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Neanderthals in the Landscape: The Impact of Terrain and Environmental Variability on Raw Material Economy in the Late Middle Palaeolithic of Northeast Italy

by

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ABSTRACT

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Neanderthals were reliant upon the landscape to meet vital resource needs, including lithic raw materials; however, these resources were neither ubiquitously distributed nor of equal quality or abundance. Raw material economy studies are particularly effective in assessing Neanderthal behavioural ecology, as lithic artefacts represent a constant feature of Middle Palaeolithic archaeological assemblages that can also be reconstructed and linked to their past distributions and character in palaeolandscapes. Therefore, lithic assemblages yield significant informational potential on Neanderthal technological adaptations to environmental constraints. However, while such studies have repeatedly demonstrated evidence for lithic raw material management and maintenance in response to procurement distances, methodologies must go further to consider not only distance, but terrain as well. This can be demonstrated by delineating economic zonation over modelled three-dimensional landscapes rather than planar space, and utilising these to determining the energetic and time constraints on mobility. Additional costs and constraints can be indicated by palaeoenvironmental reconstructions, including the distribution and character of lithic raw materials as well as climate conditions, faunal, and vegetative distributions,which would have influenced site placement and subsistence and mobility strategies as well as technological provisioning strategies.

To address these issues, this research employed an interdisciplinary approach to the study of Neanderthal raw material economy in three late Middle Palaeolithic sites in northeast Italy: Grotta di Fumane, Grotta Maggiore di San Bernardino, and Grotta del Broion. Lithic prospection determined the uneven distribution and variable quality and abundance of lithic raw materials around each site. Palaeoenvironmental reconstructions demonstrated that biomes were variably distributed and productive. Terrain modelling generated least-cost paths and energetic and temporal costs surfaces based on terrain difficulty. Linking these in terms of mobility to the techno-economic assemblages of the study sites, the results of this research showed that technological provisioning strategies reflect Neanderthal ecological adaptations to the costs and constraints imposed by their landscapes. Inter-site comparisons demonstrated that the environmental variability specific to each site played a role in determining its use and function within a regional system of residential mobility. In conclusion, this research demonstrates that Neanderthal technological behaviours can be perceived within the ecological contexts of settlements systems.

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DECLARATION OF AUTHORSHIP

I, Kristen Joy Heasley,

declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

Neanderthals in the Landscape: The Impact of Terrain and Environmental Variability on Raw Material Economy in the Late Middle Palaeolithic of Northeast Italy

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. None of this work has been published before submission:

Signed:

Date:

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Glossary of Terms: Definitions and Abbreviations

ABOx-SC: acid-base-oxidation pretreatment method to remove carbon contaminants from charcoal samples in AMS radiocarbon dating.

Allochthonous: geological term utilised in this research to refer to a deposit of lithic materials that originated at a distance from where it was found; *e.g.* secondary flint deposits

AQ: attractiveness quotient

Bei: beige, yellow to caramel coloured Biancone flint

Bi: Biancone flint, also referred to as *Maiolica* flint

Biome: an ecosystem characterised by similarities in climate conditions, such as humidity and elevation, vegetation variables, such as plant and leaf types, and terrestrial or aquatic features. A biome may not be homogenous, in that it may contain several *biotopes.* Examples of biomes include boreal forests, temperate grasslands, and woodlands.

Biotope: uniform environments that are specific to certain faunal and floral groups. Also generally referred to as *habitats.*

Discoidal: method of prepared core reductions; technique created 'turtle' core silhouette due to removals from striking and flaking platform to shape the core for preferential flake removals, typically in a centripetal method

Eoc: Eocene flint

Ecotone: Transitional area between two biomes

ESR: Electronic spin resonance; absolute dating method that measures the accumulated beta doses of radiated radio-elements uranium, thorium, and potassium. Age range up to one to two million years. In archaeological contexts typically applied to fossil hominid or mammal dental enamel.

Euclidean distance: two-dimensional, straight-line distance between two points in space

Exogenous: for this research, lithic raw materials derived from an external source

Habitat: see *biotope*

ka BP: thousands of years before present

ka cal BP: calibrated thousands of years before present

Levallois: method of core reduction attributed to Neanderthals, where a raw material block is prepared into a core, and removals are arranged such that the top half of the core is prepared for the preferential removal of a Levallois flake.

LRM: lithic raw material; natural occurring stone with knapping potential

Lithotype- lithic raw material types within an archaeological record

mSV: brown (marrone) Scaglia Variegata flint

npp: net primary productivity (of simulated vegetation)

npppft: net primary productivity of plant functional types

nSV: black (nera) Scaglia Variegata flint

Ool: Oolitic flint

Peoc: Palaeocene flint

Pft: plant functional type

RA: Rosso Ammonitico flint

RMES: raw material economy studies

Ros: pink (rosa) Biancone flint

SCA: site catchment analysis

SR: Scaglia Rossa flint

SV: Scaglia Variegata flint

U-Th: Uranium-thorium radiometric method of dating calcium carbonate materials based on the stage of the equilibrium achieved between the radioactive isotopes uranium 234 and thorium230, age limit ~500,000 years

Chapter 1: *Problems, Perspectives, and Prospects: Raw Material Economy Studies of the Late Middle Palaeolithic*

1.1 Introduction: Landscape Archaeology and Neanderthal Raw Material Economy

The organisation and structure of Neanderthal material remains directly reflect the influence of environmental variability and constraints on the procurement and maintenance of vital subsistence resources, including lithic raw materials. Within this paradigm, Palaeolithic life is not confined to the site, but can be seen over a larger, seemingly archaeologically-negative area. Foley (1981:2) neatly summarises this scenario: “The archaeological inference….is that human activities are not centred solely on settlements or home bases that may ultimately be preserved as archaeological sites, but are distributed fully across the landscape.” Therefore, it is critical to assess not only archaeological sites, but the ecological contexts in which Neanderthals lived, travelled, and procured vital resources.

Landscape archaeology utilises interdisciplinary approaches, including geology and geography, in the study of the material record. While archaeological assemblages record the material remnants of activities occurring at different points in space, they can also indicate the interrelations between Neanderthals and other biological organisms and the Palaeolithic landscape, or *ecology*. In this framework, *landscape* refers to the physical, natural, and heterogeneous ecological contexts, including terrain and lithic raw material distribution, within which these interactions took place. Raw material economy studies (RMES) are a crucial facet of landscape archaeology, as they enable the placement of populations *beyond* the site and into this landscape. RMES are also a particularly effective means of studying Neanderthal ecology as they focus on lithic artefacts, which are ubiquitously recovered from Palaeolithic archaeological assemblages. By correlating techno-economic analyses with the variable distribution and character of lithic raw materials sources, the technological record can be seen to reflect mobility and technological provisioning strategies, and thus Neanderthal ecological responses to the costs and constraints of maintaining vital lithic resources in diverse landscapes.

In conjunction with techno-economic analyses, the originally geographic concept of site catchment analysis is typically utilised in RMES to delineate economic zones of lithic exploitation around a site. Economic zonation, and its implication for technological provisioning and mobility, has been considered for the Middle Palaeolithic in terms of ‘local’ versus ‘exotic’ resources (e.g. Geneste 1985; Féblot-Augustins 1997a). By linking raw material acquisition sources with *chaînes opératoires*, RMES have repeatedly demonstrated correlations between economic zonation and the technological organisation of the archaeological record. For instance, a correlation between a complete, or nearly complete, reduction sequence and a local raw material source is repeatedly observed. Conversely, truncated reduction sequences and a high degree of retouch are linked to exotic lithic materials (e.g. Geneste 1985, 1989; Turq 1990a, 1992; Féblot-Augustins 1993; 1997a).

However, these correlations often do not consider several important palaeolandscape variables: because lithic raw material (LRM) procurement and management represents a facet of a wider economic landscape that included subsistence activities and settlement patterning, it is therefore critical that archaeologists consider those climatic, geological, and topographic conditions influencing economic zonation. The following paragraphs will address and describe the reconstruction and incorporation of these variables into raw material economy studies in order to extract the most data from the archaeological record. The results of such interdisciplinary research will provide more insight into Neanderthal raw material choices and technological provisioning, mobility and subsistence strategies. This discussion will focus on:

- real distances and topography
- palaeoclimate reconstructions
- determination of habitat exploitation
- lithic prospection through pedestrian survey.

In considering lithic transport distances in Palaeolithic raw material economy studies, research has historically employed two-dimensional Euclidean, as-the-crow-flies, delineations of economic zonation. These distances do not, however, account for **topography**, and thus, the ***real distances*** of mobility: the procurement of resources across varied terrain would have incurred considerably different costs in terms of time and energy. Therefore, geographic considerations of real distances must account for topographic variations in slope and elevation. Further, reconstructing economic zones using planar radii suggests that mobility occurred within a concentric area around a central place. Based on the issues of terrain and geographic features described above, as well as the uneven distribution of faunal and vegetative remains (discussed below), movement within past environments was likely anything but contained within a uniform geometric shape. Rather, economic zonation, or site catchments, were impacted and shaped by the energetic and time costs of resource procurement.

Thorough **palaeoclimate reconstructions,** drawing from multiple datasets, demonstrate diverse ecological conditions in the off-site landscape, including biomes, subsistence resources, and LRM distributions in addition to variable topography. The role of climate as an influence on the archaeological character of a site and settlement systems has been a tenet of the field for nearly half a century. Some researchers go so far as to pinpoint it as playing a large role in Neanderthal demise (e.g. Finlayson and Carrión 2007; Finlayson *et al.* 2006; Tzedakis *et al.* 2007; Müller *et al.* 2011). Yet systematic research integrating interdisciplinary data on past climates with the archaeological record is underrepresented in Palaeolithic research. This may be explained by the scope of such endeavours: correlating climate, which fluctuated rapidly during the late Middle Palaeolithic, with site-level studies is a complex problem that involves defining a 'site,' interpreting its record, and putting it into a broader, often fluctuating, landscape perspective using ecological approaches that are often underdeveloped (Conard 2001). Linking climate events to human occupations is further complicated by the lack or limited reliability of absolute dates in the Palaeolithic of Europe (e.g. Higham *et al.* 2006; Higham *et al.* 2009; Wood *et al.* 2013). As archaeological date ranges span thousands of years, correlation of these to the rapidly fluctuating palaeoclimate record is difficult to achieve with any degree of certainty.

Despite these challenges, the reconstruction of palaeoenvironments is critical to any study of Neanderthal ecology, as the distribution and composition of biomes from which vital floral and faunal resources were procured influenced subsistence strategies, mobility, and settlement dynamics. Binford (1980: 4) succinctly summarises why such exercises are crucial:

…it is possible to anticipate both differences in settlement-*subsistence strategies and patterning in the archaeological record through a more detailed knowledge of the distribution of environmental variables.*

In light of advancements in palaeoclimate reconstructions, through increased sediment core analyses at the regional level, and global climate models based on isotopic analyses of marine cores, the determination of a cross-referenced and reliable model of past climate and environment is becoming achievable. However, raw material economy studies that draw from such external palaeoclimate indicators as well as site-level data to model palaeoenvironments are rare.

The faunal and anthracological assemblages recovered from Middle Palaeolithic sites indicate that settlement patterning was influenced by site proximity to diverse ecological contexts, and that subsistence strategies reflect the **differential exploitation of resource patches.** Therefore, archaeologically-driven data on subsistence strategies, such as lithic cut marks on bone, directly indicate exploited biomes. As fluctuating climates impacted biome, and thus faunal and vegetative resource distribution, palaeoenvironmental reconstructions derived from on-site datasets are a critical component of assessing Neanderthal ecology, particularly subsistence and mobility.

In contrast to seasonally and environmentally fluctuating fauna and vegetation, LRM represents a more static resource, which can also more easily be reconstructed to demonstrate its distribution and character in a site's landscape. However, the lack of **lithic prospection** through pedestrian survey is a critical issue in raw material economy studies. Frequently, studies rely solely on geological maps to inform on where lithic resources were procured, yet these maps only indicate LRM *potential*, and do not accurately identify the location, abundance, or quality of those lithotypes observed in the artefact record. Therefore, the precise identification and reconstruction of LRM sources through lithic prospection is critical to demonstrating the variability of the economic landscape and the movement of people and objects within it, as LRM can be considered a proxy for Neanderthal mobility.

The prolific late Middle Palaeolithic record of northeast Italy is ideal for addressing these methodological issues in raw material economy studies. The diverse geography, well-preserved archaeology, and detailed palaeoclimate records of this region yield the potential to inform on Neanderthal ecological behaviours. The primary goal of this research is to demonstrate the influence of palaeoenvironment variability on Neanderthal economic behaviours through analysis and correlation of the archaeological record with the off-site environment. This will include linking the technological record with reconstructed LRM distribution, and considering the role of lithic procurement in subsistence strategies. An additional goal of this research is to identify the impact of topography on lithic provisioning strategies, through consideration of differential energy and time expenditures needed to access primary and secondary raw material sources across uneven terrain.

This thesis is organised in a manner in keeping with the trajectory of an interdisciplinary raw material economy study. The remainder of this chapter will outline the research questions addressed in this thesis. Chapter 2 will discuss the theoretical background and analytical methods utilised in landscape archaeology and raw material economy studies to address the impact of environmental variability on Palaeolithic technological provisioning. Chapter 3 presents a detailed synthesis of the Palaeolithic character of the study region. The context in which the archaeological record is considered and interpreted is provided in Chapter 4, with an overview of the current state of knowledge of the palaeoclimate of the region during Marine Oxygen Isotope Stage 3 (MOIS-3), 60,000- 25,000 years ago. Chapter 5 will detail the methodologies employed in this research, which will follow a multi-disciplinary framework for analysing site-level and off-site data. Chapter 6 will describe the results of the major analytic foci of this research: palaeoenvironmental reconstructions, techno-economic analyses, lithic prospection, and terrain modelling. Palaeoenvironmental reconstructions, derived from multiple datasets, will report faunal and vegetation remains, as well as climatic conditions and the presence and distribution of biomes. Techno-economic analyses of each archaeological level will focus on the lithotypes observed, their *chaînes opératoires*, retouch, and cortex. Lithic prospection will report the distribution of primary and secondary LRM sources within the local economic radius around each site, as identified during pedestrian survey. Lastly, for each site, potential lithic procurement routes will be modelled, to demonstrate the impact of three-dimensional topography on energetic and time costs, and the constraints these imposed on mobility. Chapter 7 will conclude this thesis, beginning with regional interpretations of the research results, followed by conclusions on the ecology and the organisation of Neanderthal settlement systems in northeast Italy during MOIS-3, and the implications of these research findings to Palaeolithic study.

