version of the paper. Special thanks go to Dr Verpoorte who, acting as reviewer for this article, provided crucial comments for implementing and ameliorating the initial draft of the paper.

References

Aimar, A., Alciati, G., Broglio, A., Castelletti, L., Cattani, L., D'Amico, C., Giacobini, G., Maspero, A. and Peresani M.. 1992. Les abris Villabruna dans la vallée du Cismòn. *Preistoria Alpina*, 28, 227-254.

Aimar, A., Alciati, G., Broglio, A., Castelletti, L., Cattani, L., Giacobini, G. and Maspero, A. 1994 . Abri Villabruna. *Preistoria Alpina* 28, 227-254.

Albertini, D. and Tagliacozzo, A. 2005. I resti di pesce provenienti dai livelli preistorici di Riparo Cogola. *Preistoria Alpina* 40, 187-191.

Angelucci, D.E., Frigo, G., Martello, G.V and Peresani, M., 1999. The Open Mountain sites at Cima Dodici (Asiago Plateau – Italy): New Data on Early Holocene Settlement of the Southern PreAlps. In: Thevenin, A. (ed) – *L'Europe des derniers chasseurs*, 5ème Colloque International VIII Comm. UISPP: 449-455.

Arndt, S. and Newcomer, M.H., 1986. Breakage patterns on prehistoric bone points: an experimental study. In; D. A. Roe (ed.) *Studies in the Upper Palaeolithic of Britain and Northwest Europe*. BAR International Series, 296. Oxford:1.65-173.

Averbouh, A. and Christensen, M. (eds), 2003. *Transformation et utilisation préhistoriques des matières osseuses*. Préhistoire et Anthropologie Méditerranéennes, 12.

Averbouh, A. and Provenzano, N., 1999. *Propositions pour une terminologie du travail préhistorique des matiéres osseuses: I – Les techniques*. Préhistoire et Anthropologie méditerranéennes, 7, 5-26.

Bagolini, B. and Dalmeri, G. 1987. I siti mesolitici del Colbricon. Analisi spaziale e fruizione del territorio, *Preistoria Alpina* 23, 7-188.

Bartolomei, G., Broglio, A., Cattani, L., Cremaschi, M., Guerreschi ,A., Mantovani, E., Peretto, C. and Sala, B. 1985. I depositi wurmiani del Riparo Tagliente. *Ann. Univ. Ferrara,* 3,4, 61-105.

Bergman, C. A. 1987. Hafting and use of von and antler poins from Ksar Akil, Lebanon. In: D. Stordeur-Yedid (Ed.) *La Main et l'Outil: Manches et Emmanchements Prehistoriques*, Travaux de la Maison de l'Orient, 15, CNRS, Paris, 117-126.

Bertola, S., Broglio, A., Cassoli, P., Cilli, C., Cusinato, A., Dalmeri, G., De Stefani, M., Fiore, I., Fontana, F., Giacobini, G., Guerreschi, A., Gurioli, F., Lemorini, C., Liagre, J., Malerba, G., Montoya, C., Peresani, M., Rocci Ris, A., Rossetti, P., Tagliacozzo, A. and Ziggiotti, S., 2007. L'Epigravettiano recente nell'area prealpina e alpina orientale. In: Martini F. (ed), *L'Italia tra 15.000 e10.000 anni fa. Cosmopolitismo e regionalità nel Tardoglaciale*. Atti della Tavola Rotonda 2005, Millenni -Firenze: Studi di Archeologia preistorica, 39-94.

Bisi, F., Broglio, A., Guerreschi, A., and Radmilli, M. 1983. 'L'epigravettien evolue et final dans la zone haute et moyenne Adriatique, *Rivista di Scienze Preistoriche* 38, 229-265.

Borgia, V., Boschin F., Ronchitelli A. 2015. Bone and antler working at Grotta Paglicci (Rignano Garganico, Foggia, southern Italy), Quaternary International, 403, 23-39.

Bradbury, A. P., and Franklin, J. D. 2000. Raw material variability, package size, and mass analysis. *Lithic Technology*, 25(1), 42-58.

Brizzi, V. 2002. Dinamica dell'arco e balistica della freccia nel cacciatore preitorico. In Bellintani, P. and Cavulli F. (eds) *Catene operative dell'arco preistorico. Incontro di archeologia sperimentale*, San Lorenzo in Banale e Fiavé (Trento) 30 agosto – 1 settembre 2002, 67-108.

Broglio, A., Bertola, S., De Stefani, M., Marini, D., Lemorini, C., Rossetti, P. 2005. La production lamellaire et les armatures lamellaires de l'Aurignacien ancien de la Grotte de Fumane (Monts Lessini, Vénétie). In Productions lamellaires attribuèes à l'Aurignacien, Actes des XIV Congres UISPP, Archèologiques 1, Musée National d'Histoire et d'Art, Luxembourg, 415-436.

Broglio, A., and Dalmeri, G. (Eds.) 2005. *Pitture paleolitiche nelle prealpi Venete: grotta di Fumane e riparo Dalmeri* (Vol. 9). Museo Civico di Storia Naturale.

Broglio, A., Cilli, C., Giacobini, G., Gurioli, F. 2006. Osso, palco, dente e conchiglia: i supporti in materia dura animale dei manufatti dei primi uomini moderni a Fumane (Verona). In: *Atti della XXXVII Riunone Scientifica IIPP*, Scalea, 816-827.

Campana, D., 1989. Natufian and Protoneolithic Bone Tools. The Manufacture and Use of Bone Implements in the Zagros and the Levant. Oxford: British Archaeological Reports International Series 494.

Camps-Fabrer H. (ed.) 1988. *Fiches typologiques de l'industrie osseuse préhistorique*. Cahier I – Sagaies. Éditions de l'Université de Provence, Aix-en Provence.

Camps-Fabrer H. (ed.), 1990 – *Fiches typologiques de l'industrie osseuse préhistorique*. Cahier III – Poinçons, pointes, poignards, aiguilles. Éditions de l'Université de Provence, Aix-en Provence.

Camps-Fabrer, H., Cattelain, P., Choi, S.-Y., David, E., Pasqual-Benito, J.-L., Provenzano, N., Ramseyer, D. (Eds) 1998. *Fiches typologiques de l'Industrie osseuse préhistorique*. Cahier VIII. Biseaux et tranchants. Editions du CEDARC, Treignes.

Cassoli, P.F., Dalmeri, G., Fiore, I. and Tagliacozzo, A. 1999. Abri Dalmeri (Trente, Italie): la chasse dans un gise- ment Epigravettien de montagne. In: Thévenin A. and Bintz P. (Eds), Actes du 5 Coll. International U.I.S.P.P., Grenoble (Isère, Francia). Paris: Editions du CTHS, 457-464.

Cattelain, P. 1994. La chasse au paléolitique superieur. Arc ou propulseur, ou les deux? *Archéo-Situla,* 21-24, 5-26.

Cattelain, P. 1997. Hunting during the Upper Palaeolithic: Bow, spearthrower or both? In H. Knecht (Ed.), *Projectile technology.* New York: Plenum press Corporation.

Christidou, R. and Legrand A., 2005. Hide working and bone tools: experimentation design and applications. 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 artefacts from Prehistoric Times to the Present*. Proceedings of the 4th Meeting of the (ICAZ) Worked Bone Research Group, Tallinn (Estonie), 26-31 août 2003. Muinasaja Teadus, 15, 385-396.

Christidou, R., 1999. Outils en os néolithiques du Nord de la Grèce. Étude technologique, thèse de doctorat de l'Université Paris X-Nanterre.

Cilli, C., 2002. I manufatti in materia dura animale provenienti da siti del Paleolitico superiore dell'Italia Nord-orientale. Analisi tecnologica e riflessioni museografiche. Tesi di dottorato di ricerca in Archeo-Antropologia, Torino.

Cilli, C., and Gurioli, F. 2005. Lavorazione delle materie dure animali. Strumenti in osso e palco. In Martini F. (Ed.) L'Italia tra 15.000 e 10.000 anni fa cosmopolitismo e regionalità nel Tardoglaciale, Firenze, 72-82.

Cilli, C., Giacobini, G., Guerreschi, A., and Gurioli, F. 2006. L'industria e gli oggetti ornamentali in materia dura animale dell'Epigravettiano di Riparo Tagliente, Verona. *Atti della XXXIX Riunione scientifica*, 843-854.

Cristiani, E., Lemorini, C., Dalmeri, D. 2012. Ground stone tool production and use in Late Upper Palaeolithic: The evidence from Riparo Dalmeri (Venetian Prealps, Italy), *Journal of Field Archaeology*, 37 (1), 34-50.

Cristiani, E. 2008. Analisi funzionale dei manufatti in materia dura animale del Riparo Dalmeri (Altopiano della Marcesina, Trento). *Preistoria Alpina*, 43, 259-287.

Dalmeri, G. and Grimaldi, S. 2002. Osservazioni sperimentali sulle punte di freccia del Mesolitico antico in Trentino. In Bellintani P. and Cavulli F. (eds.), *Catene operative dell'arco preistorico. Incontro di archeologia sperimentale*, San Lorenzo in Banale e Fiavé (Trento) 30 agosto – 1 settembre 2002, 109-140.

Cristiani, E. 2009. Osseous artefacts from the Mesolithic levels of Pradestel rockshelter, (north-eastern Italy): A morphological and techno-functional analysis *Preistoria Alpina,* 44, 1-6.

Dalmeri, G. and Lanzinger, M., 1992. Il Mesolitico del Lagorai nell'area del Lago delle Buse: prospezioni e sondaggi. *Preistoria Alpina*, 25, 219-222.

Dalmeri, G. and Lanzinger, M., 1989. Ricerche paletnologiche e paleoambientali al Riparo Dalmeri (Trento). *Preistoria Alpina* 25, 223-229.

Dalmeri, G., Bassetti, M., Cusinato, A., Kompatscher, K. and Hrozny Kompatscher M. 2005. The discovery of a painted anthropomorphic figure at Riparo Dalmeri and new insights into alpine Epigravettian art. *Preistoria Alpina* 41, 163-169.

Dalmeri, G., Grimaldi, S. and Lanzinger M. 2001. Il Paleolitico e il Mesolitico. In: Lanzinger M., Marzatico F. and Pedrotti A. (eds), *Storia del Trentino, Vol. I: La preistoria e la protostoria*. Bologna: Il Mulino, 76-85.

David, E., 2004. Fiche transformation des matières dures d'origine animale dans le Mésolithique ancien d'Europe du nord. In: Ramseyer D. (ed.), *Fiches typologiques de l'industrie osseuse préhistorique*. Cahier XI – Matières et Techniques. Éditions Société Préhistorique Française, Paris: 113-149.

d'Errico, F., Giacobini, G., Puech, P.-F. 1984. Varnish replicas. A new method for studying worked bone surfaces. *OSSA*, Int. J. Skeletal Res. 9/10, 29e51.

Duches, R., Peresani, M., Pasetti, P. 2017. Success of a flexible behaviour. Considerations on the manufacture of Late Epigravettian lithic projectile implements according to experimental tests. Archaeol. Anthropol. Sci. DOI 10.1007/s12520-017-0473-x.

Fiore, I., Tagliacozzo, A., Cassoli, PF. 2001. Ibex exploitation at Dalmeri rockshelter (TN) and "specialized hunting" in the sites of the Eastern Alps during the Tardiglacial and the Early Holocene. *Preistoria Alpina* 34, 173-183.

Fiore, I., Tagliacozzo, A. 2008. Oltre lo stambecco: gli altri mammiferi della struttura abitativa dell'US 26c a Riparo Dalmeri (Trento). *Preistoria Alpina* 43, 209-236.

Fiore, I., and Tagliacozzo, A., 2004. Riparo Cogola: il contesto paleoecologico e lo sfruttamento delle risorse animali tra Epigravettiano e Mesolitico antico. *Preistoria Alpina*, 40, 159-186.

Fiore, I., and Tagliacozzo, A. 2005. Lo sfruttamento delle risorse animali nei siti di altura e di fondovalle nel Tardiglaciale dell'Italia nord-orientale. *Atti*, *4*, 97-109.

Fontana, F., Guerreschi, A., Liagre, J. 2002. Riparo Tagliente. La serie epigravettiana. In: Aspes A. (ed.), *Preistoria Veronese. Contributi e aggiornamenti*, Memorie del Museo Civico di Storia Naturale di Verona, 2a serie, sez. Scienze dell'Uomo, 5, 42-47.

Guerreschi, A. (ed.) 1996. *Il sito preistorico del Riparo di Biarzo:(Valle del Natisone, Friuli)*. Ed. del Museo Friulano di Storia Naturale.

Gurioli, F. 2008. Analisi tecnologica dei manufatti in materia dura animale dell'E-pigravettiano recente di Riparo Dalmeri (Altopiano della Marcesina, Trento). *Preistoria Alpina* 43, 237-258.

Gurioli, F. 2004. I manufatti in osso provenienti dai livelli dell'Epigravettiano recente delle Grotte Verdi di Pradis (Prealpi Friulane, PN). *Boll. Soc. Nat. "Silvia Zenari"* 28, 39-48.

Hays, M. and Surmely, F. 2005. Réflexions sur la function des microgravettes et la question de l'utilization de l'arc au gravettian ancient. *Paléo* 17, 145-156.

Legrand, A., and Sidéra, I. 2007. Methods, means and results when studying European bone industries. In *Bones as tools: current methods and interpretations in worked bone studies* Oxford: Oxbow 1622, 67-79.

Lemorini, C., Rossetti, P., Cusinato, A., Dalmeri, G., Hrozny Kompatscher, M., Kompatscher, K. 2005. L'analisi delle tracce d'uso e l'elaborazione spaziale: il riconoscimento di un'area specializzata nel sito epigravettiano di Riparo Dalmeri, livelli 26b e 26c (Trento). *Preistoria Alpina,* 41, 171-197.

Maigrot, Y., 1997. Tracéologie des outils tranchants en os des Ve et IVe millénaires av. J.-C. en Bassin parisien. Essai méthodologique et application. *Bulletin de la Société Préhistorique Française,* 94 (2), 198-216.

Montoya, C. 2008. Apport de l'analyse technique à la compréhen- sion de l'évolution des groupes humains épigravettiens d'Italie Nord Orientale: la production lithique de l'US 15a-65 du Riparo Dalmeri. In Dalmeri G. and Neri S. (eds.) Riparo Dalmeri e l'occupazione epigravettiana, *Preistoria Alpina* 43, 191-208.

Mussi, M. and Peresani, M. 2011. Human settlement of Italy during the Younger Dryas. *Quaternary international*, *242*(2), 360-370.

Pétillon, J.M. 2000. Les pointes à base fourchue magdaléniennes : approche fonctionnelle, *Préhistoire et anthropologie méditerranéennes*, 9, 29-55.

Pétillon, J.M. 2006. *Des Magdaléniens en armes. Technologie des armatures de projectile en bois de cervidé du Magdalénien supérieur de la grotte d'Isturitz (Pyrénées- Atlantiques)*, Treignes, CEDARC (Artefacts 10).

Ramseyer, D.. Chauvière, F. X., Christensen, M., David, E. 2004. *Fiches typologiques de l'industrie osseuse préhistorique*. Cahier 11 : Matières et techniques,Paris: Éd. Société Préhistorique Française.

Ravazzi, C. 2003. An overview of the quaternary continental stratigraphic units based on biological and climatic events in Italy. *Il Quaternario* – Volume Speciale INQUA Italian Journal of Quaternary Sciences 16(1Bis), 11-18.

Stodiek, U., 1993. Zur Technologie der jungpaläolithischen Speerschleuder. Eine Studie auf Basis archäologischer, ethnologischer und experimenteller Erkenntnisse. Tübinger Monographien zur Urgeschichte, 9.

Stordeur, D. 1979. *Les aiguilles à chas au Paléolithique*. Paris, Gallia Préhistoire 13 supplement. Éditions du CNRS.

Tyzzer, E.E. 1936. The "simple bone point" of the shell-heaps of the northeastern Algonkian area and its probable significance. *American Antiquity* 1, 261-279.

Valentin, B. 2008. *Jalons pour une Paléohistoire des Dernier Chasseurs (XIVe-VIe millénaire avant J.-C.).* Paris: Publications de la Sorbonne.

New Insights into the Paleolithic Chronology and Funerary Ritual of Caverna delle Arene Candide

Julien Riel-Salvatore[1], *Claudine Gravel-Miguel* [1,2], *Roberto Maggi*[3], *Gabriele Martino*[4], *Stefano Rossi* [4,5] *& Vitale Stefano Sparacello*[6]

Abstract

This paper presents preliminary results of renewed field research conducted at Caverna delle Arene Candide, with a specific focus on the implications of these new field observations for our understanding of the heretofore underappreciated richness of the funerary ritual of the cave's Epigravettian occupants. The paper begins with a review of the work undertaken at the site during the 2008-13 field program. Specific attention is given to the chronology and site formation history of the cave's Pleistocene deposits. These new data definitively confirm the Gravettian age of the burial known as the "Young Prince" and have implications for the age of Level P1, which is shown to date to ca. 15-15.5 ky BP. Additionally, the oldest exposed deposits at the site are confidently shown to be coeval with the Classic Aurignacian at the Balzi Rossi. Finally, the paper presents some results from our recent field research at the site. This includes, for the Epigravettian levels, the discovery of new human remains and of artifacts suggesting

1 Département d'anthropologie, Université de Montréal, Pavillon Lionel-Groulx, 3150 Rue Jean-Brillant, Montréal, QC, H3T 1N8, Canada. E-mail: julien.riel-salvatore@umontreal.ca (corresponding author).
2 School of Human Evolution and Social Change, Arizona State University, PO Box 872242, Tempe, AZ, 85281-2242, USA.
3 Istituto Internazionale di Studi Liguri, sez. Tigullia, via Costaguta 4, 16043 Chiavari, Italy.
4 Soprintendenza Archeologia, Belle Arti e Paesaggio per la città metropolitana di Genova e le province di Imperia, La Spezia e Savona, Via Balbi, 10, 16126 Genova, Italy.
5 DISTAV, Università di Genova, Corso Europa, 26, 16132 Genova, Italy.
6 UMR5199 PACEA, Université de Bordeaux – CNRS, Bâtiment B8, Allée Geoffroy Saint Hilaire, CS 50023, 33615 Pessac cedex, France.

in: Borgia, V. and E. Cristiani (eds.) 2018: *Palaeolithic Italy. Advanced studies on early human adaptations in the Apennine peninsula*, Sidestone Press Academics (Leiden), pp. 335-356.

that a complex and multifaceted ritual, perhaps shamanistic in nature, accompanied the burial of dead ones at the site. We summarize here evidence that this ritual included the ceremonial 'killing' of ochred pebble tools used to prepare and apply ochre to the dead bodies.

Keywords: Arene Candide, Final Epigravettian, Gravettian, Upper Paleolithic, radiocarbon dates, burials, funerary rituals, pebble tools.

1. Introduction

In a review of Upper Paleolithic burials, two of us recently suggested that research on Paleolithic burials should be "focusing on teasing out information about the socioritual and economic contexts of burials [and] trying to understand how they articulate with other forms of mortuary ritual" (Riel-Salvatore and Gravel-Miguel 2013: 336). While we did not discuss further how this may be accomplished, one approach would be for active projects to develop integrated research protocols that explicitly incorporate the analysis of material not directly associated with burials. For burials found in older excavations, however, this often entails re-excavating those parts of the site located immediately next to the area where the original excavation focused. A challenge inherent to this second approach is that of directly associating the new and old excavations, which can be achieved through a combination of absolute dating, geoarchaeological observation and archival work. One site that has afforded such a possibility is Caverna delle Arene Candide. Recent targeted fieldwork at the site has yielded a wealth of new information that not only allows us to gain a finer understanding of its occupation dynamics during the Paleolithic but also permits us to resolve long-standing chrono-stratigraphic ambiguities and to develop a more holistic understanding of Final Epigravettian funerary practices.

This paper builds on this recent research at Caverna delle Arene Candide (Fig. 1) to flesh out the breadth of practices that characterized the ritual framework within which bodies were interred at the site during the Final Epigravettian (ca. 12-10ky BP). It summarizes direct observations made during this fieldwork combined with archival research on the results of prior excavations in the Pleistocene deposits of the site. This dual framework allows us to propose a revised chronology and updated stratigraphy of the site which explains the discordance between some prior radiocarbon dates and their apparent stratigraphic position. This has implications for both the age of the Gravettian burial known as the "Young Prince" and the age of the oldest exposed deposits at the site, which are now securely shown to be coeval with the Classic Aurignacian elsewhere in Liguria. Finally, the paper presents some results from our recent excavation at the site. This includes, for the Epigravettian levels, the discovery of new human remains and of artifacts suggesting that a complex and multifaceted ritual accompanied the burial of deceased individuals at the Arene Candide. We present here a summary of evidence that this ritual included the ceremonial 'killing' of decorated pebble tools used to prepare and apply ochre to dead bodies. Further, as an avenue for future research, we highlight some elements of the Arene Candide Paleolithic record that indicate the possible presence of other rituals that would have accompanied these rites. Combined, these data indicate the importance of considering material from the area surrounding

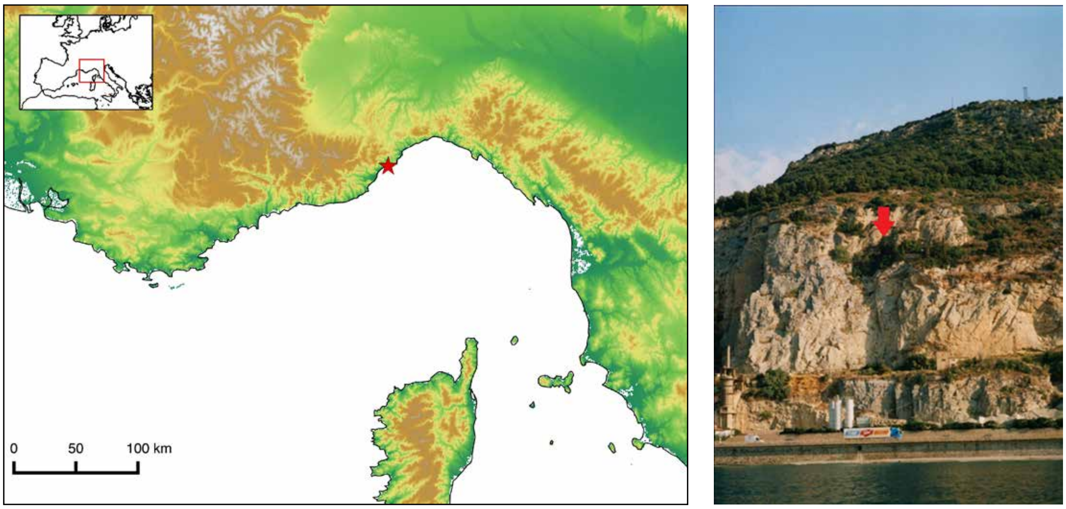


Figure 1. Location (left) and modern position (right) of Caverna delle Arene Candide (star). The black line represents the modern shoreline superimposed on the prehistoric shoreline of the Final Epigravettian (ca. 55m below modern sea level).

Paleolithic burials in order to properly reconstruct the full set of behaviors that defined prehistoric mortuary practices.

2. Caverna delle Arene Candide: The re-excavation of a key site

Opening about 90m above the modern sea level, on the southern edge of the Caprazoppa promontory and overlooking a limestone quarry that abuts into the Ligurian Sea, Caverna delle Arene is a large (70x20m) chamber that is part of an extensive karstic system (Fig. 2). The promontory comprises mostly Upper Jurassic Val Tanarello limestone and Upper Oligocene to Middle Miocene bioclastic limestone known as "Pietra del Finale" and has been heavily affected by karstic processes (Biancotti and Motta 1998). The site's archaeological notoriety comes from the deep sequence of Pleistocene and Holocene deposits that have accumulated in the cavity and which have made it a key site to understand the Paleolithic and Neolithic of the Western Mediterranean (Bernabò Brea 1946, Cardini 1980, Bietti 1994, Maggi 1997).

After early excavations in the 19th Century (Issel 1908; Morelli 1890), L. Bernabò Brea and L. Cardini conducted systematic excavations at the site during the 1940s and established its importance as a reference sequence for the Western Mediterranean as a whole. Beyond its rich and storied Neolithic levels, the site is also known for its unique Paleolithic sequence (Maggi *et al.* 2014). In addition to a Final Epigravettian 'necropolis' comprising ca. 20 individuals (Cardini 1980; Formicola *et al.* 2005; Paoli *et al.* 1980; Sparacello *et al.*, 2018), the Paleolithic levels of the site have also yielded one of the most elaborate Gravettian burials known to date (the individual known as the "Young Prince") as well as late Upper Paleolithic parietal incisions (Cardini 1942; Pettitt *et al.* 2003, Mussi *et al.* 2008). Following Cardini's untimely death, an edited monograph was published that described in detail the abundant archaeological record of the Pleistocene deposits at the site (*i.e.*, the M and P levels; Bietti 1994). This posthumous work, and a comparable synthetic treatment of the site's Neolithic levels (Maggi 1997), highlighted that the remaining *in situ* Pleistocene deposits of the Arene Candide likely still held much promise for future work, including the possibility of yielding the data needed to answer unresolved questions about the site's stratigraphy and chronology and to refine our understanding of the funerary behavior of the cave's occupants during the Paleolithic.

With these goals in mind, the "Programma integrato di conoscenza e fruizione: La Caverna delle Arene Candide" research program allowed an international team of researchers to conduct renewed fieldwork at the site from 2008 to 2013, under the aegis of the *Soprintendenza per i beni archeologici della Liguria* and the University of Colorado Denver, where the lead author was based at the time. This research allowed us to resolves issues concerning the site's stratigraphic and sedimentary history, and it led to the recovery of new archaeological material important to contextualize the observations made by Cardini in the 1940s. Our fieldwork re-exposed the original trench excavated by Bernabò Brea and Cardini, which allowed us to resample the entirety of the Arene Candide's Paleolithic sequence (see also Riel-Salvatore *et al.* 2010, Martino *et al.* 2011) and develop a finer-grained understanding of the site formation processes in the lower levels at the site (Rellini *et al.* 2013). An analysis of a distinctive pebble tool assemblage yielding key information on the complexity of Epigravettian funerary ritual was also published recently (*i.e.*, Gravel-Miguel *et al.* 2017). However, the present paper is the first general summary of the results of the work conducted from 2008-2013, which will be complemented by the publication of the full results of the excavations in the near future.

As shown in Figures 2 and 3, our excavations uncovered intact *in situ* deposits to the east and the west of Cardini and Bernabò Brea's trench. Work in the western part of the exposed area mostly yielded information about the site's Gravettian levels, while sampling in the central part of the trench allowed us to resolve question about its overall chronology and targeted excavations immediately east of the original trench permitted the recovery of new *in situ* Final Epigravettian archaeological material. Each of these sets of data allowed us to answer different, complementary sets of questions: what recently obtained radiocarbon dates can tell us about the depositional history of the site; how they can help resolve some uncertainties about the age of some of the levels at the Arene Candide; and, what analyses of new materials tell us about the heretofore underappreciated complexity of Epigravettian funeral rites at the site.

3. Revision of the Arene Candide's Chrono-Stratigraphy

One of the major achievements of our projects was to greatly clarify the Arene Candide's chrono-stratigraphy, especially for the P levels that underlie the necropolis (to help situate the reader, Figure 3 presents an updated version of Bernabò Brea and Cardini's composite stratigraphy for the site). Table 1 compiles all the existing radiocarbon dates for the Paleolithic deposits at the site, including four dates on charcoal samples collected during our excavations. The first of these is attributable to level P1 and yields an age range of 15,465 ± 80 BP (LTL 3771A), having been collected about 50 cm below the base of the necropolis (Gravel-Miguel *et al.* 2017). This new date is statistically equivalent to another

Level	Layer	Material	Lab #	Age	SD	Reference
M	1	bone	Beta – 49694	9980	140	MacPhail *et al.* 1994
M	1-2.	charcoal	Beta – 53091	10740	90	MacPhail *et al.* 1994
M	1-2.	charcoal	R-740	10910	90	Bietti 1987
M	3-4.	charcoal	R-743	11750	95	Bietti 1987
M	n/a	charcoal	R-100	10330	95	Alessio *et al.* 1966
M	Burial III	human bone	OxA-10998	10065	55	Formicola *et al.* 2005
M	Burial Vb	human bone	OxA-10999	9925	50	Formicola *et al.* 2005
M	Burial Vib	human bone	OxA-11000	10585	55	Formicola *et al.* 2005
M	Burial VIII	human bone	OxA-11001	10655	55	Formicola *et al.* 2005
M	Burial XII	human bone	OxA-11002	10720	55	Formicola *et al.* 2005
M	Burial XIV	human bone	OxA-11003	10735	55	Formicola *et al.* 2005
M	Burial X	human bone	GX-16960-A	11605	445	MacPhail *et al.* 1994
M	Burial XII	human bone	GX-16964-K	11510	385	MacPhail *et al.* 1994
P	1?	Charcoal	R-745	18560	210	Bietti 1987
P	1	Sediment	Beta-56693	15110	200	MacPhail *et al.* 1994
P	**1**	**charcoal**	**LTL3771A**	**15465**	**80**	**Gravel-Miguel et al. 2017**
P	3	charcoal	R-2546	18950	245	Bietti & Molari 1994
P	4	charcoal	R-2550	18820	260	Bietti & Molari 1994
P	7.3?	charcoal	R-2533	19400	230	Bietti & Molari 1994
P	8 → 7.3	charcoal	Beta-48684	19630	250	MacPhail *et al.* 1994
P	9 → 8	charcoal	R-2541	20470	320	Bietti & Molari 1994
P	12 → 9	charcoal	Beta-53983	23450	220	MacPhail *et al.* 1994
P	13 → 10	charcoal	Beta-53982	25620	200	MacPhail *et al.* 1994
P	13 → 10	charcoal	Beta-56692	25620	200	MacPhail *et al.* 1994
P	Young Prince	human bone	OxA-10700	23440	190	Pettitt *et al.* (2003)
P	**11**	**Charcoal**	**LTL3770A**	**26693**	**150**	**This paper**
P	**12**	**Charcoal**	**LTL3769A**	**27381**	**200**	**Rellini et al. 2013**
P	**13**	**Charcoal**	**LTL4575A**	**28693**	**250**	**This paper**
P	**Below 13?**	**Charcoal**	**LTL4574A**	**30233**	**250**	**This paper**

Table 1. Available dates for the Paleolithic levels of Caverna delle Arene Candide. Dates in bold indicate AMS radiocarbon dates on samples obtained during the 2008-2013 excavations. Arrows indicate the correction from the level attribution of the 1991 dating program to that resulting from the revision proposed in this paper.

date of 15,110 ± 200BP (Beta-56693) for Level P1 that Bietti (1987) had previously considered unreliable because it had been obtained on sediment and because it disagreed with the age of 18,560 ± 210BP (R-743) derived from a charcoal sample attributed to Level P1 by the original excavators. In light of our new date, this older sample is probably best considered the result of an unrecognized disturbance or mixing during the original excavations. An age of ca. 15-15.5 ky BP also lengthens the time over which the top four P levels accumulated at the Arene Candide (see Table 1) from a few hundred to a few

Figure 2. Planimetry of the site, with the exposed Paleolithic deposits highlighted in red. The eastern highlighted area shows the location of the work described here. (Modified from Sparacello et al. 2018).

thousand years, bringing it closer to the rate documented in the rest of the P levels. Its likelihood is also bolstered by the consistency between the ages obtained by two modern laboratories for this phase of occupation, both of them derived from samples collected in primary context by the investigators responsible for commissioning the dates; in contrast, the sample dated by Bietti comes from the original excavations, which predate the development of radiocarbon dating as a method and did not document the marked sloping in the Pleistocene deposits our excavations did (*cf.* Figs. 4, 6, and 8). This new age range also significantly reduces the depositional hiatus between the Epigravettian necropolis levels and those from earlier Upper Paleolithic occupations, from about 7,000 years to about 3,500 years. A corollary of this is that the time span represented in the P units is much longer, therefore drawing out the sedimentation rates at the site. However, dated sample LTL3771A was collected about 50cm of *in situ* deposits *below* the base of Level M (Fig. 4), which indicates that the synthetic stratigraphic profile reported by the original excavators (Fig. 3) does not correspond to the stratigraphic reality of the eastern part of the cave where our activity focused, and that the hiatus may in fact be shorter than had heretofore been thought.

The second sample has yielded an age range of 26,693 ± 150 BP (LTL 3770A) and was recovered from a level of well-sorted and clast-supported limestone fragments described as Unit C in Rellini *et al.* (2013) that directly underlies the unit in which the Gravettian burial known as the "Young Prince" was recovered. It thus corresponds to Level P11 in Cardini's stratigraphy and is in stratigraphic agreement with the third new date of 27,381±200 BP (LTL 3769A) obtained for Level P12 reported in Rellini *et al.* (2013). These two dates, along with direct field observations (see below), provide important contextual information that settles a debate over the actual age of the Young Prince. Recovered in Level P10, the skeleton was directly dated to 23,440 ± 190 BP (Pettitt *et al.* 2003), which is statistically undistinguishable from the age of 23,450 ±

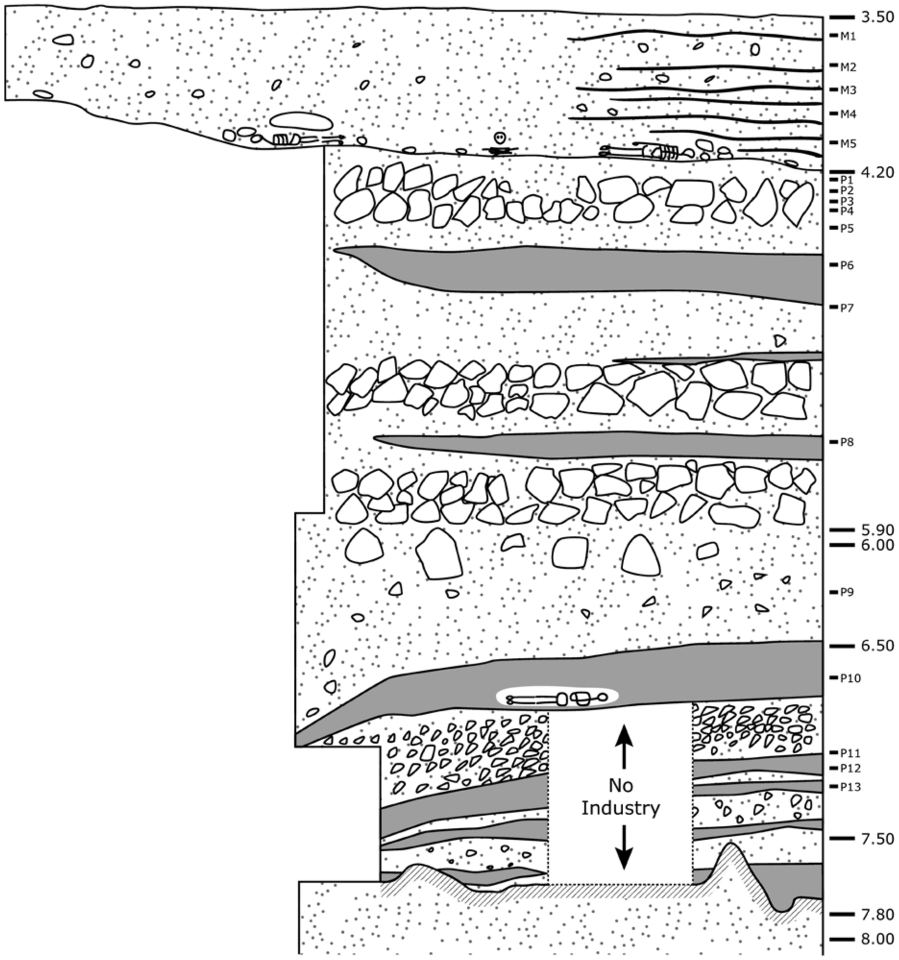


Figure 3. Updated version of the composite stratigraphy of the Paleolithic levels (i.e., the M and P levels) of Cardini and Bernabò Brea's excavations. Note that the sequence is in actuality capped by a 3.5m-thick series of Holocene deposits that are not drawn here. Depth in meters below datum and level names shown along the right margin; grey lenses represent 'hearts' in the original stratigraphy.

220 BP obtained for Level P12 by MacPhail *et al.* (1994), who had also obtained two identical dates of 25,620 ± 200 BP for Level P13.

These apparent discrepancies led Palma di Cesnola (2006: 32) to argue that the direct date must be wrong and that, on typological grounds, the Young Prince should be considered Early Epigravettian in age (*i.e.*, younger than ca. 20,000 BP):

> *"Esiste una data, ottenuta recentement, per il "Giovane Principe", di 23440 ± 190" (Petit et alii 2003 [sic]), che appare nettamente in contrasto col contesto dell'Epigravettiano antico a Foliati in cui sepolto (sotto Focolare V) e che per altro richiama esattamente la data relativa al Focolare VI, posto inferiormente, al di sotto di un livello a pietrisco sterile (23450 ± 220 BP).*"

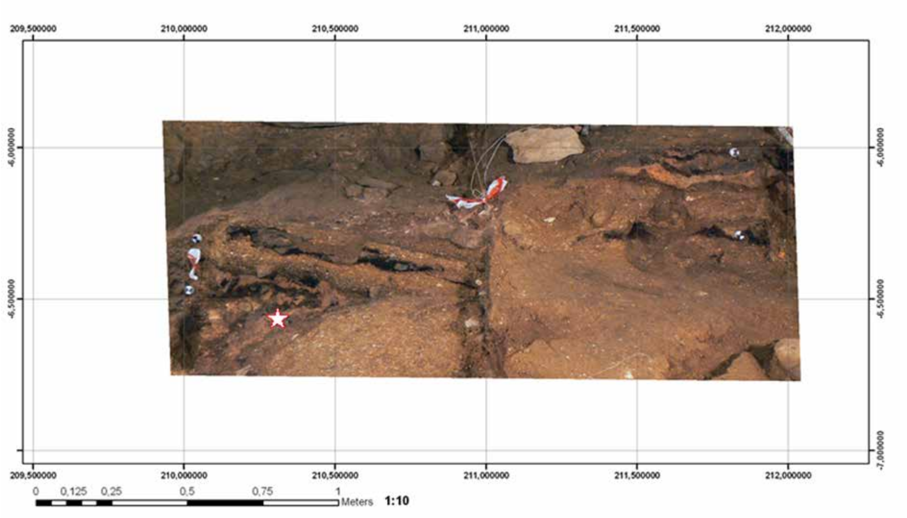


Figure 4. Georectified image of the northern section of the 2008 test pit, with position of the dated sample shown (star); the upper right of the section corresponds to the base of the level of the necropolis.

Figure 5. Photo of the small sondage identified below Level P10 during the 2008 field season.

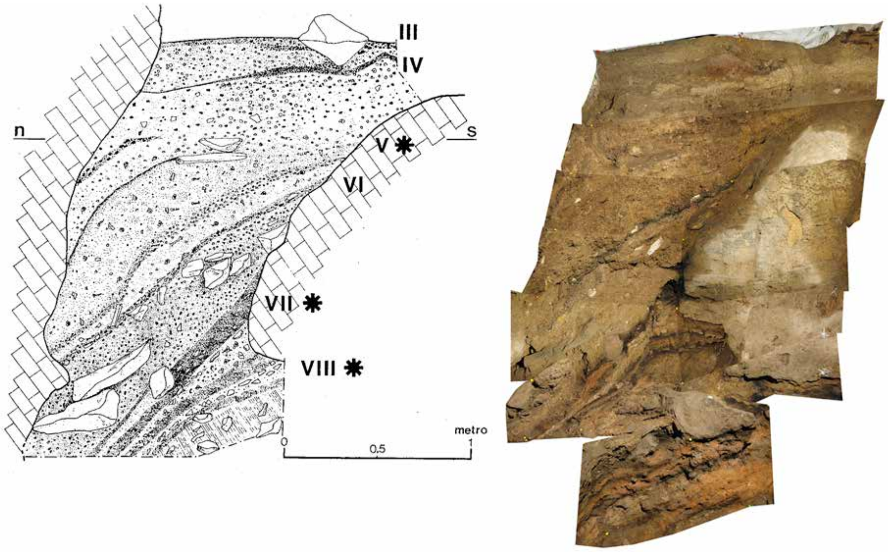


Figure 6. Left: 1991 drawing showing the eastern section of the "Young Prince Trench" sampled in MacPhail (1994). Right: Georectified composite photograph of the same in 2008, with the sondage including Levels P11-P13 included.

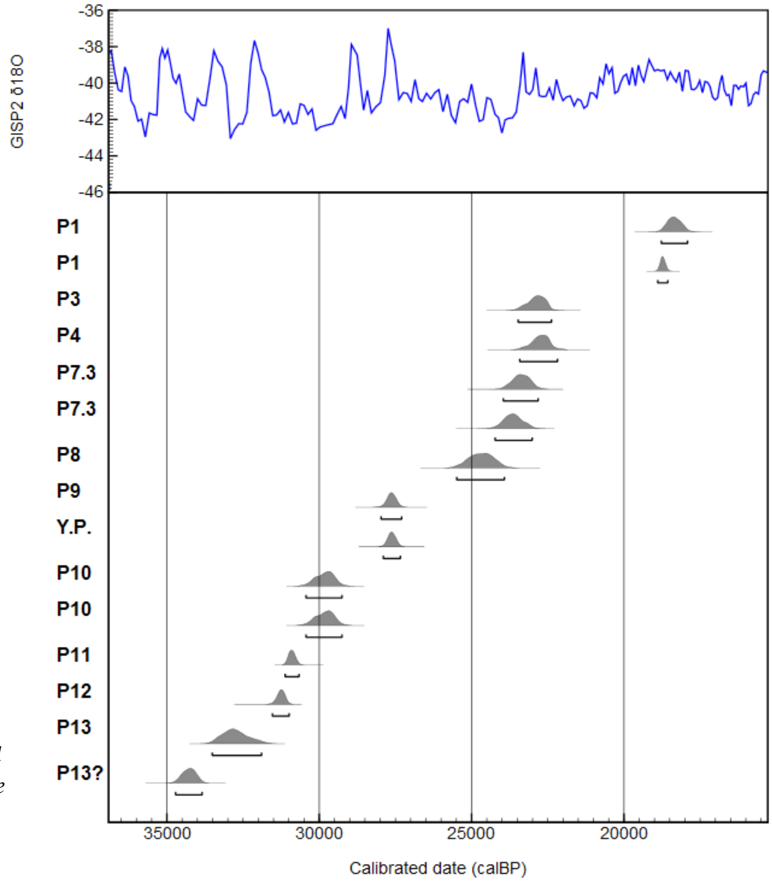


Figure 7. Age distributions in calendar years and paleoclimatic correlations for the P levels of the Arene Candide (calibrated using OxCal 4.3.2). Y.P. = direct date on the 'Young Prince'.

There is a recently obtained date of 23,440 ±300 for the "Young Prince" that stands in marked contrast with the Early Epigravettian with foliates context into which it was buried (below Hearth V) and that is exactly the same as the age of Hearth VI, found below it, under a sterile roof spall level (23,450 ± 320).

During the 2008 season, however, as our team emptied out the trench corresponding to where the Young Prince had originally been found and which had since been filled by debris and backdirt from other excavations at the site, we identified at the bottom of it a small, backfilled *sondage* (Fig. 6). Upon locating the test pit, one of us (R.M.) who had also been involved with the dating program of the exposed Pleistocene deposits undertaken in 1991 noted that MacPhail *et al.* had not, in fact, included this feature, which comprises levels P11-13 of the 1942 stratigraphy in their stratigraphic correlation (see also MacPhail *et al.* 1994: 97). This realization has important implications for the stratigraphic position of the dates published by MacPhail *et al.* (1994) since it indicates that the deposits immediately above the small *sondage* (*i.e.*, level P10, *into* which the Young Prince had been buried) must therefore be the ones to date to ca. 25,620BP (Fig. 6). It is logical that the Young Prince should be younger than the deposits into which he was buried, meaning presumably that the pit in which he was buried was dug into level P10 from the level of Hearth VII (dated ca. 23,450BP), which must therefore correspond to a part of level P9 not singled out as especially 'hearth-like' by Bernabò Brea and Cardini. The fact that Level P11 is now dated to ca. 26,700 BP and Level P12 to ca. 27,400 BP confirms this reconstruction and reconciles the 1942 stratigraphy with the results of both the 1991 dating program and the chronometric age of the Young Prince in a coherent manner. The direct age of the Young Prince is also stratigraphically and logically validated, confirming that it is indeed a Gravettian-age burial.

Finally, two dates from the bottom of the *sondage* (*i.e.*, Level P13 and perhaps deeper) have yielded ages of 28,693 ± 250 (LTL 4575A) and 30,233 ± 250 (LTL 4574A). These indicate that these levels, which are unfortunately so far explored over a very limited area and have yet to yield human-made artifacts, are coeval with the Classic Aurignacian of Level F at Riparo Mochi dated to between ca. 26,030-32,000 BP (Bietti *et al.* 2004, Douka *et al.* 2012). Future excavations in these deposits at the Arene Candide thus have the potential to yield precious information about this otherwise poorly documented period of human prehistory of Liguria (Negrino and Riel-Salvatore, 2018), and to correlate it and later phases of the Upper Paleolithic of the region to specific paleoclimatic regimes (Fig. 7).

4. New human remains and funerary artifacts from the Final Epigravettian

An area of ca. 3m^2 immediately to the east of Cardini and Bernabò Brea's original trench was excavated in 2009 and 2011 (Fig. 2). Its stratigraphy and location, the reddish color of its sediments and its association with human remains constrained by absolute ages, allow us to securely attribute these deposits to the Final Epigravettian and to establish that they were associated chronologically and stratigraphically with the necropolis discovered in the 1940s. The Final Epigravettian necropolis of the Arene

Candide contained the remains of ca. 20 individuals, including both adults and children (Cardini 1980, Paoli *et al.* 1980). In at least two cases, a previously interred skeleton was apparently disturbed to make room for a more recent burial, leading to the creation of clusters of human remains in secondary position. Additionally, at least two adults were interred together with a child. Formicola *et al.* (2005) has shown that the Arene Candide were used as a burial ground in two distinct 'phases' during the Final Epigravettian, dated respectively to ca. 10,790-10,530 BP and 10,120-9,875 BP. In spite of the variability in burial treatment, the grave goods and ritual accompanying the deceased remained comparable across almost 1,000 years (Cardini 1980; Riel-Salvatore and Gravel-Miguel 2013): All burials were deposited on a layer of ochre powder, which gave these levels (the "M" levels in Cardini's nomenclature) a marked reddish hue; the precise source of origin of this ochre remains unknown, as is the case for that recovered during our excavation. Flat oblong pebbles were also identified among the grave goods of several of the inhumations during both phases (Cardini 1980; Granato 2011). Some of these pebbles bear painted ochre lines on their mid-section or extremities (Cardini 1946, 1972, 1980) that recall the motifs seen on similarly shaped pebbles found in other Italian Epigravettian sites (*e.g.*, Martini 1993, 2012) and on decorated pebbles found in contemporaneous Azilian sites (Couraud 1985; d'Errico 1994).

Our excavations exposed deposits up to 65cm thick that include our excavation units USP 31-48, corresponding to stratigraphic units 6, 7, 8, 10 and 11 (Fig. 8). These levels are characterized by an overall dark brown-grey loamy sedimentary matrix rich in organic material, ochre that gives the surrounding sediments a reddish color and pockets of lighter-colored silty loess-like sediment. The deposits contain abundant roof spall fragments 5-15cm in maximum dimensions, the angularity of which decreases lower in the sequence. The roof spall is much rarer in level 8. Levels 10 and 11 are in continuity with levels 6 and 7 respectively, being distinguished mainly on the basis of their heavily concreted nature. The material recovered appears to be essentially in primary context: the low density of artifacts and the fact that the excavation area is located away from the cave walls indicate this area is unlikely to have been a midden. The absence of distinct artefact clusters or definite hearths in this deep part of the cave also imply that it was not a living area, thus suggesting that these deposits may well have been an area on the margins of – but related to – the burial ground. If this interpretation is correct, the recovered ornaments, ochre and fauna may have been related to ritual activities that accompanied the burying the deceased at the site.

Additionally, in 2011, a human left talus was recovered in USP 45 (Fig. 9); this is the first new Paleolithic human remains to be recovered at the site since the early 1970s (Formicola and Toscani 2014). Based on its size, it can be attributed to a young adult individual of unknown sex. Intriguingly, it perfectly articulates with the left calcaneus, and is contralateral of the right talus found in cluster XIII (Cardini, 1980) belonging to the individual AC 13 (Sparacello *et al.*, 2018), which in all likelihood dates to the "old" phase of interment in the Final Epigravettian necropolis. This indicates that this unit corresponds to Levels M1-M2 of Cardini's stratigraphy and dates to ca. 10,530-10,790 BP (Formicola *et al.* 2005); it is worth noting that this departs from Cardini's composite stratigraphy (Fig. 3), which indicates the necropolis was found at the bottom of the M levels, yet another discrepancy between that document and the archaeological reality documented during our recent fieldwork. In any case, perhaps the most important aspect pertaining to the AC 13 talus is that it directly connects our excavation to the necropolis, thus strengthening our arguments that the other recovered artifacts were likely linked to funerary rituals that took place when members of the group were interred at the Arene Candide.

Of interest here is another class of artefact that apparently links the area excavated in 2009-2011 to the necropolis, namely flat, ochred pebbles, of which we recovered 31 (both broken and complete) during our excavations (Fig. 10). In a recently published paper, we provide the detailed arguments explaining why and how it can be established that these distinctive objects represent a heretofore unrecognized, but important, part of the funerary rituals that took place at the Arene Candide (Gravel-Miguel *et al.* 2017). Nonetheless, we summarize some of our key observations here, since they underscore how new information about prehistoric ritual at the Arene Candide can be gleaned from even the limited area we excavated.

While Cardini (1946) reported that over 600 such pebbles had been found during his excavations, research on this class of distinctive artifacts has been very limited. In fact, only some of those found in the necropolis were illustrated and given a summary description, with no additional analysis being performed at the time (Cardini 1972, 1980). Hinting at their ritual use, Cardini (1980: 36) mentioned that none of the 600+ recovered pebbles bore marks like those usually found on hammerstones of various types, while other researchers have proposed that these pebbles' shape and use-wear suggest that some could have served as retouchers or percussors for indirect percussion (Bietti 1987, p. 189) or as 'lissoirs' (Gazzoni and Fontana 2011, p. 65). In contrast, in a detailed study of all of the pebble tools found in the necropolis, Granato (2011) concluded that they served as spatulas to apply ochre on corpses before they were buried.

The new sample of 31 flat, oblong limestone pebbles recovered during our excavations provides an independent means to test these various claims objectively; interestingly, the largest number of these pebbles (n = 12) has been recovered from USP 45, the very unit in which the AC 13 human talus described above was recovered. Of these 31, two could be refitted to matching pieces, yielding a sample of 29 distinct pebbles, of which fully 15 (ca. 52%) were found as incomplete fragments. This is in marked contrast to those reported by Cardini (1980) and studied by Granato (2011), which are all complete. In terms of their shape and dimensions, our sample is, however, statistically undistinguishable from that illustrated by Cardini (Fig. 10; Gravel-Miguel *et al.* 2017). While their smoothness indicates that they were abraded by water action, their flat, elongated morphology is encountered only infrequently on beaches and even more rarely in rivers; however, the presence on the surface of many of our pebbles of traces made by invertebrates of the *Serpulidae* family indicates they are of marine origin (see *e.g.*, the pebbles from USP 32 in Fig. 10). Therefore, the dominance of this distinct elongated 'blade-like' morphology (*sensu* Krumbein 1941) in our assemblage, suggests that they were carefully sought out on the beach before being brought into the cave. While we cannot at present determine with certainty which beach they originated from, the most parsimonious view is that they were collected on the beach at the base of the cliff into which the cave opens.

Having established their marine origin and that their uncommon shape was specifically selected, what can we say about the purposes these pebble tools served? Microscopic analysis was conducted on of 25 pebbles, since four had to be excluded

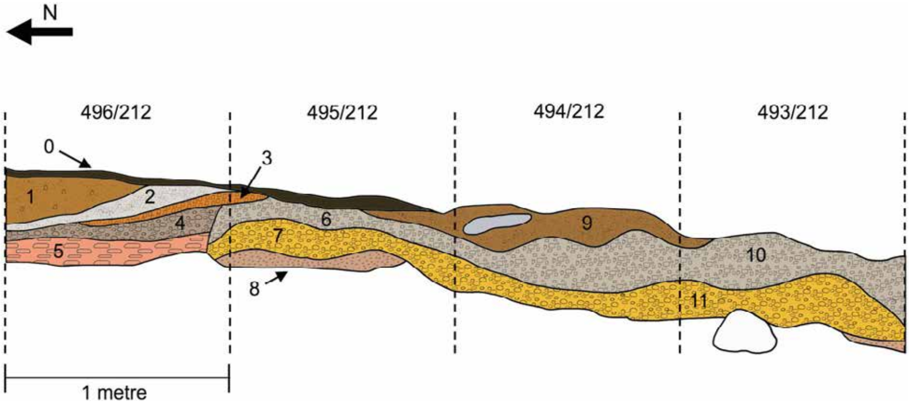


Figure 8. Section of the eastern wall of the 2009-2011 excavation in the Final Epigravettian levels. (From Gravel-Miguel et al. 2017).

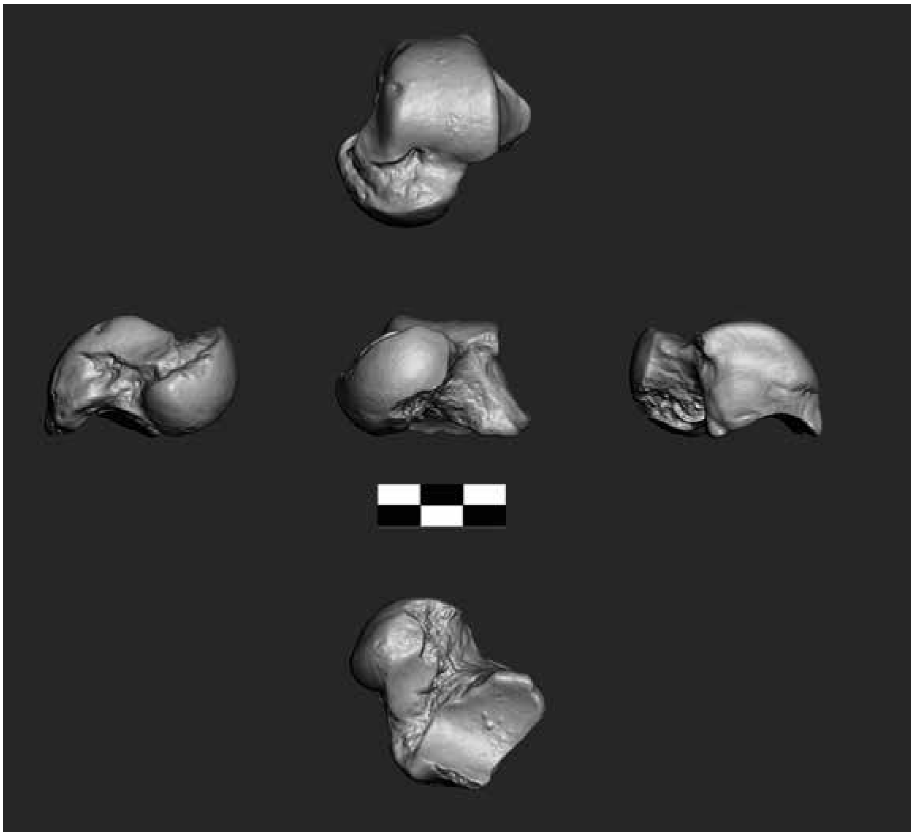


Figure 9. Tridimensional scan of the AC 29 talus recovered in 2011 in USP 45 (scan by V.S. Sparacello).

from consideration because they were too fragmented. Only 9/25 pebbles bear potential traces of percussion; among these, six show crushed or chipped tips and only one shows surface pitting (Gravel-Miguel *et al.* 2017). Likewise, only 4/25 bear incisions on their surface, none of which are representational. In contrast, fully 22/25 (88%) of the pebbles bear traces of ochre. Excluding the two refitted pebbles which are clear outliers, being as they are almost completely covered in ochre (see Fig. 10), that coloring material is prevalently concentrated on the edges of the pebbles. This indicates that, as far as ochre is concerned, the pebbles were principally used in tasks requiring the edges, although ochre is also often found on their planar surfaces (Gravel-Miguel *et al.* 2017). Along with the fact that the necropolis yielded four ochre-covered grindstones (Cardini 1980), we interpret this pattern as potential evidence that the pebbles may have had multiple uses related to ochre, such as applying an ochre paint or paste to surfaces, or mixing ochre with a binder to create these coloring materials. Given that most ochre in the Final Epigravettian levels is associated with the burials, however, it is reasonable to conclude that these ochre-related uses were somehow linked to the necropolis, perhaps for instance, for applying thin lines of coloring material to hides, clothes, or even directly to the bodies inhumed in the necropolis located just a few meters away (*cf.* Granato 2011).

Perhaps the most striking aspect of our sample, however, is that it is so extensively fragmented. It is unlikely that the pebbles were collected already broken, since most breaks appear fresh which contrasts with the rounded morphology we would expect to find on beach-collected breaks. Further, our analysis of ochre distribution shows that ochre traces are abruptly interrupted by the breaks, which suggests that the break took place after or during ochre-processing tasks. Due to the lack of wear on the pebbles, the breaks are unlikely to be the result of the pebbles' heavy usage, however, and the low number of refits argues against post-depositional processes being responsible for these breaks, since if that had been the case, we might reasonably expect to find at least some of the broken pieces in close proximity. Finally, a breaking experiment shows that the kind of clean break documented in our sample usually results from directly hitting a pebble on its flat surface or snapping onto a larger rock (Gravel-Miguel *et al.* 2017).

These convergent observations indicate that the fragmented pebbles were broken intentionally, generally after being used as spatulas to apply ochre. To account for both the ochre and the breakage patterns on the fragmented pebbles in our sample, we have suggested elsewhere the possibility that these objects may well have been ritually 'killed' by deliberately breaking them following their use in the funerary rituals that accompanied the burying of individuals in the necropolis (Gravel-Miguel *et al.* 207). This kind of ritual fragmentation in the context of burial rites is well-documented in many other prehistoric contexts (Chapman 2000, Chapman and Gaydarska 2006, Grinsell 1961). Of specific interest here, Grinsell (1961) describes funerary contexts in which items were broken and one piece was discarded while the other was kept by the living to symbolize a lasting bond across life and death. A behavior of this sort could help explain why there are almost no refits in our sample of broken pebbles. He also mentions other cases where objects were intentionally broken so as to not spoil their symbolic power after coming into contact with a dead body. The fact that only some pebbles were broken may indicate that only one, perhaps the last, of the series of pebbles used to decorate the body of a deceased group member was 'killed' in this manner. This would also agree with the observation that the two pebbles with the highest amount of ochre were found broken.

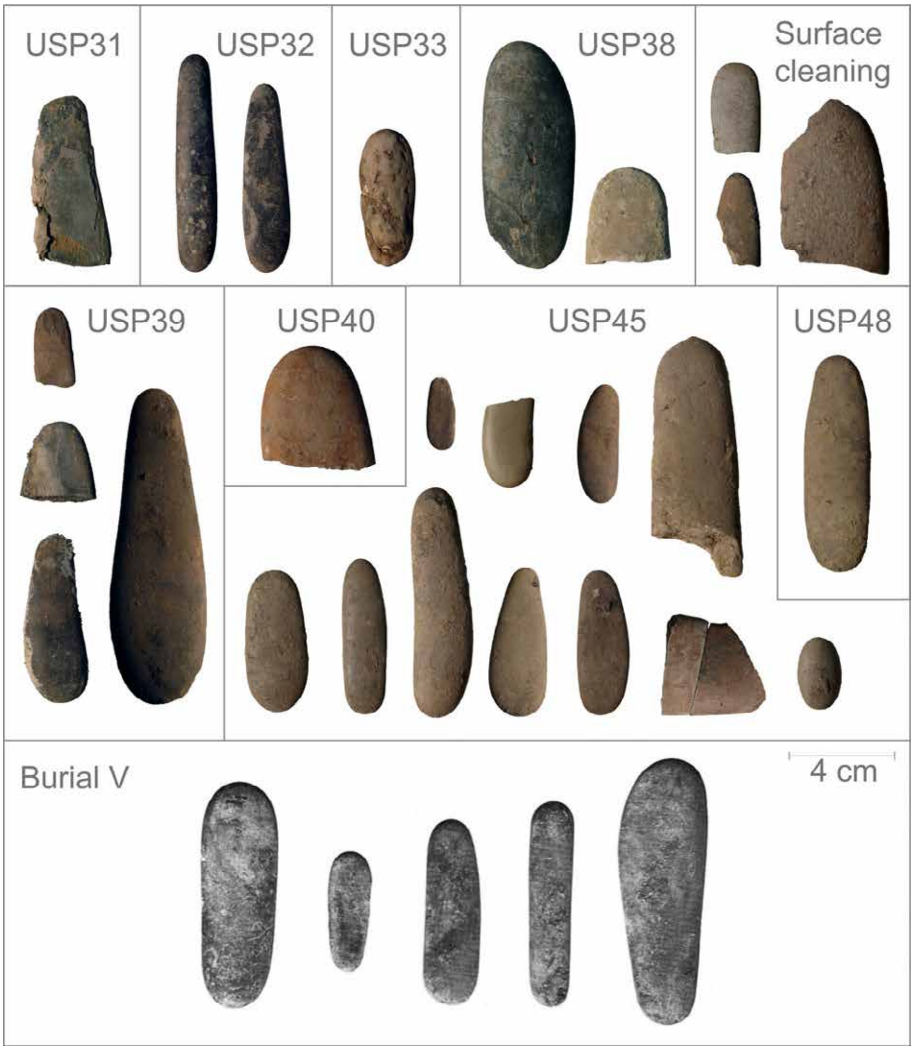


Figure 10. Sample of the oblong pebbles found in the 2009-11 excavation, compared to 5 pebbles found in the 1940s in association with burial V (modified from Gravel-Miguel et al. 2017).

If our interpretation is correct, the ritual killing of carefully selected objects used in mortuary rituals is currently the oldest documented evidence of the intentional ritual fragmentation of material culture. It also provides a new datum that broadens our understanding of mortuary traditions during the Upper Paleolithic and that underscores the importance of paying due attention to seemingly unimportant artifacts, such as broken unmodified rocks that often are considered as sedimentary noise and get discarded during excavation. Proper study of at-first-glance trivial artifacts can in fact reveal previously unknown practices in the Paleolithic funerary canon.

5. Discussion and Conclusions

Having shown that the funerary ritual at the site during the Final Epigravettian was more complex that so far appreciated, we now turn to a discussion of some other aspects of that period's record that may prove fruitful to investigate in the future in order to get the fullest understanding of the ritual activities that may have been part of funerary behavior at the site. Indeed, the revised chrono-stratigraphy proposed above and its implications for how some of the deposits accumulated at the Arene Candide may warrant taking a fresh look at peculiar patterns in the archaeological material of the M levels that may have so far been underappreciated. This follows on a study by Alhaique and Molari (2006) who analyzed material from the Arene Candide pertaining to the necropolis and housed at the *Istituto Italiano di Paleontologia Umana*. Among other observations, they reported that a previously unnoticed part of the funerary ritual at the site was the incorporation into individual burials of the wings, beaks and/or claws of various bird species, notably the corn crake (*Crex crex*), the red-crested pochard (*Netta rufiina*), the goosander (*Mergus merganser*), the European herring gull (*Larus argentatus*), and, in one instance, the Alpine chough (*Pyrrhocorax graculus*). They also report the presence of cranial fragments of a young adult that accompanied Burial Va and is interpreted as a kind of 'trophy skull' (Alhaique and Molari 2006: 214-215).

Here, we can add to this by highlighting the presence in the M levels of a single left back paw of a wolverine (*Gulo gulo*) represented by two complementary broken metatarsals (Cassoli and Tagliacozzo 1994: 161-163). This is the only evidence of that animal in the entire Paleolithic sequence and, like the bird remains, it is unlikely to have accumulated in the cave naturally, the alternative being that it was introduced by humans in the levels of the necropolis. Given the rarity, ingenuity and ferociousness of the wolverine, this behavior may have had specific cultural importance to the site's occupants. Likewise, a damaged left hemimandible of a beaver (*Castor fiber*) broken into two pieces was also recovered in the M levels (Cassoli and Tagliacozzo 1994: 127-128). The only other instances of beaver remains for the entirety of the Arene Candide Paleolithic sequence are two right hemimandibles recovered in burial Va, again suggesting that these animal parts had specific ritual significance and links to the burial rites undertaken at the site. Another peculiar pattern concerns brown bears, which in spite of being quite abundant in the M levels, are represented almost exclusively by teeth and cranial fragments (Cassoli and Tagliacozzo 1994: 136-143), the latter of which, especially the zygomatics, often bear cut marks related to skinning activities (Alhaique 1994). This has led these authors to suggest that bears were most likely brought to the cave by humans in the form of pelts to which parts of the skull were still attached. Again, this suggests a targeted selection by humans of dangerous animals that were relatively rare, especially considering that bears are otherwise completely absent at the site, except in the lowest levels (P9 – P13) when the site was devoid of sustained human occupation (Alhaique 1994).

This suggests that looking at the faunal collections of the original excavations with a new eye might yield interesting results, especially since the five M levels that span only 0.7m in depth have yielded roughly the same number of animal remains as all thirteen of the P levels, which span over 3.5m. While the M levels have admittedly been excavated over a somewhat larger area (Bietti and Molari 1994), the disparity is nonetheless striking. As concerns species used as food, for instance, the two most abundant prey species are the red deer (*Cervus elaphus*; MNI = 63, NISP = 2468) and the boar (*Sus scrofa*; MNI = 41, NISP = 687). Red deer are represented by the whole skeleton, with phalange fragments being especially numerous, suggesting that they were brought whole to the site (Cassoli and Tagliacozzo 1994: 210-222; *cf.* Alhaique 1994). Strikingly, however, over half of identified individuals were very young, under three years of age. Likewise, boars are represented by the entire skeletons, and piglets are extremely abundant, with fully 26/41 (~63%) individuals being under two years of age (Cassoli and Tagliacozzo 1994: 186-192). In contrast the roe deer and ibex, the next two most abundant ungulate species, display no extremely young individuals and proportionally many fewer juveniles. This suggests that the focus on juvenile red deer and boars may also perhaps reflect a cultural preference in the context of the funerary activities that took place at the site.

As an avenue for future research, it is possible to link these anecdotic observations on the representation of individual animal species into a coherent framework that could be linked to the broader ritual context of the funerary activities that took place in the Final Epigravettian of the Arene Candide. For instance, Hayden (2003) has argued that the ritual organization of Upper Paleolithic Western Europe was largely shamanistic in nature and that in this context, events such as funerals in particular could have served as settings for feasts (Hayden 2009). While feasting in particular is generally associated with more sedentary societies, it has been documented in some terminal Pleistocene forager groups, such as at the Natufian site of Hilazon Tachtit (Munro and Grosman 2010). That this feasting is associated with the burial of a shaman interred with select parts of powerful animals (Grosman *et al.* 2008) provides further analogies to some of the patterns highlighted in the Arene Candide faunal record. In sum, without claiming that the funerary rites accompanied by the ritual killing of artifacts documented at the site imply that these activities took place in a shamanistic context, a number of elements are certainly compatible with such a setting, which could provide interesting avenues for future research at the site aiming to develop an integrated view of Final Epigravettian ritual activities.

In conclusion, this paper provides an update on our ongoing analyses of the material recovered during our excavations at Caverna delle Arene Candide from 2008-2013. We have shown that the site still holds enormous scientific potential and have clarified here several important aspects of its sequence. Chronologically, we have settled the age of Level P1 at ca. 15-15.5 ky BP and recalibrated the chrono-stratigraphy of the basal levels at the sites, showing that the direct age on the Young Prince is coherent with its stratigraphic positions. We have also presented some results from our targeted excavations directly to the east of Cardini and Bernabò Brea's original trench. These have yielded new human remains that directly link the record from our excavation to the necropolis excavated in the 1940s, showing that it is necessary to broaden our view beyond the burials themselves to get the proper resolution on the scope at which funerary activities played out in the cave. This has allowed us to connect a set of broken ochred oblong pebble tools to the necropolis and to suggest that these carefully selected artifacts were intentionally broken, with part of them discarded at the site, likely as part of a form of ritual killing of these objects. This expansion of the funerary ritual framework, lastly, led us to explore the possibility that the burials and the ritual killing of ochred pebbles may have been part of a larger set of shamanistic and feasting practices at the site during the Final Epigravettian, ideas that are amenable to testing in future excavations. While much work remains to be done at the Arene Candide, this preliminary report clearly shows the value of re-excavating reference sites, both to answer unresolved question pertaining to their specific sequence and to more generally help refine our understanding of prehistoric lifeways through the use of modern excavation and analytical methods.

Acknowledgements

We wish to express our heartfelt thanks to Valentina Borgia and Emanuela Cristiani for inviting us to participate to the Cambridge "Out of Italy" meeting where we presented a first version of this paper. We also take this occasion to thank them very kindly for their patience while we delivered the written version included in the resulting edited volume. Funding for our work at Caverna delle Arene Candide was provided by the *Programma di Conoscenza e Fruizione della Caverna delle Arene Candide* on behalf of the *Soprintendenza per I beni archeologici della Liguria,* funded by the Ministry of Cultural Goods and Tourism of Liguria, with support from the city of Finale Ligure and *Società Cava Arene Candide S.r.l.* Additional funding for the excavations at the site and the subsequent analyses was provided by Freddy S.p.A., the Social Sciences and Humanities Research Council of Canada, Université de Montréal, Arizona State University and the University of Colorado Denver. Helpful discussions on various aspects of the work presented here with Enzo Formicola, Fabio Negrino, Giuseppe Vicino and Michael Barton are gratefully acknowledged, as is the unfailing support of the Museo Archeologico del Finale and the many volunteers who participated in our project. We also gratefully acknowledge the comments of the editors and two additional anonymous reviewers who helped make this a more focused study; any errors of fact or logic remain, however, strictly ours.

References

Alhaique, F. 1994. Taphonomic analysis of the faunal remains from the "P" and "M" layers of the Arene Candide (Savona, Italy), Quaternaria Nova, IV: 263-296.

Alhaique, F., Molari, C., 2006. Nuove considerazioni sulle sepolture delle Arene Candide alla luce della revisione dei materiali conservati presso l'Istituto Italiano di Paleontologia Umana di Roma. In: Martini, F. (Ed.), La cultura del morire, origines, progetti, III. Firenze: Istituto Italiano di Preistoria e Protostoria, pp. 211-238.

Bahn, P.G. and C. Couraud, 1984. Azilian pebbles: an unsolved mystery, Endeavour, 8(4):156-8.

Biancotti, A., Motta, M., 1998. Morfotettonica dell'Altopiano delle Manie e Zone Circostanti (Liguria Occidentale). In: Suppl. Geografia Fisica Dinamica Quaternaria I, pp. 45-68.

Bietti, A., 1987. Some remarks on the new radiocarbon dates from Arene Candide cave (Savona, Italy). Hum. Evol. 2,185-190.

Bietti, A., 1994. The Upper Pleistocene deposit of the Arene Candide cave (Savona, Italy) new studies on the 1940-42 excavations. Quat. Nova. IV.

Bietti, A., Molari, C., 1994. The Upper Pleistocene deposit of the Arene Candide cave (Savona, Italy): general introduction and stratigraphy. Quat. Nova. 4,9-27.

Bietti, A., Boschian, G., Crisci, G.M., Danese, E., De Francesco, A.M., Dini, M., Fontana, F., Gianpietri, A., Grifoni, R., Guerreschi, A., Liagre, J., Negrino, F.,Radi, G., Tozzi, C., Tykot, R., 2004. Inorganic raw material economy and provenance of chipped industry in some stone age sites of northern and central Italy. Collegium Anthropologicum 28, 41-54.

Cardini, L., 1942. Nuovi documenti sull'antichità dell'uomo in Italia: reperto umano del Paleolitico superiore della Grotta delle Arene Candide. Raz. Civil. 3,5-25.

Cardini, L., 1946. Gli strati mesolitici e paleolitici della caverna delle Arene Candide. Riv. Stud. Lig. 12,29-37.

Cardini L. 1972. Dipinti schematici antropomorfi della Grotta Romanelli e su ciottoli dei livelli mesolitici della Caverna delle Arene Candide e della Grotta della Madonna a Praia a Mare. Atti della XIV Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria: 225-235

Cardini, L., 1980. La necropoli mesolitica delle Arene Candide. Mem. Ist. Ital. Paleont. Um. 3,9-31.

Cassoli, P.F. and Tagliacozzo, A., 1994. I micromammiferi dei livelli tardopleistocenici delle Arene Candide (Savona, Italia): considerazioni paleontologiche e archeozoologiche. Quaternaria Nova, IV: 101-262.

Chapman, J.C. 2000. Fragmentation in Archaeology: People, Places and Broken Objects in the Prehistory of South Eastern Europe. London: Routledge.

Chapman, J.C. and Gaydarska, B.I., 2006. Parts and Wholes: Fragmentation in Prehistoric Context. Oxford: Oxbow Books.

Couraud, C., 1985. L'art Azilien : Origine, Survivance, Editions du Centre national de la recherche scientifique, Paris.

d'Errico, F., 1994, L'art Gravé Azilien: de la Technique à la Signification, Paris: Éditions du CNRS.

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: 286-299.

Formicola, V. and Toscani, F., 2014. A Late Epigravettian skeleton of an adolescent from Arene Candide Cave (Excavations 1970-1971). Bull. Mus. Anthropol. Préhist. Monaco. 54,131-138.

Formicola, V., Pettitt, P.B., Maggi, R. and Hedges, R., 2005. Tempo and mode of formation of the Late Epigravettian necropolis of Arene Candide cave (Italy): direct radiocarbon evidence. J. Archaeol. Sci. 32,1598-1602.

Gazzoni, V. and F. Fontana, 2011. Quelle mort? Quelle vie? Pratiques funéraires et organisation sociale des chasseurs-cueilleurs de la péninsule italienne, Bulletins et Mémoires de la Société d'Anthropologie de Paris 23(1-2), 52-69.

Granato, D., 2011, Le arene candide, i livelli epigravettiani: macine ed altri strumenti per la lavorazione dell' ocra, Origini 33, 39-60.

Gravel-Miguel, C., Riel-Salvatore, J., Martino, G., Maggi, R., Rossi, S. and Sparacello, V.S., 2017. The Breaking of Ochred Pebble Tools as Part of Funerary Ritual in the Arene Candide Epigravettian Cemetery. Cambridge Archaeological Journal 27: 331-350.

Grinsell, L.V. 1961. The breaking of objects as a funerary rite. Folklore 72: 75-491.

Grosman, L., N.D. Munro, and A. Belfer-Cohen. 2008. A 12,000-year-old shaman burial from the southern Levant (Israel). Proceedings of the National Academy of Sciences 105: 17665-17669.

Hayden, B. 2003. Shamans, Sorcerers, and Saints: a Prehistory of Religion. Washington (DC): Smithsonian Books.

Hayden, B. 2009. Funerals As Feasts: Why Are They So Important? Cambridge Archaeological Journal 19:29-52.

Issel, A., 1908. Liguria Preistorica, vol. XL. Atti Società Ligure di Storia Patria, Genova.

Krumbein, W.C., 1941. Measurement and geological significance of shape and roundness of sedimentary particles, Journal of Sedimentary Research, 11(2):64-72.

MacPhail, R.I., Hater, J., Hillson, S. and Maggi, R., 1994. The Upper Pleistocene deposits at Arene Candide: soil micromorphology of some samples from the Cardini 1940-42 excavations. Quat. Nova. 4: 79-100.

Maggi, R., 1997. Arene Candide: a Functional and Environmental Assessment of the Holocene Sequence (Excavations Bernabò Brea e Cardini 1940-1950). In: Memorie dell'Istituto Italiano di Paleontologia Umana, pp. 1-643.

Maggi, R. 1997. The excavations by Luigi Bernabò Brea and Luigi Cardini of the cave of Arene Candide within the historical context of the study of Prehistory in Italy. In R. Maggi (ed.) Arene Candide: a functional and environmental assessment of the Holocene sequence (excavations Bernabò Brea-Cardini 1940-1950). Memorie dell'Istituto Italiano di Paleontologia Umana, n.s. 5, 11-30.

Maggi, R., Martino, G. and J. Riel-Salvatore. 2014. Caverna delle Arene Candide, scavi 1941-42: la scoperta del Paleolitico. In 150 Anni di Preistoria e Protostoria in Italia (A. Guidi, A. de Pascale, and M. Tarantini, eds.), pp. 433-438. Atti della XLVI Riunione Scientifica, Istituto Italiano di Preistoria e Protostoria, Florence.

Martini, F., 1992. I ciottoli dipinti di Grotta della Serratura (Salerno) osservazioni sulla cronologia e sui contesti industriali dell'arte aziliana in Italia. Atti della XXVIII riunione scientifica IIPP "L'arte in Italia dal Paleolitico all'Età del Bronzo" (Firenze 20-22 Novembre 1989). Firenze, Istituto Italiano di Preistoria eProtostoria, 261-75

Martini, F., 2012. La cultura visuale del Paleolitico e del Mesolitico in Italia. *T*emi, Linguaggi Iconografici, Aspetti Formali. Atti XLII IIPP, 17-30.

Martino, G., Riel-Salvatore, J., Maggi, R. and Rossi, S., 2011. Caverna delle Arene Candide: il sondaggio 1941-42 rivisitato. Paper presented at the 46th Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria, Rome, Italy.

Morelli, N., 1890. Resti organici rinvenuti nella caverna delle Arene Candide, Atti della Soc. Ligustica di Sc. Nat. e Geog. 1(1), 273-317

Munro, N.D., and Grosman, L., 2010. Early evidence (ca. 12,000 B.P.) for feasting at a burial cave in Israel. Proceedings of the National Academy of Sciences 107: 15362-15366.

Mussi, M., Bahn, P. and Maggi, R., 2008. Parietal art discovered at Arene Candide Cave (Liguria, Italy). Antiquity 82: 265-270.

Negrino, F., and Riel-Salvatore, J. 2018 (this volume). From Neanderthals to Anatomically Modern Humans in Liguria: the current state of knowledge. In Palaeolithic Italy: Advanced Studies on Early Human Adaptations in the Apennine Peninsula (V. Borgia & E. Cristiani, eds.), pp. 159-180. Leiden, Netherlands: Sidestone Press.

Palma di Cesnola, A. 2006. Sepolture e rituali funerari del Paleolitico superiore in Italia. In La Cultura del Morire nelle Società Preistoriche e Protostoriche Italiane : Studio Interdisciplinare dei Dati e loro Trattamento Informatico. Dal Paleolitico all'Età delRame. (F. Martini, ed.), pp. 29-45. Origines 3. Istituto Italiano di Preistoria e Protostoria, Florence.

Paoli, G., Parenti, R., Sergi, S., 1980. Gli scheletri mesolitici della caverna delle Arene Candide (Liguria). Mem. Ist. It. Paleont. Um. 3,31-154.

Pettitt, P.B., Richards, M., Maggi, R., Formicola, V., 2003. The Gravettian burial known as the Prince ("Il Principe"): new evidence for his age and diet. Antiq. 77, 15-19.

Rellini, I., Firpo, M., Martino, G., Riel-Salvatore, J., Maggi, R., 2013. Climate and environmental changes recognized by micromorphology in Paleolithic deposits at Arene Candide (Liguria, Italy). Quat. Int. 30,1-14.