1.2 The Research Problem

This thesis will conduct raw material economy studies of the MOIS-3 assemblages of three late Middle Palaeolithic sites in northeast Italy. To overcome the methodological issues discussed above, this research will integrate palaeoclimate reconstructions and geographical information systems (GIS) with techno-economic analyses, lithic prospection, and topography. This interdisciplinary approach will serve to address the following research questions:

- *To what extent did the character and distribution of lithic raw materials in the landscape influence the organisation of technology that is observable in the lithic artefact record?*

- *What was the impact of terrain on technological provisioning strategies and site formation?*

- *What was the role of technological provisioning within the wider sphere of Neanderthal ecology, including land-use patterns and resource scheduling?*

- *Through inter- and intra-site comparatives of Neanderthal raw material economy, can we begin to better understand mobility, subsistence strategies, and settlement dynamics on a regional scale?*

1.3 The Study Area

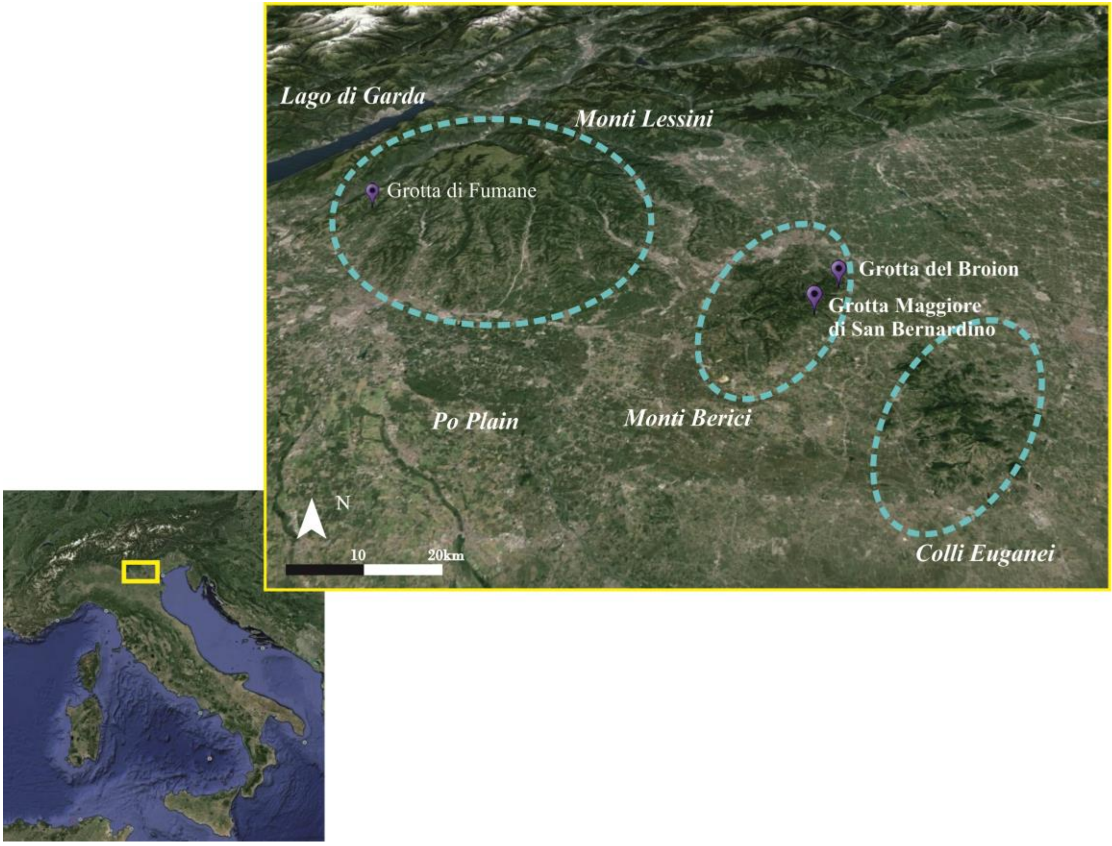

Figure 1.1: The study region, showing the major geographic units and the focal late Middle Palaeolithic sites of this research and their geolocations (WGS84 coordinates): Grotta di Fumane (45.591768N, 10.90518E), Grotta Maggiore di San Bernardino (45.426489N, 11.554685E), and Grotta del Broion (45.4662N, 11.5900E) (Basemaps: Google Earth 2014).

The geographic and geological diversity of northeast Italy, together with multiple indicators of diverse palaeoenvironments and a rich archaeological record attributed to MOIS-3, create an ideal region in which to address the research questions outlined in the previous section. The Palaeolithic study region can be divided into three distinct geophysical units: the pre-Alps, the Po Plain, and the sub-Alpine foothills (Figure 1.1). The Monti Lessini pre-Alps represent the southern foothills of the Alps, and are generally characterised by steep slopes dissected by rivers and streams; however, the Lessini Plateau slopes gently northward in the western extent of the region. The sub-Alpine foothills, Monti Berici and Colli Euganei, are hill units rising from the Po Plain. These are geographically diverse, with steep slopes, undulating hills, and plateaus. The flat Po Plain, dissected by major rivers including the Po, Astico and Bacchiglione, stretches from the pre-Alps and Apennine mountains in the west to the Adriatic Sea in the east.

Additionally, the high peaks of the Alps dividing Italy and central Europe border the study region in the north. These peaks range from 3,000 to over 4,000 metres above sea level (m asl) and are currently still partially covered with glaciers (Mussi 2001). Whilst not occupied during MOIS-3, the high peaks of the Alps would have impacted Palaeolithic life, forming a physical boundary for population movement, particularly during cold climate events when ice caps would have been significantly larger. Glacial action would also have influenced Neanderthal settlement systems, as their expansion and contraction impacted the range and composition of faunal and floral habitats, and thus the subsistence range of populations around the mountainous regions (Peresani 2001).

The late Middle Palaeolithic archaeological sites of the study region typically contain Mousterian lithic artefact assemblages and multiple occupation levels, and thus ample materials to study the impact of environmental variability on technological provisioning strategies from a regional perspective. Situated across the contemporary Veneto region of northeast Italy, archaeological sites are associated with diverse geographic features. This variability in terrain will aid in demonstrations of differential resource transport and navigation from a three-dimensional perspective. Additionally, the uneven distribution and quality of LRM resources across the region will facilitate determinations of Neanderthal lithic acquisition strategies and mobility as ecological adaptations.

The three focal sites of this research: Grotta di Fumane, Grotta Maggiore di San Bernardino, and Grotta del Broion, are each located in caves formed from the limestone bedrock that characterises most of the study area and contain well-preserved archaeological assemblages. The site levels under study share a temporal assignment to MOIS-3, Mousterian lithic technology (most frequently the Typical Levallois Mousterian *sensu* Bordes 1961), and the utilisation of the same flint varieties. It is for these geographic and technological reasons that these sites are considered to be *regional*. This research will focus on the late Mousterian levels of the sites, which contain an appropriate and manageable sample on which to conduct this comparative raw material economy study.

Despite the observed commonalities between these sites, each contains distinct artefact assemblages that reflect Neanderthal responses to their diverse settings. These responses include differential activity and occupational signatures that are potentially indicative of varied site-use and resource management strategies. In regards to temporal data, each site in the sample has been dated, using various methods. In the case of the late Mousterian levels of Grotta di Fumane, a multitude of reliable AMS radiocarbon dates achieved from ABOx–SC pre-treated charcoal are available (Higham *et al.* 2009). However, older radiocarbon, ESR, and U/Th dates of lesser reliability have been obtained for Grotta Maggiore di San Bernardino and Grotta del Broion. Therefore, establishing contemporaneity of site occupations is not possible. As direct evidence for the concurrent occupation of the three sites is lacking, this research seeks to identify regional trends of economic behaviours in MOIS-3.

Grotta di Fumane

Grotta di Fumane is a southwest facing cave located at 350m asl in the Monti Lessini pre-Alps, located on slopes bound by intermittently flowing streambeds to the east and west. Above the site at higher elevations, the Lessini Plateau slopes gently northward. Flint is locally abundant in the area, and can be found in primary position in outcrops, as well as abundantly in secondary position in streambeds. The late Mousterian levels considered in this research are levels A8+A9, A6, and A5-A5+A6. These record the repeated occupation of the site at varying levels of intensity. The varied hunted faunal records attest the exploitation of diverse environments, including forests, open forests, and alpine grasslands (Cassoli and Tagliacozzo 1994b; Peresani and Porraz 2004; Porraz and Peresani 2006). Aside from the sterile unit A7, the late Middle Palaeolithic levels contain predominantly Typical Levallois Mousterian lithic assemblages, with the exception of level A8+A9, where Discoidal technology was exclusive, and marks a noticeable departure from the preceding and proceeding Levallois levels (Peresani 1998, 2001).

Grotta Maggiore di San Bernardino

Grotta Maggiore di San Bernardino is located at 135m asl within a cave on the southeast-facing slopes of the southern Monti Berici. The site is located in proximity to the Berici Plain to the south, the Berici Plateau at the top of the landform, and Lago di Fimon to the northeast. Lithic raw materials are found in the form of mid-quality flint, the nearest sources within one to three kilometres south of the site. Higher quality flint is found beyond 6km (Peresani 1995-1006). Site occupation spans from MOIS-6, with fluctuating archaeological densities recording changing occupational frequencies in response to environmental conditions (Peresani 1995-1996, 2001). This study focuses on the late Middle Palaeolithic MOIS-3 Unit II, which records evidence for intensive use of the site for lithic manufacture and subsistence activities. As at Grotta di Fumane, the predominant lithic technology is the Levallois Mousterian, and the faunal record indicates the exploitation of diverse biomes, including forests, grasslands, and marshy areas (Cassoli and Tagliacozzo 1994a).

Grotta del Broion

Grotta del Broion is a cave site located at 130m asl, approximately 5km as-the-crow-flies northeast of Grotta Maggiore di San Bernardino in the Monti Berici. Although there is no evidence of subsistence activities at the site, the carnivore-accumulated faunal assemblage records diverse ecological scenarios in the surroundings. Mixed forests, wetlands and lacustrine conditions, and open forests/grasslands were found in proximity to the site (Cattani and Renault-Miskovsky 1983). Lithic raw materials are lacking in the local Broion landscape. The archaeological record documents repeated sporadic use of the site. The sparse lithic record and lack of evidence for food procurement and hearths of the late Mousterian Unit ES2 indicates the repeated short-term, task-specific use of the site (Peresani 2001; Peresani and Porraz 2004). The lithic assemblage contains truncated Levallois reduction sequences with a scarce presence of cores in relation to a high percentage of tool blanks, retouched, and reworked implements (Peresani and Porraz 2004; Porraz and Peresani 2006).

1.4 Methodologies

The methodologies employed in this research will consider the archaeological assemblages of these three late Middle Palaeolithic sites from an ecological perspective, to enable the maximal extraction of information from the finite material record. To this end, interdisciplinary raw material economy studies, emphasising the lithic material record, and drawing from the fields of geography and geology, will be employed to test current theoretical frameworks regarding economic zonation, and to assess technological provisioning, resource scheduling, mobility, and settlement patterns.

The interdisciplinary approaches utilised by this research include: palaeoclimate reconstructions, techno-economic analyses, lithic prospection, and terrain modelling. The methodologies employed will include both the archaeological record and regional data on palaeoclimate, environment, geography, and geology as well as palaeoclimate simulations. The methodologies are transferable, and can be applied to Mousterian sites outside of the study region to determine the impact of environmental variability on Neanderthal lifeways.

Raw material economy studies are a particularly effective facet of landscape archaeology, as these enable linkages between site material records and reconstructed off-site environments. Through correlating lithic assemblage composition with the distribution of exploited lithic raw materials, the impact of the off-site environment on Neanderthal behaviour and thus site formation can be clearly addressed. These studies are further developed through the inclusion of palaeoenvironmental reconstructions and terrain modelling of topography and mobility alongside lithic prospection.

The results of this research will demonstrate the relationship between lithic resource distribution and technology, where local discrepancies in the quality and abundance of raw materials impacted the lithotype frequency and reduction sequences at the site level. Raw material management strategies will demonstrate Neanderthal's capacity to anticipate resource scarcity and to organise technological behaviours to meet lithic resource needs. Linking these findings to palaeoenvironmental reconstructions will indicate that the regional settlement system was influenced by numerous ecological variables.

Modelling the physical distribution of LRM in a three-dimensional archaeological landscape will enable determinations of the differing time and energy costs involved in resource procurement. Modelling and measuring potential mobility routes, based on physical distance from the source to the site and accounting for terrain costs, will lead to re-evaluations of how economic zonation, mobility, and procurement strategies, including the notion of *embedded procurement* (*sensu* Binford 1979), were impacted by the diversity of the late Middle Palaeolithic landscapes of northeast Italy.

1.5 Chapter 1 Summary

Chapter 1 has provided an overview of the research problem by providing a context for its importance, followed by a discussion of the study area and a description of the methodologies that will be employed in this study. To summarise:

While Neanderthal behaviour and resultant site formation can be perceived as the result of multivariate environmental, functional, and social causes, raw material economy studies represent a valuable analytic tool for interpreting lithic technologies within an ecological framework. A better understanding of the off-site environment, correlated with the lithic record, has elevated raw material economy studies to a high standard of complex, integrative landscape archaeology.

Because of the diverse topographic, geological, and archaeological characteristics of northeast Italy, it is an ideal setting for observations of Neanderthal raw material economy studies. Through a detailed evaluation of the MOIS-3 assemblages of Grotta di Fumane, Grotta Maggiore di San Bernardino, and Grotta del Broion, this thesis will elucidate the impact of lithic resource variability on Neanderthal technology. Relating these findings to palaeoclimate and topographic modelling, mobility, subsistence strategies, and settlement patterning can be perceived as ecological adaptations to environmental variability.

Chapter 2 will develop the theoretical background and analytic methods fundamental to landscape archaeology for addressing Palaeolithic ecological behaviours.

Chapter 2: *The Site in Context: Theoretical Frameworks for Raw Material Economy Studies*

2.1 Introduction

As outlined in Chapter 1, this thesis is grounded in a landscape archaeology approach that seeks to identify the impact of landscape variability on Neanderthal technological provisioning strategies, mobility, and settlement patterning through a raw material economy approach. This chapter will provide an overview and critique of the theoretical frameworks that have led to modern approaches and methodologies, beginning with a discussion of interpretations of the material record at the individual site-level and the determination of site 'types'. Emphasis will be placed on the need to consider off-site environmental variability as highly influential on Neanderthal subsistence strategies, technological provisioning, and mobility. The chapter will continue on to discuss regional perspectives of site patterning and settlement systems. Following the theoretical frameworks of landscape archaeology studies, the second half of this chapter will provide a history of raw material economy studies, a critical discussion of relevant research frameworks, and an overview of significant studies of Mousterian lithic technology from across the wider Middle Palaeolithic realm.

2.2 Interpreting the Archaeological Record

It is widely accepted that Neanderthals were hunter-gatherers who were reliant upon the environment for vital resources, and therefore, it is imperative to perceive the archaeological record as the product of their interactions with these dynamic landscapes, *beyond* the site. The archaeological record, therefore, is the material remains of these interactions, representing the activities that occurred at a place, which signify "an organizational aspect or phase of operation of the cultural system under study" (Binford 1982: 5).

Neanderthal sites are characterised by the ubiquitous presence of lithic artefacts and the frequent remains of large hunted herbivores. Less frequently, structural remains can be observed. For the Mousterian record, these are largely represented by hearths. Infrequently, human or vegetal remains are recovered from a site. These remains represent the material basis on which archaeological interpretations of site types and functions can be made. The following section will, therefore, focus on the archaeological record in relation to interpretations of **site type and function**, from which **regional syntheses** of settlement patterns and systems are derived.

2.2.1 Interpretations of site 'types' and function

Palaeolithic site 'types,' are based on archaeologically-observed similarities or differences in site activities and functions within a framework of wider settlement pattern, as based on artefact assemblage composition. For example, Binford and Binford (1966) posit that site types reflect those tasks performed and the size and make-up of the groups carrying out said tasks: for "technologically simple societies" such as those of the Palaeolithic, settlement systems are expected to include two site (settlement) types, *base camps* or *work camps*, reflecting respectively *maintenance* or *extractive* activities, or tasks. A base camp, or central location, where food processing and consumption as well as lithic manufacture took place and yielding a rich archaeological assemblage, would be situated central to resource distribution, be of sufficient size, and would provide shelter. While the latter two variables are common facets of Central Place Theory, it is the foremost that is particularly interesting from an ecological perspective: this will be returned to in Section 2.3.1. Conversely, a work camp, or *location* (Binford 1980), would contain a less dense archaeological record, as only select members of the population, carrying out *extractive*, task-specific activities utilised the location. The work camp would be situated in proximity to whatever resource was being extracted (e.g. a lithic quarry or a kill site).

For the Palaeolithic, site 'type' concepts have historically been based on the transference of ethnographic observations of modern hunter-gatherer settlement patterns. Although Binford utilised ethnographic methods, he acknowledged their limitations (Binford 1982b:179):

"The societies of early hominids cannot be understood by projecting backwards from what is in many cases a poor understanding of modern hunter-gatherers… I am equally convinced that functional arguments projected from modern logistical hunter-gatherers are likely to be inaccurate."

Despite these reservations, he argued that such an approach is applicable to Upper Palaeolithic populations, producing observations that could be compared to Middle Palaeolithic assemblages. Indeed, these concepts have, albeit with varying terminology, been applied to the Neanderthal record, and have served as a means of interpreting the archaeological assemblages to determine site types and functions and develop an understanding of settlement systems.

Therefore, the role of a site in a settlement system is determined in part by artefact density and in part by the record of activities that took place there. Neither of these archaeological observations, however, is without interpretive issues. While fluctuating intra- and inter-site artefact densities over time can be interpreted as changes in occupational intensity and stasis or change in site use, these determinations are necessarily relative. Density is determined in relation to other levels within a site, archaeological assemblages from nearby sites, or to a general paradigm of what constitutes density, based on how many artefacts are recovered relative to the extent of excavation: there is no formal categorisation of artefact density. Not only is artefact density relative, but it can be misleading in interpreting occupational intensity. An *occupation* is a singular event that took place in a singular location, which we perceive through the material accumulations that comprise an archaeological assemblage. However, one must consider that these assemblages' structure and *grain* (Binford 1982) reflects not only human activity, but natural or even deliberate (re-use of an older artefact) post-depositional effects. *Grain* therefore refers to the temporal and spatial delay between the use of a site and the deposition of artefacts as they appear to archaeologists. The impact of post-depositional effects on the archaeological record means that perceptions of occupation levels are flawed, and thus it is difficult to determine whether a perceived occupation is the result of a single event or multiple uses by populations seasonally, yearly, or even over millennia. As dense archaeological records may represent palimpsests of multiple, less 'intense' site use, temporally-discrete site occupations are difficult to determine in the Middle Palaeolithic.

The impact of post-depositional effects and the low grain of the Palaeolithic record have bearings not only on our interpretations site types based on occupational intensity, but on perceptions of on-site activities, as these may be over- or under-represented. Further, post-depositional effects may render the archaeological record incomplete, as materials potentially were displaced by humans or carnivores, and organic materials representing occupation and activities may not have been preserved. For instance, at Grotta Breuil in west-central Italy, based on the richness and denseness of the lithic and faunal assemblages, previous interpretations of the site postulated constant, long-term residential occupations (Stiner 1990-1991; Grimaldi and Spinapolice 2010). However, re-interpretations of the lithic assemblages using refitting, spatial distribution, and studies of reduction sequences indicate that the dense assemblage actually represents palimpsests of distinct site use and on-site activities, and differing site functions over time (Spinapolice 2006, 2007; Grimaldi and Spinapolice 2010).

Bearing in mind the interpretive issues surrounding artefact density and on-site activities, a site's type and role is best observed from an ecological perspective, where the distribution of subsistence resources within the landscape played a fundamental role in site placement and function. For example, in northern Italy, there is an observable move from high altitude open air site placement in MOIS-4 to the use of lower altitude cave and rockshelters in MOIS-3 (Peresani 2010): this change in site location and function likely correlates to shifts in subsistence resource distributions resultant of climate fluctuations in these periods. Throughout MOIS-3 climatic fluctuations in temperature and precipitation would have led to changes in resource availability, distribution, and visibility that would have impacted subsistence strategies and mobility: these impacts would be manifested as diachronic changes in a site's archaeological record. Therefore, the environmental conditions impacting site type and function can be best observed through a reconstruction of past environments in which vital resources are projected on a regional scale and linked to their representation in the archaeological record.

Within this framework, Neanderthal ecology can be perceived by linking the archaeological record with environmental reconstructions, including the distribution of subsistence resources (including lithic raw material) and the physical character of the off-site environment. Stasis or fluctuations in land-use strategies through time, reflected in site-level activities, therefore provide a stepping-off point for assessing the influence of environmental variability on site type and function (being wary, of course, of the aforementioned interpretive issues of grain and visibility).

The archaeological record can directly indicate Neanderthal ecology; for example, the presence of charcoal from pine wood in a hearth signals the presence and exploitation of this tree species. In the late Middle Palaeolithic record of Grotta Maggiore di San Bernardino, lithic cut-marks on the skeletal remains of beavers (Malerba and Giacobini 1998a) demonstrate that Neanderthals had access to and were exploiting wetland areas for resources. Therefore, the faunal and vegetative record of an archaeological assemblage can serve as a tool to reconstruct past climate conditions and resource distribution, and demonstrates the presence and exploitation of diverse biomes by Neanderthal.

The exploitation of these biomes can also be inferred by archaeological evidence for Neanderthal subsistence activities. For instance, complete red and roe deer skeletons are prevalent over other hunted herbivores at Grotta di Fumane and Grotta Maggiore di San Bernardino (Peresani 2010). These cervid species are indicative of forested conditions (Fiore *et al.* 2004). The presence of this biome is supported by other site-level data, as well as regional lacustrine sediment cores (Ferrara *et al.* 2004; Pini *et al.* 2009, 2010; Monegato *et al.* 2011) and palaeoclimate simulations (Huntley *et al.* 2003).

Sediment core analyses and palaeoclimate simulations serve to reconstruct landscapes at a regional level. These yield a diverse range of data that inform on past environments, including biomes distribution and productivity, temperature, and precipitation. These reconstructions are open to some interpretative issues. Kelly (1983), for example, demonstrates that the determination of net primary productivity does not necessarily correlate with resource accessibility, the energy and time investment necessary to procure vegetative and faunal resources. For example, despite that a forest may be highly productive, vegetative competition for light or water favours trees, whose high branches get first access to the sun and rain, blocking and limiting ground-level plants. In contrast, grassland species may be more accessible, as these may be easier for herbivores and humans to procure and process than, for example, nuts and seeds. While net primary productivity may negatively correlate with vegetative accessibility, it could positively relate to faunal accessibility and Neanderthal strategies. For example, within grasslands, large, slow-moving, and aggregating herbivores would have represented relatively easy prey as compared to small, swift, and solitary woodland creatures such as deer. Therefore, productivity can be seen as linked to subsistence strategies, depending on resource need, and influenced by the ecological scenario presented. For these reasons, access to diverse biomes, with variable productivity that would have facilitated diverse subsistence strategies, and likely influenced the placement of residential sites (c.f. Binford 1980, 1982).

In considering Neanderthal ecology through raw material economy studies, environmental reconstructions must include LRM, as these were also key resources and can also be interpreted as proxies for mobility, as they were moved from an identifiable point A to point B (the site); however, how they were moved will be discussed later in this chapter in Section 2.3.1. To consider LRM from a raw material economy perspective, the primary and secondary source distributions of these materials as well as their quality, accessibility, and abundance must be taken into account, as the complete, and heterogeneous, lithic character of the landscape impacted technological provisioning strategies and thus lithic assemblage composition (Wilson 2007a, Browne and Wilson 2011). Unlike other subsistence resources, such as mobile prey species or non-extant vegetation, those LRM exploited by Neanderthals largely *can* be sourced, placing populations at specific points in space despite that no material evidence of past behaviour was accumulated (or preserved). Still, correlating lithic artefacts with their original source to reconstruct LRM distribution is limited by some issues of visibility and accessibility: the argument has been made that palaeosources may not be comparable to current distributions (e.g. Turq 2005) due to alluvial deposits or glacial action, and further, while flint sources can be identified, one can neither assume that these were equally accessible in the past nor that Neanderthals had knowledge of them. However, because once extant sources can largely be identified today, these issues are outweighed by the positive outcomes of this exercise, which is the generation of empirical data from which lithic resource distribution can be modelled to reconstruct this aspect of the palaeoenvironment. Positively linking lithic source areas with their presence in archaeological site records effectively links two points in space, from which hypothetical mobility routes can be derived, demonstrating minimum transport distances and procurement costs that can be factored into delineations of economic zonation. Thus, these methods represent a valuable source of data in linking site formation and patterning to variable landscapes.

2.2.2 Regional synthesis of archaeological interpretations

To approach a regional analysis of settlement systems both inter- and intra-site archaeological data together, viewed from a perspective including environmental reconstructions, most clearly elucidate those multivariate forces impacting the organisation and structure of land-use and resource scheduling. Empirical observations of site materials, in conjunction with environmental data, as discussed above, enable the integration of multiple sites into a single geographic unit. Just as multiple occupation levels can indicate stasis or change in site character over time, comparisons of site records across time and space can indicate the forces and constraints behind land-use strategies. From a raw material economy perspective, a regional assessment of Neanderthal lithic assemblages, associated with the distribution of exploited LRM in the landscape, will highlight the influence of Neanderthal ecology on technology.

The primary difficulty in regional analyses is justifying linkages between sites: what characteristics co-existing between sites warrant their comparisons? Reliable criteria involve multivariate links of commonalities, including physical proximity, relatively contemporaneous occupations as determined by dating, lithic techno-cultural similarities, and the use of the same resources. The issues in meeting these criteria are particularly relevant to the limited archaeological record of the Middle Palaeolithic, and thus it is imperative that these are considered when conducting inter-regional landscape archaeology studies. These issues are discussed below.

Despite that the known late distribution of Middle Palaeolithic sites in the study region, which number approximately 60 (Peresani 2011) could be considered physically proximal, in that they are generally located within 10km of one another, direct evidence of intra-site contemporaneity is lacking (e.g. refitting of lithic materials between sites). Further, while establishing chronological occupation overlap can tentatively link the sites, due to limitations in dating methods, the chronology of this time period is of a low resolution, and the margin of error of occupation events (discreet archaeological levels, which may, as previously discussed, be palimpsests of numerous site-use episodes) can range millennia. While recent improvements in radiocarbon sample pre-treatment methods have yielded more precise AMS dates for the final Middle Palaeolithic levels of Grotta di Fumane, the re-sampling of previously dated materials demonstrated that the older radiocarbon dates where contaminates were not removed through ultrafiltration methods were far too young (Higham *et al.* 2009). These findings call into question the accuracy of the dating of Grotta Maggiore di San Bernardino and Grotta del Broion, whose dates were obtained decades ago: the radiocarbon dates from Unit ES2 at Grotta del Broion were reported in 1967 (Vogel and Waterbolk 1967) and 1966 (Leonardi and Broglio 1966), while the relatively newer AMS and ESR dates from Grotta Maggiore di San Bernardino Unit II (Gruppioni 2004) have yielded significant margins of error (e.g. >40,000 uncal BP). Because of these issues, intra-site chronological contemporaneity cannot reliably be established; however, each of the dates obtained for these sites, despite their range of errors, falls well within MOIS-3.