Riel-Salvatore, J., Boschian, G., Formicola, V., Maggi, R., Martino, G. and Rossi, S. 2010. A revised chrono-stratigraphy for the Paleolithic sequence of Caverna delle Arene Candide, Italy. PaleoAnthropology 2010: A28.

Riel-Salvatore, J. and Gravel-Miguel, C. 2013. Upper Palaeolithic mortuary practices in Eurasia. A critical look at the burial record, in Tarlow S. and L. Nilsson Stutz (eds), The Oxford Handbook of the Archaeology of Death and Burial, Oxford University Press, Oxford, pp. 303-46

Sparacello, V.S., Rossi, S., Roberts, C., Pettitt, P., Riel-Salvatore, J. and Formicola, V., 2018. New insights on Final Epigravettian funerary behavior at Arene Candide Cave (Western Liguria, Italy). Journal of Anthropological Sciences, 96, in press.

Changing mobility patterns at the Pleistocene-Holocene transition

Lower limb biomechanics of Italian Gravettian and Mesolithic individuals

Vitale Stefano Sparacello[1,2], *Sébastien Villotte*[1], *Colin N. Shaw*[3], *Federica Fontana*[4], *Elisabetta Mottes*[5], *Elisabetta Starnini*[6], *Giampaolo Dalmeri*[7] *& Damiano Marchi*[8]

Abstract

Evidence from archaeological and anthropological research suggest major changes in human adaptations at the Pleistocene-Holocene boundary. In Western Europe, hunter-gatherers which had long-distance network and extremely high mobility in the Middle Upper Palaeolithic were forced into southerly refugia with the Last Glacial Maximum. During de-glaciation, Late Upper Palaeolithic human groups re-colonized higher latitudes and altitudes, while large coastal plains disappeared. With the Holocene, open steppe environments were replaced by forests in large portions of the continent. These changes are assumed to have impacted mobility levels in humans, which decreased in the Late Upper Palaeolithic from the extremely high levels of

1 Univ. Bordeaux, CNRS, PACEA, UMR 5199, 33616 Pessac, France. E-mail: vitale.sparacello@u-bordeaux.fr
2 Department of Archaeology. Durham University, UK.
3 McDonald Institute, University of Cambridge, UK. E-mail: cshaw111@mac.com.
4 Dipartimento di Studi Umanistici, Sezione di Scienze Preistoriche e Antropologiche, Università degli Studi di Ferrara, Italy. E-mail: federica.fontana@unife.it.
5 Provincia Autonoma di Trento, Soprintendenza per i Beni Culturali, Ufficio Beni Archeologici.
6 Dipartimento di Civiltà e Forme del Sapere, Università di Pisa, Italy. E-mail: elisabetta.starnini@unipi.it.
7 MuSe Museo delle Scienze di Trento, Italy. E-mail: giampaolo.dalmeri@muse.it.
8 Università degli Studi di Pisa, Dipartimento di Biologia, Italy. E-mail: damiano.marchi@unipi.it.

in: Borgia, V. and E. Cristiani (eds.) 2018: *Palaeolithic Italy. Advanced studies on early human adaptations in the Apennine peninsula*, Sidestone Press Academics (Leiden), pp. 357-396.

the Middle Upper Palaeolithic. With the Mesolithic, a further decrease in mobility to quasi-sedentary levels has been proposed. In this chapter, we compare the Middle Upper Palaeolithic individuals from the Grimaldi Caves (Bausu da Ture and Barma Grande, Ventimiglia, Italy) and the Mesolithic individuals from the North-Eastern Alps (Mezzocorona-Borgonuovo, Mondevàl de Sora, Vatte di Zambana, Italy) with an Upper Palaeolithic European sample and modern athletes. We suggest that femoral biomechanical properties might be influenced by differences in bone length, and used the tibia and the fibula to make inferences about mobility levels and patterns. Experimental evidence shows that the biomechanics of the tibio-fibular complex can discriminate between sedentary controls and athletes with different locomotor patterns, in particular long distance cross-country runners and field hockey players. Results show no clear differences in biomechanical patterns between the Middle and Late Upper Palaeolithic: most individuals resemble modern runners in a multivariate setting. In addition, results suggest that the levels of mechanical strains that prehistoric people were subject to largely surpassed what a modern athlete could experience. Mesolithic individuals do not appear sedentary, but all of the three individuals show pathological conditions or trauma that could have affected their gait.

Keywords: Mobility, lower limb biomechanics, Upper Palaeolithic, Mesolithic.

1. Introduction

Changes in human adaptations, including biological traits, appear to have been influenced by the major climatic shift at the end of the Last Glacial Maximum (LGM; 20,000 years BP; Clark *et al.* 2009). Previous studies on lower limb biomechanics recognized a general trend towards a reduction in mobility levels from the Mid Upper to the Late Upper Palaeolithic (Holt, 1999, 2003). However, the influence of changing mobility types and levels on the postcranium might be more complex than previously recognized (Pearson *et al.* 2014). In addition, mobility could change in more subtle ways than simply increasing or decreasing, for example when human groups change their terrain of choice for subsistence activities (Carlson and Marchi 2014; Sparacello *et al.* 2014). This chapter focuses on the Gravettian individuals from Grimaldi caves (north-western coast of Italy; Formicola and Holt 2015) and Mesolithic from Mezzocorona-Borgonuovo, Mondevàl de Sora, and Vatte di Zambana (north-east of Italy; Corrain *et al.* 1976; Guerreschi and Gerhardinger 1988; Gerhardinger and Guerreschi, 1989; Alciati *et al.* 1992; Dalmeri *et al.* 1998; Dalmeri et al. 2002; Fontana *et al.* 2016), and further investigates the issue of mobility changes as inferred from lower limb skeletal properties using a multivariate approach.

1.1. Archaeological Background

The Last Glacial Maximum (LGM; 20,000 years BP; Clark *et al.* 2009) marks the divide between the Mid Upper Palaeolithic (MUP, 30-20,000 years BP), characterized by the Gravettian techno-cultural complex (Mussi *et al.* 2000), and the postglacial, Late Upper Palaeolithic cultures (LUP, 20-10,000 years BP). The cooling peak, which actually lasted about 7,500 years (26.5 to 19,000 BP; Clark *et al.* 2009), broke what appear to have been a pan-European cultural unity (Wojtal and Wilczyński

2015a). Late Upper Palaeolithic techno-cultural complexes are characterized by the Epigravettian (Italy, Balkans and East Europe; Bietti 1990; Kozłowski 1999; Mussi 2001; Kozłowski and Kaczanowska 2004; Germonpré *et al.* 2008; Farbsteing *et al.* 2012) and the Magdalenian complexes (western and central Europe; Straus, 2012). Temperatures began to rise steadily only from about 16,000 BP (Mussi 2001), albeit with significant oscillations (Straus, 1995; Ravazzi *et al.* 2007). The precise dating of the Pleistocene-Holocene boundary is problematic (Lowe and Walker, 2000), but is conventionally placed at 10,000 BP [*e.g.*, Mangerud *et al.*, 1974; or c. 11,700 yr b2k (before AD2000; Walker *et al.* 2009) using polar ice cores]. The various techno-cultural complexes comprised between the last Upper Palaeolithic cultures and the diffusion of the Neolithic "package" between 8-5,000 BP (Bogucki 1996, 2000, 2001; Zvelebil 2008) are generally called "Mesolithic".

Parallel to the major environmental changes that occurred all over Europe during glaciation and deglaciation, shifts in subsistence practices took place alongside cultural diversification and fragmentation. The culturally-homogeneous Gravettian world appears to have focused on hunting mid- to large-size ungulates, from the mammoths of central and eastern Europe (Wojtal and Wilczyński 2015b) to mainly red deer and ibex in peninsular Italy (Mussi 2001). Climatic deterioration forced human groups into southern refugia, where they had to intensify exploitation of existing resources and increasingly acquire high-cost/low-yield resources, such as marine and freshwater fish, shellfish, and birds (Straus *et al.* 1981; Clark and Straus 1986; Stiner *et al.* 1999; Mussi 2001). After the LGM, the arid glacial steppe gradually gave way to a more varied environment, with an increase in the presence of trees culminating into the mesophyll Holocenic forest (Gamble 1986; Davies *et al.* 2003; Ravazzi *et al.*, 2007; Magri, 2008). While coastal plains shrank and disappeared, high mountain ranges become accessible, and entire portions of the continent could be recolonized (Mussi 2001). The Italian peninsula, due to its complex geomorphology, presented a variety of niches for human adaptation, from coastal lagoons and marshes to hillsides and mountains (Mussi 2001). North of the Alps, the environment between 16,000 and 13,000 years BP was still mostly one of steppes where herds of reindeer, bison, and horse thrived (Gamble 1986). However, the herds of megafauna such as mammoths and woolly rhinos had mostly disappeared and large mammal biomass was reduced (Delpech 2003).

Subsistence practices of Late Upper Palaeolithic human groups reflect increased ecological diversity: hunting of megafauna endured in those areas where it survived (Germonpré *et al.*, 2008), but mostly the exploitation of both freshwater or marine and terrestrial resources continued (Stiner and Munro 2011; Gazzoni *et al.* 2012; Mannino *et al.* 2011a). Depending on the local ecologies, in some areas the terrestrial (Cassoli and Tagliacozzo 1994; Richards *et al.* 2000; Craig *et al.* 2010; Stevens *et al.* 2010; Mannino *et al.* 2011b) or the marine/freshwater component (Richards at al. 2005) became predominant, anticipating what happened in the Mesolithic (about 10-5,000 BP), where at coastal sites in the Baltic, UK, Portugal, and France, up to 100% protein in the diet is supposed to have derived from sea (Mannino and Thomas 2001; Schulting and Richards 2001; Richards *et al.* 2005; Zvelebil 2008). The explanation provided for this shift is that expanding groups of reindeer hunters rapidly turned to marine and freshwater resources in those areas, such as the Baltic, where river estuaries, vast intertidal areas, and high sea productivity make it advantageous (Zvelebil 2008).

In the Mediterranean, Mesolithic groups continued a less specialized, mixed terrestrial/marine-freshwater subsistence (Stiner and Munro 2001; Mannino *et al.* 2011a, 2012), which appears to have included high-altitude hunting in the Alpine and Apennine areas (Fontana *et al.* 2009; Moore 2014; Fontana and Visentin, 2016).

Multidisciplinary archaeological studies suggest a shift from a European continent homogeneously inhabited by mobile hunters with vast territories and long-distance procurement and exchange networks (Hahn 1987; Rensink *et al.* 1991; Scheer 1993; Féblot-Augustin 1999; Mussi *et al.* 2000; Negrino and Starnini 2010), *i.e.* the "open system" (cfr Gamble 1986), to a more fragmented, diverse array of subsistence modes and smaller catchment areas (Price 1985; 1987; Woodman 1985; Straus 1995, 1996; Grimaldi 2006; Zvelebil 2008; Negrino and Starnini 2010; Biagi and Starnini 2015; Fontana and Visentin, 2016). This shift is reflected in the postcranial skeletal adaptations and patterns of enthesopaties in those populations, which on average display skeletal traits linked to extreme mobility in the Mid-Upper Palaeolithic, and show evidence of decreased mobility in the Mesolithic (Holt 1999, 2003; Holt *et al.* 2000; Holt and Formicola 2008; Villotte 2011; Shaw and Stock 2013). Among those skeletal traits, we explore structural adaptations of the lower limb bones, mainly related to patterns of cortical buttressing of the diaphysis, which are studied via biomechanical techniques (Holt 2003; Carlson and Marchi 2014).

1.2. Biomechanical background

It is generally recognized that human bone tissue responds dynamically to bending stresses and strains to optimize itself to its mechanical environment. Cross-sectional geometry (CSG) is a biomechanical technique that studies the change in size and shape of long bones cross sections in response to activity, including mobility patterns (for reviews see Pearson and Lieberman 2004; Ruff *et al.* 2006b; Carlson and Marchi 2014; and references therein). The rationale is that high terrestrial mobility will increase the frequency, stressfulness, and amount of antero-posteriorly directed loading, and therefore bending, of bones in the lower limb, which will lead to increased strength and high "shape indices" at midshaft diaphysis. Shape indices are the ratios between the antero-posterior (I_x) and medio-lateral (I_y) bending rigidity calculated from the cross section (in the tibia, I_{max}/I_{min} is used, *i.e.* the ratio between the maximum and minimum bone rigidity; Ruff and Hayes 1983). Femoral I_x/I_y is considered so highly correlated with mobility patterns to be normally referred to as a "mobility index" (Carlson and Marchi 2014). Accordingly, highly mobile hunter-gatherers, including Mid-Upper Palaeolithic humans, generally show higher values of femoral shape ratios (I_x/I_y and I_{max}/I_{min}) than sedentary agriculturalists (*e.g.* Ruff and Hayes 1983; Ruff 1987, 1999; Larsen 1995; Stock and Pfeiffer 2001; Holt 2003; Ruff *et al.* 2006a; Sládek at al. 2006a,b; Marchi 2008; Marchi *et al.* 2011; Sparacello *et al.* 2014).

The reliability of femoral CSG shape for making inferences about mobility was partially undermined by the suggestion that body proportions may significantly influence the amount of medio-lateral loading on midshaft femur (Ruff 1995). Low-latitude populations with relatively narrow hips, such as the Gravettian people (Holliday 1995, 1997, 2002) would therefore experience less medio-lateral strains than wide-hipped, cold-adapted, high-latitude people. Given the shift towards broader body proportions that is apparent between the Mid Upper and the Late Upper Palaeolithic (Holliday

1995, 1997, 2002), researchers suggested that the extremely high femoral shape indices of the earlier group might have been in part due to their narrower bodies, in addition to their higher mobility. Some evidence for this relationship was found by Ruff *et al.* (2006a); in a bioarchaeological sample spanning from the Mid Upper Palaeolithic to the Bronze Age, they found that broader bodies resulted in a greater increase in medio-lateral bending strength in the femur relative to the tibia. However, Pearson *et al.* (2014) did not find the same result, which calls for further verifications. Despite this possible confounding factor acting on femoral shape, this variable continues to be used to make inferences about mobility, with the caveat that body proportions should be similar among groups being compared (*e.g.* Sparacello *et al.* 2014).

A relationship between mobility and the shape of the tibia has been proposed from the beginning of the application of CSG methods, with platycnemic tibiae indicating greater antero-posterior exertion (Lovejoy *et al.* 1976; Ruff and Hayes 1983). Accordingly, experimental evidence shows that cross-country runners have increased antero-posterior buttressing of the tibia compared to sedentary people (Shaw and Stock, 2009). In contrast, several bioarchaeological studies could not find a consistent correspondence between tibial shape (as revealed by I_{max}/I_{min} ratio) and presumed changes in mobility levels (Stock and Pfeiffer 2001; Holt 2003; Marchi 2008; Marchi *et al.* 2011). Contrary to theoretical expectations, the correlation between femoral and tibial shape indices is weak at best (Pearson *et al.* 2014). In addition to the influence of body proportions, several explanations has been proposed for this discordance, including different phases of sensitivity to mobility in the leg and thigh bones during ontogeny, with tibial sections being more influenced by mobility in adulthood (Pearson *et al.* 2014). Moreover, the tibia is possibly more influenced by medio-lateral bending loads generated by frequent swerving and/or walking on uneven substrata (Carlson *et al.* 2005; Demes *et al.* 2006; Carlson and Judex 2007; Marchi 2007; Marchi and Shaw 2011; Marchi *et al.* 2011), leading to low shape indices even in a context of high mobility. Again, experimental evidence supports this idea, showing similarly shaped tibiae in field hockey players and sedentary controls, despite the higher mobility of the former (Shaw and Stock 2009). However, field hockey players have significantly more robust tibiae overall, suggesting that high mobility and frequent change of direction buttressed the tibia in both the antero-posterior and medio-lateral direction (Stock 2006; Shaw and Stock 2009; Marchi and Shaw 2011). Among prehistoric groups, similarly leg loading patterns may have been caused by mobility in highly uneven and mountainous terrains (Marchi *et al.* 2011; Higgins 2014).

In addition, the tibia does not exert its mechanical function in isolation, but together with the fibula. Marchi and Shaw (2011) analysed fibular robusticity and tibio-fibular ratios (fibular robusticity divided by tibial robusticity) in university varsity athletes and controls, in order to assess whether fibular properties are influenced by the intensity and type of mobility (*i.e.* straight line movement vs. frequent changes of direction). Results showed a trend of increased fibular diaphyseal robusticity from controls to runners to field hockey players, with a significant difference between field hockey players and controls. Moreover, relative tibio-fibular ratio were significantly greater in hockey players compared to runners. The authors concluded that fibular robusticity and relative fibula/tibia robusticity may reflect adaptation to patterns of mobility that incorporate high degrees of foot eversion and inversion. Sparacello *et* *al.* (2014) applied this framework to bioarchaeological groups with various level of presumed mobility (from Pleistocene hunters to Medieval agriculturalists) in different terrain (mountainous and plain) and found that groups settled in mountainous areas had robust fibulae and greater tibio-fibular ratios regardless of mobility levels. The authors proposed that traversing uneven terrains might generate high levels of medio-lateral loadings and foot eversion/inversion, resulting in a tibio-fibular complex similar to field hockey players. This model has been supported by recent bioarchaeological research on Jomon hunter-gatherers (Hagihara and Nara, 2016).

Overall, biomechanical studies of human groups with different mobility levels and types evidence the complexity of the functional adaptation of the lower limb, which is not completely understood, but also the potential for gaining information on past subsistence patterns from the concomitant analysis of femoral, tibial, and fibular biomechanics.

1.3. Purpose of this study

In this chapter, we will further explore two issues regarding presumed changes in mobility levels and types at the Pleistocene-Holocene boundary through the comparison between lower limb biomechanical properties of prehistoric humans with modern varsity athlete samples and sedentary controls (Shaw and Stock 2009; Marchi and Shaw 2011). We will employ a multivariate approach to determine which CSG variables, or combination of variables, characterize the locomotor patterns of different athletes and sedentary individuals, and then apply this framework to make inferences about past mobility.

The first presumed mobility change is the decrease in mobility between the Mid-Upper and the Late Upper Palaeolithic. Based on a decrease in the femoral shape index I_x/I_y (significant in females), Holt (1999, 2003) proposed that levels of activity involving large amounts of running and walking reduced substantially in the Late Upper Palaeolithic. Holt (1999, 2003) suggested that Late Pleistocene human groups, forced into southerly refugia by the LGM, reduced their territories and intensified the exploitation of low-rank resources, resulting in a net decrease of high-mobility tasks. However, most of the Late Upper Palaeolithic skeletons available are from post-13,000 years BP (Riel-Salvatore and Gravel-Miguel 2013), a time of human expansion and re-colonization of the continent (Mussi 2001). Another change which might have had an impact on mobility patterns is the re-colonization of the mountains and the disappearance of the coastal plains with de-glaciation (Lambeck *et al.* 2012). However, a recent re-assessment of changes in femoral shape between the Mid and Late Upper Palaeolithic using additional data found no significant difference between the two periods (Trinkaus, 2015). In addition, no significant change in tibial CSG was detected in previous studies (Holt 1999, 2003), which goes against what is expected on the basis of experimental evidence (Shaw and Stock 2009; Marchi and Shaw 2011).

The first part of the analysis involves a re-assessment of the diachronic changes in structural adaptations and their possible link with mobility levels and types by: 1) further testing whether changes in femoral shape might be due to body proportions, in addition to mobility levels; 2) applying a multivariate approach which includes the tibia and fibula, to verify whether a signal of changes in mobility levels or types between periods is detectable. Changes in mobility levels will be inferred by using the differences in postcranial adaptations between runners and sedentary controls as a model. Changes in mobility types will be evaluated using the differences between cross-country runners (long-distance running in a straight line) and field hockey players (high foot inversion/eversion due to frequent swerving), which we will use as a proxy for hunting on plain or mountainous areas. Given that comparative samples come from mixed terrains, we will further investigate the above issues by factoring out terrain, and considering only diachronic samples coming from the same geographical area, *i.e.* Liguria (northern Italy).

Second, we will test the presumed further reduction in mobility in the Mesolithic, which led to femoral midshaft sections approaching circularity (Holt 1999, 2003). Most of the skeletal series included in previous studies belong to groups settled along the Atlantic and Baltic coasts (Holt 1999; 2003). We consider here three individuals from the north-eastern Italian Alps (Mezzocorona-Borgonuovo, Mondevàl de Sora, Vatte di Zambana), whose groups appear to have practiced a subsistence based on seasonal high-mountain hunting (Fontana *et al.* 2009, 2011). We predict that their lower limb functional adaptations should reflect a subsistence patterns of high mobility in a rugged terrain, and therefore be comparable to the ones shown by contemporary field hockey players (Sparacello *et al.* 2014).

2. Materials and Methods

2.1. The sample

Biomechanical data have been collected from the femur, tibia, and fibula, as available, of five Mid Upper Palaeolithic individuals from Barma Grande (BG 2, 5, and 6, preserved at the museum Museo Preistorico Nazionale dei Balzi Rossi, Ventimiglia; Formicola *et al.* 2004) and Bausu da Ture (BT 1 and 2, preserved respectively at the Musée Lorrain, Nancy, and currently under study at the University of Bordeaux, and at the Musée d'Archéologie Nationale, Saint-Germain-en-Laye; Villotte and Henry-Gambier, 2010; Villotte *et al.* 2011), which are part of the Grimaldi cave complex (Ventimiglia, north-western Italy; Mussi 1986a,b, 1996, 2001; Formicola and Holt 2015). We could not access individuals discovered in other Grimaldi caves (Grotta del Caviglione and Grotte des Enfants); their data derives from the literature and does not include the fibula (Table 1). Three Mesolithic individuals from the north-east of Italy were included: Mondevàl de Sora from the Veneto region (preserved in the Museo Civico Della Val Fiorentina Vittorino Cazzetta, Selva di Cadore, Belluno), Mezzocorona-Borgonuovo (preserved at the Ufficio Beni Archeologici di Trento) and Vatte di Zambana (preserved at MUSE Museo delle Scienze, Trento) from the Trentino region. The three individuals constitute the totality of the Mesolithic skeletal series from northern Italy. The distribution of the sites included in this study is mapped in Figure 1.

For Bausu da Ture, cross-sections were extracted from CT-scans using Avizo 8.1 and Netfabb basic, and CSG properties were calculated using a version of the program SLICE (Nagurka and Hayes 1980) adapted as a macro routine inserted in Scion Image release Beta 4.03. For Barma Grande, Mezzocorona-Borgonuovo, Mondevàl de Sora, and Vatte di Zambana, periosteal contours were reconstructed via 3D structured-light scanning (DAVID® SLS-2), and CSG properties were calculated using the AsciiSection

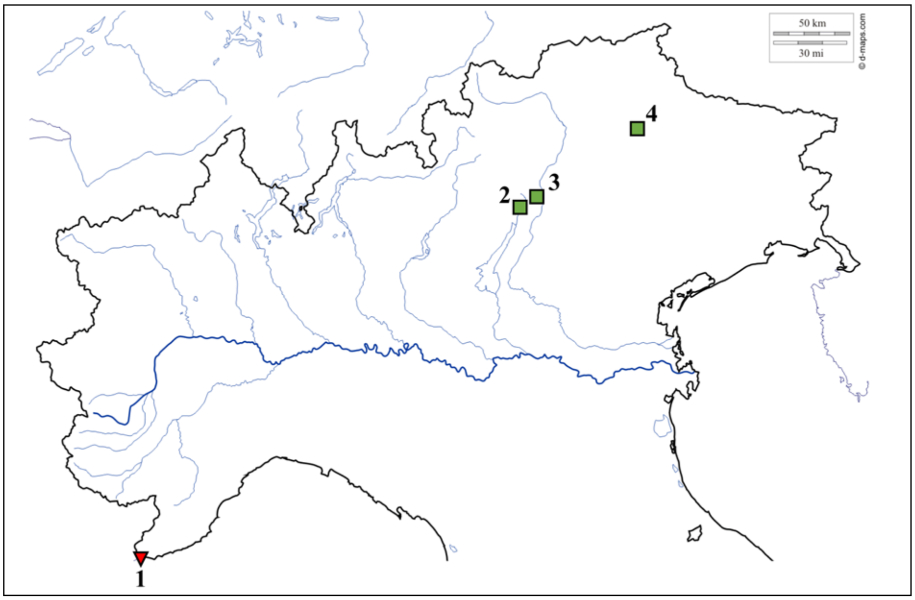


Figure 1. Geographic collocation of the Grimaldi cave complex (1: Bausu da Ture and Barma Grande), Vatte di Zambana (2), Mezzocorona-Borgonuovo (3), and Mondevàl de Sora (4). Map template from http://www.d-maps.com/carte.php?num_car=5891&lang=en.

software (Davies *et al.* 2012) on "solid sections", *i.e.* without reconstructing the medullary cavity (see below).

The comparative samples include six prehistoric and historic groups, and three modern skeletal series. Bioarchaeological samples include 36 Mid Upper Palaeolithic, 26 Late Upper Palaeolithic, 51 Mesolithic, 35 Neolithic, 52 Iron Age, and 26 medieval individuals (Table 1). The modern samples include 15 field hockey players (referred to as "hockey players"), 15 cross-country runners (referred to as "runners"), and 21 sedentary control individuals (Shaw and Stock, 2009). As in previous research, two additional individuals practicing rugby were included in the hockey players' sample, given the similarity of the movements involved in the two sports (Marchi and Shaw 2011; Sparacello *et al.* 2014). The total number of individuals is therefore 279, although the sample size for each analysis may vary based on the availability of skeletal elements for each individual.

2.2. Cross-sectional geometry

The methodology used to calculate the CSG properties for each sample is detailed in the references listed in Table 1. They include the Latex Cast (O'Neill and Ruff 2004) or the SolidCSG Methods (Sparacello and Pearson 2010; Marchi *et al.* 2011) (Table 1). When periosteal CSG was calculated, "hollow bone" CSG properties (*i.e.* taking into account the area of the medullary cavity) were estimated using regression equations (Sparacello and Pearson 2010; Marchi *et al.* 2011). This method has been proven to reasonably approximate actual CSG data when bi-planar radiographs or computed tomography are not feasible options (Stock and Shaw 2007; Davies at al. 2012). Finally, for some individuals for which only midshaft diameters were available, CSG was cal-

Cultural Period	N	Individuals	Data Source
Mid Upper Palaeolithic	Total: 36; Males: 22; Females: 8; Undetermined Sex: 6.	Barma Grande 2, 5, 6; Bausso da Ture 1, 2; Barma del Caviglione 1; Cro Magnon 1 (4296), 2 (4293), 4322, 4324, 4330, 4333; Dolní Věstonice 3, 13, 14, 16, 35; Grotte des Enfants 4, 5; La Rochette; Mladeč 27; Nahal 'En-Gev 1; Paglicci 25; Parabita 1, 2; Paviland 1; Pavlov 1; Předmostí 1, 3, 4, 5, 9, 10, 14; Sunghir 1, 4.	Vernau, 1906; Matiegka, 1934; Pearson, 1997; Holt, 1999; Sládek *et al.*, 2000; Trinkaus and Ruff, 2012; Trinkaus *et al.*, 2014; this study.
Late Upper Palaeolithic	Total: 26; Males: 19; Females: 7.	Arene Candide 2, 3, 4, 5, 10, 12; Bichon; Cap Blanc; Chancelade; Gough's Cave; Grotte des Enfants 3; Lafaye; Neuessing 2; Oberkassel 1, 2; Riparo Continenza; Riparo Tagliente; Rochereil; Romito 3, 7, 8; Romanelli 1; San Teodoro 1, 4; Saint-Germain-de-la-Rivière 4; Villabruna.	Holt, 1999; Sparacello *et al.*, 2014, 2015; this study.
Mesolithic	Total: 51; Males: 34; Females: 17.	Birsmatten; Blocksbjerg 251; Bottendorf; Culoz 1, 2; Dragsholm A, B; Gramat 1; Hoëdic 1, 2, 4, 5, 6, 8, 9, 10; Holmegaard; Koelbjerg; Korsor Glas; Le Rastel; Loschbour; Melby; Mezzocorona-Borgonuovo; Mondevàl de Sora; Moita de Sebastiao 1, 2, 3, 7, 9, 18, 31; Sejerø; Téviec 1, 3, 4, 7, 8, 9, 11, 16; Unseburg; Uzzo 2, 5, 7; Vaegensø; Vatte di Zambana; Vedbæk 2, 3, 5, 10.	Holt, 1999; this study.
Neolithic	Total: 35; Males: 22; Females: 13.	Arene Candide 2 (Tinè), 6 Pe, 7 Pe, 8 Pe, IV Pe, VI Pe; III Roma, IV Roma; V Roma; VIII Fin; IX Fin; XII Fin, XIII Fin; Arma dell'Aquila I, II, III, V; Bergeggi 2, 3, 4, 5; Boragni 1, 2; Arma del Morto III; Pollera 1, 10, 12, 13, 14, 22, 30, 32, 33, 6246; Tana I.	Marchi *et al.*, 2006, 2011; Marchi, 2008; Sparacello and Marchi, 2008; Sparacello *et al.*, 2011, 2014.
Iron Age	Total: 52; Males: 35; Females: 17.	Alfedena 1, 4, 5, 6, 8, 9, 10, 18, 19, 21, 37, 40, 41, 49, 53, 65, 66, 67, 68, 69, 70, 73, 76, 79, 82, 83, 84, 88, 89, 90, 91, 93, 97, 98, 102, 105, 109, 110, 113, 114, 115, 116, 118, 119, 121, 122, 124, 126, 127, 128, 130, 132.	Sparacello *et al.*, 2011, 2014.
Medieval	Total: 26; Males: 14; Females: 12.	Neuburg M_109, M_111, M_126_97, M_166A, M_167, M_169, M_170, M_171, M_172, M_175, M_176, M_181, M_189, M_202, M_48_26, M_61, M_65_57, M_75, M_80, M_88, M_B21, M_B26, M_B28, M101_73, Z_24, Z_98.	Marchi, 2004; Sparacello *et al.*, 2014.

Table 1. The bioarchaeological samples employed in this study, and the references used for published data.

culated using regression equations (Pearson *et al.* 2006; Pearson and Sparacello 2017). The CSG variables considered in this study are the second moment of area (SMAs) of the femur, tibia, and fibula. SMAs are indicated with the letter I, and are proportional to bending rigidity of a cross section with reference to an axis. I_x is the bending rigidity with reference to the x axis (antero-posterior, or AP bending rigidity); I_y is the bending rigidity with reference to the y axis (medio-lateral, or ML bending rigidity); I_{max} is the maximum rigidity of a section; I_{min} is the minimum bending rigidity of a section. The cross-sectional variable Z_p (section modulus) is used here to evaluate overall bone rigidity in both the tibia and the fibula. Z_p is calculated by raising the polar second moment of area (J) to the power of 0.73 (Ruff 1995, 2000). J is proportional to the torsional rigidity of a bone and is calculated as the sum of two perpendicular SMAs.

Mechanical loading of long bones is a function of physical activity, bone length, and body mass (Ruff, 2000). To control for body size, and therefore identify behaviourally significant differences in bone rigidity (*i.e.* the "robusticity"), Z_p was divided by bone mechanical length and body mass (Ruff 2000, 2002). Given that the tibia and fibula act as a complex, the mechanical length of the tibia was used to standardize both tibial and fibular J (Sparacello *et al.*, 2014). SMAs (I_x, I_y, I_{max}, I_{min}) were standardized by raising them by the power of 0.73 and dividing by the product of bone mass and bone length, obtaining scaled Z_x, Z_y, Z_{max}, and Z_{min} for each bone (Tables 2-4).

Body mass was estimated from the superoinferior diameter of the femoral head following the guidelines in Trinkaus and Ruff (2012). According to Trinkaus and Ruff (2012), the three available sets of formulae for body mass estimation (all from recent humans) are differentially appropriate for individuals of contrasting body sizes. Briefly, the formula from McHenry (1994) should be used for individuals with femoral head superoinferior diameters of <38 mm; an average of the estimates from McHenry (1992), Ruff *et al.* (1991), and Grine *et al.* (1995) is advisable for individuals whose femoral head diameter is between 38 and 47 mm; data resulting from an average of Ruff *et al.* (1991) and Grine *et al.* (1995) are recommended for individuals whose femoral head diameter exceeds 47 mm.

Given the fragmentary nature of some fossil specimens, some approximations and estimation of measurements were necessary. In most cases, the approximation involved the estimation of the length of one lower limb segment from another via period-specific regression equations. Those equations generally had high predictive power, with r^2 ranging from 0.73 to 0.96. In some Mid Upper Palaeolithic individuals (Barma Grande 5, Bausu da Ture 1 and 2, Cro Magnon 2, Cro Magnon 4330) the femoral head was missing or damaged. Details on the estimation methods are provided in Table 5. The reliability of the results based on those estimations will be discussed below.

Regarding shape indices femoral I_x/I_y (ratio of SMAs calculated about ML and AP planes) was reported in Table 2, while, for the tibia, I_{max}/I_{min} (ratio of the maximum and minimum SMA) was reported in Table 3. The choice of using different indices evaluating the deviation of the section from circularity is due to the fact that – although the direction of tibial maximum bending rigidity is always antero-posterior in adult age (Gosman *et al.* 2013) – the tibia is usually more problematic to position, and small changes in orientation of a very elliptical section may significantly affect I_x/I_y, making results less reliable. In fact, most studies use I_{max}/I_{min} for the tibia. In the femur, I_x/I_y is preferred because the direction of maximum bending rigidity might be medio-laterally oriented in the femur, especially in sedentary samples (Sparacello, 2013). However, the index I_x/I_y of the tibia was calculated and used to test previous research (see below). In order to evaluate the degree of fibular involvement during mobility, the relative fibular robusticity was calculated as 100 × (J fibula/J tibia) (Marchi and Shaw, 2011). Shape indices and relative fibular robusticity are derived from unstandardized data.

Given the stepwise nature of the analysis, more details on the statistical methodology are given in the results. We first verified whether CSG indices correlated with bone length, in order to assess which bone segment is less likely to be influenced by differences in body proportions. Then, using the athlete samples from Shaw and Stock (2009) and Marchi and Shaw (2011), we determined which CSG variables (among tibial and fibular Imax, Imin, Zp, shape Imax/Imin, and fibular robusticity relative to the tibia J_{FIB}/J_{TIB}) best discriminate between known mobility patterns and types using a multivariate discriminant function approach. We applied the forward and backward stepwise method of inclusion of variables offered by the statistical packages SPSS and Statistica, but we also proceeded empirically by trying different combination of variables, as suggested by applied statisticians given the well-known limits of the stepwise approach (*e.g.* Huberty, 1989; Snyder, 1991). The choice of the model was based on the statistical significance of the distance between centroids, on the absence of multicollinearity (the value of tolerance should not be close to 0), and on the classification results. Using the best discriminant model, we calculated the canonical scores for prehistoric individuals, in order to determine how they compare to athletes and sedentary individuals.

Statistical analysis was performed using SPSS 21, Statistica 10, and Minitab 17.

3. Results

Tables 2-5 report the values for the CSG variables, osteometric measurements, and body size included in this study for the new Mid Upper Palaeolithic and Mesolithic individuals, as well as the sample statistics for the comparative samples (SMAs are size-standardized). Mid Upper Palaeolithic individuals from Liguria display all the hallmarks of a group with extremely high levels of mobility: they show among the highest femoral shape indices (Table 2); their tibia are robust and with a high shape index as well (Table 3); they are similar to runners in having fibulae that tend to be relatively gracile compared to the tibiae (Table 4). However, Bausu da Ture 2 has a low tibial shape index despite showing the highest femoral shape index in the sample. Similar discrepancies are present in the Mesolithic individuals. The expectation that they would be similar to hockey players is met by the two females, Mezzocorona-Borgonuovo and Vatte di Zambana, who show high tibio-fibular ratios (Table 4). However, both females show a rather gracile tibia when scaled to body size, which is a characteristic of non-mobile samples (*e.g.* the Medieval or the control sample, Table 3). The male from Mondevàl de Sora shows a very low tibio-fibular ratio, which makes it similar to runners (Table 4). However, he also shows a very low tibial shape, typical of sedentary samples (Table 3). When considering the femur, we would conclude that Mondevàl de Sora and Vatte di Zambana were highly mobile, while Mezzocorona-Borgonuovo is similar to the comparative Mesolithic sample. Given those incongruences between conclusions based on single bones, we attempt to improve the interpretation by finding the best discriminant variables between samples with known mobility. We begin by determining whether the proximal or distal segment of the lower limb are affected by body proportions.

3.1. Correlation of femoral and tibial cross-sectional geometry with body size and proportions

The correlation between femoral and tibial shape indices (femoral I_x/I_y and tibial I_{max}/I_{min}) is significant ($p<0.05$) but weak ($r=0.19$; $r^2=0.04$; $n=152$; when using femoral and tibial I_x/I_y there is no significant correlation: $p=0.92$; $n=89$). The significance is probably mainly due to the fact that cross sections tend to be antero-posteriorly oriented in both the femur and the tibia, but there appears to be no correspondence between the degree of deviation from circularity in the two limb segments, as also seen in previous studies (Pearson *et al.* 2014).

In order to evaluate differences in mediolateral buttressing of the femur compared to the tibia with changing body shape, we attempted to replicate the results of Ruff *et al.* (2006a). Figure 6 in Ruff *et al.* (2006a, p. 97) shows the ratios of femoral-to-tibial M-L (Z_y) and A-P (Z_x) bending strengths, relative to pelvic bi-iliac breadth/stature in a sample spanning from the Mid Upper Palaeolithic to the Bronze Age Europe (n=21). Bending strengths were size-standardized. The authors

Individual	Period	Sex		Z_x			Z_y			Z_p			I_x/I_y	
Barma Grande 2	MUP	M		69.69			49.57			99.42			1.59	
Barma Grande 5	MUP	M		-			-			-			-	
Barma Grande 6	MUP	M		99.36			63.16			136.06			1.86	
Bausu da Ture 1	MUP	M		94.98			57.93			128.19			1.97	
Bausu da Ture 2	MUP	M		99.42			59.48			133.33			2.02	
Mezzocorona-Borgonuovo	MESO	F		58.92			51.92			91.94			1.19	
Mondevàl de Sora	MESO	M		72.02			57.12			107.31			1.37	
Vatte di Zambana	MESO	F		51.39			39.95			75.95			1.41	
			n	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**
	MUP	M	10	70.52	19.09	10	52.02	10.24	15	100.11	20.73	16	1.42	0.21
	MUP	F	6	71.16	14.42	6	55.70	6.41	9	109.7	17.29	8	1.37	0.21
	MUP	IND	3	58.99	12.56	3	42.09	10.16	3	84.28	18.69	4	1.61	0.13
	LUP	M	19	69.82	7.76	19	56.92	7.03	19	105.38	10.16	19	1.35	0.25
	LUP	F	7	62.36	10.24	7	54.86	7.06	7	97.36	13.66	7	1.19	0.18
	MESO	M	24	63.39	9.86	24	58.8	8.75	24	101.41	14.43	32	1.16	0.2
	MESO	F	10	58.70	6.92	10	55.45	8.55	10	94.75	11.84	15	1.1	0.18
	NEOL	M	13	66.43	11.44	13	54.13	8.96	18	103.66	15.81	19	1.36	0.19
	NEOL	F	10	62.42	10.07	10	54.85	5.9	13	98.32	11.06	13	1.22	0.19
	IRONAGE	M	27	62.81	7.66	27	61.9	8.77	27	103.38	12.75	27	1.03	0.14
	IRONAGE	F	15	54.43	10.18	15	56.94	11.25	15	92.35	16.95	15	0.95	0.15

Table 2. Size-standardized femoral CSG data of the Italian Middle Upper Palaeolithic (MUP) and Mesolithic (MESO) individuals studied here, and of comparative samples. Other acronyms: IND: undetermined sex; LUP, Late Upper Palaeolithic; NEOL, Ligurian Neolithic; IRONAGE, Iron Age from Alfedena.