While contemporaneity of occupational levels beyond their shared attribution to MOIS-3 cannot be determined, similarities in lithic techno-cultures and their associated *chaînes opératoires* can be observed and used to determine regional linkages. Lithic techno-cultures, for this research, refer to which extrinsically communicated rather than intuitively known techniques of lithic manufacture to produce implements and tools. For northeast Italy, the dominant techno-culture observed in the study sites is the Typical Levallois Mousterian, in which the operative sequence of reductions is as follows: a Levallois core is decorticated and shaped via recurrent unidirectional removals to prepare its surface for the removal of a Levallois flake; after one or more Levallois flakes is produced, recurrent centripetal removals and/or preferential removals produce further flakes and reshape the core face for the removal of another Levallois flake (Peresani 1995-1996, 2010; Longo and Giunti 2010). Slight variations in this reduction sequence are occasionally observed, including recurrent bidirectional modalities and opportunistic removals (Peresani 1995-1996). Secondary *chaînes opératoires* utilising flakes as cores and the manufacture of Kombewa flakes are observed in the region, in an inferior role (Peresani 1995-1996, 2011b; Peresani and Porraz 2004). Discoidal technologies have also observed in the study region in the final Mousterian levels of Riparo Tagliente (Arzarello and Peretto 2005), Grotta Maggiore di San Bernardino, Grotta di Fumane (Peresani 1995-1996, 1998, 2003), and Riparo di Mezzena (Giunti and Longo 2008; Giunti *et al.* 2011) in a limited frequency as compared to the predominantly Levallois assemblages. The exception to this is levels A8+A9 from Grotta di Fumane, where the Discoidal technique is exclusive, marking an interesting departure from the dominant Levallois observed above and below it in the stratigraphic sequence (Peresani 1998, 2002, 2003; Lemorini *et al.* 2003).

Because of the archaeological evidence demonstrating the dominance of Typical Levallois Mousterian rich in scrapers techno-cultures in each of the study sites, and the analytical and refitting evidence demonstrating that the same *chaînes opératoires* were followed (Peresani 1995-1996, 2011, 2012; Peresani and Porraz 2004; Porraz and Peresani 2006), this research posits that the manufacturing populations of the study region were largely following the same techno-cultural ‘traditions’ *sensu* Gamble (1999). The large coincidence of technologies observed at the study sites means that these assemblages are regionally comparable, although their contemporaneity cannot be assumed. These commonalities also have implications for Neanderthal land-use strategies, in that the communication of manufacturing techniques over a large geographic area could signify long distance population movements, seasonal mobility strategies, high residential mobility, or extended logistical foraging forays.

The success of this variable as an inter-site comparative to determine regionality is mirrored in a perspective that considers economic resources: the identification of the same LRM types at each of the three study sites (lithotypes) may suggest an economic link, hypothetically that either that the same populations were utilising each of these sites, which would indicate the organisation of settlement patterning in the region, or that the shared resource zones were exploited by different populations. The latter hypothesis implies that, due to the uneven distribution of LRM resources, source locations could have been communicated for more effective foraging strategies. However, like contemporaneity between the assemblages, a direct economic link between the sites cannot be explicitly demonstrated with the available data, and therefore, neither hypothesis can be proven or even assumed. What is evident, however, from the available lithic data from the three sites, is that the same LRM types were transported over short to long (up to 80km) distances to each of the three sites of the study region, and that these were transported by either individuals or groups adhering to the same techno-cultural concepts at a regional scale and lithic assemblages were manufactured using similar *chaînes opératoires*.

2.2.3 Summary: the site in context

As the structures and compositions of sites vary across time and space in response to environmental variability, as resources, including lithic raw materials, were not uniformly distributed, accessible, or of equal quality, these therefore yield great informational potential on Neanderthal interactions with the landscape. Observations of Middle Palaeolithic site 'types' in their landscape context can indicate site function and settlement patterns, which elucidate the organisation of regional land-use and mobility strategies. This is best achieved by looking to the archaeological record alongside its reconstructed environment. Because lithic artefacts are ubiquitous at Middle Palaeolithic sites, and because LRM sources can largely be identified today, raw material economy studies that consider technological lithic assemblages in response to environmental variability are the most revealing and accessible strategy for assessing Neanderthal ecology and settlement systems.

2.3 The Organisation of the Neanderthal Landscape

The previous section discussed the determination of site types and the importance of considering the archaeological record in its ecological context. The benefits and risks of inter-site comparisons of site type and function were also discussed, with the conclusion that for the Middle Palaeolithic, regional analyses of assemblages can indicate *trends* across an organised landscape. While the archaeological record does present issues of reliability as an analytical tool, the information that it can yield through careful consideration of post-depositional effects and palimpsests is invaluable to land-use studies. As Isaac (1981: 134) described it, the archaeological record is "…a partial image, albeit distorted and blurred…" However, he continued on to say that through careful analysis, the accumulation of materials, or 'visiting cards' of past populations, can yield the greatest information on settlement patterns and past lifeways.

The following section will therefore discuss how the integration of archaeological data, particularly from lithic assemblages, can indicate those off-site environmental constraints impacting **subsistence strategies, economic zonation,** and **mobility strategies** within a **settlement system**.

2.3.1 Settlement systems and the organisation of the palaeolandscape

Beyond the accumulations of material remnants of past behaviours that are considered sites, the palaeolandscape appears to be archaeologically "negative," in that there are no direct material indicators of past behaviour, either because these were not generated, were lost or discarded, or because post-depositional processes have hindered their visibility. The concept of *off-site* archaeology was developed as a theoretical framework based on the hypothesis that, "due to several factors the archaeological record is spatially continuous, and that its structure may be described in terms of variable artefact density across a landscape" (Foley 1981:2). Isaac (1981), along similar lines, calls this line of research *scatters and patches analysis* to emphasise that sites of apparent intensive use (patches) and isolated finds (scatters) are part of a settlement pattern.

Flannery (1976: 162) defines *settlement patterns* as:

...the pattern of sites on the regional landscape; it is empirically derived by sampling or total survey, and is usually studied by counting sites, measuring their sizes and the distance between them, and so on.

Following Flannery's definition, then, to determine a Palaeolithic settlement pattern, one must determine where sites are, consider their archaeological contents and size, and formulate the distances between them. Each of these exercises is reliant on the archaeological assemblage, which, as already discussed, presents issues of visibility and grain, and therefore the effect of these on determining settlement patterns must be considered. Despite the likely incomplete record of settlement patterns based on site distribution, the variable assemblages of known sites can indicate the organisational processes surrounding resource procurement and subsistence activities.

Therefore, settlement patterns reflect the organisation of the settlement *system*. According to Flannery (1976: 162), the *settlement system* is:

...the set of "rules" that generated the [settlement] pattern in the first place. It cannot be empirically derived, but at least some of the rules can be deduced by simulation or the use of probabilistic methods.

For Flannery, the "rules" are set in place by the population to navigate resource variability and maintain subsistence and provisioning strategies. In the same vein, Jochim (1976) assumed that the determination of resource use precedes and conditions site placement in the landscape, and posited that the organisation of settlement patterns in a regional landscape is contingent upon the availability of vital resources. According to his research, settlement systems are derived from three primary goals (or "rules"): proximity to economic resources, shelter and protection, and a viewshed where prey or other people can be observed.

The distribution of sites in northeast Italy appears to have been influenced by these rules, as they reflect their ecological surroundings. Grotta di Fumane is located near diverse and abundant raw material resources, and is within a cave that would have provided shelter. Grotta Maggiore di San Bernardino is also located within a cave, whose position would have afforded an excellent view of the Monti Berici foothills, the Berici Plain, and the Colli Euganei some 20km to the south. Grotta del Broion also provided shelter, and was equally in a location where a wide viewshed was available. Further, the diversity in each site's faunal and pollen records indicate that they were proximal to a range of ecological contexts affording access to multiple subsistence resources.

Therefore, the settlement system of northeast Italy can be deduced through a landscape archaeology approach that considers assemblage composition and site type within the framework of their distribution in a reconstructed environment where variability, and in particular, LRM resources, influenced Neanderthal ecology and settlement patterning. However, to better ascertain what variables were considered attractive in influencing site placement and use, it is necessary to consider the repeated exploitation and avoidance of resources, climatological conditions, and topographic features at a regional scale, relying not only on site-level data, but environmental reconstructions including terrain using DEM and GIS software

Subsistence strategies

Neanderthal subsistence strategies indicate the timing and organisation of resource scheduling, and may also indicate the site functions within a wider settlement pattern. For example, in Middle Palaeolithic assemblages in the study region, including Grotta di Fumane, Grotta Maggiore di San Bernardino and Riparo Tagliente, evidence of multiple maintenance tasks, including butchery on herbivore remains, lithic artefacts, and hearths (Bartolomei *et al.* 1992; Cassoli and Tagliacozzo 1994a, 1994b; Malerba and Giacobini 1998a; Thun Hohenstein and Peretto 2005; Thun Hohenstein 2006) signify that these may have served as home bases *sensu* Binford (1966).

Species	Climate Event	Environment
Elk	Cold	Humid, marshy clearings
Ibex	Cold	Arid, rocky, montane grasslands
Chamois	Cold	Less arid, alpine grasslands/steppe
Red deer	Warm/Cold	Forest
Roe deer	Warm	Woodland and forest
Wild boar	Warm	Woodlands, humid clearings

Table 2.1: Ungulate species remains as indicators of palaeoenvironmental conditions encountered beyond the site (after Fiore *et al.* 2004: 283).

Subsistence activities further indicate past environments, as discussed in Section 2.2.1, and alongside anthropogenic evidence for hunting (i.e. lithic cutmarks on bone), exploited resources patches can be determined (Table 2.1). Anthracological analyses also indicate exploited environments, where recovered charcoals from combustion structures determine those arboreal species used for fuel. Pollen remains and sediment data also contribute to an understanding of palaeolandscapes, as do lithic artefacts, which can be linked to determinable LRM sources. These linkages demonstrate Neanderthal resource acquisition at a point in space in the off-site environment, and the management of the resource over time and space until its discard.

As food, water, fuel, and stone materials were vital resources, the determination of where these were provisioned is informative of economic zonation. Where and how these were procured is also indicates mobility patterns and overall land-use strategies. Lithic raw materials can be interpreted as a proxy for mobility, with lithic resource scheduling interpreted in two ways: the concept of *embedded procurement* refers to the provisioning of lithic materials in conjunction with subsistence resources during off-site activities, which is in contrast to *direct procurement,* in which specific trips functioned to gather potential materials for tool-making or tool repair (Binford 1979). Embedded procurement is indicative of Neanderthal behavioural ecology, as it is linked to subsistence resources as well as landscape variability; LRM are linked to other activities in the landscape, and thus their costs, and the mobility associated with their acquisition and transfer, are different to the task-specific costs and routes associated with direct procurement strategies.

Embedded procurement is typically assumed as the obvious raw material procurement strategy in the Middle Palaeolithic (e.g. Binford 1979, 1989; Féblot-Augustins 1993, 1999b; Gamble

1995). This assumption is based on the concept that the technological signature of the lithic artefact record is directly related to the environment, and so the concurrent procurement of multiple resources would be an effective provisioning strategy. Geneste (1991: 2) says directly “L'approvisionnement ne peut être envisagé sans référence aux divers champs du système culturel auxquels il s'intègre méthodologiquement.” However, the distribution of food, water, and fuel resources can be shown to have been widely dispersed, necessitating the exploitation of different ecological contexts at variable distances and incurring different costs. Embedded procurement should therefore be determined rather than assumed in Neanderthal subsistence strategies, by linking the material record with the reconstructed palaeolandscape.

Further, the procurement of resources in the landscape involved various costs and risks. Costs include the time and energy of procurement, versus the return rate of the resource. Risk, aside from a paucity of resources, relates to confrontational encounters with other hominids and carnivores, and danger of injury or death. Costs and risks would likely have been specific to each resource need. In this paradigm, economic behaviours including food, fuel, and raw material procurement were the results of active *decisions*, and activities and settlement were deliberately organised based on the fulfilment of certain goals: to achieve secure levels of vital resources, and to minimise *costs* while managing *risks*.

Optimal foraging theory relies on the assumption that foraging efficiency is directly related to the evolutionary and/or cultural fitness of the animal, including hunter-gatherers, where efficiency is computed as a ‘currency,’ such as energy (e.g. Pyke *et al.* 1977; Smith 1978; Winterhalder 1981, 1983). Different approaches to the study of hunter-gatherer subsistence strategies model resource choice (optimal diet), habitat choice (optimal patch choice), time given to each resource patch (optimal time allocation) and patterns and speeds of movement (optimal mobility). Optimal foraging models consider behaviours to be generated by various environmental constraints, and the resource procured can itself be viewed as a range of costs- capture costs, handling costs, processing costs- each of which impact the *worth* of the resource, and thus its representation in the archaeological record.

The character of an archaeological record can thus be seen to indicate strategies to negotiate costs and risks, and the anticipation and preparing/planning for needs through the *curation* or caching of resources (e.g. Binford 1989, Gamble 1995, Toth and Schick 1993). In raw material economy studies, correlating the lithic assemblage with the distribution and character of raw materials in the off-site landscape can indicate *planning depth* in subsistence activities (Binford 1989: 19):

The potentially variable length of time between anticipatory actions and the actions they facilitate, amount of investment in anticipatory actions, and the proportions of activities so facilitated...

The related concept of *tactical depth*- the ability to spontaneously react to one's needs in the short-term- is considered to be a characteristic of modern human technology and cognitive ability (Binford 1989). Kuhn (1995), however, argues that Mousterian assemblages can indicate both management strategies to meet technological design and supply needs: design refers to the shape and function of a lithic artefact; supply means having lithic implements available when and where they are needed. For instance, the presence of retouched tools manufactured from an exotic material source in the lithic record is indicative of mobile toolkits, which represent anticipatory behaviours by mobile Neanderthal populations to maintain raw material supplies and situational needs. Therefore, lithic variability can indicate how Neanderthal populations managed and sustained their resources to meet functional and economic needs.

The degree to which planning and tactical depth were circumstances of resource scheduling and need is considered to be largely related to the ecological character of a population's environment and settlement systems. Kuhn (1995: 20-21) summarises the issue:

Because of the uneven distribution of different kinds of activities, factors such as the frequency of residential mobility, the duration of occupations, and the locations of living sites relative to sources of raw material must have played important roles in determining how Middle Paleolithic populations coped with maintaining a ready supply of "manufacture and maintenance" tools.

Kuhn's (1995) concept of *technological provisioning strategies* refers to planning behaviours by hunter-gatherers to meet lithic resource supply needs, the evidence of which is reflected in the technological record of an archaeological assemblage. *Provisioning of individuals*, like personal gear (Binford 1973, 1979), is the mobile supply of tools (mobile toolkits) with optimal utility, such as tool blanks and retouched tools, designed in anticipation of future need or indicating retouch in response to use over time and space. *Provisioning of places* represents the accumulation of raw materials at a residential site to create an on-site artificial source of stone and toolmaking potential. These strategies were impacted by environmental variability, as LRM were typically of uneven quality and abundance.

Further, the management and maintenance of lithic materials over time and space also have implications for diminishing foraging returns, where the distance (and thus time and energy) of a resource and its transport directly factor into cost. In regards to flake production technology, Kuhn (1995: 32) states: "Balancing the quantities, shapes, and sizes of blanks should be especially crucial where raw materials are small or difficult to obtain." This is a response to balancing the cost and energy of raw material need. In an area where raw material is scarce, for instance, a greater emphasis on *provisioning of places* might favour a core reduction strategy that maximises the number of flakes, and thus usable edges, per core, ensuring the maximum efficiency of the available materials.

The relationship between subsistence strategies, resource scheduling, and site formation is thus a complex, involving resource distances and costs and as well as quality, abundance, and accessibility. The manifestations of Neanderthal responses to these variables are directly observable in the lithic assemblage, where the biggest influence appears to be the physical distribution of raw materials in the off-site environment. This distribution delineates economic zonation, also referred to as resource areas (e.g. Browne and Wilson 2011), site catchments (Vita-Finzi and Higgs 1970), or resource patches (Isaac 1981). The following section will expound upon these concepts.

Economic zonation

The terms *zone* and *territory* have many implications, each of which contains its own inherent flaws in its applicability to the Palaeolithic. Life sciences fields, such as zoology, define territory as a geographic area in which an animal, or group of animals, lives. As hominids are animals, this usage holds some relevance. However, central to zoological definitions is the concept that a role of an inhabitant is to defend its territory; as there is a lack of evidence for Neanderthal populations defending their territories, it is not wholly suitable to archaeological studies. Of greater import, however, is that the instinct-based tenets that accompany animal studies do not include the notion of choice, that behaviours were intentionally and deliberately performed with foresight, which is, in this thesis, attributed to Neanderthal action.

If one assumes the role of choice in shaping the archaeological record, zone or territory can be defined from an **economic perspective**, in which Neanderthal ecology reflects variable resource environments. The advantage of this method is that physical delineations of economic zonation can be deduced using concrete archaeological data to demonstrate procurement distances. To define the range of material transfers, which is frequently unknown in prehistoric studies, researchers utilise site catchment analyses to determine economic space. Each of the following applications is based on the assumption that the distribution of resources played a role in economic zonation and mobility.

The term *site catchment analysis* (SCA) and its applications to archaeological methodology were introduced by Vita-Finzi and Higgs (1970:5), who described it as "…the study of the relationship between technology [observed in the archaeological record] and those natural resources lying within **economic range** of individual sites." The term has its roots in geography, where catchment refers to the area from which a stream gets its water; therefore, a catchment area, in archaeological terms, refers to the area from which a site's occupants derive their resources (Roper 1979). **Site catchments, then, refer to the area encompassing the**

nearest sources of those resources observed in the archaeological record. SCA are useful when applied to a single site but, as Foley's (1981) *off-site archaeology* model and Isaac's (1981) *scatters and patches* approach have shown, the efficacy of these analyses is best demonstrated through inter-regional comparisons.

For determinations of hypothetical *site exploitation territories* for hunter-gatherers, researchers (e.g. Vita-Finzi and Higgs 1970; Jochim 1976; Flannery 1976; Binford 1980; Kelly 1983; Dusseldorp 2009) rely on cost-benefit frameworks to determine daily maximum forays for resource exploitation. Vita-Finzi and Higgs (1970) considered that environmental variables such as terrain would impact energy costs, and postulated that hominins' proposed 10km daily foraging distance would translate into a generic time radius of two walking hours. Within this territory, *transit sites*, or locations, served as activity areas for extractive tasks. The second economic zone, the *annual territory*, is the total land area exploited by a population in a year, and can comprise more than exploitation territories.

Similar to Vita-Finzi and Higgs' (1970) site exploitation territories, Binford (1982) similarly delineated space, but from a cultural-economic perspective (Figure 2.1). Within his model, the area immediately surrounding a site is the *play radius*, where resources are quickly over-exploited. Beyond the play radius is the *foraging radius*. The foraging radius is the area habitually exploited around a site, or home base, and is generally located within 6km, or two walking hours, of a residential site. It is within this foraging radius that locations, or task-specific sites, occur. Beyond the foraging radius, the *logistical* radius is a zone far enough from the home base that activity sites may be used for variable amounts of time by individuals or small groups before returning to the residential camp, within a pattern of *logistical mobility* (Binford 1980). In this model, the archaeological signature of sites in the logistical radius would show evidence of resource exploitation and processing, as well as typical occupation remains with food consumption and perhaps a hearth. Beyond the logistical radius is the *extended range*, which populations are somewhat familiar with in terms of resources, although these might not regularly be exploited. The *visiting zone* is found beyond the extended zone, and contains other populations and their foraging radii. However, not enough is known of Palaeolithic social networks to establish quantitative criteria for a *visiting zone* where social interaction was potentially likely to occur, and it is also difficult to differentiate between a home base and a site within the logistical radius.

SCA assume that lower cost options of resource procurement were preferable, and that greater distances equate to greater energy costs, culminating in cost thresholds beyond which procurement would be expensive and thus uneconomical (Vita-Finzi and Higgs 1970). However, as this thesis will demonstrate, greater distances do not necessarily equate to greater costs, as shorter distances, dependent on topography, may indeed be more energetically costly. That some resources are 'worth' more than others because of the costs of procurement, handling, and transport is echoed in Jochim's (1976) 'hierarchy of importance of resources' that assumes that energy expenditure is inherent in economic choice. In the application of these methods to prehistoric sites, it is assumed that populations were aware of the decreased advantage of more distant and/or costly resources, and therefore their settlement systems reflect cost minimisation choices.

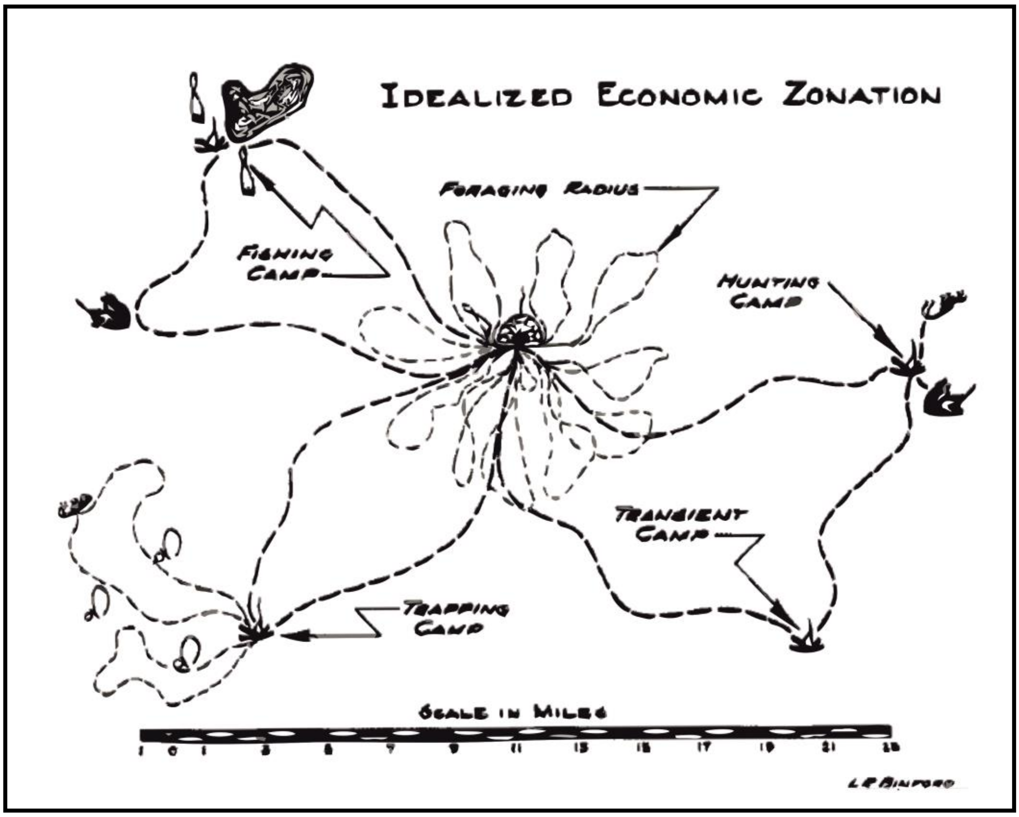

Figure 2.1: Binford's (1982: 9) idealised economic zonation for highly mobile hunter-gatherers, showing radiating mobility to/from a residential site within the foraging radius, and specialised camps in the logistical foraging radius.

However, while economy may indeed be linked to the energetic costs of procurement, this needs to be quantitatively demonstrated by linking the archaeological record to the distribution of resources with the off-site landscape, as will be done in this thesis. Rather than linking energy costs to linear distances, energy can and should also be linked to the *real* distances imposed by topography. Further, terrain should be considered as unique to each site; as not increased distances but also greater costs incursions can be demonstrated from moving over uneven surfaces.

Therefore, the distance and energy costs of resource procurement impacted site catchments and can be seen as a response to off-site variability, with increased resource availability and accessibility, and thus lower costs, correlating with larger archaeological assemblages (however, see discussion of archaeological grain in Section 2.2.1). For raw material economy studies, the attractiveness and value of LRM was also likely determined by source distribution, quality, rheological characteristics, and accessibility. For instance, Boëda *et al.* (1990) consider that, in determining the characteristics of raw materials that were utilised by past populations, the most important variables to consider are shape and size, which would have impacted transport methods (splitting larger blocks), the visibility of cortex during initial reduction, and the mode of reduction sequences employed. In contrast, Browne and Wilson (2011), for example, identify quality and procurement costs as more impactful on procurement strategies, which demonstrates the value of considering these variables in RMES.

For the late Middle Palaeolithic, where stone materials are the typical indicators of human presence and their sources can frequently be determined, linking the archaeological assemblage with resource distribution can provide concrete evidence of off-site exploitation and can suggest Neanderthal mobility. These methods echo Flannery's (1976) site catchment analyses that began with the archaeological record, and looked *outward* to empirically delineate site catchments based on the determined provenance of artefacts. Applied to raw lithic materials, quantitatively-based distances can be established, rather than assuming that resources may have been found within an arbitrary or theoretical radius that does not reflect actual human movement. The transport of these raw materials can thus also demonstrate population movement across archaeologically negative due to a lack or low visibility of artefacts or sites.

In raw material economy studies, visual and microscopic analyses of stone artefacts serve to identify lithotypes in archaeological assemblages. These are often linked to their potential provenance using geological and lithological maps. However, these maps can only indicate potentially flint-bearing geological formations, and thus the *potential* of a LRM source, but do not indicate the precise location of actual flint sources and exploitable outcrops. Therefore, a sole reliance upon these maps is problematic for several reasons: the use of these maps can lead to the false assumption that raw materials are ubiquitously distributed within the identified area of potential. Another assumption involves the interpretation of raw material quality and accessibility as static variables. In reality, raw materials are of variable quality with differing rheological characteristics, are unevenly abundant (or scarce), and vary in accessibility. However, because geological maps at least serve to generally indicate flint potential, these methods are preferable to delineations of catchments based on ethnographic observations or economic findings from other regions, or potentially, different cultural periods.

Pedestrian survey to prospect for lithic raw materials, rather than a reliance solely on geological maps, provides the most effective method by which to determine their source, quality, and accessibility in a landscape. Pedestrian survey is typically physically constrained, as is exemplified by Jochim's (1976) approach to site catchment analysis that utilises geographic features such as watersheds to delineate natural catchment areas of economic zonation. For example, the Agro Pontino survey (1979-1989), carried out by Voorrips *et al.* (1991) (see also Holstrom *et al.* 2004) in west central Italy, prospecting for archaeological sites rather than resources, limited its coverage to the Agro Pontino basin, a geographically constrained area. Pedestrian survey in the Colli Euganei (within the study region of this research) was limited to the geographic limits of this hill series, ending where the hills meet the Berici and Po Plains (Duches *et al.* 2008). Such methods enable researchers to study the distribution of archaeological sites in relation to the environments and resources available in a distinct area, although it should be considered that resources were not limited to particular geographic features, and nor were past populations.

Economic Zone	Radius in Km
Local	0-5
Semi-local	6-20
Exotic	30-100
Exotic*	200-300

Table 2.2: Economic zonation of raw material acquisition observed at Middle Palaeolithic sites in the Aquitaine Basin, France (after data determined by Geneste 1985, 1988; Turq 1992; *Féblot-Augustins 1993, 1997a, 1997b).

The first major application of such lithic prospection survey for Middle Palaeolithic raw material economy studies was conducted by Geneste (1985), who identified lithic resources in the Aquitaine basin in France, and linked these to the archaeological record to determine the economic zonation (Table 2.2). His findings, influenced by Binford's (1982) delineations of economic space, suggest a 'local' zone, up to 5km, corresponds roughly to 'foraging radius,' and 'semi-local' zone, up to 20km, similarly to with 'logistical radius.' 'Exotic,' refers to raw materials from greater distances from a site, typically beyond the 20km range, and extending to around 100-120km in western and central Europe (Geneste 1985, 1988). Although less frequent, transport distances of 200-300km have been regularly observed in in the Middle Palaeolithic (e.g. Féblot-Augustins 1993, 1999a, 1999b; Porraz and Negrino 2008).

The methodologies employed by Geneste (1985) have become the framework for numerous Middle Palaeolithic studies of its ilk (Martinez 2008), which have repeatedly determined similar economic zonation for Mousterian assemblages (e.g. Féblot-Augustins 1993, 1997a, 1997b 1999a, 1999b; Geneste 1988, 1989; Turq 1990, 1992). From a quantitative perspective, raw material transfers are the most effective means of determining mobility and economic catchments when the archaeological data can be linked with high resolution reconstructions of a site's past environs, and thus for the Middle Palaeolithic, these zonations are generally accepted in relation to lithic procurement.

Féblot-Augustins (1999a) reconsidered the assumptions made about economic zonation in regards to how the distances were typically delineated. She theorised that materials may have been circulated in three alternative ways. The first is a straight line, where the material has moved through the hands of different individuals. In the second case, a single individual carries the raw material, but along a longer, non-linear "détour" (Féblot-Augustins 1999a: 224). The third hypothetical situation is that the raw material is successively moved along a longer path by different individuals. These different types of movement may indicate that the ways in which we interpret distance along direct routes are wrong. The first proposed case indicates that the distance travelled is over-estimated, and the second and third indicate that the distances over which we perceive raw material transport to site are under-estimated. These hypothetical transfers represent something to be considered, but furthermore, the motivations for mobility routes should be evaluated, including terrain variables, resource distribution, and subsistence strategies: these will be considered in the terrain modelling aspect of this research.