Individual	Period	Sex		Z_{max}			Z_{min}			Z_p			I_{max}/I_{min}	
Barma Grande 2	MUP	M		96.88			39.06			116.91			3.41	
Barma Grande 5	MUP	M		140.81			63.20			173.75			3.00	
Barma Grande 6	MUP	M		123.11			57.15			153.22			2.86	
Bausu da Ture 1	MUP	M		99.67			54.38			129.81			2.29	
Bausu da Ture 2	MUP	M		89.72			56.39			122.34			1.89	
Mezzocorona-Borgonuovo	MESO	F		66.53			31.07			82.95			2.83	
Mondevàl de Sora	MESO	M		90.1			63.13			127.81			1.63	
Vatte di Zambana	MESO	F		60.62			32.57			78.59			2.34	
			n	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**
	MUP	M	12	76.86	17.45	12	35.99	7.96	12	95.82	20.33	13	2.91	0.64
	MUP	F	5	80.05	26.20	5	45.12	13.47	5	105.02	33.15	7	2.25	0.26
	MUP	IND	1	109.59		1	56.75		1	140.54		2	2.42	0.06
	LUP	M	17	83.98	10.04	17	39.93	6.59	17	105.39	11.16	17	2.70	0.76
	LUP	F	5	75.63	6.46	5	45.00	3.84	5	101.28	8.43	5	1.95	0.17
	MESO	M	21	83.38	16.78	21	42.17	8.64	21	106.20	20.37	27	2.37	0.51
	MESO	F	8	72.44	15.51	8	37.00	7.9	8	92.6	19.39	10	2.33	0.39
	NEOL	M	18	87.2	12.37	18	45.11	6.70	18	111.82	14.96	19	2.53	0.42
	NEOL	F	13	74.81	8.40	13	40.96	6.17	13	97.51	11.16	13	2.33	0.44
	IRONAGE	M	33	74.48	8.37	33	41.51	6	33	97.62	10.77	33	2.27	0.37
	IRONAGE	F	14	63.28	14.03	14	38.73	6.49	14	85.54	16.51	14	1.96	0.43
	MEDGER	M	14	64.51	10.49	14	40	5.47	14	87.59	12.84	14	1.93	0.29
	MEDGER	F	12	56.56	10.94	12	37.45	6.75	12	78.61	14.00	12	1.78	0.34
	HOCKEY	M	17	70.16	7.47	17	39.46	4.71	17	92.27	9.33	17	2.22	0.26
	RUNNERS	M	15	81.05	8.63	15	41.11	5.73	15	103.4	10.1	15	2.60	0.5
	CONTROL	M	21	65.13	8.17	21	36.12	4.05	21	85.28	9.7	21	2.26	0.28

Table 3. Size-standardized tibial CSG data of the Italian Middle Upper Palaeolithic (MUP) and Mesolithic (MESO) individuals studied here, and of comparative samples. Other acronyms: IND: undetermined sex; LUP, Late Upper Palaeolithic; NEOL, Ligurian Neolithic; IRONAGE, Iron Age from Alfedena; MEDGER, Medieval from Germany; HOCKEY: hockey players; RUNNERS: cross-country runners; CONTROL: sedentary controls.

Individual	Period	Sex		Z_{max}			Z_{min}			Z_p			I_{max}/I_{min}			J_{FIB}/J_{TIB}	
Barma Grande 2	MUP	M		10.19			6.5			13.97			1.85			5.45	
Barma Grande 5	MUP	M		20.25			10.98			26.32			2.31			7.54	
Barma Grande 6	MUP	M		15.5			6.63			18.9			3.20			5.69	
Bausu da Ture 1	MUP	M		-			-			-			-			-	
Bausu da Ture 2	MUP	M		11.62			6.45			15.22			2.24			5.75	
Mezzocorona-Borgonuovo	MESO	F		14.32			7.53			18.45			2.41			12.75	
Mondevàl de Sora	MESO	M		7.96			6.22			11.79			1.40			3.82	
Vatte di Zambana	MESO	F		10.66			6.17			14.15			2.11			9.55	
			n	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**
	MUP	M		-			-			-			-			-	
	MUP	F		-			-			-			-			-	
	MUP	IND		-			-			-			-			-	
	LUP	M	11	12.47	3.18	11	7.1	1.57	11	16.47	3.59	11	2.24	0.74	10	7.55	2.26
	LUP	F	2	15.81	3.71	2	8.67	2.15	2	20.72	1.80	2	2.54	1.58	2	10.32	0.37
	MESO	M		-			-			-			-			-	
	MESO	F		-			-			-			-			-	
	NEOL	M	15	11.31	2.43	15	7.48	1.93	15	15.73	3.30	16	1.85	0.51	15	7.04	1.77
	NEOL	F	7	10.68	2.55	7	6.07	0.90	7	14.11	2.88	7	2.19	0.45	7	7.29	1.99
	IRONAGE	M	21	10.04	2.59	21	6.21	1.33	21	13.64	3.06	21	1.99	0.55	21	7.04	2
	IRONAGE	F	8	9.14	2.99	8	5.31	1.98	8	12.16	4.03	8	2.19	0.58	8	7.08	1.56
	MEDGER	M	14	7.31	1.71	14	5.07	0.99	14	10.35	2.08	14	1.69	0.43	14	5.45	1.32
	MEDGER	F	12	7.15	2.22	12	4.99	1.53	12	10.13	3.1	12	1.65	0.23	12	6.2	2.21
	HOCKEY	M	17	8.94	2.09	17	5.28	1.29	17	11.97	2.51	17	2.22	0.77	17	6.18	1.72
	RUNNERS	M	15	8.68	2.26	15	4.88	1.38	15	11.44	2.72	15	2.39	0.89	15	4.91	1.23
	CONTROL	M	21	7.74	1.80	21	4.61	1.20	21	10.38	2.30	21	2.21	0.98	21	5.70	1.72

Table 4. Size-standardized fibular CSG data of the Italian Middle Upper Palaeolithic (MUP) and Mesolithic (MESO) individuals studied here, and of comparative samples. Other acronyms: IND: undetermined sex; LUP, Late Upper Palaeolithic; NEOL, Ligurian Neolithic; IRONAGE, Iron Age from Alfedena; MEDGER, Medieval from Germany; HOCKEY: hockey players; RUNNERS: cross-country runners; CONTROL: sedentary controls.

Individual	Period	Sex	Body Mass (kg)			Femoral HSI (mm)			Femoral Mechanical Length (mm)			Tibial Mechanical Length (mm)			Bi-iliac breadth		
Barma Grande 2	MUP	M		81.8			52.7			499			413			292	
Barma Grande 5	MUP	M		85			54[1]						385				
Barma Grande 6	MUP	M		69.7			47.6			472[2]			400[3]				
Bausu da Ture 1	MUP	M		78			51[4]			457[2]			385[5]				
Bausu da Ture 2	MUP	M		73			49[6]			458[7]			383[2]				
Mezzocorona-Borgonuovo	MESO	F		56.6			41.5			361			297.5			259.5	
Mondevàl de Sora	MESO	M		72.6			48.8			428			346			278.5	
Vatte di Zambana	MESO	F		64.3			45			425			360[8]				
			n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
	MUP	M	16	69.01	9.45	12	47.67	3.69	16	438.56	37.71	12	379.59	24.04	5	276.8	13.7
	MUP	F	9	63.18	7.16	7	44.90	2.80	9	413.08	31.42	5	356.48	18.42	2	279.6	0.6
	MUP	IND	4	69.10	5.41	1	46.5		3	436.67	37.98	3	345.71	30.79			
	LUP	M	19	69.18	6.43	17	47.80	2.47	19	410.67	21.81	18	348.77	19.97	10	274.3	17.9
	LUP	F	7	61.68	8.94	6	43.78	4.13	7	391.64	17.38	5	337.90	18.42	4	268.3	13.7
	MESO	M	24	63.64	5.85	15	46.16	2.55	29	396.53	19.89	29	336.61	19.83	3	269.3	6.7
	MESO	F	10	58.63	4.92	7	42.91	2.43	12	380.16	15.82	12	318.71	16.17	1	244.0	
	NEOL	M	19	63.34	6.44	19	45.21	2.64	18	399.22	21.78	19	335.31	18.34	5	261.8	18.3
	NEOL	F	13	52.54	5.83	13	39.94	2.24	13	371.18	21.98	13	311.16	17.25	5	250.8	12.0
	IRONAGE	M	35	69.02	5.88	35	47.47	2.33	27	425.35	13.48	33	351.03	15.77			
	IRONAGE	F	17	62.03	4.26	17	43.91	1.79	15	400.37	20.02	14	324.50	12.70			
	MEDGER	M	14	75.84	6.80	14	48.78	2.42				14	350.71	22.16			
	MEDGER	F	12	65.01	5.85	12	44.27	2.39				12	324.50	26.42			
	HOCKEY	M	17	75.53	11.42							17	367.76	29.11			
	RUNNERS	M	15	68.21	5.90							15	386.47	28.24			
	CONTROL	M	21	69.72	11.38							21	383.45	16.36			

Table 5. Osteometrics and body proportions of the Italian Middle Upper Palaeolithic (MUP) and Mesolithic (MESO) individuals studied here, and of comparative samples. Other acronyms: IND: undetermined sex; Femoral HSI: femoral head supero-inferior diameter LUP, Late Upper Palaeolithic; NEOL, Ligurian Neolithic; IRONAGE, Iron Age from Alfedena; MEDGER, Medieval from Germany; HOCKEY: hockey players; RUNNERS: cross-country runners; CONTROL: sedentary controls. [1] Estimated from tibial plates area following regression equations in Trinkaus (2009). [2] Estimated using the regression equation between tibial and femoral length calibrated on the rest of the MUP sample (r^2 = 0.74). [3] Estimated by comparison of right (distal) and left (proximal) fragments of the same individual, which largely overlap at midshaft. [4] Estimated using a regression based on femoral lateral condyle AP diameter using 40 modern femora (r^2 = 0.886; Trinkaus and Ruff, 2012). [5] Proximal portion missing; length estimated by comparison with BG5, whose nutrient foramen lies at the same level when the distal articular surfaces are placed as the same level. [6] Estimated using a regression based on femoral lateral condyle height and breadth, and femoral neck diameters using 40 modern femora (r^2 = 0.886; Trinkaus, pers. comm.). [7] The medial condyle is damaged and was virtually reconstructed in 3D for measurement by using the distal portion of BT1 femur. [8] Estimated from femoral length using the regression equation calibrated on the rest of the MESO sample (r^2 = 0.76). For some Upper Palaeolithic and Mesolithic comparative individuals, body mass derives from a modified version of the "cylindrical method" based on femoral length (Holt, 1999). This explains the discrepancy between the number of estimates of body mass and the number of available femoral head or bi-iliac breadth measurements.

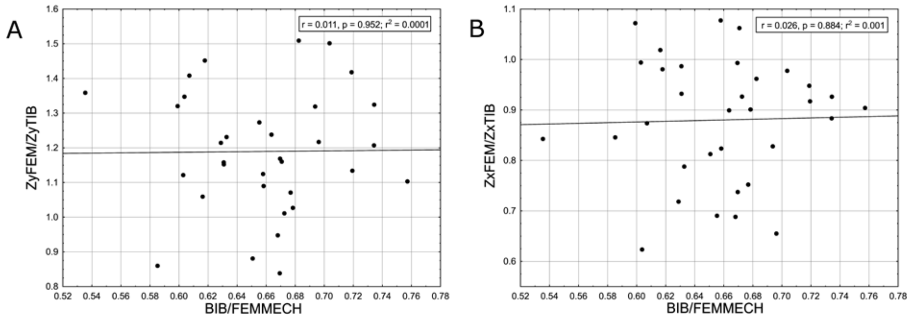


Figure 2. Relationship between femoral-to-tibial relative strengths (section moduli/bone length) and body shape (bi-iliac breadth/femoral length) in the available comparative sample (n=33; MUP: Barma Grande 2, Dolní Věstonice 14, 16, Grotte des Enfants 4, Parabita 1, 2, Paviland 1; LUP: Arene Candide 2, 3, 4, 5, Bichon, Cap Blanc 1, Gough's Cave, Riparo Continenza, Romito 7, 8, San Teodoro 4, Saint-Germain-de-la-Rivière 4; MESO: Hoëdic 8, Mezzocorona-Borgonuovo, Mondevàl de Sora, Téviec 11, 16; NEOL: Arene Candide 7 Pe, 8 Pe, EVI Pe, Arma dell'Aquila 1 Fin, 5 Fin, Pollera 12, 14, 30, 33). Least square regression parameters and fitting line are shown in the plot. (A) Femoral/tibial relative medio-lateral bending strength (ZyFEM/ZyTIB) vs. bi-iliac breadth/femoral length (BIB/FEMMECH). (B) Femoral/tibial relative antero-posterior bending strength (ZxFEM/ZxTIB) vs. bi-iliac breadth/ stature (BIB/FEMMECH). Femoral length is femoral mechanical length (Ruff, 2002).

note that: "(…) theoretically, M-L bending strength should be more dependent on pelvic (body) proportions more proximally in the lower limb, *i.e.*, in the femur, while A-P bending strength should show no such locational dependence" (Ruff *et al.* 2006a, p. 96). Their results supported this prediction: the greater the relative pelvic breadth, the greater the increase in M-L bending strength of the femur relative to the tibia (r= 0.420, p=0.058), while there was not a similar relationship between bi-iliac breadth/stature and femoral/tibial relative A-P bending strength (r=0.090, p=0.70). We used a similar sample spanning from the Mid Upper Palaeolithic to the Neolithic (n=33) but we could not replicate Ruff et al (2006a) results. Figure 2 shows the ratios of femoral-to-tibial M-L (Z_y) and A-P (Z_x) bending strengths (standardized) against bi-iliac breadth (BIB) and femoral maximum length (as a proxy for stature). Both anteroposterior and mediolateral differential buttressing of the femur and tibia do not appear to be influenced by body proportions. When samples are divided by sex, as done in Ruff et al (2006a), results are not significant in either males (n=22; for femoral/tibial Z_x ratio: r=0.021, p=0.926; r^2=0.0004; for femoral/tibial Z_y ratio: r= 0.026, p= 0.908; r^2=0.001) or females (n=11; for femoral/tibial Z_x ratio: r=-0.009, p=0.978; r^2=0.0001; for femoral/tibial Zy ratio: r=-0.003, p= 0.993; r^2=0.00001). Using the ratios of femoral-to-tibial minimum (Z_{min}) and maximum (Z_{max}) bending strengths allows for the addition of four more individuals with preserved BIB and both segments of the lower limb (Mid Upper Palaeolithic: Caviglione 1; LUP: Villabruna; Mesolithic: Gramat 1; Neolithic: Arene Candide IX Fin). However, no difference in the results can be appreciated, both when using the femoral/tibial Z_{max} ratio and femoral/tibial Z_{min} or the femoral Z_x/tibial Z_{max} ratio and femoral Z_y/tibial Z_{min} ratio. Therefore, according to our results, differences in body shape (long-limbed and narrow-waist Mid Upper Palaeolithic vs broad-bodied post LGM people) do not

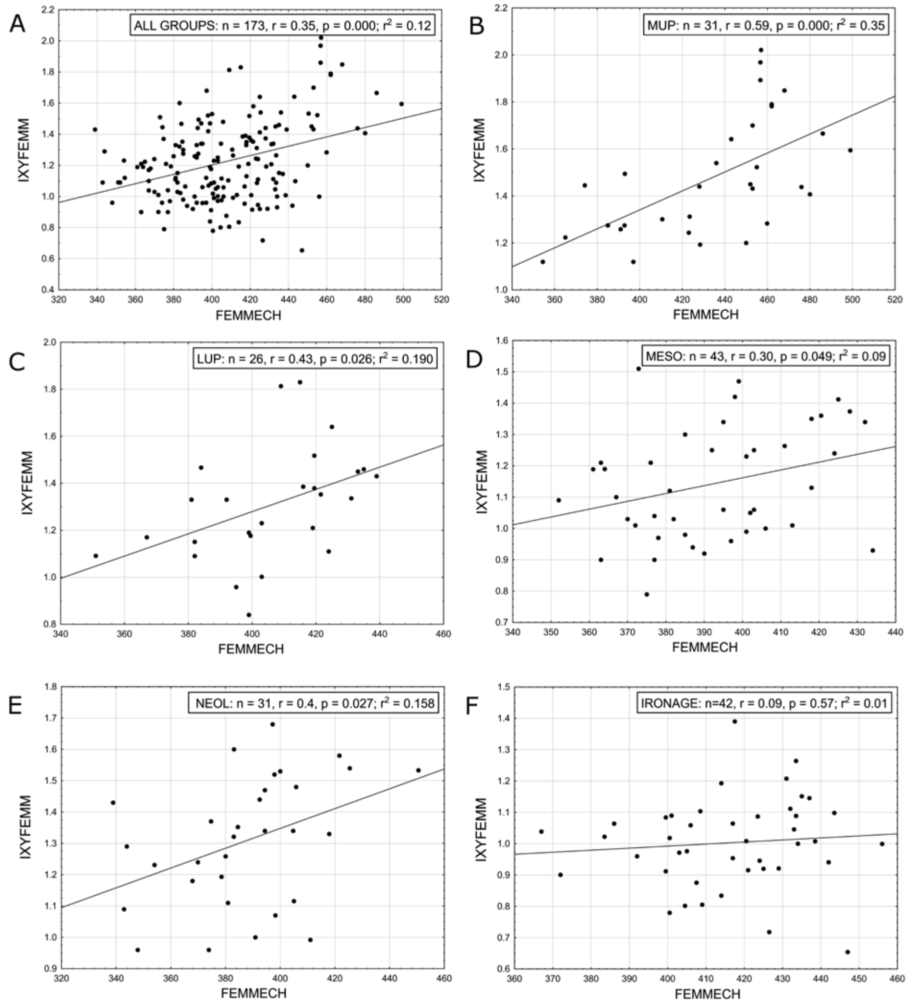


Figure 3. Relationship between femoral shape index I_x/I_y (IXYFEM; ration between antero-posterior and medio-lateral bending moment) and femoral mechanical length (length' in Ruff, 2002) in the pooled bioarchaeological sample (A) and in the subsamples based on period (B-F). Sex is pooled. Least square regression parameters and fitting line are shown in the plot.

appear to appreciably influence the medio-lateral loading of the femur. However, it should be noted that a larger sample size would be needed to better address this issue.

There is another factor that might link the extremely high femoral shape indices of Mid Upper Palaeolithic people with body proportions in addition to high mobility. In our results, the femoral shape index I_x/I_y positively correlates with femoral length (Figure 3; femoral mechanical length was used to maximize sample size, see Ruff 2002); this is true in the pooled sample (Fig. 3A), and in all prehistoric samples except the Iron Age people (Fig. 3B-F). Interestingly, the strength of the correlation appears to increase with the presumed level of mobility of the sample, with the most "sedentary" sample, *i.e.* the Iron Age one, showing no correlation. This correlation is not driven by differences among samples in body proportions and mobility-induced

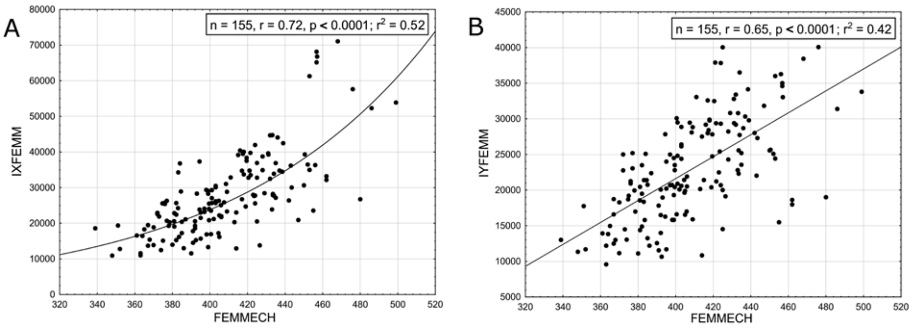


Figure 4. Relationship between (A) the antero-posterior femoral bending moment I_x (IXFEM) and femoral mechanical length (length' Ruff, 2002); (B) the medio-lateral femoral bending moment I_y (IYFEM) and femoral mechanical length (FEMMECH; Ruff, 2002). Least square regression parameters are shown in the plot and refer to the linear regression. The fitting line in A is exponential.

femoral shape (*i.e.* tall and narrow-bodied Mid Upper Palaeolithic people also happen to be the ones with higher mobility and therefore higher shape indices), because it is present also within groups. It could be, however, partially driven by the concomitance of sexual dimorphism in size and differences in mobility levels between sexes, *i.e.* the fact that males tend to have longer femora and higher shape indices than females. In the male only sample, the correlation is still positive and significant in the Mid Upper Palaeolithic (n=20, r=0.487, $p<0.05$, $r^2=0.237$), but it is significant only at the $p<0.1$ level in the Late Upper Palaeolithic (n=19, r=0.42, p=0.07, $r^2=0.177$), and in the Mesolithic (r=0.356, p=0.06, $r^2=0.127$). The correlation does not appear to be due to increased ML buttressing in broad-bodied people, but might be related to a stronger correlation between length and I_x when compared to length and I_y (Fig. 4). In addition, the relationship between femoral length and I_x appears better fitted by an exponential curve (as done in Fig. 4A). A similar result is found when correlating unstandardized Z_x and Z_y with bone length and estimated body mass (*i.e.* when scaling section moduli by body size, n=151): although the relationship is highly significant in both cases ($p<0.0001$), the correlation is stronger (r=0.767 versus r=0.693) and has greater predictive power ($r^2=0.59$ vs $r^2=0.48$) when considering SMAs in the antero-posterior axis (however slopes are not significantly different). It is possible that body size, and in particular bone length might contribute in shaping femoral midhaft shape. It should be noted, however, that results often become non-significant when subsamples are created based on period and sex. This is probably due to low sample size, but might indicate that results are influenced by sexual dimorphism and behavioural differences in mobility between sexes.

Contrary to the femur, there is no correlation between tibial length and tibial I_x/I_y, in the pooled sample (n=90, p=0.72) or by group. There is a weak but significant positive correlation (n = 160, r=0.19, $p<0.05$) between tibial length and tibial I_{max}/I_{min}, but with little predictive power ($r^2=0.04$). Therefore, tibial CSG shape appears to be less influenced than femoral by the length of the bone, and might be a better reflection of functional adaptations to mobility. We explore this possible relationship by analysing the tibio-fibular complex of athletes with known mobility levels and types in a multivariate setting.

3.2. Multivariate analysis to discriminate between locomotor patters of athletes and controls

We used the athlete samples from Shaw and Stock (2009) and Marchi and Shaw (2011), and included all CSG variables (tibial and fibular Imax, Imin, Zp, shape Imax/Imin, and fibular robusticity relative to the tibia J_{FIB}/J_{TIB}) in a discriminant analysis. Despite the significant differences in the mean of tibial and fibular polar moment of area between field hockey players and controls (T-test $p<0.05$; Shaw and Stock 2009; Marchi and Shaw 2011), we could not find a multivariate model that could discriminate between those two groups. In fact, the maximum distance between the centroids of the field hockey and controls we obtained was $0.1<p<0.05$, while the distance of the runners' centroid from both was always highly significant. Since sample size was probably an issue, we created a larger sedentary sample (n=47; total sample size n=79) by pooling the controls sample with the Medieval sample, which had low mobility levels (Marchi 2007; Sparacello *et al.* 2014) and whose individuals predominantly (17/26) classified as controls in this model.

With this setting, we obtained four models that were able to discriminate among the three mobility groups (significant distance between centroids). The best discriminant model based on the correct post-hoc classification of the initial cases includes tibial and fibular Z_{max} and Z_{min} (4 variables, Table 6). However, the classification power is not high overall (65.8%), and only about half of the hockey players and sedentary cases are correctly classified. The overlap between hockey players and sedentary samples is apparent in the plot of the individual scores for the two canonical discriminant functions displayed in Figure 5.

Function 1 explains 93.3% of the variance in the samples; it positively correlates with tibial Z_{max} (r=0.879), and tibial Z_{min} (r=0.299). It appears to discriminate between samples with high mobility on the right, and low mobility on the left (Figure 5). Function 2 explains the remaining 6.8% of the variance and correlates mainly with fibular Z_{max} (r=0.940) and Z_{min} (r=0.599). Although the centroids are much closer along the y axis, this function appears to discriminate groups with high levels of stressful eversion/inversion of the foot, as expected given the known mobility patterns described above and the involvement of the fibula in this types of loads (Marchi *et al.* 2011; Marchi and Shaw 2011; Sparacello *et al.* 2014). When the discriminant functions are applied to the prehistoric samples, the individuals classify as in Table 7.

Samples for which high mobility levels are commonly presumed due to their subsistence patterns (MUP and LUP, but also the Ligurian NEOL, see Marchi *et al.* 2006, 2011) classify as runners or hockey players. All of the MUP individuals classify as runners, except for Bausu da Ture 2, which classifies as hockey player, like all the Mesolithic individuals. Individuals classified as sedentary become frequent only with the Iron Age, as expected from the passage to a settled agriculture (Sparacello *et al.* 2011).

The scatter plot of the canonical scores provides a better visualization of where the prehistoric individuals fall in the multivariate plane (Fig. 6). It can be noticed how the prehistoric individuals scatter well beyond the range of the modern samples, both along Function 1 (which we suggest discriminate between mobility levels) and Function 2 (which we suggests correlates with stressful eversion/inversion of the foot). Despite the overlap between groups, the distribution of prehistoric individuals seems to be consistent both with their presumed subsistence patterns, and is coherent

Input Variables	Selection of variables	Variables in the model	Box's M	p-value	Tolerance	Wilks' Lambda	Distance between centroids: Runners-Hockey	Distance between centroids: Runners-Sedentary	Distance between centroids: Sedentary-Hockey	Classification of cases (%)[1]: Runners	Classification of cases (%)[1]: Hockey	Classification of cases (%)[1]: Sedentary	Classification of cases (%)[1]: Total
Z_{max} TIB Z_{max} FIB Z_{min} TIB Z_{min} FIB Z_p TIB Z_p FIB I_{max}/I_{min} TIB I_{max}/I_{min} FIB J_{FIB}/J_{TIB}	stepwise forward	Z_{max} TIB Z_{min} FIB I_{max}/I_{min} TIB Z_p FIB	NS	P<0.001 P=0.196 P=0.187 P=0.250	0.664 0.305 0.776 0.284	P<0.001	P<0.01	P<0.001	P<0.05	86.7	52.94	61.7	64.6
	stepwise backward	Z_p TIB	NS	P<0.001	1	P<0.001	P<0.01	P<0.001	P<0.05	73.3	35.3	61.7	58.2
	empirical	Z_{max} TIB Z_{max} FIB Z_{min} TIB Z_{min} FIB	NS	P<0.001 P=0.210 P=0.258 P=0.123	0.515 0.626 0.546 0.575	P<0.001	P<0.01	P<0.001	P<0.05	93.3	52.9	61.7	65.8
	empirical	Z_p TIB I_{max}/I_{min} TIB Z_p FIB	NS	P<0.001 P<0.01 P=0.082	0.822 0.913 0.794	P<0.001	P<0.01	P<0.001	P<0.05	80.0	52.9	59.6	62.0
	ratios only	I_{max}/I_{min} TIB I_{max}/I_{min} FIB J_{FIB}/J_{TIB}	NS	P<0.001 P=0.342 P<0.05	0.959 0.987 0.971	P<0.001	P<0.01	P<0.001	P=0.191	80.0	41.2	57.4	58.2

Table 6. Summary of the discriminant models between runners, hockey players, and sedentary samples based on tibial (TIB) and fibular (FIB) CSG variables. Models obtained via automated stepwise methods are listed, as well as models based on empirical selection of variables. [1] Percentage of individuals correctly classified in their group when applying the discriminant equations.

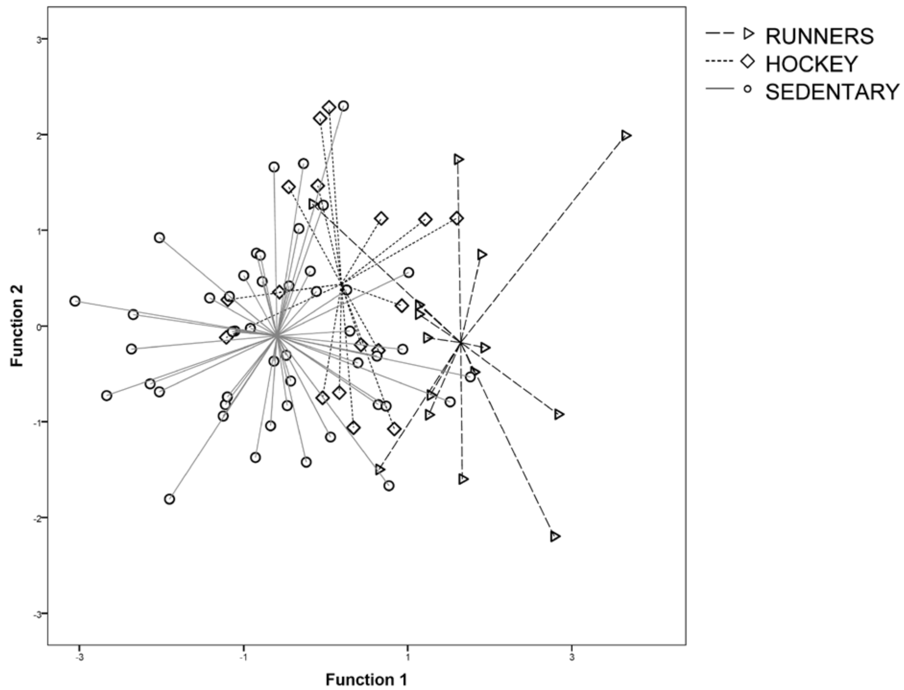


Figure 5. Scatter plot of the canonical scores for the discriminant analysis between varsity athletes and controls. Variables included in the model: Z_p of the tibia and fibula, I_{max}/I_{min} of the tibia. The spikes departing from each point converge towards the centroid of each group. HOCKEY: Hockey players; RUNNERS: Cross-country runners; SEDENTARY: modern control sample and Medieval people.

Period	RUNNERS	HOCKEY	SEDENTARY	TOT
MUP	3	1	0	4
LUP	8	4	0	12
MESO	0	3	0	3
NEOL	9	11	2	22
IRONAGE	5	18	6	29
HOCKEY	2	9	6	17
RUNNERS	14	1	0	15
SEDENTARY	6	12	29	47

Table 7. Classification of bioarchaeological cases using the discriminant function created using varsity athletes and sedentary people (variables included in the function: Zmax TIB, Zmax FIB, Zmin TIB, Zmin FIB, see table 6). MUP: Middle Upper Palaeolithic; LUP: Late Upper Palaeolithic; MESO: Mesolithic; NEOL: Neolithic from Liguria; IRONAGE: Iron Age from Alfedena, central Italy; HOCKEY: Hockey players; RUNNERS: Cross-country runners; SEDENTARY: modern control sample and Medieval people; FEM: femur; TIB: tibia; FIB: fibula.

with our interpretation of the discriminant functions. Only Iron Age individuals fall within the area occupied exclusively by sedentary individuals (in grey in Figure 6), and it is again an Iron Age individual which falls beyond that area on the bottom left corner. Prehistoric groups with increasingly high levels of mobility in a mountainous terrain (NEOL and LUP) occupy the areas delimited by hockey players and runners, and fall in many cases beyond those, but in directions that are consistent with higher mobility levels and higher levels of foot eversion/inversion. The most extreme individuals are the MUP Barma Grande 5 and 6, mainly due to them having the highest levels of robusticity (size-standardized Z_{max} and Z_{min}) in both the tibia and the fibula in the whole pooled-periods sample. Based on the biomechanical adaptations of the tibio-fibular complex, it appears that, in the past, the levels of terrestrial mobility and mediolateral loading (due to frequent change of directions, mobility in mountainous areas, high-impact loading; Rantalainen *et al.* 2010; Marchi and Shaw 2011; Marchi *et al.* 2011; Sparacello *et al.* 2014) could have far surpassed what can be experienced by contemporary college student athletes (see also Shaw and Stock 2013).

However, as explained in the Materials and Methods section, some body mass estimates for Mid Upper Palaeolithic individuals were calculated from femoral head diameters estimated via regression equations. Given that the discriminant analysis includes size-standardized Z_p values, the position of those individuals in Figure 6 might not reflect actual mobility-induced postcranial adaptations. We therefore ran a discriminant analysis on the athlete samples by analysing only variables not dependant on body size standardization, *i.e.* the shape indices I_{max}/I_{min} of the tibia and fibula, and the relative (to the tibia) fibular robusticity J_{FIB}/J_{TIB}. As in the previous analysis, sedentary controls and medieval people were pooled (Table 6). The two discriminant functions included the three variables above (a stepwise analysis would not exclude any variable). Function 1 mainly correlates with the shape of the tibia (I_{max}/I_{min} r=0.912), and explains most (92.8%) of the variance in the sample. The remaining 7.2% is explained by the second function, which correlates with relative fibular robusticity (J_{FIB}/J_{TIB} r=0.835). Therefore, the discriminant function appear to correlate with similar structural adapta-

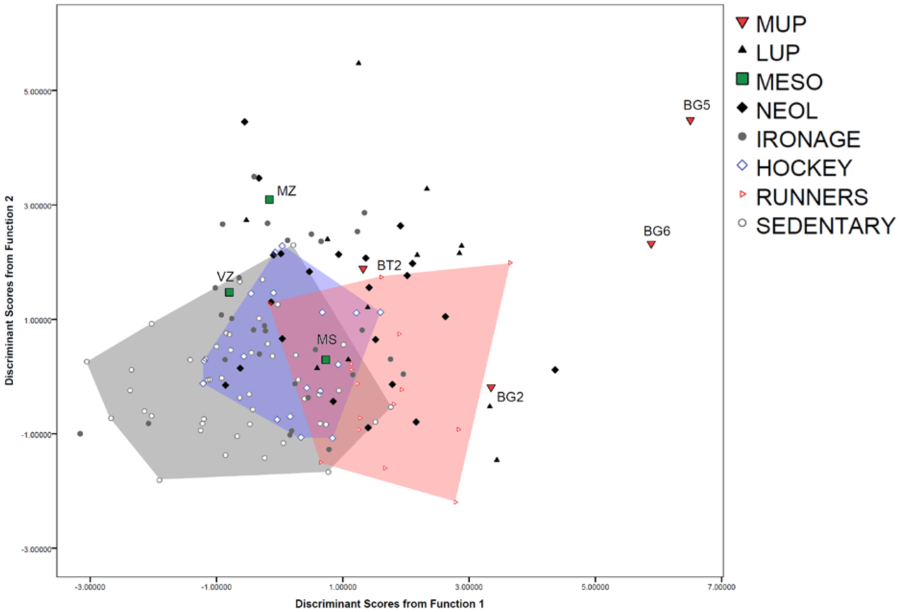


Figure 6. Scatter plot of the canonical scores for the best discriminant analysis model between varsity athletes and sedentary people, with the scores obtained for the prehistoric samples. Variables included in the model: Z_p of the tibia and fibula, I_{max}/I_{min} of the tibia. Convex hulls indicate the area of the varsity athletes' and controls' scores (grey: sedentary; blue: hockey players; red: runners). MUP: Mid Upper Palaeolithic; LUP: Late Upper Palaeolithic; MESO: Mesolithic; NEOL: Neolithic from Liguria; IRONAGE: Iron Age from Alfedena, central Italy; HOCKEY: Hockey players; RUNNERS: Cross-country runners; SEDENTARY: modern control sample and Medieval people. Labelled individuals are: BG, Barma Grande; BT, Bausu da Ture; MZ, Mezzocorona-Borgonuovo; MS, Mondevàl de Sora; VZ, Vatte di Zambana.

tions of the tibio-fibular complex, *i.e.* increased AP loading (function 1) and increased foot eversion-inversion (function 2). However, the classification power of this analysis is lower (58.2% of original grouped cases classified correctly; n=79), and the distance between the centroids is significant between hockey players and runners ($p<0.01$) and runners and sedentary controls ($p<0.001$), but not between sedentary controls and hockey players ($p=0.19$). Therefore, the inferences based on this analysis are more tentative than for the previous. Nevertheless, the Mid Upper Palaeolithic individuals again fall within the range of runners, albeit Bausu da Ture 2 is in an area of overlap between the three samples and classifies as sedentary (Fig. 7). The discriminant functions classify Barma Grande 2, 5, and 6 as runners, but this time none of them appears to be an outlier. Indeed, the extreme scores obtained in the previous analysis were mainly due to robusticity rather than shape. Among the Italian Mesolithic individuals, Mondevàl de Sora changed significantly its position, and here falls within the sedentary range, mainly due to his low tibial shape index (1.63, Table 3).

Finally, we performed the analysis by considering only the Ligurian individuals spanning from the Mid Upper Palaeolithic to the Neolithic. When considering the commonly used CSG mobility correlates, the significant decrease in femoral shape index from the Mid Upper to the Late Upper Palaeolithic contrasts with a concomitant increase in tibial

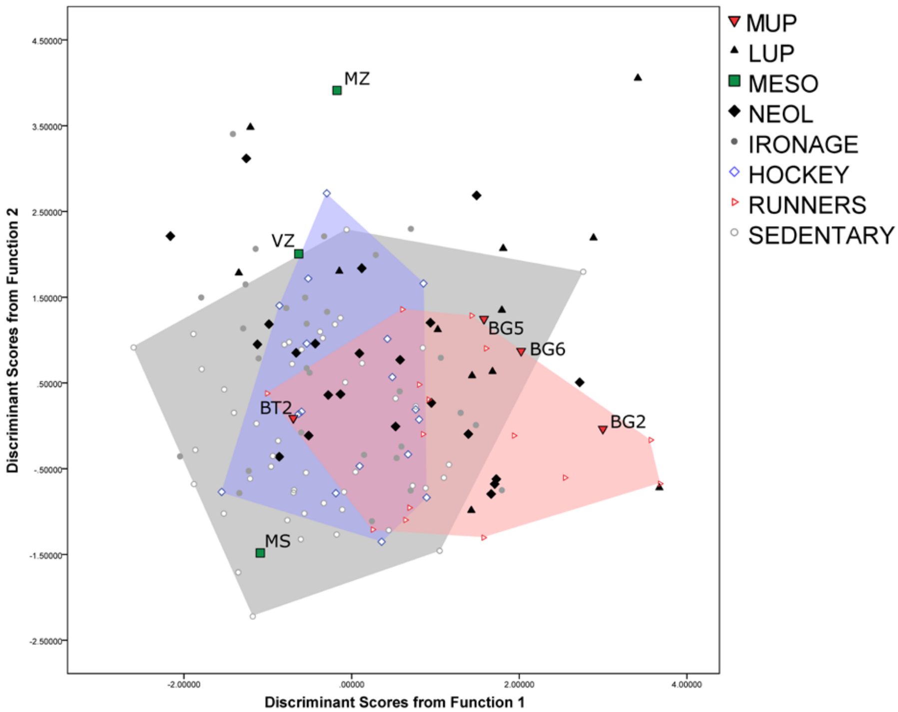


Figure 7. Scatter plot of the canonical scores for the discriminant analysis between varsity athletes and sedentary people, with the scores obtained for the prehistoric samples. Only ratios were used in this analysis: I_{max}/I_{min} of the tibia and fibula, and relative fibular robusticity J_{FIB}/J_{TIB}. Convex hulls indicate the area of the varsity athletes' and controls' scores (grey: sedentary; blue: hockey players; red: runners). MUP: Mid Upper Palaeolithic; LUP: Late Upper Palaeolithic; MESO: Mesolithic; NEOL: Neolithic from Liguria; IRONAGE: Iron Age from Alfedena, central Italy; HOCKEY: Hockey players; RUNNERS: Cross-country runners; SEDENTARY: modern control sample and Medieval people. Labelled individuals are: BG, Barma Grande; BT, Bausu da Ture; MZ, Mezzocorona-Borgonuovo; MS, Mondevàl de Sora; VZ, Vatte di Zambana.

shape index, which is tipical of runners (Table 8). In addition, Mid Upper Palaeolithic individuals have significantly longer lower limbs, which may have played a role in the shaping of their femoral section (see above). To characterize the samples in a multivariate setting, we applied the two discriminant functions described above, calculated the canonical scores, and plotted the results in Figure 8. In addition, we calculated the posterior probabilities for the individuals of belonging to the runners, hockey players, or sedentary category (Table 9). When considering the number of individuals falling in each category, there is no apparent change between the Mid and Late Upper Palaeolithic samples: both are composed by individuals falling predominantly in the runners category. It is only with the Neolithic that individuals fall mainly in the hockey players group. On the other hand, it could be noticed that posterior probabilities of belonging to the runners category are lower in the Late Upper Palaeolithic sample when compared to the Mid Upper Palaeolithic (Table 8), and that individuals of the two period do not cluster together in the plots of canonical scores (Fig. 8).