Recently, the work of Wilson (2007a, 2007b, 2011b) and Browne and Wilson (2011, 2013) on the Middle Palaeolithic of France has taken to addressing these factors in an assessment of raw material economies. In addition to characteristics such as the distribution and quality of raw material sources, determined through decades of pedestrian survey, macroscopic, microscopic, and geochemical analyses, terrain difficulty and the energy expenditure needed for resource exploitation are also considered. The latter present a novel way of re-approaching the lithic/environmental relationship. This complete view of the lithic character of the region determines not only precise LRM distributions in a three-dimensional landscape, and thus economic zonation, but also a more reliable means of linking those artefacts found at the site with their external provenances. In this framework, mobility routes from site to raw material source are tested, and indicate that raw materials from less costly routes in terms of energy expenditure are better represented in the lithic assemblages. These concepts will be discussed later in this chapter in Section 2.4.2.

Mobility strategies

Hunter-gatherer paradigms

As we have seen in the previous section, mobility is linked to subsistence strategies and economic zonation in Palaeolithic landscape organisation, with mobility strategies representing the means by which hunter-gatherer populations met resource needs in spatially, temporally, and productively diverse environments. Evidence for mobility can be either directly or indirectly observed in the archaeological record. Binford (1982: 6) describes this relationship between the assemblage and mobility as:

The "fallout" from the events that "moved across" fixed places [that] establishes the character of the archaeological remains on sites. To understand the past we must understand places.

Binford (1980) proposed two types of mobility based on subsistence activities: residential and logistical. Residential mobility is the movement of an entire population from one home base to another. Within a residential mobility scheme, "mapping on" entails bringing the consumer, a *forager*, to the desired resource, which will result in the formation of either the home base or the location. In contrast, a logistically-organised system of mobility involves moving the resource to its consumer, a *collector*. A logistical mobility system will create additional site types, including field camps, stations, and caches, which may be linked to the procurement of seasonal resources. While Binford (1982: 1980) acknowledges the impact of environmentally-varied resources on the development and use of sites (locations), as well as field camps, stations, and caches, his appraisal of mobility is central to the notion of the residential camp.

Isaac (1981: 131) considers land use to be composed of a "web of pathways over a piece of terrain." The mobility observed for humans would be radiating from a 'settlement,' which is returned to repeatedly. The settlement or home base records dense amounts of artefacts, as opposed to scatters that indicate transient camps, which are not necessarily returned to. These accumulations of materials are 'nodes,' although their character is not without interpretive issues. The preservation of materials, natural or deliberate removal of discarded remains from their original deposition, and sampling bias each contribute to muddling our perceptions of land-use and mobility.

Similarly, Gamble's (1999) notion of paths and tracks sees the movement of an individual along (intersecting) paths composing spatial networks. Paths and tracks represent the movement of an individual through their environment, along which *encounters* (with other individuals or resource opportunities) take place. Encounters do not leave a material record, but gatherings, which are lasting *locales,* do. The material left from an encounter is significant of a social context, although this may not be evident in the patterns of activity observed. The spatial network of these subsistence activities and social behaviour is the local hominid network, or *landscape of habit*, which is a continuous process that involves interaction between individuals (Gamble 1993a, 1995b, 1999).

For this research, site catchment defines the range of *economic potential* around a site: it is not a social construct, but rather, it is primarily ecologically determined, and geologically, in reference to LRM. However, while mobility within a catchment likely *is* linked to an itinerary, one based on managing resource needs within an ecologically-constrained environment, a degree of cognitive choices by Neanderthals, can be assumed to have influenced ecological behaviours and thus the formation of a locale. Following a paradigm where mobility is linked to an itinerary that is determined by resource needs and is influenced by off-site variables (resource distribution, terrain, climate, competition) such ecologically-constrained choices can be observed in landscape organisation.

As exemplified in the theories discussed above, studies of hunter-gatherer mobility tend to focus on the movement of populations from a site, and in particular, one deemed to be a home base. According to Binford (1982: 6)

One of the more distinctive features of human systems is their special focus on a "home base" or a residential camp.

This paradigm is fundamental to Central Place Theory (Isaac 1978; 1981; Schoener 1979), in which mobility is viewed as radiating from a central place (aka home base, residential base). There are two fields of thought in regards to the concept of a home base, and the line is typically draw to differentiate between modern humans and non-human primates (including Middle and Lower Palaeolithic hominids) (Kolen 1999). The central place is either a social or symbolic place evident of human *cultural geography*, out of which societies exploit resources and "sustain both themselves and their cultural construct" (Binford 1987: 18), or it is a *niche geography*, in which movement in the environment is for the obtainment of vital resources necessary for fitness. The latter application of the term is the foundation of optimal foraging theory and it is the approach to Central Place Theory that is often adopted for Middle Palaeolithic research.

However, despite the inclinations toward an animalistic sense of place, many of the features described to define a central place draw directly from our modern conceptions. Listed by Dusseldorp (2009: 31), but developed by numerous researchers (e.g. Isaac 1981; Potts 1988) a central place is determined if the following five criteria are met:

- structures such as hearths
- large number of stone artefacts (density), demonstrating complete reduction sequences
- large amounts of bone, showing traces of anthropic action
- minimal carnivore indicators
- spatially-discrete activity areas.

Indeed, numerous Middle Palaeolithic sites appear to meet the criteria described above. However, it is critical to keep in mind the low grain of the archaeological record; the assumption that structures indicate a central place does not consider post-depositional effects, particularly in the destruction of hearths, which are the only consistent structural feature in Mousterian sites. Further, as conditions in MOIS-3 were cold, and while perhaps Neanderthals were more physically suited to withstand such conditions (e.g. Steegman *et al.* 2002; Weaver 2003), they clearly had the capacity to make fires (see Gowlett 2006; Roebroeks and Villa 2011), and likely chose to do so for warmth, cooking, or protection, whenever or wherever the need arose (not just at a central place). However, despite the potential low resolution of the Middle Palaeolithic archaeological record, the accumulation of a material record at any place, in any form, can be perceived theoretically as a central place, which was provisioned through the introduction, acquisition, and/or the discard of materials. In this sense, a wider spatial network of economic activities can be observed through linking material accumulations, from a ‘home base’ or ‘location,’ to the provenance of these in the landscape, thus improving our understanding of land-use strategies and organisation.

Considering the Neanderthal archaeological record as the product of adaptations resulting from the interplay between behaviour, ecology, and biology provides a conceptual framework for linking the site record with its off-site environments. In this framework, the character of lithic technology can be perceived as a behaviour serving not only to meet Neanderthal biological needs (subsistence), and variations, either diachronically or regionally, can be seen as adaptations to heterogeneous environmental settings.

The costs and constraints of mobility

The procurement of resources included various costs and risks, where economic behaviours such as mobility were the result of active *decisions,* and activities and settlement choices were deliberately organised based on the fulfilment of certain goals: to achieve secure levels of vital resources, and to minimise energy *costs* while managing *risks*. Mobility costs include the time and energy expended in procurement, including carrying costs and distance, versus the return rate of the resource.

These variables factor into *diminishing returns*: the greater the occupation duration, the more extensively resource patches around a site are diminished, and thus, procurement costs begin to outweigh returns as populations would have had to travel longer distances (Winterhalder 1981; Lieberman and Shea 1994). For faunal and vegetative subsistence resources, such returns may have fluctuated due to seasonal changes and over-exploitation. Seasonal mobility would address the issue of diminishing returns, particularly in biomes that were not prolific enough to meet the annual needs of a population, and would therefore serve as an adaptive strategy to meet subsistence needs, resulting in the procurement of different resources or changing scales of exploitation (Winterhalder 1981, 1983; Belovsky *et al.* 1989).

The limited seasonality data in the Middle Palaeolithic, however, has led some researchers to propose that Neanderthal exploited the same resources year round. For instance, on the basis of cementum-increment analyses of herbivore species from sites in the Middle East, Lieberman and Shea (1994) attribute a *radiating* mobility pattern to Mousterian populations organised around a year-round residential site, after the settlement pattern models (*radiating* versus *circulating*) developed by Marks and Freidel (1977) for the Upper Palaeolithic assemblages of the Negev, Israel. This is similar to Binford's (1980) concept of a 'collector,' following a logistical mobility from a home base situated in an environment with dense, but unevenly distributed, resources. Others argue that the population sizes of Neanderthal foraging groups may not have necessitated seasonal moves, resulting in overwintering, or that mobility strategies may have been more flexible. Finlayson (2004), for instance, argues that Neanderthals likely practiced *both* radiating and circulating mobility patterns within a small annual territory, the end effect being that the archaeological assemblage *appears* to show year-round exploitation. This argument is in agreement with Kuhn (1995), who asserts that mobility strategies varied in response to resource availability and territory size. Therefore, Neanderthals were neither strictly collectors nor foragers. Rather, mobility was a key Neanderthal tactic to mitigate seasonal shortfalls (and abundances) and to meet actual and anticipated resource needs (Riel-Salvatore and Barton 2007).

Mobility and Raw Material Economy

As previously discussed, the grain of the Palaeolithic record does not easily facilitate reconstructions of food and fuel resource distribution and accessibility. Lithic raw material patches, however, presented relatively static resources to Neanderthal populations, whose distribution in the landscape can be linked to the archaeological record through techno-economic analyses and lithological surveys. The determined variability of these LRM sources, in terms of distance, quality, abundance, and accessibility, impacted mobility and foraging strategies, can be seen reflected in the varied lithic assemblage composition.

It is precisely this variability in stone tool manufacture that Kuhn (1995) focuses on in his study of techno-economic behaviours in Mousterian sites from west central Italy. Kuhn's *provisioning strategies* perceive lithic assemblage variability as the product of Neanderthal responses to environmental variability. *Provisioning of individuals* refers to the provisioning of a hunter-gatherer with a transportable, pre-made lithic toolkit; according to this model, those sites that demonstrate evidence of provisioning of individuals should contain a large proportion of pre-formed tool blanks and retouched tools to cores and manufacturing debris, as they were introduced to the site in that form. Blanks could be used to create tools ad hoc, and the latter should be multi-purpose in nature to accommodate a variety of tool needs as the occasion arose. Further, these should show evidence of resharpening as they were reused, or maintained.

These types of assemblages may be seen in areas where there exists a natural paucity of raw materials, and likely represent 'locations' (Binford 1982) or 'transit' sites (Vita-Finzi and Higgs 1970), used briefly by mobile groups carrying out extractive tasks. As described by Kuhn (1995: 26):

Short-duration occupations and places used ephemerally should be less frequently provisioned, and should therefore yield relatively large numbers of tools carried by mobile individuals, regardless of the overall organization of the system.

The p*rovisioning of places* model describes a situation where LRM is brought *to* a site, to create an artificial abundance. Binford describes a similar situation with regard to the storage of subsistence materials at a residential site or location in response to a decreased growing season (over-wintering) (Binford 1980). Storage would essentially insure resource availability when needed or otherwise scarce, and could be accomplished through the accumulation of these materials when they were available or when they were encountered at a high density. Such findings could suggest a settlement pattern influenced by the distribution of resources. As opposed to a high frequency of blanks and retouched pieces as seen in the provisioning of individuals model, the archaeological record of a provisioned place would be composed of a higher number of pieces of raw materials and cores, as well as manufacturing debris.

To reiterate: whether the archaeologist sees one provisioning strategy or the other is therefore related to technological needs and settlement patterning, and potentially to raw material variability and availability in the palaeolandscape. For example, Geneste (1985, 1988) observes for the Middle Palaeolithic of the Aquitaine Basin, France, that sites located in *local* proximity to abundant raw materials contain lithic assemblages predominated by these materials, showing full *chaînes opératoires*, which is in line with a provisioning of places strategy, where an artificial abundance of LRM is created on-site. In contrast, artefacts from *exotic* lithic sources are much less frequent, and were typically introduced in the later stages of reduction, as carrying LRM across greater distances would be more energetically costly, and a risk would be incurred by not having a tool when need arose. Further, as *semi-local* or *exotic* provisioning distances are demonstrated, the implements in these lithotypes are generally in deferential quantities to local LRM, with increased maintenance and management tactics employed to conserve the resource; these actions can be interpreted as *economising* behaviours (Kuhn 1991), concerned with not only LRM conservation, but mobility and transport costs, falling into a provisioning of individuals strategy (Kuhn 1995).

The replication of these findings in other archaeological contexts across Mousterian Europe (e.g. Geneste 1988, 1989; Turq 1989, 1991; Féblot-Augustins 1993, 1997a, 1997b, 1999a, 1999b; Wilson 2007, 2011b) demonstrates that differing LRM provisioning has implications for our understanding Neanderthals' ability to anticipate and respond to procurement costs and functional and material needs, with the scale of movement proportional to planning depth (*sensu* Binford 1989). Long distance material transport, as observed by lithic materials from distances greater than 20-50km, indicates Neanderthals' cognitive ability to foresee the need for raw materials or tools in impending scenarios. For instance, truncated reduction sequences, which are the partial representation of a *chaîne opératoire* sequence, and retouch of exotic materials, could represent the *mobile toolkit* of a highly mobile individual (falling into a *provisioning of individuals* strategy). Provisioning of places with a created stockpile of LRM suggests that the need to have stone on hand is anticipated.

Anatomically Modern Human (AMH) assemblages frequently demonstrate long distance resource transport, which has been attributed to a logistical mobility and an increased opportunity to interact with other populations (e.g. Mellars 1989, 1996; Gamble 1999; Bar-Yosef 2002; Barton *et al.* 2011; Barton and Riel-Salvatore 2012). These long distance social networks, where objects served as proxies for absent people, is thought to be a characteristic of modern behaviour, singular to AMH, who had achieved *release from proximity* (Gamble 1998). Neanderthal, on the other hand, are postulated to have had a more restricted home range, where resources were procured from within a geographically smaller area, and where social and biological interactions occurred at a more restricted level (e.g. Mellars 1996; Gamble 1999; Gamble *et al.* 2004). However, long-distance movements as seen through exogenous lithic artefacts, be they the product of increased logistical mobility due to the incongruent distribution of resources or 'modern behaviours,' can be observed in late Mousterian assemblages. For instance, as previously discussed, lithic transport distances of 200-300km are observed in central Europe (Féblot-Augustins 1993; 1999b; Porraz and Negrino 2008), and marine shell transfer distances greater than 100km (Peresani 2013b) have been observed at Grotta di Fumane in the study region.