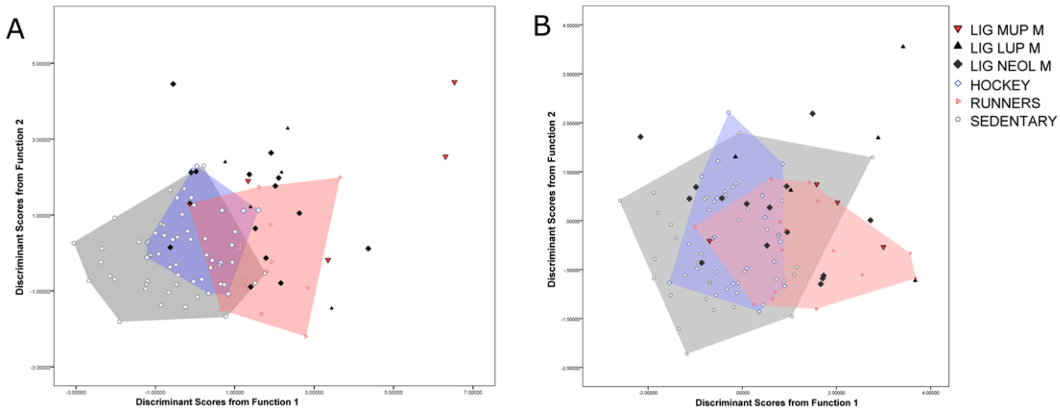


Figure 8. Scatter plot of the canonical scores for the discriminant analysis between varsity athletes and sedentary people, with the scores obtained for the Ligurian prehistoric samples. (A) Variables included in the model: Z_p of the tibia and fibula, I_{max}/I_{min} of the tibia. (B) Variables included in the model: I_{max}/I_{min} of the tibia and fibula, and relative fibular robusticity J_{FIB}/J_{TIB}. LIG: Ligurian; MUP: Mid Upper Palaeolithic; LUP: Late Upper Palaeolithic; NEOL: Neolithic; HOCKEY: Hockey players; RUNNERS: Cross-country runners; SEDENTARY: modern control sample and Medieval people.

	Ligurian MUP M			Ligurian LUP M			Ligurian NEOL M			Post-Hoc Tukey's HSD		
Variable	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**MUP-LUP**	**MUP-NEOL**	**LUP-NEOL**
Z_p Femur	5	120	20	6	99.06	9.76	18	103.66	15.81	0.1<p<0.05	NS	NS
I_x/I_y Femur	5	1.82	0.19	6	1.21	0.18	19	1.36	0.19	p<0.001	p<0.001	NS
Z_p Tibia	6	132.90	29.19	5	103.29	6.86	18	111.82	14.96	p<0.05	p<0.05	NS
I_{max}/I_{min} Tibia	6	2.61	0.57	5	3.29	0.76	19	2.53	0.42	0.1<p<0.05	NS	p<0.05
Z_p Fibula	4	18.81	5.61	6	17.26	4.32	15	15.73	3.30	NS	NS	NS
J_{FIB}/J_{TIB}	4	6.11	0.96	5	8.16	2.87	15	7.04	1.77	NS	NS	NS
Body Mass	6	78.26	5.91	6	70.57	4.46	19	63.34	6.44	0.1<p<0.05	p<0.001	p<0.05
Femoral Length	5	471.08	20.08	6	401.17	29.42	18	399.23	21.78	p<0.001	p<0.001	NS
Tibial Length	6	396.75	20.63	6	334.50	22.85	19	335.31	18.34	p<0.001	p<0.001	NS
Bi-Iliac breadth	2	29.25	0.07	4	27.15	1.60	5	26.18	1.23	NS	0.1<p<0.05	NS

Table 8. CSG properties and osteometric measurements of the Ligurian Mid Upper Palaeolithic (MUP), Late Upper Palaeolithic (LUP) and Neolithic (NEOL), males only. Significance level of the comparison between groups is based on an ANOVA.

4. Discussion

The aim of this chapter was to frame new biomechanical data from the northern Italian Mid Upper Palaeolithic (Barma Grande and Bausu da Ture) and Mesolithic (Mezzocorona-Borgonuovo, Mondevàl de Sora, and Vatte di Zambana) in our current comparative framework of bioarchaeological samples and modern varsity athletes (Shaw and Stock 2009; Marchi and Shaw 2011), and to interpret the results based on our understanding of postcranial functional adaptations (CSG method, Ruff *et al.* 2006b). In doing so, we re-explored certain theoretical expectations and previous results suggesting changes in mobility patterns at the Pleistocene-Holocene transition. From the theoretical point of view, we wanted to assess which lower limb segment and CSG variables are more reliable as indicators of mobility levels and types, given the inconsistencies found in previous studies. We therefore re-assessed whether body proportions influence CSG variables, and used a multivariate approach to find which variables discriminate better between athletes (cross-country runners and field hockey players) and sedentary controls. Regarding bioarchaeological expectations, the addition of new Gravettian individuals allowed for further evaluating the proposed decrease in mobility between the Mid and Late Upper Palaeolithic (Holt 1999, 2003, but see Trinkaus, 2015), and possible changes in hunting grounds from the plains to the mountains with de-glaciation (Mussi 2001; Fontana *et al.* 2011). Examining Mesolithic individuals from mountainous areas of north eastern Italy had the potential to offer a different perspective on early Holocene mobility patterns beyond the semi-permanent Atlantic coastal sites.

Our results suggest that the mobility index (*i.e.* I_x/I_y) is not influenced by body proportions. This is in contrast with previous studies (Ruff *et al.* 2006a) which suggested that relatively broader bodies result in increased medio-lateral loading on the femur, thus influencing I_x/I_y. In the context of Pleistocene human groups, this would mean that the extremely high femoral shape indices of Mid Upper Palaeolithic individuals (Holt 1999, 2003, but see Trinkaus, 2015) were in part due to their narrow and tropical-adapted bodies (Holliday 1995, 1997, 2002). Although the theoretical framework behind this reasoning is solid (Ruff 1995), we could not replicate the results, as also discussed in previous research (Pearson *et al.* 2014). It is possible that the influence of body width is more significant in the proximal portion of the femur, and it becomes negligible at midshaft, where other influences become more important (Pearson *et al.* 2014).

According to our results, it is femoral length that correlates more significantly than body breadth with femoral shape. Moreover, the strength and statistical significance of the correlation between length and I_x/I_y increase with the presumed mobility levels of a group: it is strongest in the Mid Upper Palaeolithic sample, and absent in the sedentary Iron Age people. The relationship is present also in the male-only samples in a similar fashion, indicating that sexual dimorphism only partially drives the results (*i.e.* in most groups, females tend to be smaller and have lower shape indices). Moreover, femoral size is not a proxy for body shape here (*i.e.* in general, taller people tend to be narrower-hipped), because the relationship does not appear to be due to increased medio-lateral loading in wider-hipped peoples. Since body size appears to scale more effectively antero-posterior than medio-lateral bending moments, we hypothesize that the correlation between femoral shape and length might be due to some form of synergy between mobility and body size, particularly bone length. Longer bones would be disproportionally influenced by antero-posterior loadings, resulting in a femoral shape partially dictated by body size. Some form of scaling of femoral shape indices would therefore be advisable before comparing groups with major differences in diaphyseal length. However, further analyses are necessary to verify the possible confounding factors influencing femoral midshaft shape, possibly using large samples with known mobility patterns and varying size.

Our analysis also suggests that the tibio-fibular complex could be the best proxy for mobility patterns presently available for bioarchaeological analysis. The tibia appears to be less influenced by body size than the femur, and both theoretical (Stock 2006) and experimental evidence (Shaw and Stock 2009; Rantalainen *et al.* 2010; Marchi and Shaw 2011) show that both robusticity and shape of the tibio-fibular complex correlate with mobility levels and types. Comparatively, fewer studies have investigated changes in midshaft femur with exercise in humans (*e.g.* Duncan *et al.* 2002; Vainionpää *et al.* 2007), and none investigated specifically changes in femoral shape. For clinical reasons related to the impact of osteoporosis, most experimental studies concentrated on the proximal femur (*e.g.* Hind *et al.* 2011; review in Hamilton *et al.* 2010).

Our discriminant analysis suggests that a combination of tibio-fibular variables may have the potential to discriminate between sedentary individuals (controls from Marchi and Shaw 2011, and Medieval individuals from Marchi 2007), individuals with high mobility in a relatively straight line (runners, Shaw and Stock 2009), and individuals with high mobility performing frequent swerving (hockey players, Shaw and Stock 2009). Being able to discriminate between types of mobility is particularly useful for making inferences on prehistoric samples, because the frequent swerving during playing hockey may impose on the tibio-fibular complex loadings that could be theoretically comparable to the ones generated by traversing mountainous terrains (Sparacello *et al.* 2014). However, even the best model has a low correct classification rate (around 65%), and shows considerable overlap between athlete groups, although the distance between the groups' centroids is significant. A larger sample of professional athletes is necessary to obtain equations with adequate discriminant power.

When the discriminant scores are calculated for bioarchaeological samples, and individuals are classified as either runners, hockey players, or controls, results appear consistent with presumed mobility levels. Highly-mobile Late Upper Palaeolithic hunters (Holt 1999, 2003) classify mostly as runners, and no individual in this sample is classified as sedentary. Neolithic herders practicing small scale and short-range transhumance in the mountainous Liguria region (Marchi *et al.* 2006; Sparacello and Marchi 2008) are classified mainly as hockey players. Individuals classified as sedentary appear among the Iron Age people from the mountainous Abruzzo region. This is consistent with their subsistence economy: although they practiced large scale transhumant pastoralism, this activity was performed by a small subset of the population, while most people were farmers (Sparacello *et al.* 2011). Still, many individuals in this sample classify as hockey players, possibly due to the influence of terrain properties in strengthening the fibula (Sparacello *et al.* 2014).

The four Mid Upper Palaeolithic individuals from Grimaldi Cave display postcranial adaptations typical of highly-mobile groups: three classify as runners, and one resembles hockey players. This was expected, given archaeological evidence of high mobility and large territories in the Gravettian (Hahn 1987; Rensink *et al.* 1991; Scheer 1993; Mussi *et al.* 2000), as well as previous studies on postcranial functional adaptations (Holt 1999, 2003; Shaw and Stock 2013). It is not surprising that, similarly to many individuals in other bioarchaeological samples, the scores obtained for the Mid Upper Palaeolithic individuals surpass the range of modern college athletes. Prehistoric subsistence was probably more physically demanding, and performed since a younger age, than most modern training programs.

However, some of the scores for the individuals from Grimaldi Cave might have been biased by the approximations made to obtain body mass, and therefore to scale tibial and fibular rigidity by body size. We therefore created a discriminant model which included only self-scaling indices, namely the CSG shape of the tibia and fibula, and the ration between fibular and tibial mechanical rigidity. Using this model, which is less powerful in discriminating hockey players but still able to distinguish runners from sedentary controls, Grimaldi Cave individuals still fall within the runners' range.

Another aim of this study was further testing if a signal of decreased mobility in the passage from the Mid Upper to the Late Upper Palaeolithic was still detectable with our research design. Mid Upper Palaeolithic hunters, more limited in vertical territorial excursion by colder climate, tended to dwell more on the coastal plains; on the other hand, archaeological evidence shows that Late Upper Palaeolithic hunters re-colonized mountains while coastal planes were disappearing (Mussi 2001; Fontana *et al.*, 2011). Inferences about changes in mobility between the two periods were mainly based on femoral shape, while tibial properties did not show marked differences (Holt 1999, 2003). Interestingly, another significant change between the Mid Upper and Late Upper Palaeolithic is the decrease in femoral length, while tibial length reduction was non-significant (Holt 1999, 2003; Formicola and Holt 2007). We have shown that femoral shape indices may positively correlate with femoral length, which called for a re-assessment of changes in mobility based on the tibio-fibular complex. Provided that our interpretative framework is correct, Mid Upper Palaeolithic Hunters would have been expected to be more similar to modern runners, while Late Upper Palaeolithic individuals to hockey players. Our results show that a similar ratio of Mid and Late Upper Palaeolithic individuals are classified as runners and hockey players, with more individuals falling in the former category therefore suggesting high mobility levels for both groups.

However, the Late Upper Palaeolithic sample is not geographically and chronologically homogeneous: it contains a few individuals that belong to the earlier phases of the Magdalenian and Solutrean (Table 1). We therefore performed the analysis considering only the individuals from Liguria, a region that is ideal to test this scenario due to its ruggedness and the presence of a (now disappeared) coastal plain during the colder phases of the Wurm (Shackelton *et al.* 1984; Van Andel and Tzedakis 1996). However, no clear indication of a shift from a "runner" to a "hockey player" biomechanical profile in the tibio-fibular complex was detected. Of the Ligurian Late Upper Palaeolithic individuals for which data were available (Arene Candide 2, 3, 4, 5, 10), only one (Arene Candide 3) classifies as hockey player, while the other four classified as runners, albeit with lower posterior probabilities than in the case of Middle Upper Palaeolithic Ligurians. In addition, Late Upper Palaeolithic individuals from Liguria show a nearly-significant increase in tibial shape compared to their Mid Upper Palaeolithic counterparts, a characteristic that is typical of runners (Shaw and Stock 2009). However, it is difficult to draw conclusions in this setting, given the small bioarchaeological sample, and the limitations of the model based on athletes described above. We suggest that, at the moment, there is not enough evidence to suggest significant changes in mobility patterns between Ligurian Mid Upper and Late Upper Palaeolithic people; a larger sample (both of athletes and Upper Palaeolithic people) would be desirable to further test the above hypotheses.

	Discriminant function analysis 1			Discriminant function analysis 2		
	RUNNERS	**HOCKEY**	**SEDENTARY**	**RUNNERS**	**HOCKEY**	**SEDENTARY**
Barma Grande 2	0.97[1]	0.02	0.00	0.95	0.04	0.01
Barma Grande 5	1.00	0.00	0.00	0.61	0.31	0.08
Barma Grande 6	1.00	0.00	0.00	0.77	0.18	0.05
Bausso da Ture 2	0.36	0.58	0.07	0.07	0.41	0.52
Ligurian MUP	**3**	**1**	**0**	**3**	**0**	**1**
Arene Candide 2	0.53	0.46	0.01	0.86	0.14	0.00
Arene Candide 3	0.15	0.75	0.11	0.10	0.62	0.28
Arene Candide 4	0.99	0.01	0.00	0.98	0.01	0.00
Arene Candide 5	0.64	0.34	0.02	0.87	0.12	0.01
Arene Candide 10	0.47	0.45	0.07	0.43	0.42	0.15
Ligurian LUP	**4**	**1**	**0**	**4**	**1**	**0**
Arene Candide 2 (Tinè)	0.01	0.88	0.11	0.00	0.52	0.48
Arene Candide 7 Pe	0.72	0.19	0.10	0.78	0.14	0.08
Arene Candide 8 Pe	0.47	0.51	0.03	0.44	0.48	0.07
Arene Candide VI Pe	0.99	0.01	0.00	0.78	0.14	0.08
Arene Candide IX Fin	0.05	0.72	0.23	0.03	0.48	0.49
Arene Candide XIII Fin	0.04	0.40	0.56	0.06	0.35	0.59
Arma dell'Aquila I	0.02	0.83	0.15	0.01	0.70	0.29
Arma dell'Aquila II	0.06	0.73	0.21	0.03	0.52	0.45
Bergeggi 2	0.77	0.19	0.05	0.91	0.07	0.02
Bergeggi 3	0.35	0.59	0.06	0.17	0.51	0.32
Boragni 2	0.63	0.34	0.03	0.30	0.46	0.24
Pollera 10	0.89	0.08	0.02	0.77	0.14	0.09
Pollera 13	0.63	0.35	0.02	0.39	0.45	0.16
Pollera 30	0.07	0.62	0.32	0.08	0.52	0.40
Pollera 32	0.59	0.34	0.07	0.33	0.38	0.29
Pollera 6246	0.87	0.13	0.01	0.46	0.34	0.19
Ligurian NEOL	**8**	**7**	**1**	**5**	**9**	**2**

Table 9. Individual posterior probabilities and classification of male Ligurian bioarchaeological cases using the discriminant function created using varsity athletes and sedentary people (variables included in discriminant function 1: Zmax TIB, Zmax FIB, Zmin TIB, Zmin FIB. Variables included discriminant function 2: I_{max}/I_{min} TIB, I_{max}/I_{min} FIB,J_{FIB}/J_{TIB}; see table 6).
[1] posterior probability (%). MUP: Middle Upper Palaeolithic; LUP: Late Upper Palaeolithic; MESO: Mesolithic; NEOL: Neolithic from Liguria; IRONAGE: Iron Age from Alfedena, central Italy; HOCKEY: Hockey players; RUNNERS: Cross-country runners; SEDENTARY: modern control sample and Medieval people; FEM: femur; TIB: tibia; FIB: fibula.

The three Mesolithic individuals from north eastern Italy analysed here, Mezzocorona-Borgonuovo, Mondevàl de Sora, and Vatte di Zambana, constitute the first biomechanical evidence to make inference about subsistence-dictated adaptations in high-altitude hunting grounds in this period (Fontana *et al.* 2009; Moore 2014). As expected, they are similar to hockey players, which suggests structural adaptations to high mobility in mountainous areas. However, it appears that all the individuals might have had altered mobility patterns, or altered diaphyseal morphology due to pathology.

Mezzocorona-Borgonuovo is a short and relatively gracile individual which has a robust fibula and one of the highest tibio-fibular ratio in the sample, which suggests high levels of foot-eversion/inversion. However, there is evidence of a healed lateral malleolus fracture in the contralateral tibio-fibular complex. Further studies will verify if an unbalanced gait might be the reason for Mezzocorona-Borgonuovo's structural adaptations.

Vatte di Zambana falls within the hockey players as well; however, this individual has obvious deformities in the upper limb: her forearms, shortened and flattened, are almost un-recognizable, and the olecranon is bilaterally detached from the ulnar diaphysis (Corrain *et al.* 1976). Multiple fractures have been suggested as a possible case for the observed abnormalities (Corrain *et al.* 1976); we suspect a congenital metabolic disease, and we will further diagnose this individual in future research. Regardless of the origin of the deformities, the obvious disability in the upper limb most likely affected the behavioural patterns of this individual, including mobility levels.

The Mesolithic male from Mondevàl de Sora still falls within hockey players, but, when considering shape indices, he falls within the sedentary sample, mainly due to his very low tibial shape. The combination of variables displayed by this individual appears anomalous, and does not fit with the interpretative framework based on athletes. The tibia of Mondevàl de Sora shows abundant perimortem periosteal remodeling, which appears to be due to systemic disturbances (possibly a form of Paget's disease, Alciati *et al.* 1997) rather than to periostitis (*e.g.* the Late Upper Palaeolithic individual from Villabruna; Vercellotti *et al.* 2008). Periosteal remodeling might have altered tibial geometry, leading to this unusual combination of variables; however no other bone appears to be significantly misshapen. Further analyses will diagnose the pathology of Mondevàl de Sora and further investigate its effects on the postcranium.

5. Conclusions

This study re-assessed which lower limb segments and structural properties could be influenced by mobility levels and types. We found that femoral shape, which is considered a mobility index in biomechanical research aimed to infer past behavioural patterns (Holt 1999, 2003, Carlson and Marchi 2014), appears to be more influenced by bone length than body breadth (Ruff *et al.* 2006). Our results by no means exclude that mobility is involved in shaping the midshaft femur, and call for further verification with larger controlled sample to exclude biases due to sexual dimorphism and culturally-induced behavioural differences.

Our results also suggest that inferences based on the tibio-fibular complex might be more reliable, further substantiating previous studies on the relationship between tibia and fibula diaphyseal robusticity and mobility patterns (Marchi and Shaw 2011; Marchi *et al.* 2011; Sparacello *et al.* 2014). Building from previous works about the importance of the tibio-fibular pair to determine mobility patterns in human and non-human primates (Marchi and Borgognini 2004; Marchi 2007, 2015; Marchi and Shaw 2011), we created a multivariate comparative framework based on the tibio-fibular complex of athletes practicing different mobility patterns, and applied it to bioarchaeological samples. With our sample, which is admittedly small, results suggest that the Mid Upper and Late Upper Palaeolithic hunters had similar mobility levels and types. Both groups were highly mobile, and evidence suggests that the level of loads imposed on the lower limb of prehistoric people often surpassed what can be experienced by modern athletes. Furthermore, we could not find clear evidence of a shift from a "runner" to a "hockey player" profile in Ligurian Mid and Upper Palaeolithic samples, which would have suggested that they had high mobility in different terrains. However, more research is needed: a larger sample of athletes with known mobility patterns, including also femoral data, would allow for the creation of a more powerful multivariate discriminant model.

Mesolithic individuals do not appear to show clear evidence of low mobility levels; this result is compatible with the expected subsistence based on seasonal high-altitude hunting. However, all the three Mesolithic individuals show some degree of bone abnormality, either due to trauma or to (possible) congenital systemic disease, making them probably not fully representative of the mobility patterns of their group.

Acknowledgements

Research funded by the Marie-Curie European Union COFUND/Durham Junior Research Fellowship [under EU grant agreement number 267209], the Wolfson Institute for Health and Wellbeing, Durham,UK, and the British Academy Small Grants.

The authors thank the Soprintendenza Archeologia Belle Arti e Paesaggio per la città metropolitana di Genova e le province di Imperia, La Spezia e Savona, Soprintendenza Archeologia del Veneto, and the Soprintendenza per i Beni Culturali della Provincia Autonoma di Trento for the permission to conduct this work. For assistance during data collection and collaboration during the analysis we thank the curators and staff of the Museo di Archeologia Ligure, Civico Museo Archeologico del Finale, Museo Preistorico Nazionale dei Balzi Rossi, MuSe Museo della Scienza di Trento, Museo di Storia Naturale di Verona, Museo Civico Della Val Fiorentina Vittorino Cazzetta, Museo di Storia Naturale dell'Università di Firenze Sezione di Antropologia e Etnologia, Musée Lorrain of Nancy, and of the Musée d'Archéologie Nationale, Saint-Germain en Laye. We are also grateful to the following people (in alphabetical order) for assistance and suggestions during data collection and analysis: Daniele Arobba, Antoine Balzeau, Erica Ceccarelli, Giampaolo Dalmeri, Andrea De Pascale, Angiolo Del Lucchese, Irene Dori, Sarah Elton, Vincenzo Formicola, Patrizia Garibaldi, Antonio Guerreschi, Dominique Henry-Gambier, Isabelle Huynh-Charlier, Tina Jakob, Roberto Maggi, Gabriele Martino, Jacopo Moggi, Irene Molinari, Fabio Negrino, Chiara Panelli, Guido Rossi, Maria Antonietta Segre, Antonella Traverso, Giuseppe "Cisque" Vicino, Maria Tagliafico, and Monica Zavattaro. Thanks to Dalibor Ivezic of DAVID Vision System and Kamal Badreshany for technical assistance during the elaboration of 3D images. We are grateful to Erik Trinkaus for comments and suggestions on an earlier version of the manuscript.

References

Alciati, G., Cattani, L., Fontana, F., Gerhardinger, E., Guerreschi, A., Milliken, S, Mozzi, P. and Rowley-Conwy, P. 1992. Mondevàl de Sora: a high altitude Mesolithic campsite in the Italian Dolomites. *Preistoria Alpina* 28, 351-366.

Alciati, G., Pesce Delfino, V. and Vacca, E. 1997. Evidenze patologiche rilevate sullo scheletro di Mondevàl de Sora. *Antropologia Contemporanea, Atti XII Congresso dell'Associazione Antropologica Italiana.* Palermo: Alia, 1-3.

Biagi, P. and Starnini, E. 2015. Human Settlement and Environmental Exploitation of Valcamonica-Valtrompia Watershed from the Beginning of the Holocene to the Middle Age. *Annali del Museo Civico di Scienze Naturali di Brescia* 39, 195.

Bietti, A. 1990. The Late Upper Paleolithic in Italy: an overview. *Journal of World Prehistory* 4, 95-155.

Bräuer, G. 1988. Osteometrie, in: Knußmann R. (ed.), *Anthopologie: handbucj der vergleichenden biolgie des menschen*. Volume I. Stuttgard: Gustav Fischler Verlag, 160-232.

Carlson, K.J., Demes, B. and Franz, T.M. 2005. Mediolateral forces associated with quadrupedal gaits of lemurids. *Journal of Zoology, London* 266, 261-273.

Carlson, K.J. and Judex, S. 2007. Increased non-linear locomotion alters diaphyseal bone shape. *Journal of Experimental Biology* 17, 3117-3125.

Carlson, K.J. and Marchi, D. 2014. Introduction: towards refining the concept of mobility, in Carlson, K.J. and Marchi, D. (eds.), *Reconstructing mobility. Environmental, behavioural, and morphological determinants*. New York: Springer. 1-12.

Cassoli, P.F. and Tagliacozzo, A. 1994. I macromammiferi dei livelli tardopleistocenici delle Arene Candide (Savona, Liguria): considerazioni paleontologiche e archaeozoologiche. *Quaternaria Nova* 4, 101-262.

Clark, G.A. and Straus, L.G. 1986. Synthesis and conclusions–part I: Upper Paleolithic and Mesolithic hunter-gatherer subsistence in northern Spain, in: Straus, L.G. and Clark, G.A. (eds.), La *Riera Cave: Stone Age hunter-gatherer adaptations in northern Spain*. Tempe: Arizona State University anthropological research papers 36. 351-365.

Corrain, C., Graziati, G. and Leonardi, P. 1976. La sepoltura epipaleolitica nel riparo di Vatte di Zambana (Trento). *Preistoria Alpina* 12, 175-212.

Craig, O.E., Biazzo, M., Colonese, A.C., Di Giuseppe, Z., Martinez-Labarga, C., Lo Vetro, D., Lelli, R., Martini, F. and Rickards, O., 2010. Stable isotope analysis of Late Upper Palaeolithic human and faunal remains from Grotta del Romito (Cosenza), Italy. *Journal of Archaeological Science* 37, 2504-2512.

Dalmeri, G., Mottes, E. and Nicolis, F. 1998. The Mesolithic burial of Mezzocorona-Borgonuovo (Trento) some preliminary comments. *Preistoria Alpina* 34, 129-138.

Dalmeri, G., Mottes, E., and Nicolis, F. 2002. La sepoltura mesolitica di Mezzocorona-Borgonuovo (Trento). Prime considerazioni. Atti della XXXIII Riunione Scientifica dell'I.I.P.P. vol 1. Firenze: Istituto Italiano di Preistoria e Protostoria, 189-203.

Davies, T.G., Shaw, C.N. and Stock, J.T. 2012. A test of a new method and software for the rapid estimation of cross-sectional geometric properties of long bone diaphyses from 3D laser surface scans. *Archaeological and Anthropological Sciences* 4, 277-290.

Delpech, F., 2003. L'environnement animal des européens au Paléolithique supérieur, in: Desbrosse, R., Thévenin, A. (eds.), *Préhistoire de l'Europe. Des origines à l'Age du Bronze*. Actes des 125e Congré s Nationaux des Société s Historiques et Scientifiques, Lille 2000. Paris: Editions du CTHS, 271-289.

Demes, B., Carlson, K.J. and Franz, T.M. 2006. Cutting corners: the dynamics of turning behaviors in two primate species. *Journal of Experimental Biology* 209, 927-937.

Duncan, C.S., Blimkie, C.J., Kemp, A., Higgs, W., Cowell, C.T., Woodhead, H., Briody, J.N. and Howman-Giles, R. 2002. Mid-femur geometry and biomechanical properties in 15- to 18-yr-old female athletes. *Medicine & Science in Sports & Exercise* 34, 673-681.

Farbstein, R., Radić, D., Brajković, D. and Miracle, P.T. 2012. First Epigravettian ceramic figurines from Europe (Vela Spila, Croatia). *PLoS ONE* 7, e41437.

Féblot-Augustin, J. 1999. La mobilité des groupes paléolithiques. *Bulletins et Mémoires de la Société d'anthropologie de Paris* 11/3, 219-260.

Fontana, F., Govoni, L., Guerreschi, A., Padoanello, S., Siviero, A., Thun Hohenstein, U. and Ziggiotti, S. 2009. L'occupazione sauveterriana di Mondevàl de Sora 1, settore I (San Vito di Cadore, Belluno) in bilico tra accampamento residenziale e campo da caccia. *Preistoria Alpina* 44, 207-226.

Fontana, F., Guerreschi, A. and Peresani M. 2011. The visible landscape. Inferring Mesolithic settlement dynamics from multifaceted evidence in the south-eastern Alps, in: Van Leusen, M., Pizziolo, G. and Sarti, L. (eds.), *Hidden landscapes of Mediterranean Europe. Cultural and methodological biases in pre- and protohistoric landscape studies, Proceeding of the International Conference, Siena, 25-27 May 2007.* British Archaeological Reports International Series 2320. Oxford: Archaeopress, 71-81.

Fontana F., Guerreschi A., Bertola S., Briois F. and Ziggiotti S. 2016. The Castelnovian burial of Mondevàl de Sora (San Vito di Cadore, Belluno, Italy): evidence for changes in the social organization of late Mesolithic hunter-gatherers in north-eastern Italy, in Grünberg, J.M., Gramsch, B., Larsson, L., Orschiedt, J. and Meller, H. (eds.), *Proceedings of the International Conference on "Mesolithic burials – Rites, symbols and social organisation of early Postglacial communities" Halle, 18-21 September 2013. Tagungen des Landesmuseum für Vorgeschichte Halle (Saale), Band 13.*

Fontana, F. and Visentin, D. 2016. Between the Venetian Alps and the Emilian Apennines (Northern Italy): highland vs. lowland occupation in the early Mesolithic. *Quaternary International* 423, 266-278. doi:10.1016/j.quaint.2015.12.014.

Formicola, V., Pettitt, P.B. and Del Lucchese, A. 2004. A direct AMS radiocarbon date on the Barma Grande 6 Upper Paleolithic skeleton. *Current Anthropology* 45, 144-118.

Formicola, V. and Holt, M.B. 2007. Resource availability and stature decrease in Upper Paleolithic Europe. A microevolutionary adaptive model. *Journal of Anthropological Sciences (Rivista di Antropologia)* 85, 153-164.

Formicola, V. and Holt, B.M. 2015. Tall guys and fat ladies: Grimaldi's Upper Paleolithic burials and figurines in an historical perspective. *Journal of Anthropological Sciences* 93, 71-88.

Gamble, C. 1986. *The Paleolithic settlement of Europe*. Cambridge: Cambridge University Press.

Gazzoni, V., Goude, G., Herrscher, E., Guerreschi, A., Antonioli, F. and Fontana, F. 2012. Late Upper Palaeolithic human diet: first stable isotope evidence from Riparo Tagliente (Verona, Italy). *Bulletins et mémoires de la Société d'Anthropologie de Paris* 25, 103-117.

Gerhardinger, E. and Guerreschi, A. 1989. La découverte d'une sépulture mésolithique à Mondevàl de Sora (Belluno, Italie), in: Giacobini, G. (ed.), *Hominidae. Proceedings of the 2nd international congress of human palaeontology (Milano 1989)*. Milano: Jaca Book, 511-513.

Germonpré, M., Sablin, M., Khlopachev, G.A. and Grigorieva, G.V. 2008. Possible evidence of mammoth hunting during the Epigravettian at Yudinovo, Russian Plain. *Journal of Anthropological Archaeology* 27, 475-492.

Gosman, J.H., Hubbell, Z.R., Shaw, C.N. and Ryan, T.M. 2013. Development of cortical bone geometry in the human femoral and tibial diaphysis. *The Anatomical Record* 296:774-787.

Grimaldi, S. 2010. Un tentativo di definire un modello di territorio e mobilità per i cacciatori raccoglitori sauveterriani dell'Italia nord-orientale. *Preistoria Alpina* 41, 73-88.

Grine, F.E., Jungers, W.L., Tobias, P.V. and Pearson, O.M. 1995. Fossil *Homo* femur from Berg Aukas, northern Namibia. *American Journal of Physical Anthropology* 26, 67-78.

Guerreschi, A. and Gerhardinger, M.E. 1988. Un sito mesolitico a Mondevàl de Sora (Bl.). Archivio per l'Alto Adige: *Rivista di Studi Alpini* 82, 251-3.

Hagihara, Y. and Nara, T. 2016. Morphological features of the fibula in Jomon hunter-gatherers from the shell mounds of the Pacific coastal area. *American Journal of Physical Anthropology* 160, 708-718.

Hahn, J. 1987. Aurignacian and Gravettian settlement patterns in Central Europe, in: Soffer, O. (ed.), The Pleistocene Old World: regional perspectives. New York: Plenum Press, 251-261.

Hind, K., Gannon, L., Whatley, E., Cooke, C. and Truscott, J. 2011. Bone cross-sectional geometry in male runners, gymnasts, swimmers and non-athletic controls: a hip-structural analysis study. *European Journal of Applied Physiology* 112, 535-41.

Holliday, T.W. 1995. *Body size and proportions in the Late Pleistocene western Old World and the origins of modern humans*. PhD Thesis, University of New Mexico.

Holliday, T.W. 1997. Body proportions in Late Pleistocene Europe and modern human origins. *Journal of Human Evolution* 32, 423-447.

Holliday, T.W. 2002. Body size and postcranial robusticity of European Upper Paleolithic hominins. *Journal of Human Evolution* 43, 513-528.

Hamilton, C.J., Swan, V.J.D. and Jamal, S.A. 2010. The effects of exercise and physical activity participation on bone mass and geometry in postmenopausal women: a systematic review of pQCT studies. *Osteoporosis International* 21, 11-23.

Higgins, R.W. 2014. The effects of terrain on long bone robusticity and cross-sectional shape in lower limb bones of bovids, Neanderthals, and Upper Paleolithic modern humans, in: Carlson, K. and Marchi, D. (eds.), Reconstructing mobility: environmental, behavioral, and morphological determinants. New York: Springer, 227-252.

Holt, B.M. 1999. *Mobility in Upper Paleolithic and Mesolithic Europe: biomechanical evidence from the lower limb*. PhD Thesis, University of Missouri.

Holt, B.M. 2003. Mobility in Upper Paleolithic and Mesolithic Europe: evidence from the lower limb. *American Journal of Physical Anthropology* 122, 200-215.

Holt, B.M, Mussi, M., Churchill, S.E. and Formicola, V. 2000. Biological and cultural trends in Upper Palaeolithic Europe. *Rivista di Antropologia* 78, 179-182.

Holt, B.M. and Formicola, V. 2008. Hunters of the Ice Age: the biology of Upper Paleolithic people. *Yearbook of Physical Anthropology* 51, 70-99.

Huberty, C. J. 1989. Problems with stepwise methods: Better alternatives, in: Thompson, B. (ed.), Advances in social science methodology (Vol. 1). Greenwich, CT: JAI Press, 43-70.

Kozłowski, J.K. 1999. *Gravettian/Epigravettian sequences in the Balkans: environment, technologies, hunting strategies and raw material procurement Vol. 3*. The Palaeolithic Archaeology of Greece and Adjacent Areas: Proceedings of the ICOPAG Conference, Ioannina, September 1994. Athens: British School at Athens Studies, 319-329.

Kozłowski, J.K. and Kaczanowska, M. 2004. Gravettian/Epigravettian sequences in the Balkans and Anatolia. *Mediterranean Archaeology and Archaeometry* 4/1, 5-18.

Lambeck, K., Yokoyama, Y. and Purcell T. 2002. Into and out of the Last Glacial Maximum: sea-level change during Oxygen Isotope Stages 3 and 2. *Quaternary Science Reviews*, 21, 343-360.

Larsen, C.S. 1995. Biological changes in human populations with agriculture. *Annual Review of Anthropology* 24, 185-213.

Lovejoy, C.O., Burstein, H. and Heiple, K. 1976. The biomechanical analysis of bone strength: a method and its application to Platycnemia. *American Journal of Physical Anthropology* 44, 489-506.

Lowe, J.J. and Walker, M.J.C. 2000. Radio carbon dating the Last Glacial – Interglacial Transition (ca. 14-9 14C ka BP) in terrestrial and marine records: the need for new quality assurance protocols: *Radiocarbon* 42, 53-68.

Magri, D. 2007. Advances in Italian palynological studies: late Pleistocene and Holocene records. *GFF* 129, 333-340.

Magri, D. 2008. Lineamenti della vegetazione tardoglaciale in Italia peninsulare e in Sicilia, in: Mussi, M. (ed.). *Il Tardiglaciale in Italia. Lavori in corso.* British Archaeological Reports International Series 2320. Oxford: Archaeopress, 1859.

Mangerud, J., Anderson, S.T., Berglund, B.E. and Donner, J.J. 1974. Quaternary stratigraphy of Norden: a proposal for terminology and classification. *Boreas* 3, 109-126.

Mannino, M.A., Thomas, K.D., Leng, M.J., Di Salvo, R. and Richards, M.P. 2011a. Stuck to the shore? Investigating prehistoric hunter-gatherer subsistence, mobility and territoriality in a Mediterranean coastal landscape through isotope analyses on marine mollusc shell carbonates and human bone collagen. *Quaternary International* 244, 88-104.

Mannino, M.A., Di Salvo, R., Schimmenti, V., Di Patti, C., Incarbona, A., Sineo, L. and Richards, M.P. 2011b. Upper Palaeolithic hunter-gatherer subsistence in Mediterranean coastal environments: an isotopic study of the diets of the earliest directly-dated humans from Sicily. *Journal of Archaeological Science* 38, 3094-3100.

Mannino, M.A., Catalano, G., Talamo, S., Mannino, G., Di Salvo, R., Schimmenti, V., Lalueza-Fox, C., Messina, A., Pertuso, D., Caramelli, D., Richards, M.P. and Sineo, L. 2012. Origin and Diet of the Prehistoric Hunter-Gatherers on the Mediterranean Island of Favignana (Ègadi Islands, Sicily). *PLoS ONE* 7, e49802.

Mannino, M.A. and Thomas, K.D. 2001. Intensive Mesolithic exploitation of coastal resources? Evidence from a shell deposit on the Isle of Portland (Southern England) for the impact of human foraging on populations of inter-tidal rocky shore molluscs. *Journal of Archaeological Science* 28, 1101-1114.

Marchi, D. 2004. Cross-sectional geometry of the limb bones of the Hominoidea: its relationships with locomotion and posture. PhD Thesis, University of Pisa.

Marchi, D. 2007. Relative strength of the tibia and fibula and locomotor behavior in hominoids. *Journal of Human Evolution* 53, 647-655.

Marchi, D. 2008. Relationships between lower limb cross-sectional geometry and mobility: The case of a Neolithic sample from Italy. *American Journal of Physical Anthropology* 137, 188-200.

Marchi, D. 2015. Variation in tibia and fibula diaphyseal strength and its relationship with arboreal and terrestrial locomotion: extending the investigation to non-hominoid primates. *Journal of Anthropological Sciences* 93, 1-4.

Marchi, D. and Borgognigni-Tarli, S.M. 2004. Cross-sectional geometry of the limb bones of the Hominoidea by biplanar radiography and moulding techniques. *Journal of Anthropological Sciences* 82, 89-102.

Marchi, D. and Shaw, C.N. 2011. Variation in fibular robusticity reflects variation in mobility patterns. *Journal of Human Evolution* 61, 609-616.

Marchi, D., Sparacello, V.S., Holt, B.M. and Formicola, V. 2006. Biomechanical approach to the reconstruction of activity patterns in Neolithic Western Liguria, Italy. *American Journal of Physical Anthropology* 131, 447-455.

Marchi, D., Sparacello, V.S. and Shaw, C.N. 2011. Mobility and lower limb robusticity of a pastoralist Neolithic population from North-Western Italy, in: Pinhasi R. and Stock, J.Y. (eds.), *Human bioarchaeology of the Transition to Agriculture*. New York: John Wiley & Sons, 317-346.

Matiegka, J. l934. *Homo Předmostensis*. Fosilní člověk z Předmostí na Moravě. Praha: Česká akademie věd a umění.

McHenry, H.M. 1992. Body size and proportions in early Hominids. *American Journal of Physical Anthropology* 87, 407-431.

Moore, A.M.T. 2014. Post-glacial transformations among hunter-gatherer societies in the Mediterranean and western Asia, in: Cummings, V., Jordan, P. and Zvelebil. M. (eds.), *The Oxford handbook of the archaeology and anthropology of hunter-gatherers*. Oxford: Oxford Handbooks Online, 456-478.

Mussi, M. 1986a. On the chronology of the burials found in the Grimaldi caves. *Antropologia Contemporanea* 9, 95-99.

Mussi, M. 1986b. Italian Palaeolithic and Mesolithic burials. *Human Evolution*. 1, 545-556.

Mussi, M. 1996. Rituels funéraires dans les sépultures gravettiennes des grottes de Grimaldi et de la Grotte delle Arene Candide: une mise au point, in: Otte, M. (ed.), *Nature et Culture*. Liège, Eraul, 68, 822-830.

Mussi, M., Roebroeks, W. and Svoboda, J. 2000. Introduction, in: Roebroeks, W., Mussi, M., Svoboda, J. and Fennema, K. (eds). *Hunters of the Golden Age: the Mid Upper Palaeolithic of Eurasia (30.000-20.000 bp)*. Leiden: Leiden University Press, 1-12.

Mussi, M. 2001. *Earliest Italy: An Overview of the Italian Paleolithic and Mesolithic*. New York: Kluwer and Plenum.

Nagurka, M.L. and Hayes, W.C. 1980. An interactive graphics package for calculating cross-sectional properties of complex shapes. *Journal of Biomechanics* 13, 59-64.

Negrino, F. and Starnini, E. 2010. Dinamiche di sfruttamento e circolazione delle materie prime silice per l'industria litica scheggiata in Liguria tra Paleolitico inferiore ed Età del Rame, in: Odetti, G (ed.). *L'uomo e la terra ligure, Atti della tavola rotonda,Genova, 10-11 Febbraio 2005*. Genova: Università degli Studi di Genova, 21-34.

O'Neill, M.C. and Ruff, C.B. 2004. Estimating human long bone cross-sectional geometric properties: a comparison of noninvasive methods. *Journal of Human Evolution* 47, 221-235.

Pearson, O.M. 1997. Postcranial morphology and the origin of modern humans. PhD. Thesis, State University of New York at Stony Brook.

Pearson, O.M., Cordero, R.M, and Busby, A.M. 2006. How different were Neanderthals' habitual activities? A comparative analysis with diverse groups of recent humans, in: Harvati, K. and Harrison, T. (eds.), *Neanderthals Revisited: New Approaches and Perspectives*. New York: Springer, 135-156.

Pearson, O.M. and Lieberman, D.E. 2004. The aging of Wolff 's 'Law': ontogeny and response to mechanical loading in cortical bone. *American Journal of Physical Anthropology* 47, 63-99.

Pearson, O.M., Petersen, T.R., Sparacello, V.S., Daneshvari, S. and Grine, F.E. 2014. Activity, "body shape", and cross-sectional geometry of the femur and tibia, in: Carlson, K. and Marchi, D. (eds.), *Reconstructing mobility: environmental, behavioral, and morphological determinants*. New York: Springer, 133-153.

Pearson, O. and, Sparacello, V.S. 2017. Behavioral differences between near eastern Neanderthals and early modern humans from Skhul and Qafzeh: an assessment based on comparative samples of Holocene humans, in: Hovers, E. and Marom, A. (eds.), *Human Paleontology and Prehistory: Contributions in Honor of Yoel Rak*. New York: Springer, 175-186.

Price, T.D. 1985. Affluent foragers of Mesolithic southern Scandinavia, in: Price, T.D. and Brown, J.A. (eds.), *Prehistoric hunter-gatherers: the emergence of cultural complexity*. Orlando: Academic Press, 341-363.

Price, T.D. 1987. The Mesolithic of Europe. *Journal of World Prehistory* 1, 225-305.

Rantalainen, T., Nikander, R., Heinonen, A., Suominen, H. and Sievänen, H. 2010. Direction-specific diaphyseal geometry and mineral mass distribution of tibia and fibula: a pQCT study of female athletes representing different exercise loading types. *Calcified Tissue International* 86, 447-454.

Ravazzi, C., Peresani, M., Pini, R. and Vescovi E. 2007. Il Tardoglaciale nelle Alpi italiane e in Pianura Padana. Evoluzione stratigrafica, storia della vegetazione e del popolamento antropico. *Il Quaternario* 20, 163-184.

Rensinck, E., Kolen, J. and Spieksma, A. 1991. Patterns of raw material distribution in the Upper Pleistocene of Northwestern and Central Europe, in: Montet-White, A. and Holen, S. (eds.), *Raw material economies among prehistoric hunter-gatherers*. Publications in anthropology 19. Lawrence: University of Kansas, 141-159.

Richards, M.P., Hedges, R.E.M., Jacobi, R., Current, A. and Stringer, C. 2000. FOCUS: Gough's Cave and Sun Hole Cave human stable isotope values indicate a high animal protein diet in the British Upper Palaeolithic. *Journal of Archaeological Science* 27, 1-3.

Richards, M.P., Jacobi, R., Cook, J., Pettitt, P.B. and Stringer, C.B. 2005. Isotope evidence for the intensive use of marine foods by Late Upper Palaeolithic humans. *Journal of Human Evolution* 49, 390-394.

Riel-Salvatore, J. and Gravel-Miguel, C. 2013. Upper Paleolithic Mortuary Practices in Eurasia: A Critical Look at the Burial Record, in: Tarlow, S. and Nilsson Stutz, L. (eds.), *The Oxford Handbook of the Archaeology of Death and Burial.* Oxford: Oxford University Press, 303-346.

Ruff, C.B. 1987. Sexual dimorphism in human lower limb bone structure: relationship to subsistence strategy and sexual division of labor. J*ournal of Human Evolution* 16, 391-416.

Ruff, C.B. 1995. Biomechanics of the hip and birth in early *Homo*. *American Journal of Physical Anthropology* 98, 527-574

Ruff, C.B. 1999. Skeletal structure and behavioral patterns of prehistoric Great Basin populations, in: Hemphill, B.E. and Larsen, C.S. (eds.), *Prehistoric lifeways in the Great Basin wetlands: bioarchaeological reconstruction and interpretation*. Salt Lake City: University of Utah Press, 290-320.

Ruff, C.B. 2000. Body size, body shape, and long bone strength in modern humans. *Journal of Human Evolution* 38, 269-290.

Ruff, C.B. 2002. Long bone articular and diaphyseal structure in Old World monkeys and apes. I: locomotor effects. *American Journal of Physical Anthropology* 119, 305-342.

Ruff, C.B. 2005. Mechanical determinants of bone form: Insights from skeletal remains. *Journal of Musculoskeletal and Neuronal Interactions* 5, 202-212.

Ruff, C.B. and Hayes, W.C. 1983. Cross-sectional geometry of Pecos Pueblo femora and tibiae – a biomechanical investigation. II. sex, age, and side differences. *American Journal of Physical Anthropology* 60, 383-400.

Ruff, C.B., Holt, B.M., Sládek, V., Berner, M., Murphy, W., zur Nedden, D., Seidler, H. and Recheis, W. 2006a. Body size, body proportions, and mobility in the Tyrolean 'Iceman'. *Journal of Human Evolution* 51, 91-101.

Ruff, C.B., Holt, B. and Trinkaus, E. 2006b. Who's afraid of the big bad Wolff? 'Wolff 's law' and bone functional adaptation. *American Journal of Physical Anthropology* 129, 484-498.

Ruff, C.B., Scott, W.W. and Liu, AY-C. 1991. Articular and diaphyseal remodeling of the proximal femur with changes in body mass in adults. *American Journal of Physical Anthropology* 86, 397-413.

Scheer, A. 1993. The organization of lithic resource use during the Gravettian in Germany, in: Knecht, H., Pike-Tay, A. and White, R. (eds.), *Before Lascaux: the complex record of the Early Upper Paleolithic*. Boca Raton: CRC Press, 193-210.

Schulting, R.J. and Richards, M.P. 2001. New palaeodietary and AMS dating evidence from the Breton Mesolithic cemeteries of Te´viec and Ho¨ edic. *Journal of Anthropology and Archaeology* 20, 314-344.

Shackleton, J.C., van Andel, T.H. and Runnels, C.N. 1984. Coastal Paleogeography of the Central and Western Mediterranean during the last 125,000 years and its archaeological implications. *Journal of Field Archaeology* 11, 307-314.

Shaw, C. and Stock, J. 2009. Intensity, repetitiveness, and directionality of habitual adolescent mobility patterns influence the tibial diaphysis morphology of athletes. *American Journal of Physical Anthropology* 140, 149-159.

Shaw, C.N. and Stock, J.T. 2013. Extreme mobility in Late Pleistocene? Comparing limb biomechanics among fossil Homo, varsity athletes and Holocene foragers. *Journal of Human Evolution* 64, 242-249.

Sládek, V., Trinkaus, E., Hillson, S.W. and Holliday, T.W. 2000. *The people of the Pavlovian – skeletal catalogue and osteometrics of the Gravettian fossil Hominids from Dolní Věstonice and Pavlov*. The Dolní Věstonice Studies Volume 5/2000. Brno: IRIS Hustopeče.

Sládek, V., Berner, M. and Sailer, R. 2006a. Mobility in Central European Late Eneolithic and Early Bronze Age: femoral cross-sectional geometry. *American Journal of Physical Anthropology* 130, 320-332.

Sládek, V., Berner, M. and Sailer, R. 2006b. Mobility in Central European Late Eneolithic and Early Bronze Age: tibial cross-sectional geometry. *Journal of Archaeological Science* 33, 470-482.

Snyder, P. 1991. Three reasons why stepwise regression methods should not be used by researchers, in: Thompson, B. (ed.), *Advances in educational research: Substantive findings, methodological developments* (Vol. 1). Greenwich, CT: JAI Press, 99-105.

Sparacello, V.S. and Marchi, D. 2008. Mobility and subsistence economy: a diachronic comparison between two groups settled in the same geographical area (Liguria, Italy). *American Journal of Physical Anthropology* 136, 485-495.

Sparacello, V.S. 2013. The bioarchaeology of changes in social stratification, warfare, and habitual activities among Iron Age Samnites of Central Italy. Ph.D. Dissertation, University of New Mexico.

Sparacello, V.S., Marchi, D. and Shaw, C.S. 2014. The importance of considering fibular robusticity when inferring the mobility patterns of past populations, in: Carlson, K. and Marchi, D. (eds.), *Reconstructing mobility: environmental, behavioral, and morphological determinants*. New York: Springer, 91-111.

Sparacello, V.S. and Pearson, O.M. 2010. The importance of accounting for the area of the medullary cavity in cross-sectional geometry: a test based on the femoral midshaft. *American Journal of Physical Anthropology* 143, 612-624.

Sparacello, V.S., Pearson, O.M., Coppa, A. and Marchi, D. 2011. Changes in robusticity in an Iron Age agropastoral group: the Samnites from the Alfedena necropolis (Abruzzo, Central Italy). *American Journal of Physical Anthropology* 144, 119-130.

Sparacello, V.S., Shaw, C.N.S. and Marchi, D. 2015. New data on Late Upper Paleolithic upper limb cross-sectional geometry from Arene Candide: implications for Tardiglacial hunting practices. *American Journal of Physical Anthropology* [Suppl] 60, 294-295.

Stevens, R.E., Jacobi, R.M. and Higham, T.F.G. 2010. Reassessing the diet of Upper Palaeolithic humans from Gough's Cave and Sun Hole, Cheddar Gorge, Somerset, UK. *Journal of Archaeological Science* 37, 52-61.

Stiner, M., Munro, N.D., Surovell, T.A., Tchernov, E. and Bar-Yosef, O. 1999. Paleolithic population growth pulses evidenced by small animal exploitation. *Science* 283:190-194.

Stiner, M.C. and Munro, N.D. 2011. On the evolution of diet and landscape during the Upper Paleolithic through Mesolithic at Franchthi Cave (Peloponnese, Greece). *Journal of Human Evolution* 60, 618-636.

Stock, J.T. 2006. Hunter-gatherer postcranial robusticity relative to patterns of mobility, climatic adaptation, and selection for tissue economy. *American Journal of Physical Anthropology* 131, 194-204.

Stock, J.T. and Pfeiffer, S. 2001. Linking structural variability in long bone diaphyses to habitual behaviors: foragers from the southern African Later Stone Age and the Andaman Islands. *American Journal of Physical Anthropology* 115, 337-348.

Straus, L.G., Altuna, G., Clark, G., González Morales, M., Laville, H., Leroi-Gourhan, M., Menéndez de la Hoz, M. and Ortea, J. 1981. Paleoecology at La Riera. *Current Anthropology* 22: 655-682.

Straus, L.G. 1995. The Upper Paleolithic of Europe: an overview. *Evolutionary Anthropology* 4, 4-16.

Straus, L.G. 1996. The archaeology of the Pleistocene-Holocene transition in Southwest Europe, in: Straus, L.G., Eriksen, B.V., Erlandson, J.M. and Yesner, D.R. (eds.), *Humans at the end of the Ice Age*. New York: Plenum Press, 83-100.

Straus, L. 2012. The Magdalenian settlement of Europe: an introduction. *Quaternary International* 272-273, 1-5.

Trinkaus, E. 2015. The appendicular skeletal remains of Oberkassel 1 and 2, in: Giemsch, L. and Schmitz, R.W. (eds.), *Oberkassel 1914-2014. 100 years of research on the late glacial burial.* Mainz: Rheinische Ausgrabungen, 1-58.

Trinkaus, E. and Ruff, C.B. 2012. Femoral and tibial diaphyseal cross-sectional geometry in Pleistocene *Homo*. *Paleoanthropology* 2012, 13-62.

Trinkaus, E., Buzhilova, A.P., Mednikova, M.B. and Dobrovolskaya, M.V. 2014. *The people of Sunghir: burials, bodies, and behavior in the Earlier Upper Paleolithic*. Oxford: Oxford University Press.

Vainionpää, A., Korpelainen, R., Sievänen, H., Vihriälä, E., Leppäluoto, J. and Jämsä, T. 2007. Effect of impact exercise and its intensity on bone geometry at weight-bearing tibia and femur. *Bone* 40, 604-611.

Van Andel, T.H. and Tzedakis, P.C. 1996. Palaeolithic landscapes of Europe and environs, 15,000-25,000 years ago: an overview. *Quaternary Science Reviews* 15, 481-500.

Verneau, R. 1906. *Les Grottes de Grimaldi (Baoussé-Roussé). Anthropologie*. Monaco: Imprimerie de Monaco.

Vercellotti, G., Alciati, G., Richards, M.P., and Formicola, V. 2008. The Late Upper Paleolithic skeleton Villabruna 1 (Italy): a source of data on biology and behaviour of a 14,000 year-old hunter. *Journal of Anthropological Sciences* 86, 143-63.

Villotte, S. and Henry-Gambier, D. 2010. The rediscovery of two Upper Palaeolithic skeletons from Baousso da Torre Cave (Liguria-Italy). *American Journal of Physical Anthropology* 141, 2-6.

Villotte, S. 2011. Les comportements au Gravettien : apport des « marqueurs osseux d'activité », in: Goutas, N., Klaric, L., Pesesse, D. and Guillermin, P. (eds.), *A la recherche des identités gravettiennes : actualités, questionnements, perspectives.* Paris: Société Préhistorique Française, 217-224.

Villotte, S., Knüsel, C.J., Mitchell, P.D. and Henry-Gambier, D. 2011. Probable carpometacarpal and tarsal coalition from Baousso da Torre Cave (Italy): implications for burial selection during the Gravettian. *Journal of Human Evolution* 61, 117-120.

Walker, M., Johnsen, S., Rasmussen, S.O., Popp, T., Steffensen, J.-P., Gibbard, P., Hoek, W., Lowe, J., Andrews, J., Björck, S., Cwynar, L.C., Hughen, K., Kershaw, P., Kromer, B., Litt, T., Lowe, D.J., Nakagawa, T., Newnham, R., and Schwander, J., 2009. Formal definition and dating of the GSSP (Global Stratotype Section and Point) for the base of the Holocene using the Greenland NGRIP ice core, and selected auxiliary records: *Journal of Quaternary Science* 24, 3-17.

Wojtal, P. and Wilczyński, J. 2015a. World of Gravettian hunters. *Quaternary International* 359-360, 1-2.

Wojtal, P. and Wilczyński, J. 2015b. Hunters of the giants: woolly mammoth hunting during the Gravettian in Central Europe. *Quaternary International* 379, 71-81.

Woodman, P.C. 1985. Mobility in the Mesolithic of northwestern Europe: an alternative explanation, in: Price, T.D. and Brown, J.A. (eds.), *Prehistoric hunter-gatherers: the emergence of cultural complexity.* Orlando: Academic Press, 325-339.

Zvelebil, M. 2008. Innovating hunter-gatherers: the Mesolithic in the Baltic, in Bailey, G. and Spikins, P. (eds.), *Mesolithic Europe*. Cambridge: Cambridge University Press, 18-59.

The role of aquatic resources in 'Italian' hunter-gatherer subsistence and diets

Marcello A. Mannino[1] *& Michael P. Richards*[2]

Abstract

Mediterranean hunter-gatherers lived in close proximity to the sea, yet the role of marine and other aquatic resources in their subsistence is unclear. Reasons for this include the bias brought onto the faunal record for such adaptations by taphonomy (especially for fish remains), as well as the difficulty linked to reconstructing human behaviour in environments that have no modern analogue and a tradition of archaeological studies in Italy not entirely favourable to such lines of research. This paper is a review of some of the most important faunal assemblages relevant for our understanding of aquatic adaptations and of all the carbon and nitrogen stable isotope data, generated in the last decade or so through the analysis of the bone collagen of Upper Palaeolithic and Mesolithic hunter-gatherers from the Mediterranean Basin. Little evidence for the exploitation of aquatic resources is available at sites pre-dating the Last Glacial Maximum. A clear expansion in aquatic adaptations took place around the Late Glacial, when 'Italian' hunter-gatherers broadened the spectrum of exploited taxa both from freshwater and marine contexts, with brackish water habitats possibly representing a greater source of food than transpires from the record at our disposal, which is also severely biased by the effects of sea level rise. The start of the Mesolithic was not marked by a further development in aquatic adaptations, which actually occurred later in this period. The isotopic database currently available for 'Italian' foragers suggests that marine resources constituted a smaller source of nutrition than for their counterparts living in Atlantic Europe, probably as a consequence of the lower productivity of the Mediterranean Sea. At times of climate change, however, Mediterranean hunt-

1 Department of Archaeology and Heritage Studies, School of Culture and Society, Aarhus University, Højbjerg, Denmark. E-mail: marcello.mannino@cas.au.dk.

2 Department of Archaeology, Simon Fraser University, Burnaby, British Columbia, Canada.

in: Borgia, V. and E. Cristiani (eds.) 2018: *Palaeolithic Italy. Advanced studies on early human adaptations in the Apennine peninsula*, Sidestone Press Academics (Leiden), pp. 397-426.

er-gatherers were able to obtain higher proportions of dietary protein from aquatic resources, amounting to around a fifth or more of their diets.

Keywords: Mediterranean, hunter-gatherers, Upper Palaeolithic, Mesolithic, aquatic adaptations, zooarchaeology, carbon and nitrogen isotope analyses.

1. Introduction

The Italian Peninsula lies at the centre of the Mediterranean Sea and it is the smallest of the three major peninsulas of southern Europe, just under one thousand kilometres long and (currently) 240km wide. Prehistoric humans living in Italy would, thus, never have been far from the coast. The same would have been true for the hunter-gatherers that around the Last Glacial Maximum (hereafter LGM), or after, settled on the islands of Sicily and Sardinia. The geography of Italy, thus, pushes us to question how important was seafood for Palaeolithic and Mesolithic foragers.

The role of aquatic resources in the subsistence and diets of past hunter-gatherers is difficult to establish and has generated an enduring worldwide debate (Erlandson 2001). One of the reasons for this is the ambiguity of the archaeological record for aquatic resource exploitation and the problems of its interpretation. Sea level change has impacted on site preservation and biased the coastal record in favour of rocky shores and against sedimentary ones, which are often associated with the most productive habitats, such as estuaries and lagoons (Bailey and Flemming 2008). Another problem is the poorer preservation of fish bones compared to mammalian bones, as well as their inadequate recovery, rarer study and unsystematic reporting. This has helped strengthen views on past subsistence grounded on the so-called 'Man the Hunter' paradigm (*i.e.* "the historical overemphasis on hunting"; Erlandson 2001: 304), relegating the potential contribution of aquatic resources (with the possible exception of marine molluscs) to the diets of Postglacial and, possibly, Late Glacial foragers.

The Italian archaeological record and its interpretation are not immune from these problems. The sites on which we base our knowledge are almost exclusively caves and rock-shelters (Bietti 1990, 1991; Mussi 2001), unavoidably biasing available data in favour of rocky shorelines, and many of them were excavated a few decades (or more) ago, thereby with methodologies that bias the record against smaller and less durable organic remains (*e.g.* fish bones). Moreover, Italian prehistoric archaeological research has traditionally been centred on caves, with little or no concerted attempts until the last decade at investigating how different sites may have been part of the same territory and at gaining a more processual understanding of hunter-gatherer subsistence (*e.g.* Clark 2000; Grimaldi and Flor 2009; Fontana and Visentin, 2016). As a result of these methodological issues and of the uncritical adoption of scenarios of subsistence change developed for environmentally very different regions to the Mediterranean (*e.g.* Atlantic Europe: Clark 1936, 1952), marine resource exploitation has commonly been considered an eminently Holocene phenomenon, since initial syntheses on the Late Upper Palaeolithic and Mesolithic of Italy (Radmilli 1960, 1974).

Radmilli explained the Mesolithic as the adaptation to Postglacial climate and environmental change and, given his site-based view of subsistence, suggested that foragers responded in different ways: some by following migrating animals 'out of Italy',

Figure 1. Central Mediterranean prehistoric sites mentioned in the text (listed by country, in order of mention): 1. Grotta di Castelcivita, 2. Arene Candide, 3. Grotta Romanelli, 4. Grotta delle Mura, 5. Grotta della Madonna di Praia a Mare, 6. Grotta della Serratura, 7. Grotta del Mezzogiorno, 8. Riparo Blanc, 9. Grotta di Pozzo, 10. Riparo Cogola, 11. Riparo Dalmeri, 12. Galgenbühel / Dos de la Forca, 13. Grotta dell'Uzzo, 14. Grotta Schiacciata & Grotta di Cala dei Genovesi, 15. Grotta d'Oriente, 16. Barma Grande, 17. Grotta del Romito, 18. Riparo Tagliente, 19. Grotta di San Teodoro, 20. Grotta Addaura Caprara, 21. Riparo Villabruna, 22. Vatte di Zambana & Mezzocorona, 23. Mondeval de Sora, 24. S'Omu S'Orku, 25. Grotta Molara, 26.Vela Spilja / Vela Luka, 27. Šandalja II Cave, 28. Pupićina Cave, 29. Monte Leone and Araguina Sennola, 30. Campu Stefanu, 31. Torre d'Aquila, 32. SHM-1 near Hergla. The map was uploaded from: https://upload.wikimedia.org/wikipedia/commons/7/79/Italy_relief_location_map.jpg.

others by continuing to concentrate on hunting, albeit broadening their subsistence base to include small animals and birds, and yet others who settled on the coast and adopted a mixed economy based on hunting, fishing and collecting of molluscs and plants (Pluciennik 2000: 172). More recent work has shown Radmilli's scenarios to be unfounded, not only because there is no evidence that the three specific subsistence adaptations mentioned above were ever strategically and exclusively pursued (Pluciennik 2000), but also because a turn towards aquatic resources actually occurred before the Mesolithic. Research in the last couple of decades has, in fact, shown that subsistence change favouring an increased dietary breadth to include marine resources occurred not only at the Pleistocene/Holocene transition, but also during the Late Glacial and even within the Mesolithic itself (*e.g.* Mussi 2001; Mannino and Thomas 2007, 2009; Martini *et al.* 2009).

This paper reviews the zooarchaeological data on aquatic resource exploitation in conjunction with recently-published isotope data, which combined allow us to reach a better understanding of hunter-gatherer subsistence and diet in the Mediterranean during the Upper Palaeolithic and Mesolithic. Carbon and nitrogen isotope analyses ($\delta^{13}C$ and $\delta^{15}N$) on bone collagen inform us mainly on dietary protein and, in particular, on its ecosystem of origin (be it terrestrial freshwater and/or marine), and trophic level, potentially providing us with a semi-quantitative estimate of the proportion of animal versus plant foodstuffs consumed (Lee-Thorp 2008).

2. Aquatic resource exploitation in the run up to and around the Last Glacial Maximum (45 – 19 ka cal. BP)

To evaluate the dietary adaptations of Mediterranean foragers we should briefly review the archaeological data on their subsistence. Prior to the arrival of anatomically modern humans, marine resource exploitation was limited to taxa acquired from the coast (*e.g.* Stiner 1994; Stringer *et al.* 2008) and, mainly, to shellfish, meagre resources in the Mediterranean (Colonese *et al.* 2011). Neanderthals had terrestrial-based diets centred on hunting and with undoubted, albeit still imponderable, contributions from plant foods (*e.g.* Fiorenza *et al.* 2015).

Very little is known about the coastal or, in general, aquatic adaptations of the Upper Palaeolithic foragers who lived before the LGM. Groups of the Uluzzian, which may represent the earliest culture associated with AMH in Europe (Benazzi *et al.* 2011), had similar subsistence strategies to those of their Mediterranean predecessors or successors. In fact, Morin (2012: 271) states that "the faunal record of western Europe suggests that Neanderthals and early modern humans shared a similar range of foraging behaviors". At Grotta di Castelcivita, in the hinterland of southwestern Italy, birds and fish were exploited both by Neanderthals and by the makers of Uluzzian and Aurignacian cultures (Cassoli and Tagliacozzo 1997). Even though fish were exploited more by the Uluzzian occupants of this cave, there is no evidence to suggest that this was actually the result of fishing. Indeed, all exploited species including European chub (*Leuciscus cephalus*), brown trout (*Salmo trutta*) and European eel (*Anguilla anguilla*) live in fast-flowing streams, where they can be captured without fishing technology (Morales Muñiz 2010). Overall, there is no evidence for any developed maritime or aquatic adaptation and it also seems unwarranted to hypothesize that Uluzzian groups had any form of seafaring technology (Mannino 2014).

The number of Uluzzian sites is roughly five times lower than that of Aurignacian sites, a disparity that according to Mussi (2001) reflects a true difference between the population sizes of the former and those of the latter culture. Aurignacian groups that chronologically succeeded Uluzzian ones are claimed to have been more mobile and spread more widely across Italy. Overall, however, the early Upper Palaeolithic sites occupied by makers of Uluzzian and Aurignacian techno-complexes are few and far between, probable archaeological evidence of an under-populated Italian peninsula (Mussi 2001). Aurignacian subsistence in the Mediterranean Basin is only known through a handful of studies, which show that it was oriented mainly to the exploitation of terrestrial resources and, particularly, to hunting of mammalian herbivores. At the Iberian site of Abreda Cave, Aurignacian people also exploited different fish species caught locally (Muñoz and Casadevall 1997), including European eel (*A. anguilla*), barbel (*Barbus* sp.), Eurasian dace (*Leuciscus* sp.), roach (*Rutilus* sp.) and brown trout (*S. trutta*). This exploitation actually started in the Mousterian and increased in the Upper Palaeolithic, lasting into the Mesolithic (with the exception of *S. trutta*). In the Italian Peninsula too, Aurignacian foragers exploited birds from a variety of environments, fish from freshwater habitats and marine molluscs, not unlike the last Neanderthals and the Uluzzians (*e.g.* Stiner 1994; Cassoli and Tagliacozzo 1997). If this patchy evidence for aquatic resource exploitation is representative, it suggests that the hypothesis of intensification of the use of aquatic foods in the early Upper Palaeolithic may not hold true for the Mediterranean, at least in its strictest definition of an increase in labour input and decrease in efficiency (Morgan 2015).

As mentioned above, the scarce evidence for the exploitation of aquatic resources by Middle-to-Upper Paleolithic transition cultures suggests that it was limited to easy-to-capture taxa either in freshwater, brackish water or other littoral settings (*e.g.* Cassoli and Tagliacozzo 1997). Current knowledge on marine resource exploitation by hunter-gatherers living around the LGM – belonging to the Gravettian, Solutrean, Magdalenian and early Epigravettian cultures – may be biased by sea level rise, which has potentially submerged sites containing significant evidence (Bailey and Flemming 2008). In fact, fish bone assemblages from sites dating to this period are small and very little data are available on them. Isotope data, however, suggest that aquatic foods contributed to the otherwise terrestrial-based diets of early and mid-Upper Paleolithic humans from Eurasia (Richards and Trinkaus 2009). Similar dietary reconstructions for Aurignacians and Gravettians have been proposed to explain dental microwear texture data from individuals from across continental Europe (El Zaatari and Hublin 2014). According to the isotope analyses, the Gravettian hunter-gatherer buried at Arene Candide in Liguria (NW Italy), and known as 'Il Principe' ('The Prince'), acquired at least 20% of his protein from aquatic (albeit not necessarily fully marine) foods (Pettitt *et al.* 2003). The isotope data and the level of technological sophistication attained by this culture warn us not to treat the present dearth of evidence at face value. We should investigate (possibly through targeted excavations) whether the aquatic adaptations suggested by isotope analyses for inland Gravettians and for groups contemporary to them (*e.g.* Richards *et al.* 2001; Richards and Trinkaus 2009) were paralleled by maritime adaptations along coastal regions.

Direct evidence for fishing during the Solutrean, which coincides with the LGM, has been retrieved from the Spanish site of Cueva de Nerja, which at the time was some 6.0 km from the coast (Cortés-Sánchez *et al.* 2008; Morales-Muñiz and Roselló-Izquierdo 2008). Here is concrete evidence for fishing in the Solutrean and for the exploitation of coastal Mediterranean species of the Sparidae family (*e.g. Sparus aurata*), migratory species of the Carangidae and Scombridae families and numerous cold-adapted Atlantic species of the Gadidae family, such as saithe (*Pollachius virens*), Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and common ling (*Molva molva*).This reflects the higher biological diversity and productivity of the Mediterranean around the LGM compared to now (Kettle *et al.* 2011). It should be pointed out that controversy surrounds the interpretation of the stratigraphy and chronology of Cueva de Nerja, with Aura *et al.* (2009) suggesting that the LGM deposits were incorrectly identified as such by Cortés-Sánchez *et al.* (2008), due to misunderstanding of site formation processes.

During the LGM, Mediterranean biodiversity and productivity were likely higher than now, both in terrestrial biomes, which were refugia for plants and animals (*e.g.* Sommer and Nadachowski 2006), and in marine biomes, which were characterized by the presence of cold-adapted species of Atlantic origin (*e.g.* Kettle *et al.* 2011). Evidence for the latter comes from sites such as Cueva de Nerja, close to the Iberian shores of the Alboran Sea (*e.g.* Cortés-Sánchez *et al.* 2008), and others across the western Mediterranean in the form of occasional skeletal remains of cold-adapted species (Kettle *et al.* 2011). Depictions of marine animals such as seals, fish and great auks, found at sites across the western and central parts of the Basin, offer us a glimpse of the Mediterranean around the LGM (*e.g.* Cleyet-Merle 1990; d'Errico 1994). These artistic representations, however, are backed by little other archaeological data. A handful of skeletal remains of the great auk (*Pinguinus impennis*) have been recovered at sites in the Italian Peninsula and the western Mediterranean, lending support to the possibility that the depictions were of locally observed animals (*e.g.* Cassoli 1980). This limited record is too patchy to say more about non-analogue Late Pleistocene Mediterranean coastal environments or, for that matter, to advance hypothesis on the possible role of cold-adapted species in the subsistence and diet of local hunter-gatherers, both of which are topics worthy of detailed investigation.

3. Late Upper Palaeolithic and Mesolithic subsistence in the western and central Mediterranean (19 – ~8 ka cal. BP)

To this day, few post-LGM sites have yielded substantial assemblages of remains belonging to marine and/or other aquatic resources, with the notable exception of Cueva de Nerja. All those studying this site (*e.g.* Cortés-Sánchez *et al.* 2008; Aura *et al.* 2009) agree that fishing from it increased significantly after the LGM, during the Magdalenian, when a richly diverse array of taxa was acquired from all aquatic habitats. At this time monk seal (*Monachus monachus*) and short-beaked common dolphin (*Delphinus delphis*) were relatively common prey. The presence of the former has been explained by hunting, whilst that of the latter is attributed to exploitation of stranded individuals (Cortés-Sánchez *et al.* 2008; Aura *et al.* 2009). The species exploited by the Upper Palaeolithic foragers could be caught from the coast, although the use of boats in shallow waters is also compatible with the evidence. Overall, the study of the late Upper Palaeolithic faunal food refuse from Cueva de Nerja suggests that marine resources from all habitats present around the cave were exploited and, altogether, must have contributed significantly to hunter-gatherer subsistence.

In Italy, an increase in the exploitation of aquatic resources is attested from the Late Glacial, particularly during the time corresponding to the Bølling-Allerød interstadial, when the Late Epigravettian was the prevailing local culture. Epigravettian hunter-gatherers subsisted mainly through specialized hunting of terrestrial herbivorous mammals, which were the main sources of protein as far as food refuse remains inform us (*e.g.* Cassoli and Tagliacozzo 1995; De Grossi Mazzorin and Tagliacozzo 1998; Tagliacozzo 2003). At sites in settings characterized by shallow soft-bottom littorals and brackish water habitats, such as Grotta Romanelli in SE Apulia, a wide range of aquatic species were acquired and consumed (Tagliacozzo 2003). Here more than 32,000 avifaunal remains, belonging to over 3650 individuals (mainly bustards and geese), were unearthed, demonstrating that Late Glacial 'Italian' foragers regularly hunted birds, including waterfowl (Gala and Tagliacozzo 2012). Small assemblages of fish bones of coastal marine taxa were recovered at Grotta Romanelli (Tagliacozzo 2003), as well as at another Apulian site, Grotta delle Mura (Albertini *et al.* 2010). Here fish remains (= 164) increase in numbers from the Early to the Late Epigravettian layers, decreasing in the Mesolithic and Neolithic ones. Both the Upper Palaeolithic and Mesolithic assemblages are dominated by mullets (Mugilidae), followed by seabass (*Dicentrarchus labrax*) and gilt-head bream (*Sparus aurata*). The prevalence of these species suggests that fishing would have taken place, using different techniques (including fish traps and harpoons), in shallow soft-bottom shore habitats present near the cave.

Apart from the Apulian evidence, little is known about fishing in the circum-Adriatic region during the Late Upper Palaeolithic and Mesolithic, which is not surprising given that for most of this time the Adriatic Sea was largely emersed (Mussi 2001; Gazzoni *et al.* 2013). The Holocene hunter-gatherers of the Dalmatian island of Korčula frequently exploited marine fish, the remains of which dominate the bone assemblage from the cave of Vela Spilja (Rainsford *et al.* 2014). In the early Mesolithic layers, fish bones (mainly of the family Scombridae and particularly of the mackerel *Scomber japonicus*) account for up to 90% of the vertebrate skeletal remains, whilst in the late Mesolithic layers they account for 50-60% and are more varied taxonomically. The Minimum Number of Individuals (MNI) of *S. japonicus* from Vela Spilja is 142 (of which 117 are early Mesolithic), a high number in the Mediterranean context (a consequence, at least in part, of the adequate recovery methods adopted during the excavation of this cave site). This assemblage is, particularly, noteworthy because it attests specialized seasonal (*i.e.* summer) fishing, which may have been performed using drift nets from boats in inshore waters, a practice that is not yet attested at other sites. Direct evidence for fishing equipment is scarce in the archaeological record of the central Mediterranean, so it is worth mentioning here that the Mesolithic occupants of Odmut in Montenegro made regular use of harpoons (Cristiani and Borić 2016). These finds attest the use of harpoon technology by circum-Adriatic Holocene hunter-gatherers, which is compatible with the exploitation of diverse animal resources (*e.g.* fish, beavers, otters) from environmental ecotones, such as those of the Dinaric

Alps. Bird hunting, fishing and shellfish collection were also practiced by the Upper Palaeolithic and Mesolithic occupants of Grotta della Madonna di Praia a Mare in NW Calabria (Durante 1978). Here around the Pleistocene/Holocene transition fishing targeted mainly *Salmo trutta*, but eel (*Anguilla anguilla*) and gilt-head bream (*Sparus aurata*) were also frequent catches. The relatively large numbers of remains attributed to *S. trutta* pushed Durante (1978) to hypothesize that this taxon may actually have been caught at the mouth of the river Noce, during migrations up or down stream, suggesting that brown trout may have been anadromous in the Mediterranean around the Pleistocene/Holocene transition. Zooarchaeological work on bone assemblages from more recent excavations at Grotta della Madonna has shown that fishing was a marginal activity in the Mesolithic, given that fish represent only 7.4% of vertebrates (Fiore *et al.* 2004).

Around thirty-four kilometres NW of Grotta della Madonna, across the Gulf of Policastro in the present-day region of Campania, evidence for fishing in coastal waters has been acquired from Grotta della Serratura, another cave site occupied in the Late Glacial and Postglacial (Wilkens 1993). Here, during the Late Epigravettian occupation, fishing was dominated by catches of European eel (*A. anguilla*), which amount to around 62% of a total 346 identified remains, followed by mullet (*Mugil* sp.), garfish (*Belone belone*) and a handful of unidentified sea bream (Sparidae) bones. This is evidence for fishing in coastal waters, particularly in brackish water habitats, and for the use of implements such as spears, fish traps and/or hook and line. The Mesolithic fish bone assemblage was very different, being dominated by *B. belone* (92% of the 204 identified specimens), with small numbers of *Mugil* sp. and species that would have been caught along rocky shores, such as grouper (*Epinephelus* sp.), Mediterranean moray eel (*Muraena helena*) and conger eel (*Conger conger*). The marine molluscs recovered at Grotta della Serratura also testify the exploitation of different coastal habitats and include rocky shore intertidal taxa (*Patella* spp. and *Phorcus* spp.), which dominate the assemblage, and soft-bottom shore taxa from brackish water habitats (*e.g. Cerastoderma*), which represent around a fifth of the shells from the earliest late Upper Palaeolithic deposits (Wilkens 1993; Colonese and Wilkens 2002). The occupiers of Grotta della Serratura adapted to changes in Late Glacial and Postglacial coastal environments exploiting a wide range of coastal taxa, although it is still not entirely clear what role such resources may have played in their subsistence and diet.