When inferring long distance material transfers from artefacts of exogenous origins, however, one cannot negate the possibility that an object may not have been transported the entire distance by a single person, as proposed by Féblot-Augustins (1999a). Still, the issue of the circulation of lithic materials is important to mobility studies. To be considered is the form of raw material movement: were raw materials circulated in a reduced form to reduce transport costs or as raw material blocks to maximise lithic yield? Were blocks tested, reduced, and then transported? Observations of these actions in the archaeological record imply that long distance transfers were not solely (or perhaps just *were not)* a function of exchange. Therefore, an approach to delineating mobility and transfer distances should consider the morphology (use-potential and size) of the technological record.

However, *how* these distances, either local or exotic, are determined and interpreted is problematic; the delineation of LRM transport in Euclidean, two-dimensional distances does not directly take into account those variables that would have impacted mobility and procurement strategies: energy and time. That environmentally-imposed costs impacted the *chaîne opératoire* observed in the lithic record is not a new concept to raw material economy studies (this will be expounded upon in Section 2.4.2). Wilson (2011: 170) succinctly summarises this problem with delineating mobility: "Setting a limit in kilometres is a misleading exercise…, because the limits between such areas must surely have depended on criteria other than just distance."

To explore these criteria impacting Neanderthal mobility and LRM procurement strategies, Wilson (2007a, 2007b) employed variations of optimal patch choice and mobility foraging models to explore how the LRM character of the Vaucluse Region of southern France shaped the lithic assemblages of its Middle Palaeolithic sites. Within this model, the lithic landscape was considered in terms of energetic costs, against the general attractiveness of LRM. To address the costs of raw material procurement, Wilson (2007a) utilised the known distribution of LRM sources to model the energetic expenditures required to move from source-to-site, following hypothetical straight-line routes, while accounting for diverse (3D) terrain. To fully account for mobility restrictions, hypothetical routes avoided slopes greater than 60 percent grade, as these were deemed unnavigable by walking. The energetic costs of these hypothetical mobility routes were based on an average adult male walking 3km/hour on a treadmill. These demographics are acknowledged to not be directly analogous to Middle Palaeolithic energy outputs; however, the success of these determinations lies in their comparability to each (Wilson 2007a).

Utilising these figures of energetic costs, the following four hypotheses were tested (Wilson 2007a: 320):

Hypothesis 1: Where the routes from two sources to a site are of similar length, but one is more difficult than the other, the site assemblage will contain more material from the source with the easier transport route.

Hypothesis 2: Where routes from two raw material sources to a site require similar overall caloric expenditure, but are of different lengths, the shorter one will seem more difficult, so raw material from that source will be less abundant in the site assemblage.

Hypothesis 3: The routes from the most distant sources represented in the assemblage would be relatively easy, or else they would not be represented in the site.

Hypothesis 4: The sources represented in the site assemblage that are reached by the most difficult routes will be located relatively close to the site

Wilson (2007a) ultimately is able to support each of these hypotheses, and clearly demonstrated that not only is terrain a major environmental constraint is Palaeolithic mobility, but also that studies of Neanderthal land- use are vastly improved through consideration of these variables.

Wilson (2007a, 2007b) further correlated terrain and distance costs with the general attractiveness of a resource to determine the impact of these variables on mobility and thus the representation of the LRM in the site record. Attractiveness is determined according to the following equation (Wilson 2007a):

$$A = \frac{(quality)(extentofsource)(100)}{(difficulty\ ofterrain)(Costofextraction)} \times \frac{size}{scarcity}$$

Each of these variables was approached quantitatively, despite that many are subjective in nature; however, these methods lead to a dataset by which inter- and intra-site assemblages can be compared. For example, *quality* refers to the homogeneity and rheological qualities of a lithic raw material source; the subjective scale ranges from 0 (very poor) to 16 (excellent). Based on the comparative advantage of quantifying LRM data through this means, this approach is adapted for this research, and each of the formula variables is expounded upon in Section 5.4.1.

Browne and Wilson (2011) rectify the methodological issues of the straight-line source-to-site mobility paths utilised in Wilson's (2007a, 2007b) previous cost-benefit analyses of lithic raw materials in the Vaucluse Region of France by conducting straight-line route as well as least-cost path analyses determined in caloric expenditures. The least-cost paths were determined in ArcGIS, also avoiding slopes greater than 60 percent, and following paths of least energetic costs in the landscape. Their findings support previous conclusions that an LRM source's determined attractiveness (using the attractiveness equation) positively correlated with its representation in site lithic assemblages. The determination of least-cost paths, however, went further so as to clearly demonstrate the optimisation of lithic procurement strategies, in that a low source attractiveness, together with terrain difficulty and thus higher energetic output, are negatively correlated to a that lithotype's representation in the lithic record. Overall, Wilson (2007a, 2007b) and Browne and Wilson (2011) demonstrate a positive correlation between procurement costs and abundance in the lithic record, *which is not necessarily a function of distance*. Based on these findings, Wilson (2011a) rightly stresses the importance of geoarchaeological methods and the significant bearing these have on our understanding of environmental impacts on Neanderthal land-use and resource scheduling.

Geographic information systems (GIS) approaches to modelling past human movement have become increasingly popular in the last few decades, as various software programmes (e.g. ArcGIS (ESRI 2014)) have become widely available, with user-friendly functions (van Leusen 1999; Kantner 2012). Existing problems with GIS modelling include its "naïve use" (van Leusen 1999: 6.2), such as a lack of understanding of the complex algorithms behind modelling least-cost path analyses and cost surfaces. Further, the reliability of digital elevation models (DEM) as compared to topographic maps should be considered; however, this issue is of less significance today, with the generation of high resolution (1 –arc sec 26.67 x 26.67m) DEMs based on satellite mapping (for a detailed discussion of the high resolution DEM and sources utilised in this research, see Section 5.5).

Of significant importance to modelling landscapes and movement within them with a high degree of *realism* is the choice of variables used to determine how cost surfaces are generated, as in what determines the costs of movement (cf. Kantner 2012 for a thorough overview of the methodological issues in determining cost surfaces and least-cost path analyses). While slope as a cost on its own has limitations (slopes of 0 register no costs), incorporated into algorithms that consider time (e.g. Tobler's (1993) Hiking Function) or energy (Pandolf's (1977) metabolic equation of human movement), more realistic results are yielded. Pandolf's equation, for instance, has been shown to be a good predictor of metabolic costs (Duggan and Heisman 1992). However, despite that Tobler's (1993) Hiking Function considers time, the aspect of mobility as a time cost has not been explicitly addressed for the Palaeolithic: to consider this cost, this research will incorporate this variable into terrain modelling to determine buffer zones based on walking distances within time thresholds, inclusive of topographic variables.

Despite the availability of GIS programmes and research on valuable cost algorithms, terrain modelling incorporating 3D topography and its associated energy and time costs are relatively uncommon in the Middle Palaeolithic, in spite of acknowledgements of the limitations of as-the-crow-flies delineations of space in archaeology (e.g. Wood and Wood 2006, Wilson 2007a, 2011a). The works of Wilson (2007a, 2007b, 2011b) and Brown and Wilson (2011) discussed above thus represent novel approaches to considering the impact of topography on mobility costs, which incorporate geoarchaeological data and sites in a 3D landscape.

Such studies demonstrate methodological potential of incorporating GIS into raw material economy studies of the Middle Palaeolithic. Combining terrain modelling with lithic prospection and determinations of LRM attractiveness, the larger picture of Neanderthal landscapes and provisioning strategies can be considered. Further, these methodologies have the potential to be transferred to other late Middle Palaeolithic landscapes. However, each region has its own characteristics that must be considered. For instance, the Vaucluse region is a particularly flint-rich area, and thus numerous flint sources of varying attractiveness were available, whereas pebble-rich west-central Italy presents predominantly small lithic raw material options (Kuhn 1993, 1995). Further, as this research will demonstrate, the determined costs of mobility from source-to-site can be taken even further than the determination of least-cost paths; creating temporal buffers of economic zonation based on hiking distances and energy expenditure accounting for terrain variability and LRM distribution will further enhance understandings of Neanderthal mobility and resource scheduling.

Mobility summary

As has been discussed, interpretations of mobility strategies in the Middle Palaeolithic are often theoretical, based on ethnographic studies, or are based on tenuous interpretations of the perceived intensity of site assemblages and site types such as a 'central place.' As in determining site type and function, the coarse grain of Palaeolithic occupation levels poses additional problems for studying mobility. It is difficult to assess an occupation level as representing a single event or an archaeological palimpsest, and the current state of site dating is unable to rectify this issue. Still, the correlation of the archaeological assemblage with the off-site landscape is the most straight forward way of determining movement in the palaeolandscape.

The best approach to studying mobility strategies in the Middle Palaeolithic of northeast Italy then is to focus on lithic assemblage variability from an inter- and intra-site perspective. Determining the costs and risks of various mobility routes through consideration of terrain, LRM quality and accessibility, and additional ecological variables such as the distribution of subsistence resources, will illuminate the ways in which Neanderthals organised subsistence and off-site activities.

2.4 The Lithic Assemblage

…the technological strategies that prehistoric populations used to cope with discontinuities in the distributions of food and raw materials, or the scheduling conflicts between foraging and toolmaking, provide a host of clues about subsistence, foraging, and mobility (Kuhn 1995: 20-21).

As discussed and reiterated throughout this chapter, lithic technology and raw material economy are the most informative tools with which to determine the impact of environmental constraints on Neanderthal ecology, in particular mobility and resource scheduling, and strategies to mitigate these. This section will provide a synthesis of the interpretive frameworks for approaching the Mousterian lithic record, followed by a discussion of current interpretations of Neanderthal mobility, land-use strategies, and resource strategies based on the results of raw material economy studies of the European Middle Palaeolithic record.

2.4.1 The Mousterian record: interpretive frameworks

Stone artefacts are the best preserved and most frequently recovered artefacts of the Middle Palaeolithic. The Mousterian , originally based on the findings from Le Moustier, is generally defined by its worked tools, including scrapers, points, and handaxes (de Mortillet 1885). From a cursory glance at the archaeological signatures of Mousterian sites, similarities in lithic industries and hunted fauna can be observed across the entirety of Europe for tens of thousands of years. Levallois reduction sequences are seen from the late Lower Palaeolithic until the end of Neanderthal record, found from the Levant to Great Britain, at latitudes from the northern-most reach of Neanderthal occupation to the southerly point of Gibraltar. Consistencies in lithic production techniques and types: flakes, scrapers, points, are observed despite dissimilarities in geographic location, climate, and hunted animal species. While the Mousterian record superficially appears to be uniform, a more intensive review of the data indicates that each site in fact possesses diverse assemblages. This variability can best be observed as the material result of past choices, impacted by multiple forces. As Binford and Binford (1966: 241) observe:

The units of "causation" of assemblage variability are separate activities, each of which may be related to both the physical and social environment, as well as interrelated in different ways.

Indeed, lithic assemblage variability has been interpreted from various socio-cultural perspectives, where typologies serve to differentiate between techno-cultures. In order to describe and classify Mousterian lithic implements, Bordes (1950, 1953, 1961) published work outlining a quantitative, typological framework for study. Based on the frequency of observable artefacts, such as Levallois flakes, scrapers, and denticulates, an assemblage could be categorised as one of six Mousterian groups (e.g. Typical Mousterian or Denticulate Mousterian). The determination of the site's techno-culture not only explained its assemblage variability, but also enabled it to be amalgamated culturally with other sites containing these industries to achieve a broader categorisation of Mousterian traditions. These methodologies led to more consistent interpretations of the stone tool variability observed in assemblages, and are followed by researchers still today.

While the Bordes' typological classification has been predominantly used across Europe to identify and type the lithic tools recovered from Mousterian sites, such methods do not describe the technological or ecological factors behind the tool typologies observed. For instance, Dibble (1987a, 1991a, 1991b), argued that the similarities of tool types across great geographic expanses could not be the product of a shared notion of form; rather, each group was seeking shared production goals of a utilitarian blank form, the shaping of which resulted in virtually indistinguishable tool forms. Further, it should be considered that unretouched flakes likely themselves served as tools for various tasks.

Chaîne opératoire therefore serves as an analytic framework that has the potential to expand our understanding of lithic variability and assemblage composition in response to technological function and resource variability, by methodologically breaking down each stage of lithic production to show a sequence of "mental operations and technical gestures" over time (see

Leroi-Gourhan 1964; Geneste 1985, 1988, 1989; Boëda 1988a, b, 1993, 1995; Geneste and Rigaud 1989; Boëda *et al*. 1990). The gestures that manufactured the artefacts are seen as representing technical or mental operations to meet desired outcomes, and the tools and implements of manufacture have been variably interpreted and debated as products of functional needs, individual skills, technical traditions, economic behaviours, as well as other, non-observable variables, such as symbolic or conceptual intention (e.g. Leroi-Gourhan 1964; Pelegrin *et al.* 1988; Dibble 1991b, 1995; Perlès 1992; Boëda 1994; Dibble and Bar-Yosef 1995; Inizan *et al*. 1995; Kuhn 1995; Turq 2013).

The traditional concept of *chaîne opératoire* was also founded on the paradigm that reduction sequences represent stages in lithic life history, with an end goal of a typologically-desired end product, representing a cultural concept (Leroi-Gourhan 1964; Lemonnier 1988). This is in contrast to the *Frison Effect* proposed by Jelinek (1976) and championed by Rolland and Dibble (1990) and Dibble (1995), which proposes that the shape of lithic implements is significantly changed by processes of retouch and resharpening; lithic implements therefore were not static forms or achieved cultural concepts at the point of discard, loss, or abandonment. Kuhn (1993, 1995) argues that retouch and resharpening indicate management and maintenance activities, and the observed reduction strategies can thus inform on economic responses to environmental constraints. This is echoed in the 'complete reduction fallacy' that sees reduction sequences as the product of lithic manufacture and maintenance in response to environmental constraints, where, for instance, retouch may not represent the forming of a tool type, but the intensity of utilisation (Turq *et al.* 2013). Therefore, an artefact represents a stage in the ongoing use-life of functional lithic implement. Functionality and technological aims, as well as environmental constraints, must also be considered to have influenced implement form, retouched or not: use-wear studies in the study region of this research have indicated that not only retouched implements, for example, denticulates, but also unretouched flakes functioned as tools, and therefore artefact form indicates not only environmental constraints, but the activities that took place at a site (e.g. Lemorini *et al.* 2003; Picin *et al.* 2011).