Evidence for the exploitation of different coastal habitats, both rocky and soft-bottom shores, has been retrieved at other Italian peninsular sites, such as Grotta del Mezzogiorno also in Campania (Colonese and Tozzi 2010) and Riparo Blanc in Latium (Taschini 1964). At the latter site, which was possibly occupied around 9,500 years cal. BP, thousands of shells of marine molluscs from rocky and soft-bottom shores (*e.g. Patella* spp., *Phorcus turbinatus*, *Ruditapes decussatus*, *Cerastoderma glaucum*) were recovered, along with remains of crustaceans, echinoderms, a few fish and terrestrial mammal bones. The abundance of marine molluscs and presence of other marine taxa at Riparo Blanc was taken by Taschini (1964), and later used amongst others by Radmilli (1974), as evidence for the almost complete reliance by Mesolithic hunter-gatherers on marine resources and, even, molluscs for their year-round survival. A recent Mediterranean-wide review of Palaeolithic and Mesolithic (including Epi-Palaeolithic) shellfish exploitation has shown that "marine molluscs constituted quantitatively unimportant but qualitatively useful supplementary resources due to their nutritional peculiarities in a diet otherwise dominated by terrestrial foods and mammalian protein" (Colonese *et al.* 2011: 98).

Paradoxically, at present, the largest Late Glacial and early Postglacial fish bone assemblages are those from the sites around the Fucino basin, as far inland as one can go in peninsular Italy. Fish remains, almost exclusively attributable to trout (*S. trutta*) have been found in their hundreds and thousands at numerous Pleistocene/Holocene transition sites around what was, back then, Lake Fucino (*e.g.* Wilkens 1994). A taphonomic study by Russ and Jones (2009) shows that the fish bones were introduced into Grotta di Pozzo by Upper Palaeolithic humans, rather than by predators, such as bears, wolves or eagle owls. Faunal remains alone do not allow us to evaluate how important fish may have been in the diet of the Fucino hunter-gatherers, nevertheless it is likely that *S. trutta* were important foodstuffs either during upland occupation by late Upper Palaeolithic and early Mesolithic groups (Mussi *et al.* 2004) or, given the under-representation of vertebrae, elsewhere (possibly at lean times of the year, such as the winter after processing and curing in the uplands; Russ and Jones 2009). Both these scenarios suggest that in the Late Glacial (and possibly the early Postglacial) trout may have been a key resource for Italian hunter-gatherers at least on a seasonal scale.

Freshwater fish were also consumed at terminal Upper Palaeolithic (late Epigravettian) and Mesolithic (Sauveterrian) sites in northern Italy, such as Riparo Cogola (Albertini and Tagliacozzo 2004a) and Riparo Dalmeri (Albertini and Tagliacozzo 2004b) in Trentino, and Galgenbühel / Dos de la Forca in South Tyrol (Bazzanella *et al.* 2007). The remains from Riparo Cogola are limited in number (n = 192) and it is not clear what proportion of the mainly indeterminable fish bones were introduced to the rock-shelter by the Epigravettian and Sauveterrian hunter-gatherers that occupied it (Albertini and Tagliacozzo 2004a). The evidence for fishing is more compelling at Riparo Dalmeri, where cyprinids, mainly represented by common barbel (*Barbus barbus*) and chub (*Squalius cephalus*), dominate the ichthyofaunal assemblage (Albertini and Tagliacozzo 2004b). Other exploited taxa include brown trout (*S. trutta*), grayling (*Thymallus thymallus*), tench (*Tinca tinca*) and pike (*Esox lucius*). The evidence from Riparo Dalmeri is compatible with regular exploitation of freshwater resources, but, on purely zooarchaeological grounds, it is hard to establish if fish were, in absolute caloric terms, an important component in the diet of the prehistoric hunter-gatherers of Trentino.

Useful information on the techniques adopted by Mesolithic (Sauveterrian) hunter-gatherers living along the valley of the Adige river, not far north the above-mentioned sites from Trentino, has been acquired from the rockshelter of Galgenbühel / Dos de la Forca (Bazzanella *et al.* 2006, 2007). At this site 10,190 fish remains were recovered in early Mesolithic deposits attributable to the Sauveterrian culture and overwhelmingly dominate the vertebrate assemblage. This also includes remains of hunted terrestrial mammals, such as red deer (*Cervus elaphus*) and wild boar (*Sus scrofa*), as well as animals living in and around wetlands, such as beaver (*Castor fiber*), otter (*Lutra lutra*) and the European pond turtle (*Emys orbicularis*). The ichthyofauna is composed almost exclusively by pike (*E. lucius*), which according to the studies by Bazzanella *et al.* (2006, 2007) was in all likelihood captured using tools for the selective capture of single individuals, such as laces with a slip-knot, harpoons, bows and arrows, *etc.* These are not strictly speaking fishing techniques, tools for which are absent in the regional Mesolithic archaeological record, contrary to harpoons and other such implements on bone and antler raw materials (*e.g.* Clark 2000; Cristiani 2009; Dalmeri *et al.* 2001). For the record, it should be noted that at Riparo di Romagnano III, another Mesolithic site in the Adige Valley, vertebrae of *E. lucius* were used as ornaments along with marine shells and mammalian teeth (Dalmeri and Nicolodi 2004). This suggests that pike may also have had a symbolic role in Mesolithic hunter-gatherer societies of northern Italy. Cyprinids were commonly caught by the occupants of the Galgenbühel / Dos de la Forca rockshelter including predominantly the rudd (*Scardinius erythrophtalmus*), the Italian roach (*Rutilus aula*) and the tench (*Tinca tinca*). A recent seasonality of growth study on the vertebrae and few other elements of *E. lucius* and *S. erythrophtalmus* has shown that the season of death coincided with the period of the year between April and October, corresponding essentially to spring and summer (Wierer *et al.* 2016). Data on the seasonality of mammal and bird mortality testifies to a broader range of seasons, albeit also with a predominant spring and summer component. Galgenbühel / Dos de la Forca represents an exception within the context of the central-upper part of the Adige Valley, given that it is the only site at which fish remains dominate the bone assemblage (Wierer *et al.* 2016). As it was likely not occupied year round, it can be concluded that the fish remains recovered within its deposits are a testimony to an important contribution to forager diets either at the site itself, during the warmer half of the year, or elsewhere in Trentino Alto Adige at leaner times of the year, after drying or smoking, for which there is not much evidence (Wierer *et al.* 2016).

Evidence for fishing during the early Holocene is also scarce from the large islands at the centre of the Mediterranean, all of which were likely settled by this time (Mannino 2014). Some data have been obtained from pre-Neolithic sites on Corsica, where marine animal taxa, including molluscs, generally do not exceed 20-30% of the total fauna recovered (*e.g.* Vigne and Desse-Berset 1995). Humans survived on this island despite the absence of large game animals, such as deer, by relying heavily on small mammals, especially lagomorphs (*e.g. Prolagus sardus*). The largest marine faunal assemblage studied in detail from the central Mediterranean is that of the Mesolithic-Neolithic site of Grotta dell'Uzzo (NW Sicily), which was occupied during the early-to-mid Holocene (Tagliacozzo 1993). Here fishing only picked up during the closing stages of the Mesolithic, increased in the so-called Mesolithic-Neolithic transition and flourished in the Neolithic (around 75% of all identifiable fish specimens originating from early Neolithic contexts; Cassoli and Tagliacozzo 1995). In each of these phases, exploited fish were almost exclusively coastal and may have been caught onshore using hooks and lines, spears and/or traps. The most abundant taxon throughout the sequence at Grotta dell'Uzzo is grouper (*Epinephelus* sp.), a large member of the Serranidae, which can be caught from the shore with large hooks. The Mesolithic-Neolithic transition layer contained hundreds of cetacean bones of one Mystecete (*Balaenoptera* sp.) and four Odontocetes (*Globicephala melas*, *Gramphus griseus*, *Delphinus delphis* and possibly *Physeter macrocephalus*). Tagliacozzo (1993) hypothesized that these cetaceans were not hunted, which would have required the use of sturdy boats, but rather exploited after strandings.

Despite the dearth of data, it seems that the pattern of exploitation of marine resources at Grotta dell'Uzzo is matched by that at other sites in NW Sicily. At Grotta

Schiacciata, on the present-day island of Levanzo, marine resource exploitation intensified only a few centuries before the start of the Neolithic (Mannino and Thomas 2010). This was contemporary to the so-called Mesolithic-Neolithic transition at Grotta dell'Uzzo and coincided with the likely time when the last hunter-gatherers had started to move more regularly by boat (Mannino 2014). Similar subsistence trajectories have been highlighted by the study of other faunal assemblages from western Sicily, such as those from Grotta di Cala dei Genovesi (Cassoli and Tagliacozzo 1982) and Grotta d'Oriente (Mannino and Thomas 2004; Martini *et al.* 2009).

4. Isotope evidence for Upper Palaeolithic diets in Italy and Sicily

Almost all the carbon and nitrogen isotope analyses on the bone collagen of Upper Palaeolithic and Mesolithic Mediterranean hunter-gatherers have been undertaken in the last ten years (Table 1). Most of these are on individuals recovered from cave sites in Italy and its islands, with some data also available for foragers from Corsica, Croatia, Spain and Tunisia (Table 2). No isotopic data are available for the early Upper Palaeolithic and only a couple of studies have been published on middle Upper Palaeolithic humans of the Gravettian culture. One of these is the above-mentioned 'Prince' from the Arene Candide cave in Liguria (NW Italy), who had a diet characterized by high levels of terrestrial animal consumption and that included also a significant proportion of protein (*i.e.* 20-25%) from aquatic fauna (Pettitt *et al.* 2003). The only other middle Upper Palaeolithic human for which data have been published is the individual from burial 6 at Barma Grande ($\delta^{13}C$: -19.7‰; $\delta^{15}N$:

Period	Site	N	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Source
mid Upper Palaeolithic	Arene Candide (Italy)	1	-17.6	12.4	Pettitt *et al.* 2003
late Upper Palaeolithic	Arene Candide (Italy)	2	-19.5±0.8	9.0±0.1	Francalacci 1988
late Upper Palaeolithic	Riparo Villabruna (Italy)	1	-19.7	8.0	Vercellotti *et al.* 2008
late Upper Palaeolithic	Riparo Tagliente (Italy)	1	-18.4	13.0	Gazzoni *et al.* 2013
late Upper Palaeolithic	Grotta del Romito (Italy)	8	-19.5±0.3	10.1±1.1	Craig *et al.* 2010
late Upper Palaeolithic	Grotta di San Teodoro (Sicily)	3	-19.7±0.4	12.0±0.4	Mannino *et al.* 2011a
late Upper Palaeolithic	Grotta Addaura Caprara (Sicily)	1	-19.7	9.6	Mannino *et al.* 2011a
late Upper Palaeolithic	Grotta d'Oriente (Sicily)	1	-19.3	11.0	Craig *et al.* 2010
Mesolithic	Grotta Addaura Caprara (Sicily)	2	-19.5±0.2	9.2±0.7	Mannino *et al.* 2011b
Mesolithic	Grotta Molara (Sicily)	2	-19.9±0.5	8.8±2.3	Mannino *et al.* 2011b
Mesolithic	Grotta dell'Uzzo (Sicily)	11	-19.8±0.7	10.3±1.1	Mannino *et al.* 2015
Mesolithic	Grotta d'Oriente (Sicily)	2	-18.4±0.8	11.0±0.5	Mannino *et al.* 2012
Mesolithic	S'Omu e S'Orku (Sardinia)	2	-19.7±0.3	9.4±0.2	Floris *et al.* 2012
Mesolithic-Neolithic transition	Grotta dell'Uzzo (Sicily)	1	-16.2	12.8	Mannino *et al.* 2015

Table 1. Carbon and nitrogen isotope data from well-preserved bone collagen of middle Upper Palaeolithic (27.9-27.3ka cal BP), late Upper Palaeolithic (17-10.5ka cal BP), Mesolithic (10.5-8.5ka cal BP) and Mesolithic-Neolithic transition (8.5-8.0ka cal BP) humans from mainland Italy, Sicily and Sardinia.

12.9‰), one of the caves at the Balzi Rossi (Formicola *et al.* 2004). These values suggest that this Gravettian also had a terrestrial-based diet with significant consumption of aquatic (possibly freshwater) protein. However, as the C:N ratio for this individual is higher (= 3.8) than the range established by DeNiro (1985) for well-preserved collagen (= 2.9-3.6), these data and especially the carbon isotope values (which become more depleted when contaminated by humic substances) should be treated with caution. During the excavations at Barma Grande, despite the inadequate recovery of pre-modern archaeology, 353 vertebrae of *S. trutta* were found and most of these were perforated to be used as beads in body ornaments (Wilkens 1995). The study of the growth increments in 17 of these vertebrae, suggest that 16 belonged to trout that died in the winter and 1 to an individual that died in spring, so at least from these data trout exploitation seems to have been highly seasonal. We cannot be sure about the contemporaneity between these specimens and the individual from burial 6, but the evidence at hand suggests that *S. trutta* may have played some role in the subsistence and diet of the Upper Palaeolithic groups of Barma Grande.

The currently available data for the late Upper Palaeolithic of Italy and Sicily have been obtained from individuals that date to after the LGM and almost exclusively to the Late Glacial. The $\delta^{13}C$ values for the analyzed hunter-gatherers range from -20.0‰ to -18.4‰. These values clearly indicate that almost all the protein was obtained from animals and plants living in a terrestrial ecosystem dominated by C_3 plants (*i.e.* those that fix carbon in photosynthesis through the so-called Calvin cycle), as expected for Europe (Ehleringer and Cerling 2002). This, in itself, attests that fully marine resources were likely not major sources of dietary protein for all these late Upper Palaeolithic individuals. The $\delta^{15}N$ values for Italian and Sicilian foragers have a wider range comprised between 8.0‰ and 13.0‰, which, in the light of nitrogen isotope data available for fauna from most of the investigated sites, suggest that meat of terrestrial herbivores was overwhelmingly the main source of dietary protein. However, some individuals with $\delta^{15}N$ values around 12.0‰ or higher, acquired significant proportions (around one fifth) of protein from aquatic resources. These individuals are from Grotta del Romito 9 (17130-16570 years cal. BP at least based on the direct radiocarbon date; Craig *et al.* 2010), Riparo Tagliente (16150-15530 years cal. BP; Gazzoni *et al.* 2013) and Grotta di San Teodoro 1 (15280-14230 years cal. BP; Mannino *et al.* 2011a) and the aquatic resources they consumed were freshwater and/or anadromous fish (*e.g. Salmo trutta*). All these individuals, therefore, date to the period between the start of deglaciation in internal Alpine valleys and the beginning of the Bølling – Allerød interstadial (circa 14700-14300 years cal. BP), which in Italy is the first part of the Late Glacial and has not been subdivided into chrono-stratigraphic biozones (Ravazzi *et al.* 2007).

The only specimen dating to the Late Glacial phase before the Bølling – Allerød interstadial that did not consume aquatic resources (at least in isotopically detectable proportions) is that from Grotta Addaura Caprara (15650-15179 years cal. BP) in NW Sicily (Mannino *et al.* 2011a). On isotopic grounds, this individual had a different diet to Grotta di San Teodoro 1 individual and the reason for this could lie in differences in the resources available in north-western Sicily, where reliefs are generally below 1,000 metres a.s.l., and north-eastern Sicily, where the Nebrodi mountain chain runs parallel to the shoreline with many peaks above 1,500 metres a.s.l. Territories in the latter areas would have offered a greater variety of resources given the steeper altitudinal cline and would have been similar to those of sites of mainland Italy, like Grotta della Madonna, where resources such as *Salmo trutta* were exploited abundantly during some phases of the Late Pleistocene and early Holocene (Durante 1978). This shows that differences in resource availability and, consequently, in human diets may have been present even within relatively small distances, as between Grotta di San Teodoro and Grotta Addaura Caprara, which are just over 100km away from each other (Mannino *et al.* 2011a).

The Epigravettian hunter-gatherer buried at Riparo Villabruna (Villabruna 1: 14190-13770 years cal. BP) dates to the early stages of the Bølling – Allerød and had a diet mainly based on the consumption of terrestrial foods (Vercellotti *et al.* 2008). Due to the restricted number of faunal samples used in the isotopic study and to the low $\delta^{15}N$ values of the analyzed fauna from periglacial conditions, it is not easy to reconstruct the diet of individual Villabruna 1 based on the available isotope data. It could be that this young adult male's dietary protein originated mainly from the meat of hunted mammals, which on the basis of the zooarchaeological study were the main animals preyed by the occupants of Riparo Villabruna. Nevertheless, given the very large difference between the $\delta^{15}N$ values of the human and those of the fauna, it cannot be excluded altogether that freshwater resources were not consumed by this individual. This possibility has been hypothesized to explain the porotic hyperostosis suffered by Villabruna 1, who may have contracted this disease consuming fish infested by a tapeworm of the genus *Diphyllobothrium* (Vercellotti *et al.* 2010). Another clue about the diet of the hunter-gatherer buried at Riparo Villabruna is represented by the occurrence of caries in this individual and by the oldest evidence for dentistry demonstrated in a recently published study by Oxilia *et al.* (2015). The occurrence of caries likely suggests a diet in which carbohydrates were regularly consumed, contrary to the limited archaeological evidence for plant food exploitation. The successful dental treatment of the carious lesion on the lower right third molar of Villabruna 1 testifies to a high degree of experience of caries and was, according to Oxilia *et al.* (2015), a habitual practice linked to recurrent occurrences of this dental disease. Carious lesions are, however, rare in the teeth of Palaeolithic foragers from Italy (*e.g.* Formicola 1986; Fabbri 1995) suggesting that not all groups consumed large quantities of cariogenic carbohydrate-rich foods.

The remaining late Upper Palaeolithic humans for whom isotope data are available seem to have had essentially terrestrial diets (Francalacci 1988; Craig *et al.* 2010; Mannino *et al.* 2011a), based on high levels of herbivore meat consumption (Table 1). Irrespectively of how far they were from the shores contemporary to them, they appear to have relied little (or not at all) on marine resources and their isotope compositions are not informative in terms of the plant foodstuffs they consumed. All these individuals date to the Bølling-Allerød interstadial, which in continental Europe was characterized by alternating mild and cold climatic episodes, the latter known as Oldest, Older and Younger Dryas. These Late Glacial downturns in climate are not detectable in environmental records throughout Italy, with the possible exception of the Younger Drays that brought the Bølling-Allerød interstadial to an end (Ravazzi *et al.* 2007). However, on the basis of the currently available chronology for the burials of these hunter-gatherers (many of which are not dated directly) it does not appear that any of them are assignable to periods of climatic deterioration. It could, thus, be that their diets represent adaptations to the prevailing environmental conditions of the Bølling-Allerød interstadial and are not representative of the periods of climatic deterioration that punctuated and ended it.

5. Isotope evidence for Mesolithic diets in Italy and in the central Mediterranean islands

Published isotope data on Mesolithic hunter-gatherers from Italy are limited to individuals from sites in Sicily and Sardinia (Table 1). Three humans from sites in north-east Italy have been analysed as part of an unpublished Ph.D. thesis by Valentina Gazzoni (2011). The isotope data are not presented here (as they are not published), although the findings reported in the above-mentioned thesis suggest that the foragers buried at Vatte di Zambana (Zambana Vecchia, Trento), Mezzocorona (Borgonuovo, Trento) and Mondeval de Sora (San Vito di Cadore, Belluno) had diets characterized by high levels of animal protein consumption originating from the meat of mammalian herbivores. The individual from Mondeval de Sora may also have consumed some aquatic resources from freshwater habitats, which would be in line with the exploitation of fish attested for instance at Mesolithic sites along the Adige Valley.

The Mesolithic humans from Sicily for which isotope data are available amount to a total sample of 18 specimens (Borgognini Tarli *et al.* 1993; Di Salvo *et al.* 2012). The majority of these are from Grotta dell'Uzzo, a cave in the north west of the island where in the early Holocene at least 13 individuals of all ages and genders were buried at a time when local subsistence was centred on hunting red deer (*C. elaphus*) and wild boar (*S. scrofa*), and exploiting marine resources was limited to occasional fishing and collecting of intertidal rocky shore gastropods (Tagliacozzo 1993). Not surprisingly, the carbon and nitrogen isotope data on the Mesolithic humans from Grotta dell'Uzzo indicate that the hunter-gatherers buried at this cave obtained most of their dietary protein from terrestrial herbivores and omnivores, with little or no marine protein consumption (Francalacci 1988; Mannino *et al.* 2015). The data from other Mesolithic sites on Sicily and from S'Omu S'Orku (Table 1), the only site on Sardinia for which we have data (Floris *et al.* 2012), are similar to those from Grotta dell'Uzzo, demonstrating that the diets of central Mediterranean Holocene foragers living along (or close to) the coast were dominated by terrestrial protein, with little nutrition acquired from seafood (Mannino *et al.* 2011b, 2012).

Isotopic data published on Corsica are overall similar to those available for Sicily and Sardinia, given that they show that Holocene hunter-gatherers had diets dominated by terrestrial resources (Pouydebat 1997; Vigne 2004; Goude *et al.* 2016). The individuals from Araguina Sennola and Monte Leone, however, have $\delta^{13}C$ values indicating that up to around a fifth of their dietary protein may have originated from marine resources. Corsica is one of the largest islands in the Mediterranean, but it had a more impoverished faunal assemblage compared to Sicily, because it was always separated from the mainland by a stretch of sea never narrower than around 15km (Palombo *et al.* 2017). A heavier reliance on marine resources could, thus, have been more of a necessity on Corsica than in Sicily; this may have been achieved, for instance by the occupants of Monte Leone, albeit only more than a couple of millennia after the beginning of the Holocene.

Period	Site	N	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Source
late Upper Palaeolithic	Šandalja II (Croatia)	3	-20.7±0.1	13.6±0.5	Richards *et al.* 2015
Mesolithic	Campu Stefanu	1	-20.4	8.9	Goude *et al.* 2016
Mesolithic	Torre d'Aquila	1	-20.3	8.1	Goude *et al.* 2016
Mesolithic	Monte Leone (Corsica)	1	-18.0	9.9	Pouydebat 1997
Mesolithic	Araguina Sennola (Corsica)	1	-18.8	10.6	Vigne 2004
Mesolithic	Pupićina Cave (Croatia)	4	-19.3	10.6	Paine *et al.* 2009
Mesolithic	Pupićina Cave (Croatia)	2	-19.2±0.1	10.5±0.3	Lightfoot *et al.* 2011
Mesolithic	Vela Spilja/Vela Luka (Croatia)	4	-18.6±0.6	9.2±1.0	Lightfoot *et al.* 2011
Mesolithic	El Collado (Spain)	9	-18.3±0.7	10.3±1.2	Garcia Guixé *et al.* 2006
Mesolithic	Santa Maira (Spain)	2	-18.1±0.1	9.1±0.4	Salazar-García *et al.* 2014
Mesolithic	Penya del Comptador (Spain)	3	-18.5±0.3	7.7±0.1	Salazar-García *et al.* 2014
Mesolithic	Cingle del Mas Nou (Spain)	4	-18.5±0.1	8.8±0.8	Salazar-García *et al.* 2014
Capsian	SHM-1, Hergla (Tunisia)	1	-14.5	10.4	Mannino & Richards 2013

Table 2. Carbon and nitrogen isotope data from well-preserved bone collagen of late Upper Palaeolithic, Mesolithic and Capsian humans from other central and western Mediterranean regions. The standard deviation could not be calculated for the data published by Paine et al. (2009), because only means were published by them.

Surprisingly, this was even the case of the hunter-gatherers who inhabited the present-day island of Favignana and who were buried at Grotta d'Oriente (Mannino *et al.* 2012). In the course of the Late Glacial and Postglacial, despite progressive isolation by rising sea levels of Favignana and of Levanzo (another island of the archipelago of the Egadi), these foragers, who were living in increasingly marginal terrestrial habitats, did not switch to consuming significantly higher proportions of seafood. Increases in the variety and quantity of marine taxa exploited by the hunter-gatherers of the Egadi Islands are attested in the course of the Mesolithic and, as at Grotta dell'Uzzo (Tagliacozzo 1993), in its later phases, albeit not at levels comparable to what is known for the westernmost part of the Mediterranean (*e.g.* Morales-Muñiz and Roselló-Izquierdo 2008) or for Atlantic and northern Europe (*e.g.* Andersen 2000; Enghoff 2011). Of the three individuals buried at Grotta d'Oriente, only the more recent one (Oriente X: 9,690-9,530 cal BP; Mannino *et al.* 2012) has carbon and nitrogen isotope ratios ($\delta^{13}C$: -17.8‰; $\delta^{15}N$: 10.6‰) suggesting that seafood contributed around a quarter of this individual's protein. At the time of this hunter-gatherer's life, Favignana was either a small peninsula off western Sicily or an island (only a study of its local palaeogeography can solve this). The higher marine component in the diet of Oriente X, relative to that of its ancestors on Favignana and of other Sicilian Mesolithic foragers, was likely a consequence of increased isolation. On small islands, marine foods may have constituted a relatively important component in the yearly subsistence of hunter-gatherers, although it should be pointed out that small islands were only fully settled in the Neolithic (Dawson 2013; Mannino 2014). The few individuals analyzed from Vela Spilja/Vela Luka on the small Croatian island of Korčula (Lightfoot *et al.* 2011) are compatible with this 'small-island dietary pattern' (Table 2), given that their $\delta^{13}C$ values are higher than those of humans from mainland Sicily and also of practically all analyzed late Upper Palaeolithic individuals. In this case, the contribution of marine foods to overall diet accounts for around one fifth of the dietary protein consumed, which is compatible with the above-mentioned seasonal evidence for fish, and particularly, mackerel (*S. japonicus*) consumption at Vela Spilja (Rainsford *et al.* 2014).

Exceptions to the generally meat-rich diets outlined above for central Mediterranean Mesolithic hunter-gatherers are represented by two individuals from caves on hillslopes encircling the Conca d'Oro coastal plain in NW Sicily: one from Grotta Molara and the other from Grotta Addaura Caprara (Mannino *et al.* 2011b). The individual labelled Molara 2 has a low $\delta^{15}N$ value for a human (= 7.1‰), which is indicative of a mixed diet in which meat had a marginal role and plant foods may have been the main source of dietary protein. Studies of dental microwear on this individual, as well as others from Grotta della Molara and Grotta dell'Uzzo (Borgognini Tarli and Repetto 1985), have shown that plants were important foodstuffs. This is also supported by the high incidence of caries in most individuals buried at these cave sites, which is suggestive of a carbohydrate-rich diet. The Mesolithic individual from Grotta Addaura Caprara with a relatively low $\delta^{15}N$ value (Addaura 2 = 8.7‰) probably also displays isotopically-detectable levels of vegetal consumption, although its main protein source was meat (Mannino *et al.* 2011b). The Mesolithic individuals from Grotta dell'Uzzo have generally higher $\delta^{15}N$ values than Addaura 2, although two have the same value (*i.e.* the female from burial 8 and the adult represented by the cranial fragment recovered in spit 3 of Trench Y). Overall, the isotopic data obtained analyzing the Mesolithic hunter-gatherers of NW Sicily suggest that, at least some of them, consumed large quantities of plant foods, only marginally attested by the macro-botanical food refuse of wild legumes, acorns and wild grape recovered at Grotta dell'Uzzo (Costantini 1989). It is possible that, sometime during the early Holocene, intensification based on plant exploitation started in NW Sicily, although more macro-botanical evidence is needed to understand the nature and scale of this adaptation.

The most significant broadening in the breadth of animal taxa exploited by the Holocene foragers of Grotta dell'Uzzo only occurred in the late Mesolithic and, particularly, during the so-called 'Mesolithic-Neolithic transition', roughly coinciding with the run up to, and duration of, the abrupt climate change known as the 8,200 years calibrated B.P. (hereafter 8.2-kyr-BP). Studies of the lithic industry have shown that this transitional phase was marked by a change in technology, which in this phase is typical of the last Mesolithic techno-complex in the region called Western Mediterranean blade and trapeze complex (Binder *et al.* 2012). A change in subsistence is also documented for this time, marked by an increase in fishing and the exploitation of a wider range of other aquatic resources, including birds, turtles and cetaceans (Tagliacozzo 1993). The only human dating to this phase of cultural and environmental transition has yielded what combined are the highest $\delta^{13}C$ and $\delta^{15}N$ values (respectively -16.2‰ and 12.8‰) of any prehistoric Mediterranean individual published to date (Mannino *et al.* 2015). These isotopic ratios are compatible with a consumption of marine protein amounting to 40-50% of protein intake, with about 32% originating from the consumption of cetacean meat. Given the absence of whaling technologies at Grotta dell'Uzzo, or for that matter at any other Mesolithic site in the Mediterranean, and considering that cetacean exploitation was temporally restricted to the time around the 8.2-kyr-BP event, the most likely explanation for the observed isotopic and zooarchaeological data is that they reflect the opportunistic exploitation of stranded cetaceans. Considering adult bone collagen turnover times, for a human to acquire such a large proportion of protein from cetaceans, their meat should have been available yearly. This may have been the case if, as hypothesized by Mannino *et al.* (2015), the strandings were the result of year-on-year changes in sea surface temperatures and salinities, as well as changes in atmospheric CO_2, and their consequences for organisms at the base of the food chain and through knock-on effects on apex predators such as marine mammals. The possibility that some form of rudimentary 'drive-hunting' may have been developed as an opportunistic adaptation to the dramatic increase in stressed or moribund cetaceans in coastal waters cannot be discarded outright. This is unlikely, however, given that it is not clear whether the Mesolithic foragers of Sicily had boats adequate for pursuing Delphinids (Mannino 2014). Moreover, had they mastered such watercraft technologies, it is improbable that they had the level of inter-group organization necessary for a complex activity such as drive hunting (Mannino *et al.* 2015). What the evidence from Grotta dell'Uzzo undisputedly shows is that, at times of abrupt climate change, Mediterranean foragers adapted opportunistically and rapidly to newly available resources.

6. Discussion

This paper constitutes a first attempt to bring together the patchy zooarchaeological record for aquatic adaptations in Italy with the growing (albeit limited) isotope database, to achieve a better understanding of central Mediterranean Upper Palaeolithic and Mesolithic subsistence and dietary strategies, particularly those that included marine and freshwater resources. In order to evaluate how much of a shift in subsistence and diet occurred during the Late Glacial and Postglacial, it is important to have a clearer picture of the role of aquatic animal foodstuffs in the diets of the earliest modern humans to have reached the Italian Peninsula. Currently this information is missing and only excavations undertaken with state-of-the-art approaches will help clarify whether the picture we have is one biased by lack of modern interdisciplinary investigations or a true reflection of the past. The synthesis of available faunal food refuse evidence for aquatic resource exploitation highlights that, although the record is patchy, for most of the Upper Palaeolithic such foodstuffs probably had a marginal role in Mediterranean human subsistence and diets. The isotope analyses on the Gravettian humans from Liguria (*i.e.* 'The Prince' and Barma Grande 6) suggest that the dearth of fish remains at middle Upper Palaeolithic sites may be at least in part due to incomplete recovery and that at times of very different environmental conditions, such as those experienced in the run up to the LGM, a whole range of resources that are not found in the Mediterranean during the Holocene may have been present and exploited by hunter-gatherers (albeit not necessarily by actual fishing).

The zooarchaeological data reviewed here suggest that an increase in fish consumption occurred during the Late Glacial, sometime around the Bølling – Allerød interstadial. The patchiness of this record and issues of archaeological and chronological resolution prevent us from having a clear view on whether such increases are linked to specific climatic episodes within the Late Glacial. Interestingly, the oldest fishhooks from Europe made of bone, recovered at Wustermark II in Germany, postdate the LGM and most date to the Bølling-Allerød (Gramsch *et al.* 2013). Late Upper Palaeolithic (*i.e.* Epigravettian) bone tool assemblages from Italy do not include artefacts that can be interpreted unambiguously as fishing tools, but only harpoons and points of different kinds (Mussi 2001; Martini 2008), suitable for spearing. The Italian Upper Palaeolithic archaeological record, thus, does not include evidence for elaborate fishing technologies and most of the humans for which carbon and nitrogen isotope data are available (*e.g.* Arene Candide, Riparo Villabruna, all the Grotta del Romito and Sicilian individuals except two) clearly had essentially terrestrial diets (Table 1). Traditional archaeological evidence and isotope data, overall, appear to be telling us a similar story. This also matches up with evidence from one of the few sites studied in detail in the eastern Mediterranean, namely Franchthi Cave in Greece, where fishing appears to have been a marginal activity in the Upper Palaeolithic (Perlès 2015).

Nevertheless, some Epigravettian hunter-gatherers dating between the start of the deglaciation and the beginning Bølling – Allerød interstadial and originating from across the Italian Peninsula (*i.e.* Riparo Tagliente and Grotta del Romito 9) and Sicily (*i.e.* Grotta di San Teodoro 1) may have acquired around a fifth of their dietary protein from aquatic resources, such as *S. trutta*. The reason for this may be that during deglaciation, or not long after it, melt waters engorged river systems with low temperature water, producing ideal conditions for salmonid spawning (Russ 2010: 207). It is also possible that other fish taxa may have benefitted from frequent Late Glacial environmental changes and this may, in turn, have been exploited by humans. The foragers from Šandalja II in nearby Istria (Croatia), for instance, have the lowest mean $\delta^{13}C$ values (= -20.7±0.1‰) and highest mean $\delta^{15}N$ values (= 13.6±0.5‰) than any of their contemporaries from Italy or Sicily, indicating that they relied heavily on freshwater resources (Richards *et al.* 2015). Late Upper Palaeolithic groups adapted their subsistence rapidly to climate-driven environmental changes, not easily-detectable through studies of bone assemblages affected by the palimpsest nature of most deposits, but which are reflected in the isotope composition of single individuals. It may be hypothesized that during climatic episodes generating favourable conditions for aquatic taxa, Mediterranean foragers would have been able to tap into resources with sufficient biomass to be useful on a seasonal scale and/or to generate surplus for lean times of the year.

The isotopic data currently available for the Mesolithic from Italy and its islands, as well as that for individuals from Pupićina Cave (Table 2), also in Istria (Paine *et al.* 2009; Lightfoot *et al.* 2011), show that marine resources were probably marginal in the diet of central Mediterranean foragers and had a very different role than in the diets of their contemporaries living along the Atlantic seaboard (*e.g.* Richards and Hedges 1999; Fischer *et al.* 2007). This has been suggested by numerous studies that have ascribed the difference to the lower primary productivity and secondary biomass levels between the Mediterranean Sea and the Atlantic Ocean, with its seas in NW Europe (*e.g.* Craig *et al.* 2006; Garcia Guixé *et al.* 2006; Mannino *et al.* 2012). The faunal food refuse from sites on the Italian Peninsula and Sicily does not suggest a dramatic increase in aquatic resource exploitation in the transition from the Pleistocene to the Holocene, which had pushed Radmilli (1960, 1974), and the generation of archaeologists that followed him, to define the Mesolithic on this basis (Pluciennik 2008). We have a very limited picture of maritime adaptations during the Holocene and the most representative site for this period is Grotta dell'Uzzo, where fishing increased only from the end of the Mesolithic to the early Neolithic (Tagliacozzo 1993). A parallel to this site is offered by Franchthi Cave in Greece, where fishing was also shore-based and where, contrary to what was originally proposed by Payne (1975), the exploitation of bluefin tuna (*Thunnus thynnus*) is not necessarily proof of deep-sea fishing (Rose 1995; Pickard and Bonsall 2004; Perlès 2015). Admittedly, most evidence comes from cave sites, which blinkers our view of maritime adaptations, reducing it almost exclusively to rocky shorelines. Our cave-centred view of Italian prehistory means that we know little about coastal adaptations in estuarine and lagoonal environments, where Late Glacial and Postglacial sea level rise must have destroyed the highest number of sites (Bailey and Flemming 2008).

Data are available for similar habitats in the western and central Mediterranean, respectively from the sites of El Collado in Spain and SHM-1 near Hergla in Tunisia (Table 2). The hunter-gatherers from El Collado have almost the highest mean $\delta^{13}C$ value in the Mediterranean and their individual values range from -19.5‰ to -17.6‰ (Garcia Guixé *et al.* 2006), suggesting that some of these individuals may have acquired at least a quarter of their dietary protein from seafood. Judging by their relatively low $\delta^{15}N$ values (mean = 10.3±1.2‰; range: 8.9‰ to 12.8‰), the marine resources consumed were mainly low trophic level animals from brackish water environments. It should also be pointed out that even some individuals living inland from El Collado, whose remains were recovered at sites such as Santa Maira and Cingle del Mas Nou (Table 2), appear to have consumed marine resources in isotopically-detectable proportions and definitely more than some of their central Mediterranean contemporaries (Salazar-García *et al.* 2014). The Capsian human from the Tunisian site of SHM-1, which is located along the shores of the Halk el Menjel lagoon, has the highest $\delta^{13}C$ value of any Mediterranean forager for which data are available in the literature (Mannino and Richards 2013). However, based on the limited data available, in this case the most likely source of enriched ^{13}C was not marine, but terrestrial. The occupiers of the site in question subsisted mainly by hunting animals, such as hartebeest (*Alcelaphus buselaphus*) and gazelles (*Gazella* spp.), by gathering plants, terrestrial and brackish water molluscs (Mulazzani 2013). Fishing was a marginal activity and the high $\delta^{13}C$ value is, in fact, best explained as resulting from the consumption of animals that fed on C_4 plants and/or of the plants themselves. This possibility can be excluded for the northern shores of the Mediterranean Basin, given that C_4 plants are rare (*e.g.* Collins and Jones 1985; Pyankov *et al.* 2010) and would have been more so before the introduction of C_4 domestic and invasive taxa in the middle Holocene or later (*e.g.* Ehleringer and Cerling 2002).

Summing up, if the evidence from Iberia is representative of adaptations by Mediterranean foragers to lagoonal habitats, it could be hypothesized that late Upper Palaeolithic and Mesolithic humans in Italy may have acquired at least around a quarter of their dietary protein from marine resources in such settings. Indeed, in one of his inspiring papers, Lewthwaite (1985) had suggested that the importance of lagoons has been greatly downplayed by available archaeological evidence. Nevertheless the Sea of Alboran and the westernmost areas of the Mediterranean Sea are more productive than the central and eastern areas of the basin. So the Mesolithic hunter-gatherers of Iberia were likely the highest consumers of seafood in the Mediterranean (Salazar-García *et* *al.* 2014). As outlined above, even individuals from islands such as Corsica (*i.e.* Monte Leone), Favignana or Korčula did not obtain more than a quarter of their dietary protein from marine resources, despite living in marginal environments from a terrestrial point of view. This, of course, does not mean that seafood was not important for the success of their subsistence strategies, given that it (a) surely contributed valuable nutrients that would not have been available in diets based exclusively on terrestrial foods (*e.g.* Mannino *et al.* 2014) and (b) must have constituted a useful source of nutrition either seasonally, when other resources dwindled, or throughout the year on a more opportunistic basis. What the observed pattern probably does mean, however, is that, contrary to other mid-latitude regions of Europe and beyond, sustained intensification (*sensu* Binford 2001) could not have been achieved by foragers exploiting marine resources in the central Mediterranean (and progressively less so as the Holocene unfolded).

The only true exception to the general trend is represented by the hunter-gatherer who lived during the Mesolithic-Neolithic transition in the territory of Grotta dell'Uzzo in NW Sicily. As discussed above, this individual obtained at least 40% of its dietary protein from marine resources and most of this from cetacean meat (Mannino *et al.* 2015). It is, thus, possible that at times of abrupt climate change, such as the 8.2-kyr BP event, Mediterranean foragers rapidly adapted their subsistence to exploit resources traditionally not part of their diet or the existence of which was little known. The impact of such short-term adaptations may be difficult to realize through 'traditional archaeological data' alone. In fact, although, Tagliacozzo (1993) had hypothesized that portions of cetaceans were taken back to Grotta dell'Uzzo for consumption, the true scale of this behaviour could only be exposed through isotope analyses (Mannino *et al.* 2015). These show not only the dietary importance of such opportunistic adaptations, but also their potential long-term effects for the innovation of subsistence strategies.

7. Conclusions and future developments

The main observations arising from this review of the archaeological and isotopic evidence for the exploitation of aquatic resources in Italy can be synthesized as follows: (i) very little evidence is available for the exploitation of aquatic vertebrates before the LGM and it is not clear to what extent fishing was actually practiced; (ii) basic fishing techniques were employed from the Late Glacial, to start off mainly in freshwater and shallow soft-bottom marine habitats; (iii) the beginning of the Mesolithic was not marked by a significant increase in fishing, clearer evidence for which is actually available for later stages of this period, when more complex techniques were developed, probably also in relation to a wider use of boats (Mannino 2014). Contrary to what has been found for Mesolithic groups living along the Atlantic seaboard of Europe (*e.g.* Richards and Hedges 1999), Mediterranean hunter-gatherers did not rely heavily on marine or other aquatic resources. The highest levels of aquatic resource consumption appear to have been associated with phases of climatic and environmental change, both in the Late Glacial and Holocene, when such foods may have been seasonally important. At times of relative climatic stability, marine resources available along rocky coastlines would have been marginal, whilst it remains to be seen what adaptations may have been possible in estuarine and lagoonal settings. It can be hypothesized that, had Neolithic farmers not introduced agro-pastoralism a couple of centuries after the

8.2-kyr-BP event, Mediterranean hunter-gatherers could never have become complex relying on an intensive exploitation of aquatic resources and/or plants foods, as they did during the Holocene along oceanic shores in other continents (Binford 2001). This may, in fact, be an explanation for the drop in Mediterranean Mesolithic populations, which probably encountered increasing difficulties in subsisting after many of the preferred mammalian prey species became extirpated, as the combined result of climate change and human predation.

Our understanding of hunting and gathering in Italy during the Late Glacial and Holocene has improved since the syntheses by Radmilli (1960, 1974), as a result of a few zooarchaeological studies and of the application of methods not available during his times, such as isotope analyses. However, the general approach to addressing the complex questions linked to the study of human subsistence in changing environments, for which we have no modern analogues, has not. Few concerted attempts have been made to reconstruct hunter-gatherer subsistence beyond individual sites at a wider and more regional territorial scale (*e.g.* Clark 2000; Grimaldi and Flor 2009; Mannino and Thomas 2009; Mannino *et al.* 2011b; Wierer *et al.* 2016; Fontana and Visentin 2016), which is essential to understand adaptations to changing resource availability across space and time. The problems plaguing Italian prehistory, in general, and subsistence studies, in particular, are linked to how archaeological theory developed (or actually failed to do so).

Unfortunately, the so-called 'New Archaeology' arrived in Italy only after 1970 and was hastily dismissed as a reactionary theoretical position, almost completely forgotten by the 1980s (Bietti Sestieri 2000). Italian prehistory, hence, did not benefit from the positive outcomes of processual theory for the development of archaeological science and in Italy (as in many non-English speaking countries) only more recently (and marginally) have changes in the way archaeology is taught or practiced taken place. Guidi (2010: 18) has stated that, at least up to 2000, "the main approach of Italian prehistory studies of the period can be considered cultural-historical". The result of all this (in our view) is that archaeological science in Italy is generally less truly inter-disciplinary than, for want of a better word, in the English-speaking world and few other isolated realities. It is not by chance that, with a single exception (*i.e.* Floris *et al.* 2012), all data reported in Table 1 were obtained through sample pretreatments and isotope analyses conducted outside of Italy. This, along with a general tendency to focus analyses mainly on human samples, has also meant that isotopic baselines for trophic webs are poorly developed. The lack of such data limits our understanding of non-analogue environments, such as those of the Mediterranean during the late Pleistocene and early Holocene. In addition, it also has an effect on the accuracy and complexity of isotope-based palaeodietary reconstructions that would benefit from larger isotopic databases, particularly including fish and bird taxa for which there are little or no data.

In conclusion, regarding the state of archaeological science in Italy, it is worth quoting Guidi (2010: 18), who stated that: "In Italian prehistory it is possible to detect the absolute lack of one of the pillars of the processual school: the attempt to create a 'scientific community' (in Kuhnian terms), with shared methodological and theoretical approaches". There may, nevertheless, be reasons for optimism, as a new generation of archaeologists (well-represented at the 'Out of Italy' conference) that has been exposed to science-based approaches to prehistory, either by working abroad or by collaborating with colleagues worldwide, beckons.

References

Albertini, D., Calattini, M. and Tagliacozzo, A. 2010. I resti di pesce del Paleolitico superiore-Mesolitico di Grotta delle Mura (Monopoli, Bari), in: Tagliacozzo, A., Fiore, I., Marconi, S. and Tecchiati, U. (eds.). *Atti del 5°Convegno Nazionale di Archeozoologia*. Rovereto (Trento): Edizioni Osiride, 101-104.

Albertini, D. and Tagliacozzo, A. 2004a. I resti di pesce provenienti dai livelli preistorici di Riparo Cogola. *Preistoria Alpina* 40, 187-191.

Albertini, D. and Tagliacozzo, A. 2004b. Fresh water fishing in Italy during the Late Glacial period: the examples of Riparo Dalmeri (Trento), in: Bugal, J.P. and Desse, J. (eds.). *Petits animaux et societés humaines. Du complément alimentaire aux ressources utilitaires*. Antibes: Éditions APDCA, 131-136.

Andersen, S.H. 2000. "Køkkenmøddinger" (shell middens) in Denmark: a survey. *Proceedings of the Prehistoric Society* 66, 361-384.

Aura, J.E., Jordá, J.F., Morales, J.V., Pérez, M., Villalba, M.-P. and Alcover, J.A. 2009. Economic transitions in *finis terra*: the western Mediterranean of Iberia, 15-7 ka BP. *Before Farming* 2009(2), article 1.

Bailey, G.N. and Flemming, N.C. 2008. Archaeology of the continental shelf: marine resources, submerged landscapes and underwater archaeology. *Quaternary Science Reviews* 27, 2153-2165.

Bazzanella, M., Betti, L. and Wierer, U. 2007. Mesolithic wetland exploitation at Galgenbühel / Dos de la Forca Italy, Eastern Alps. The fish fauna, in: Hüster Plogmann, H. (ed.). *The role of fish in ancient time.* Proceedings of the 13th Meeting of the ICAZ Fish Remains Working Group in October 4th-9th, Basel/Augst 2005. Rahden: Verlag Marie Leidorf GmbH, 93-100.

Bazzanella, M., Betti, L., Trentini, M. and Wierer, U. 2006. La pesca del luccio nel Trentino. Ricerca archeologica e metodo etnografico a confronto. *SM Annali di San Michele* 19, 157-175.

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, 525-528.

Bietti, A. 1990. The Late Upper Palaeolithic in Italy: an overview. *Journal of World Prehistory* 4, 95-155.

Bietti, A. 1991. Normal science and paradigmatic biases in Italian hunter-gatherer prehistory, in: G.A. Clark (ed.). *Perspectives on the past: Theoretical biases in Mediterranean hunting–gathering research*. Philadelphia: University of Pennsylvania Press, 258-281.

Bietti Sestieri, A.M. 2000. L'archeologia processuale in Italia, o l'impossibilità di essere normali, in: Terrenato N. (ed.). *Archeologia teorica*. X Ciclo di lezioni sulla ricerca applicate in archeologia. Certosa di Pontignano 1999. Firenze: All'Insegna del Giglio, 213-242.

Binder, D., Collina, C., Guilbert, R., Perrin, T. and Garcia-Puchol, O. 2012. Pressure-knapping blade production in the North-Western Mediterranean region during the seventh millennium cal. B.C., in: Desrosiers, P.M. (ed.). *The Emergence of Pressure Blade Making. From Origin to Modern Experimentation*. New York: Springer Science+Business Media, 199-217.

Binford, L.R. 2001. *Constructing Frames of Reference. An Analytical Method for Archaeological Theory Building Using Ethnographic and Environmental Data Sets*. Berkeley: University of California Press.

Borgognini Tarli, S.M., Canci, A. and Piperno, M. 1993. Dati archeologici e antropologici sulle sepolture mesolitiche della Grotta dell'Uzzo (Trapani). *Bullettino di Paletnologia Italiana* 84, 85-179.

Borgognini Tarli, S.M. and Repetto, E. 1985. Dietary patterns in the Mesolithic samples from Uzzo and Molara caves (Sicily): the evidence of teeth. *Journal of Human Evolution* 14, 241-254.

Cassoli, P.F. 1980. L'avifauna del pleistocene superiore delle Arene Candide (Liguria). *Memorie dell'Istituto Italiano di Paleontologia Umana* 3, 155-234.

Cassoli, P.F. and Tagliacozzo, A. 1982. La fauna della Grotta di Cala dei Genovesi a Levanzo. *Rivista di Scienze Preistoriche* 37, 48-58.

Cassoli, P.F. and Tagliacozzo, A. 1995. Lo sfruttamento delle risorse marine tra il Mesolitico e il Neolitico alla Grotta dell'Uzzo, Trapani (Sicilia). *Atti del 1° Convegno Nazionale di Archeozoologia*. Rovigo: Padusa Quaderni, 157-170.

Cassoli, P.F. and Tagliacozzo, A. 1997. Avifauna e ittiofauna di Grotta di Castelcivita: considerazioni ecologiche ed inquadramento crono-stratigrafico, in: Gambassini P. (ed.). *Il Paleolitico di Castelcivita: culture e ambiente*. Napoli: Electa, 70-74.

Clark, J.G.D. 1936. *The Mesolithic Settlement of Northern Europe: a Study of the Food-gathering Peoples of Northern Europe during the Early Post-Glacial Period*. Cambridge: Cambridge University Press.

Clark, J.G.D. 1952. *Prehistoric Europe: The Economic Basis*. Cambridge: Cambridge University Press.

Clark, R. 2000. *The Mesolithic hunters of the Trentino. A case study in hunter-gatherer settlement and subsistence from northern Italy*. Oxford: British Archaeological Reports, International Series 832.

Cleyet-Merle, J.-J. 1990. *La préhistoire de la pêche*. Paris: Editions Errance.

Collins, R.P. and Jones, M.B. 1985. The influence of climate factors on the distribution of C_4 plants in Europe. *Vegetatio* 64, 121-129.

Colonese, A.C., Mannino, M.A., Bar-Yosef Mayer, D.E., Fa, D.A., Finlayson, J.C., Lubell, D. and Stiner, M.C. 2011. Marine mollusc exploitation in Mediterranean prehistory: an overview. *Quaternary International* 239, 86-103.

Colonese, A.C. and Tozzi, C. 2010. La malacofauna di Grotta del Mezzogiorno (Salerno): aspetti culturali e paleoecologici. *Atti 5° Convegno Nazionale di Archeozoologia*. Rovereto (Trento): Edizioni Osiride, 93-96.

Colonese, A.C. and Wilkens, B. 2002. The malacofauna of the Upper Palaeolithic levels at Grotta della Seratura (Salerno, southern Italy), preliminary data, in: Bar Yosef, D. (ed.). *Archaeomalacology: Molluscs in Former Environments of Human Behaviour*. Oxford: Oxbow Books, 63-70.

Cortés-Sánchez, M., Morales-Muñiz, A., Simón-Vallejo, M.D., Bergadà-Zapata, M.M., Delgado-Huertas, A., López-García, P., López-Sáez, J.A., Lozano-Francisco, M.C., Riquelme-Cantal, J.A., Rosselló-Izquierdo, E., Sánchez-Marco, A. and Vera-Peláez, J.L. 2008. Palaeoenvironmental and cultural dynamics of the coast of Málaga (Andalusia, Spain) during the Upper Pleistocene and early Holocene. *Quaternary Science Reviews* 27, 2176-2193.

Costantini, L. 1989. Plant exploitation at Grotta dell'Uzzo, Sicily: new evidence for the transition from Mesolithic to Neolithic subsistence in southern Europe, in: Harris, D.R. and Hillman, G.C. (eds.). *Foraging and farming: the evolution of plant exploitation.* London: Unwin Hyman, 197-206.

Craig, O.E., Biazzo, M., Colonese, A.C., Di Giuseppe, Z., Martinez-Labarga, C., Lo Vetro, D., Lelli, R., Martini, F. and Rickards, O. 2010. Stable isotope analysis of Late Upper Palaeolithic human and faunal remains from Grotta del Romito (Cosenza), Italy. *Journal of Archaeological Science* 37, 2504-2512.

Craig, O.E., Biazzo, M. and Tafuri, M.A. 2006. Palaeodietary records of coastal Mediterranean populations. *Journal of Mediterranean Studies* 16, 63-77.

Cristiani, E. 2009. Osseous artefacts from the Mesolithic levels of Pradestel rockshelter, (north-eastern Italy): a morphological and techno-functional analysis. *Preistoria Alpina* 44, 1-6.

Cristiani, E. and Borić, D. 2016. Mesolithic harpoons from Odmut, Montenegro: chronological, contextual, and techno-functional analyses. *Quaternary International* 423, 166-192.

Dalmeri, G., Grimaldi, S. and Lanzinger, M. 2001. Il Paleolitico e il Mesolitico, in: Lanzinger, M., Marzatico, F. and Pedrotti, A. (eds.). *Storia del Trentino. La Preistoria e la Protostoria*. Bologna: Il Mulino Edizioni, 37-110.

Dalmeri, G. and Nicolodi, F. 2004. Siti e collezioni antropologiche, preistoriche e protostoriche provinciali del Museo Tridentino di Scienze Naturali. *Preistoria Alpina* 40, 63-81.

Dawson, H. 2013. *Mediterranean Voyages. The Archaeology of Island Colonization and Abandonment*. Walnut Creek (California): Left Coast Press.

De Grossi Mazzorin, J. and Tagliacozzo, A. 1998. Human diet of animal origin in Italy between the Palaeolithic and the Metal Age in light of archaeozoological data. *Rivista di Antropologia* (supplement) 76, 85-93.

DeNiro, M.J. 1985. Postmortem preservation and alteration of *in vivo* bone collagen isotope ratios in relation to palaeodietary reconstruction. *Nature* 317, 806-809.

d'Errico, F. 1994. Birds of the Grotte Cosquer: the Great Auk and Palaeolithic prehistory. *Antiquity* 68, 39-47.

Di Salvo, R., Mannino, M.A., Schimmenti, V., Sineo, L. and Thomas, K.D. 2012. Nuovi dati sulle sepolture della Grotta dell'Uzzo. *Atti della XLI Riunione Scientifica, Istituto Italiano di Preistoria e Protostoria*, 461-470.

Durante, S. 1978. Note on *Salmo trutta* L. in the Pleistocene of Praia a Mare (southern Italy). *Quaternaria* 10, 117-121.

Ehleringer, J.R. and Cerling, T.E. 2002. C_3 and C_4 photosynthesis, in: Mooney, H.A. and Canadell, J.G. (eds.). *Encyclopedia of Global Environmental Change, Volume 2, The Earth system: biological and ecological dimensions of global environmental change*. Chichester: John Wiley & Sons, 186-190.

El Zaatari, S. and Hublin, J.-J. 2014. Diet of Upper Paleolithic modern humans: evidence from microwear texture analysis. *American Journal of Physical Anthropology* 153, 570-581.

Enghoff, I.B. 2011. Regionality and biotope exploitation in Danish Ertebølle and adjoining periods. *Scientia Danica, Series B, Biologica* 1.

Erlandson, J.M. 2001. The archaeology of aquatic adaptations: paradigms for a new millennium. *Journal of Archaeological Research* 9, 287-350.

Fabbri, P.F. 1995. Dental anthropology of the Upper Palaeolithic sample from San Teodoro and inference on the peopling of Sicily. *Zeitschrift für Morphologie und Anthropologie* 80, 311-327.

Fiore, I., Gala, M., Pino Uría, B. and Tagliacozzo, A. 2004. Archeozoologia dei livelli mesolitici della Grotta del Santuario della Madonna di Praia a Mare (CS). *Atti della XXXVII Riunione Scientifica* 683-692.

Fiorenza, L., Benazzi, S., Henry, A.G., Salazar-García, D.C., Blasco, R., Picin, A., Wroe, S. and Kullmer, O. 2015. To meat or not to meat? New perspectives on Neanderthal ecology. *American Journal of Physical Anthropology* 156, 43-71.

Fischer, A., Olsen, J., Richards, M., Heinemeier, J., Sveinbjörnsdóttir, A.E. and Bennike, P. 2007. Coast-inland mobility and diet in the Danish Mesolithic and Neolithic: evidence from stable isotope values of humans and dogs. *Journal of Archaeological Science* 34, 2125-2150.

Floris, R., Melis, R.T., Mussi, M., Palombo, M.R., Iacumin, P., Usai, A. and Mascia, F. 2012. La presenza umana nella Sardegna centro occidentale durante l'Olocene antico: il sito di S'Omu e S'Orku (Arbus, VS). *Atti della XLIV Riunione Scientifica* 999-1004.

Fontana, F. and Visentin, D. 2016. Between the Venetian Alps and the Emilian Apennines (Northern Italy): highlands vs. lowland occupation in the early Mesolithic. *Quaternary International* 423, 266-278.

Formicola, V. 1986. Anthropologie dentaire des restes de l'Épigravettien Final retrouvés dans la grotte des Arene Candide (Ligurie). *Bulletins et Mémoires de la Société d'Anthropologie de Paris* 3, 37-46.

Formicola, V., Pettitt, P.B. and Del Lucchese, A. 2004. A direct AMS radiocarbon date on the Barma Grande 6 Upper Paleolithic skeleton. *Current Anthropology* 45, 114-118.

Francalacci, P. 1988. Comparison of archaeological trace element and stable isotope data from two Italian coastal sites. *Rivista di Antropologia* 56, 239-250.

Gala, M. and Tagliacozzo, A. 2012. Aspetti ecologici ed economici dell'avifauna del Tardoglaciale italiano. *Atti 6º Convegno Nazionale di Archeozoologia*. Lecce: Associazione Italiana di Archeozoologia, 79-88.

Garcia-Guixé, E., Richards, M.P. and Subirà, M.E. 2006. Palaeodiets of humans and fauna at the Spanish Mesolithic site of El Collado. *Current Anthropology* 47, 549-556.

Gazzoni, V. 2011. *Contributo alla ricostruzione delle identità regionali e della differenziazione sociale presso i gruppi di cacciatori-raccoglitori paleo-mesolitici. Studio della ritualità funeraria in Italia e Francia e analisi degli isotopi stabili sul campione umano del versante alpino sud-orientale*. Unpublished Ph.D. thesis, Università degli Studi di Ferrara, Ferrara (Italy).

Gazzoni, V., Goude, G., Herrscher, E., Guerreschi, A., Antonioli, F. and Fontana, F. 2013. Late Upper Palaeolithic human diet: first stable isotope evidence from Riparo Tagliente (Verona, Italy). *Bulletins et Mémoires de la Société d'Anthropologie de Paris* 25, 103-117.

Goude, G., Willmes, M., Wood, R., Courtaud, P., Leandri, F., Cesari, J. and Grün, R. 2016. New insights into Mesolithic human diet in the Mediterranean from stable isotope analysis: the sites of Campu Stefanu and Torre d'Aquila, Corsica. *International Journal of Osteoarchaeology* 27, 707-714.

Gramsch, B., Beran, J., Hanik, S. and Sommer, R.S. 2013. A Palaeolithic fishhook made of ivory and the earliest fishhook tradition in Europe. *Journal of Archaeological Science* 40, 2458-2463.

Grimaldi, S. and Flor, E. 2009. From the mountain to the sea: an ethnographic perspective for the Early Mesolithic settlement dynamics in north-east Italy, in: McCartan, S., Schulting, R., Warren, G. and Woodmann, P. (eds.). *Mesolithic Horizons, Seventh International Conference on the Mesolithic in Europe, Belfast*. Oxford: Oxbow Books, 754-759.

Guidi, A. 2010. The historical development of Italian prehistoric archaeology: a brief outline. *Bulletin of the History of Archaeology* 20, 13-21.

Kettle, A.J., Morales-Muñiz, A., Roselló-Izquierdo, E., Heinrich, D. and Vøllestad, L.A. 2011. Refugia of marine fish in the northeast Atlantic during the last glacial maximum: concordant assessment from archaeozoology and palaeotemperature reconstructions. *Climate of the Past* 7, 181-201.

Lee-Thorp, J.A. 2008. On isotope and old bones. *Archaeometry* 50, 925-950.

Lewthwaite, J. 1985. The lacuna in the lagoon: an interdisciplinary research frontier in West Mediterranean Holocene palaeoecology and prehistory. *Cahiers Ligures de Préhistoire et de Protohistoire* 2, 253-265.

Lightfoot, E., Boneva, B., Miracle, P.T., Šlaus, M. and O'Connell, T.C. 2011. Exploring the Mesolithic and Neolithic transition in Croatia through isotope investigations. *Antiquity* 85, 73-86.

Mannino, M.A. 2014. The question of voyaging by foragers who lived in the Central Mediterranean. *Eurasian Prehistory* 11, 165-184.

Mannino, M.A., Catalano, G., Talamo, S., Mannino, G., Di Salvo, R., Schimmenti, V., Lalueza-Fox, C., Messina, A., Petruso, D., Caramelli, D., Richards, M.P. and Sineo, L. 2012. Origin and diet of the prehistoric hunter-gatherers on the Mediterranean Island of Favignana (Ègadi Islands, Sicily). *PloS ONE*, 7 (11), e49802, doi:10.1371/journal.pone.0049802.

Mannino, M.A., Di Salvo, R., Schimmenti,V., Di Patti, C., Incarbona, A., Sineo, L. and Richards, M.P. 2011a. Upper Palaeolithic hunter-gatherer subsistence in Mediterranean coastal environments: an isotopic study of the diets of the earliest directly-dated humans from Sicily. *Journal of Archaeological Science* 38, 3094-3100.

Mannino, M.A. and Richards, M.P. 2013. Analisi degli isotopi stabili di carbonio ed azoto sul collagene osseo dai resti scheletrici umani e faunistici di SHM-1 (Tunisia), in : Mulazzani, S. (ed.). *Le Capsien de Hergla (Tunisie). Culture, environnement et économie*. Frankfurt am Main: Reports in African Archaeology 4, Africa Magna Verlag, 315-319.

Mannino, M.A., Talamo, S., Tagliacozzo, A., Fiore, I., Nehlich, O., Piperno, M., Tusa S., Collina, C., Di Salvo, R., Schimmenti, V. and Richards, M.P. 2015. Climate-driven environmental changes around 8,200 years ago favoured increases in cetacean strandings and Mediterranean hunter-gatherers exploited them. *Scientific Reports* 5, 16288, doi:10.1038/srep16288.

Mannino, M.A. and Thomas, K.D. 2004. Studio archeozoologico dei reperti faunistici della Grotta d'Oriente a Favignana (Trapani). *Quaderni del Museo Archeologico Regionale «Antonino Salinas»* 8, 23-54.

Mannino, M.A. and Thomas, K.D. 2007. New radiocarbon dates for hunter-gatherers and early farmers in Sicily. *Accordia Research Papers* 10, 13-33.

Mannino, M.A. and Thomas, K.D. 2009. Current research on prehistoric human coastal ecology: late Pleistocene and early Holocene hunter-gatherer transitions in NW Sicily, in: McCartan, S., Schulting, R., Warren, G. and Woodmann, P. (eds.). *Mesolithic Horizons, Seventh International Conference on the Mesolithic in Europe, Belfast*. Oxford: Oxbow Books, 140-145.

Mannino, M.A. and Thomas, K.D. 2010. Studio preliminare del campione faunistico della Grotta Schiacciata a Levanzo (Trapani). *Atti 5º Convegno Nazionale di Archeozoologia*. Rovereto (Trento): Edizioni Osiride, 97-99.

Mannino, M.A., Thomas, K.D., Crema, E.R. and Leng, M.J. 2014. A matter of taste? Mode and periodicity of marine mollusc exploitation on the Mediterranean island of Favignana (Ègadi Islands, Italy) during its isolation in the early Holocene. *Archaeofauna* 23, 133-147.

Mannino, M.A., Thomas, K.D., Leng, M.J., Di Salvo, R. and Richards, M.P. 2011b. Stuck to the shore? Investigating prehistoric hunter-gatherer subsistence, mobility and territoriality in a Mediterranean coastal landscape through isotope analyses on marine mollusc shell carbonates and human bone collagen. *Quaternary International* 244, 88-104.

Martini, F. 2008. *Archeologia del Paleolitico*. Roma: Carocci Editore.

Martini, F., Colonese, A.C., di Giuseppe, Z., Ghinassi, M., Lo Vetro, D. and Ricciardi, S. 2009. Human-environment relationships during the Late Glacial – Early Holocene transition: some examples from Campania, Calabria and Sicily. *Méditerranée* 112, 89-94.

Morales-Muñiz, A. 2010. Inferences about prehistoric fishing gear based on archaeological fish assemblages, in: Bekker-Nielsen, T. Bernal Casasola, D. (eds.). *Ancient Nets and Fishing Gear. Proceedings of the International Workshop on "Nets and Fishing Gear in Classical Antiquity: a First Approach"*. Cádiz: Universidad de Cádiz, Servicio de Publicaciones, 25-53.

Morales-Muñiz, A. and Roselló-Izquierdo, E. 2008. Twenty thousand years of fishing in the Strait:archaeological fish and shellfish assemblages from southern Iberia, in: Rick, T.C. and Erlandson, J. (eds.). *Human Impacts on Ancient Marine Ecosystems: a Global Perspective*. Berkeley and Los Angeles: University of California Press, 243-277.

Muñoz, M. and Casadevall, M. 1997. Fish remains from Arbreda Cave (Serinyà, Girona), northeast Spain, and their palaeoecological significance. *Journal of Quaternary Science* 12, 111-115.

Morgan, C.J. 2015. Is it intensification yet? Current archaeological perspectives on the evolution of hunter-gatherer economies. *Journal of Archaeological Research* 23, 163-213.

Morin, E. 2012. *Reassessing Palaeolithic subsistence. The Neanderthal and Modern Human foragers of Saint-Césaire*. Cambridge: Cambridge University Press.

Mulazzani, S. 2013. *Le Capsien de Hergla (Tunisie). Culture, environnement et économie*. Frankfurt am Main: Reports in African Archaeology 4, Africa Magna Verlag.

Mussi, M. 2001. *Earliest Italy. An Overview of the Italian Paleolithic and Mesolithic*. New York: Kluwer Academic / Plenum Publishers.

Mussi, M., D'Angelo, E. and Fiore, I. 2004. Escargots et autres «petites» ressources alimentaires: le cas de la Grotta di Pozzo (Abruzzes, Italie centrale), in: Brugal J.-P. and Desse J. (eds.). *Petits animaux et societés humaines. Du complément alimentaire aux ressources utilitaires*. Antibes: Éditions APDCA, 99-110.

Oxilia, G., Peresani, M., Romandini, M., Matteucci, C., Debono Spiteri, C., Henry, A.G., Schulz, D., Archer, W., Crezzini, J., Boschin, F., Boscato, P., Jaouen, K., Dogandzic, T., Broglio, A., Moggi-Cecchi, J., Fiorenza, L., Hublin, J.-J., Kullmer, O. and Benazzi, S. 2015. Earliest evidence of dental caries manipulation in the Late Upper Palaeolithic. *Scientific Reports* 5, 12150, doi:10.1038/srep12150.

Paine, C., O'Connell, T.C. and Miracle, P.T. 2009. Stable isotopic reconstruction of early Mesolithic diet at Pupićina Cave, in: McCartan, S., Schulting, R., Warren, G. and Woodman, P. (eds.). *Mesolithic Horizons, Seventh International Conference on the Mesolithic in Europe, Belfast*. Oxford: Oxbow Books, 210-216.

Palombo, M.R., Antonioli, F., Lo Presti, V., Mannino, M.A., Melis, R.T., Orru, P., Stocchi, P., Talamo, S., Quarta, G., Calcagnile, L., Deiana, G. and Altamura, S. 2017. The late Pleistocene to Holocene palaeogeographic evolution of the Porto Conte area: clues for a better understanding of human colonization of Sardinia and faunal dynamics during the last 30ka. *Quaternary International* 439, 117-140.

Payne, S. 1975. Faunal change at Franchthi Cave from 20,000 BC to 3000 BC, in: Clason, A.T. (ed.). *Archaeozoological Studies*. Amsterdam: North Holland / American Elsevier, 120-131.

Perlès, C. 2015. Food and ornaments: diachronic changes in the exploitation of littoral resources at Franchthi Cave (Argolid, Greece) during the Upper Palaeolithic and the Mesolithic (39,000-7000 cal BC). *Quaternary International* 407, part B, 45-58.

Pettitt, P., Richards, M.P., Maggi, R. and Formicola, V. 2003.The Gravettian burial known as the Prince ('Il Principe'): new evidence for his age and diet. *Antiquity* 295, 15-19.

Pickard, C. and Bonsall, C. 2004. Deep-sea fishing in the European Mesolithic: fact or fantasy? *European Journal of Archaeology* 7, 273-290.

Pluciennik, M. 2000. Reconsidering Radmilli's Mesolithic. *Società di Preistoria e Protostoria del Friuli-Venezia Giulia, Trieste,* Quaderno 8, 171-183.

Pluciennik, M. 2008. The coastal Mesolithic of the European Mediterranean, in: Bailey, G. and Spikins, P. (eds.). *Mesolithic Europe*. Cambridge: Cambridge University Press, 328-356.

Poudeybat, E. 1997. Approche biogéchimique de l'alimentation humaine dans le site prénéolithique du Monte Leone (VIIIe millénaire av J.-C.; Bonifacio Corse-du-Sud), Mémoire de Maîtrise d'Archéologie: Université Paris I.

Pyankov, V.I., Ziegler, H., Akhani, H., Deigele, C. and Lüttge, U. 2010. European plants with C_4 photosynthesis: geographical and taxonomic distribution and relations to climatic parameters. *Botanical Journal of the Linnean Society* 163, 283-304.

Radmilli, A. 1960. Considerazioni sul Mesolitico italiano. *Annali dell'Università di Ferrara* (n.s. sezione 15) 1(3), 29-48.

Radmilli, A. 1974. *Popoli e Civiltà dell'Italia Antica, 1*. Roma: Biblioteca di Storia Patria.

Rainsford, C., O'Connor, T. and Miracle, P. 2014. Fishing in the Adriatic at the Mesolithic-Neolithic transition: evidence from Vela Spila, Croatia. *Environmental Archaeology* 19, 311-320.

Ravazzi, C., Peresani, M., Pini, R. and Vescovi, E. 2007. Il Tardoglaciale nelle Alpi italiane e in Pianura Padana. Evoluzione stratigrafica, storia della vegetazione e del popolamento antropico. *Il Quaternario* 20, 163-184.

Richards, M.P. and Hedges, R.E.M. 1999. Stable isotope evidence for similarities in the types of marine foods used by late Mesolithic humans at sites along the Atlantic coast of Europe. *Journal of Archaeological Science* 26, 717-722.

Richards, M.P., Pettitt, P.B., Stiner, M.C. and Trinkaus, E. 2001. Stable isotope evidence for increasing dietary breadth in the European mid-Upper Paleolithic. *Proceedings of the National Academy of Sciences of the U.S.A.* 98, 6528-6532.

Richards, M.P., Karavanić, I., Pettitt, P. and Miracle, P. 2015. Isotope and faunal evidence for high levels of freshwater fish consumption by Late Glacial humans at the Late Upper Palaeolithic site of Šandalja II, Istria, Croatia. *Journal of Archaeological Science* 61, 204-212.

Richards, M.P. and Trinkaus, E. 2009. Isotopic evidence for the diets of European Neanderthals and early modern humans. *Proceedings of the National Academy of Sciences of the U.S.A.* 106, 16034-16039.

Rose, M. 1995. Fishing at Franchthi Cave, Greece: changing environments and patterns of exploitation. *Old World Archaeology Newsletter* 18, 21-26.

Russ, H. 2010. *A taphonomic approach to reconstructing Upper Palaeolithic hunter-gatherer fishing strategies*. Ph.D. Thesis, University of Bradford (United Kingdom).

Russ, H. and Jones, A.K.G. 2009. Late Upper Palaeolithic fishing in the Fucino Basin, central Italy, a detailed analysis of the remains from Grotta di Pozzo. *Environmental Archaeology* 14, 155-162.

Salazar-García, D.C., Aura, J.E., Olària, C.R., Talamo, S., Morales, J.V. and Richards, M.P. 2014. Isotope evidence for the use of marine resources in the Eastern Iberian Mesolithic. *Journal of Archaeological Science* 42, 231-240.

Sommer, R.S. and Nadachowski, A. 2006. Glacial refugia of mammals in Europe: evidence from fossil records. *Mammal Review* 36, 251-265.

Stiner, M.C. 1994. *Honor among thieves: a zooarchaeological study of Neanderthal ecology*. Princeton: Princeton University Press.

Stringer, C.B., Finlayson, J.C., Barton, R.N.E., Fernández-Jalvo, Y., Cáceres, I., Sabin, R.C., Rhodes, E.J., Currant, A.P., Rodríguez-Vidal, J., Giles-Pacheco, F. and Riquelme-Cantal, J.A. 2008. Neanderthal exploitation of marine mammals in Gibraltar. *Proceedings of the National Academy of Sciences of the U.S.A.* 105, 14319-14324.

Tagliacozzo, A. 1993. *Archeozoologia della Grotta dell'Uzzo, Sicilia. Da un'economia di caccia ad un'economia di pesca ed allevamento*. Supplemento del Bullettino di Paletnologia Italiana 84. Roma: Poligrafico e Zecca dello Stato.

Tagliacozzo, A. 2003. Archeozoologia dei livelli dell'Epigravettiano finale di Grotta Romanelli (Castro, Lecce). Strategie di caccia ed economia di sussistenza, in: Fabbri, P.F., Ingravallo, E. and Mangia, A. (eds.). *Grotta Romanelli nel centenario della sua scoperta (1900-2000)*.Galatina (Lecce): Congedo Editore, 169-216.

Taschini, M. 1964. Il livello mesolitico del Riparo Blanc al Monte Circeo. *Bullettino di Paletnologia Italiana* 73, 65-88.

Vercellotti G., Alciati G., Richards M.P. and Formicola V. 2008. The Late Upper Paleolithic skeleton Villabruna 1 (Italy): a source of data on biology and behavior of a 14.000 year-old hunter. *Journal of Anthropological Sciences* 86, 143-163.

Vercellotti G., Caramella D., Formicola V., Fornaciari G. and Larsen C.S. 2010. Porotic hyperostosis in a Late Upper Palaeolithic skeleton (Villabruna 1, Italy). *International Journal of Osteoarchaeology* 20, 358-368.

Vigne, J.-D. 2004. Accumulation de lagomorphes et de rongeurs dans le sites mésolithiques corso-sardes: origines taphonomiques, implications anthropologiques, in: Brugal, J.P. and Desse, J. (eds.). *Petits animaux et sociétés humaines: du complément alimentaire aux ressources utilitaires*. XXIVe rencontres internationales d'archéologie et d'histoire d'Antibes. Antibes: Éditions APDCA, 261-281.

Vigne, J.-D. and Desse-Berset, N. 1995. The exploitation of animal resources in the Mediterranean islands during the Pre-Neolithic: the example of Corsica, in: Fischer, A. (ed.). *Man and Sea in the Mesolithic*. Oxford, Oxbow Books, 309-302.

Wierer, U., Betti, L., Gala, M., Tagliacozzo, A. and Boscato, P. 2016. Seasonality and function of Mesolithic valley-bottom sites: results from Galgenbühel/Dos de la Forca, Adige valley (South Tyrol, Italian Alps). *Quaternary International* 423, 102-122.

Wilkens, B. 1993. Lo sfruttamento delle risorse marine, in: Martini, F. (ed.). *Grotta della Serratura a Marina di Camerota: culture e ambienti dei complessi olocenici*. Montelupo: Edizioni Garlatti e Razzai, 89-98.

Wilkens, B. 1994. The importance of fishing in the economy of the Fucino Basin (Italy) from Upper Palaeolithic to Neolithic times. *Archaeofauna* 3, 109-113.

Wilkens, B. 1995. Le vertebre di salmonidi della triplice sepoltura del Paleolitico superiore della Barma Grande (IM). *Atti del 1° Convegno Nazionale di Archeozoologia*. Rovigo: Padusa Quaderni 1, 365.

Afterword: About Italian Prehistory

It would be too easy to list important Italian sites, to describe the achieved results, to indicate successful lines of research, institutional and university activities, most significant publications…

Instead, speaking about Italian Palaeolithic research today, means understanding how scholars benefit of interdisciplinarity in a cultural context where prehistorical phenomena are conceived from a purely humanistic point of view.

In addition, it would be important to verify if the research goes beyond the limit of scholars' self referentiality', or whether results have been obtained through internationally acknowledged methodologies.

Last, it is key to verify the extent of international networks and collaborations as an inalienable support for skills transfer and quality of the undertaken work.

I believe that today, Italian Palaeolithic research is going through a very prolific period, despite the paucity of scholars and the number of research centres (mostly Universities) dedicated to the study of human origins and evolution. Multiple factors contributed to the current situation, amongst which the lack of funds for archaeological research and the current employment freeze in public Institutions, including Universities.

Last but not least, cultural heritage in Italy is mainly focused on classic archaeology with obvious consequences for prehistoric research.

However, despite what mentioned above, there are examples of great openness and development in education and research in the field of Prehistory. New specific bachelor and MA degrees have allowed a first, well structured, training in the field of ancient prehistoric times, continuing with PhD programs of excellence in several Universities. A couple of these programs have received the financial support of the European Commission, promoting the creation of large consortia of institutions from different Countries.

As a consequence we assisted to a transfer of knowledge between different disciplines, the development of interdisciplinarity approaches and the circulation of students from Europe and beyond.

The Italian system benefitted from this situation, and the vocation for international collaboration already expressed in the past decades has recently been strengthened. In the most recent years, specialists of a wide range of scientific fields have emerged in this milieu. Old collections have been reconsidered in light of new methods, interest has emerged for the exploration of important Palaeolithic sites that have remained uninvestigated for decades, new settlements have been discovered and explored in order to better understand hunter-gatherer environmental adaptations and behaviours. Publications on international scientific journals by Italian teams have increased together with international workshops, congresses and meetings such as "Out of Italy – Advanced studies on the Italian Palaeolithic", organized at the University of Cambridge.

Regrettably, Italian Palaeolithic research still suffers from a strong contrast between the high scientific level reached by the young specialists and the limited funds availability for their employment.

In my opinion, the solution to this hindrance has to be found not only in the commitment of few researchers, but in an appropriate political response able to reconsider Italian archaeological research as a whole, according to European strategies.

Carlo Peretto
University of Ferrara
Professor of Anthropology
International PhD Quaternary and Prehistory coordinator,
Master Degree "Quaternary, Prehistory and Archaeology" coordinator

PALAEOLITHIC ITALY

ADVANCED STUDIES ON EARLY HUMAN ADAPTATIONS IN THE APENNINE PENINSULA

The picture of the Palaeolithic adaptations in the Italian Peninsula has always been coarse-grained compared to various well-researched regional hotspots in central and western Europe, as a result of historical research bias preventing the application of new research methodologies. Nonetheless, discoveries regarding Neanderthal extinction and behavioural complexity, the dispersal of Anatomically Modern Humans as well as the origin and diffusion of modern technologies and symbolic behaviour in Europe have brought Italy into focus as an ideal region for understanding the evolutionary development of various hominin species that inhabited the continent in the Late Pleistocene. In particular the dynamics of the earliest human peopling of Europe, the reasons and timing of Neanderthals demise and how environmental factors affected human prehistoric behaviour, rates of technological innovation and connectivity of hunter-gatherer groups in Europe.

The edited volume "Palaeolithic Italy" aims to contribute to our better understanding of the previous, still open, research questions. This will be achieved by presenting the latest advances in Palaeolithic research in Italy due to the application of a variety of modern analytical methods and cutting-edge techniques when studying numerous collections of materials from both old and new excavations as well as the latest results of field research in the country. The volume is intended for the international academia, representing a key reference for all archaeologists and readers interested in Early Prehistory of the Mediterranean region.

Sidestone Press

ISBN: 978-90-8890-583-4

9 789088 905834 >