There has been a call to nominally distinguish *chaîne opératoire* from terms such as 'operational sequence' (Dibble and Bar Yosef 1995; Bar Yosef and Van Peer 2009) in interpretive frameworks of research. However, such distinctions are not necessary so long as the interpretive intentions are stated outright, as the methodological lens of *chaîne opératoire* is applicable to either socio-cultural, technological, or economic interpretations. This research approaches *chaîne opératoire* as a means of identifying the operational sequence of lithic production, and variations in these sequences within the assemblages reflect the costs and constraints impacting meeting technological, functional, and economic needs. This research agrees with Kuhn (1993, 1995) and Turq *et al.*(2013) that retouch can be perceived as evidence of lithic management and maintenance and utilisation in response to environmental constraints (including LRM quality and distribution and terrain) as well as functional aims. It is in this framework that the interchanging use of *chaîne opératoire* and reduction sequences will be referred. The economic approach to *chaîne opératoire* in raw material economy studies will seek patterns of technological organisation, rather than consideration of mental strategies. In this paradigm, observed reduction sequences and the variability of these across assemblages can be seen as responses to the demands and costs of raw material manufacture in a regional settlement system with varying LRM distribution and character. These patterns of economic responses in the Palaeolithic record signify planning depth and the anticipation of needs in response to environmental constraints, and highlight mobility patterns and the management of resources.

However, before moving on to the following section on raw material economy studies, the argument made by Brantingham (2003) regarding archaeological perceptions of Neanderthal mobility and LRM procurement as a product more of "random encounters" with LRM sources rather than complex economic tactics to adapt to environmental constraints should be addressed. In his neutral model of foraging for LRM, he demonstrates that, based on random encounters with LRM sources and a limited carrying capacity in line with a mobile toolkit, the generated assemblages reflect what are standardly considered in RMES to be patterns of evidence supporting relationships between distance and LRM quantity and reduction intensity. Essentially, the chance of encountering an LRM source decreases with distance, due to the amount of ground covered, and, assuming a constant rate of lithic deterioration, the greater the distance of procurement, the more likely lithic implements are to show evidence of maintenance.

Archaeological assemblage paralleling the findings of this simplistic model indicates that LRM procurement may not have been optimized to mitigate costs and risks, and may have been procured either more opportunistically upon encounter in the landscape or embedded in other subsistence activities. The implications of Brantingham's research is that how we interpret the archaeological record in regards to economic strategies should be carefully considered and tested against a neutral model of simple, non-strategic LRM encounters, particularly considering the low resolution of Middle Palaeolithic assemblages. While this does not negate the possibility that such strategies were regularly practiced by Neanderthals, it reinforces that archaeological interpretations should be critical.

2.4.2 Raw material economy studies (RMES)

Raw material economy studies seek to address the following questions:

- *To what extent did the character and distribution of lithic raw materials in the landscape influence the organisation of technology that is observable in the lithic artefact record?*

- *How can we better understand the organisation and structure of Neanderthal land-use and resource scheduling through looking at variability in the lithic technological record?*

To address these questions, RMES utilise multi-disciplinary analytical methods to discern patterns of site activity, mobility, and settlement dynamics, with an emphasis on determining raw material management, transport, and procurement strategies through lithic assemblages. **Techno-economic analyses** of lithic assemblages assess the observed *chaînes opératoires*, or operational sequences, in addition to technological choices in relation to resource variability. Resource variability is considered to be an environmental constraint, and the costs of procurement include the distance to an LRM source (energetic output over distance), raw material availability (the abundance and accessibility of a lithic resource patch), and quality (the efficacy and suitability of raw materials for desired functional needs). **Site catchment analyses** are utilised in conjunction with techno-economic studies to determine the distribution of raw materials observed in the archaeological record, and the identification of raw material sources provides empirical data on the environmental constraints (costs) discussed above. Further, the locations of these LRM sources indicate economic zonation within which the transport of raw materials, serving as a proxy for population movement across archaeologically-negative landscapes, can be observed. Inter- and intra-site comparisons of these methodologies and their findings at the regional level comprise the methodological framework of RMES.

The remainder of this chapter will focus on the application of raw material economy studies in the Middle Palaeolithic, emphasising research that conducts quantitative analyses of lithic assemblage variability through an ecological framework, as is in keeping with the methodological framework of this research.

Lithic assemblage variability: an ecological framework for determining economic zonation

Geneste's (1985) doctoral thesis on the raw material economy of the Aquitaine Basin of France correlated the observed *chaînes opératoires* of lithic assemblages with the distribution of raw lithic materials. His work identified clear patterns of economic behaviours in the Mousterian record, where observed reduction sequences in the lithic assemblages are repeatedly correlated to the distance of the site from raw material sources. In this framework, each artefact recovered has analytic potential, as each represents a past behaviour. As previously mentioned, his successful approach to determining Neanderthal techno-economic behaviours became the framework for numerous raw material economy studies (e.g. Geneste 1988; Geneste and Rigaud 1989; Turq 1989; Geneste and Boëda 1991; Féblot-Augustins 1993; 1997a, 1997b; 1999a, 1999b; Longo *et al.* 2006; Arzarello *et al.* 2007; Wilson 2007a, 2011b, Browne and Wilson 2011); these have identified similar patterns of raw material management over distances that appear to indicate common economic zonations for Neanderthal resource procurement and mobility in western and central Europe (Table 2.2).

Acquisition	Production			Consumption	Abandon
Debitage			Shaping	Utilisation	Abandon
Phase 0	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Extraction First flake Test	Shaping of raw material form Decortication Striking platform	Flake production	Retouch or *NOT* of tools: lack of retouch passes to Phase 4	Utilisation Reviving Recycling Transformations	Abandon Fracturing Attrition

Table 2.3: Schematic of Geneste's (1985: 179) proposed chronology of the general organisation of lithic tool production systems from an economic perspective. When possible, French terminology was translated using the language-conversion dictionary from Inizan et al. 1995.

Geneste (1985) broke down the *chaîne opératoire* of Mousterian lithic technology from an economical point of view (Table 2.3) to involve the **acquisition, production, consumption,** and **abandonment** of lithic materials. In a production sequence intended for tool manufacture, four subdivisions of production are identified: **debitage, shaping, consumption,** and **abandonment.** The five phases proposed represent the production and the technical life of a lithic tool. Although these adhere to the conceptual framework of reduction and production toward an intended tool type, the chronological segmentation of reduction sequences can be best observed through this schematic, as acquisition through retouch to discard can be empirically recorded and statistically analysed. Thus, it is this *chaîne opératoire* framework outlined by Geneste (1985) that this research will interpret lithic assemblages. These stages and phases of operational sequences are expounded upon below following Geneste’s 1985 definitions. The interpretations and methodological approaches of this research will also be explained (in italics below each sub-section).

Acquisition: the acquisition of raw lithic materials, and associated technology. *Identifying acquisition sources requires lithic prospection through pedestrian survey to determine the nearest raw material sources in the landscape of the lithotypes seen in the archaeological record.*

Production: the reduction of the lithic materials following successive technological actions in a chronological sequence. For Geneste (1985), the intention of these actions is to produce supports for tools. *For this research, when these supports are archaeologically observed, these represent the end of the technological sequence. However interpretations may include tool potential or that these supports serve as tools in themselves, although a conceptual future for such supports as a tool is not assumed.*

Consumption: the transformation of blanks into tools, and the use of these. *For this research, the transformation of blanks into tools through retouch may represent lithic material management strategies or the maintenance of a lithic implement for further/continued use. The appearance of retouch does not denote a conceptual Levallois or Discoidal tool. Further, unretouched flakes utilised as tools can be considered consumption.*

Abandonment: abandonment of an utilised product after recycling and re-use, or discard due to fracturing. *For this research, abandonment does not necessarily correlate only to the use of a lithic product, but also to the negligence and discard of waste products and unwanted lithic debris (including blanks that have previously been interpreted as tool potential).*

Within these major categories, four tooling operations can be identified: **debitage, shaping, utilisation, and abandonment.** Debitage and shaping are operations that fall under acquisition and production, and utilisation falls under consumption. Abandonment stands alone, and is described below.

Debitage: the obtaining of rough, unshaped products from a raw material block, which are to be used as they are, or later shaped by retouch. *From a technological point of view,* (*not considering researchers' interpretations of artefact purpose*) *debitage are the products produced during core preparation, including cortex removal, and shaping of the striking platform.*

Shaping: shaping of a support through retouch, resulting in characteristic by-products according to the methods used. Shaping also includes retouch/repair of implements that have been used (re-tooling), indicative of recycling. This can be seen, for example, through retouch on broken tools. *This definition of shaping relies on typological determinations; for instance, it assumes that retouch of an implement serves to restore its original' form.' For this research, shaping is documented by the presence of retouch, the degree to which, in terms of number of usable edges (sensu* Kuhn 1995), *retouch occurred. Tool form is not the focus of this study, although previously recorded Bordian typologies will serve to indicate the number of sides retouched (for instance, two, in reference to a double scraper) that indicate the level of retouch and therefore perhaps the maintenance paid to that implement.*

Utilisation: For Geneste, the differentiation between shaping and utilisation is theoretical: the use of a shaped tool or unshaped product for a functional purpose, as seen through reviving of tools, fracturing and recycling, and use-wear traces (all, with the exception of use-wear, falling under *shaping*), can indicate the spatial organisation of activities. *Again, for this research, a shaped tool is seen as a product that has undergone varying degrees of maintenance; this alteration in itself does not equate to utilisation per se. Without conducting use-wear analyses, determinations of implement utilisation are very difficult to determine.*

Abandonment: the abandonment of a lithic implement within any phase of the operational sequence due to end of use-life, fracturing, or attrition. *For the purposes of this research, and as stated earlier, abandonment involves negligence, discard, and loss of unwanted lithic materials. Abandonment is not necessarily a deliberate act. What is recovered in the archaeological record is not necessarily representative of an implement's value or intentionality, based on its shape or level of retouch; therefore, the recovered phase of an artefact does not necessarily signify the final use, or life stage, of an implement.*

Geneste (1985) further divided the *chaîne opératoire* framework outlined above into five distinct phases (Table 2.4). These operational phases and their behavioural implications are discussed below:

Technological Categories and Phases		
Reference Type	**Nomenclature**	**Phase**
0	Tested or rough raw material block	0
1	Decortication flake, entame with cortex >50%	
2	Flake with residual cortex (<50%) and cortical striking platform flake and blade	1
3	Natural backed knife	
4	Ordinary flakes and points, flakes from reviving the striking platform	2A
5	Ordinary blade	
6	Atypical Levallois flakes and blades, pseudo-Levallois and déjeté flakes	
7	Levallois flake	
8	Levallois blade	
9	Levallois point	
10	Pseudo-Levallois point	
11	Discoidal core	2B
12	Diverse core types	
13	Levallois flake or point core	
14	Levallois blade core	
15	Levallois débordant	
16	Core or blade edge, crested flake	
17	Core fragment	2C
18	Core on flake and Kombewa type	
19	Thinning on flake, not retouched	
20	Kombewa flake	
21	Indeterminable flake fragments without cortex	
22	Biface thinning flake	3
23	Retouch flake	
24	Debris > 30mm with or without cortex	Diverse
25	Debris <30mm with or without cortex	
26	Small diverse flakes and fragments 10-30mm	

Table 2.4: Geneste's (1985) technological phases paired with Bordes' (1961) technological categories of Levallois production (after Geneste 1985: 250)

Phase 0: involves the acquisition and choice of material. This involves the extraction of raw material blocks, extracting and sorting blocks from their various sources, such as torrents or palaeosols, and the fragmentation of large blocks to obtain viable stone (tested for quality through a removal (first removal, *entame*)), the size of which is dictated by the purpose of the operation and the nature of the material. *Phase 0 represents the inception of a lithic artefact in its life history. Choice and acquisition of raw materials are typically not fully observable within archaeological assemblages. Even when raw material blocks are observed at a site, choice and acquisition have already taken place. Phase 0 is typically observed in association with raw material sources, indicating that the testing of blocks took place at the location of extraction.*

Phase 1: the preparation of procured raw material for the production of debitage (Phase 2), or for the development of an implement, such as in biface manufacture. *Decortication in Phase 1 indicates removals after a raw material block has been selected; these are differentiated from entames, whose purpose is to test raw materials. For this research, cortical flakes, be they intentional removals or entames, are subsumed into a single category, within which it is the percentage of cortex, and the shape of the flake, that are the most informative, as is the character of the cortex itself, which indicates source location, such as primary outcrop or alluvial deposit.*

Phase 2: core removal products including flakes, blades, and points, following a technological concept, such as Levallois. Phase 2 products can be divided into those made through preparation and repair of a striking platform, debitage, and from formatting a core. The abandonment of a core also falls into this phase. *For this research, the morphologies of the blanks produced during this phase are considered useful for their shape and number of usable edges, rather than for the technological concept they may be perceived to represent.*

Phase 3: shaping of tools on the supports obtained during Phase 2 within a complex *chaînes opératoires*. This phase can be subdivided according to techno-complex (*such as Quina or Ferrassie Mousterian),* or by the absence of certain lithic artefact types (*such as handaxes or denticulates*). *To reiterate: the shaping of tools indicates the management and maintenance of a manufactured lithic implement; in this sense, the chaîne opératoire* is *more complex, as the life of the artefact is extended rather than abandoned at this point.*

Phase 4: refers to the use of lithic products manufactured or maintained during Phases 1-3. This phase also includes the reviving of products due to accidental or intentional fractures to transform the tool. *Reviving of a previously retouched blank is difficult to determine: methods involve studies of patination and retouched edge angle. Because revival and transformation extend the use of a lithic implement, these products from Phases 3 and 4 can be categorised together where such variables such as number of retouched edges, the invasiveness of retouch, retouched edge angle and simple vs. complex retouch patterning are considered indicative of the* degree *of maintenance. Use-wear of non-retouched implements must be determined macroscopically through signs of micro-flaking and abrasion, or microscopically; this has been minimally done within the study region, and further analyses are not possible within the scope of this research. This research will thus rely on those relevant publications and analyses within the study region, and will fully recognise that blanks, both cortical and cortex-free, may indeed have been used as tools by past populations. The most significant aspects of these pieces for this research, then, are the morphology of their abandoned state (size, shape, cortex %, etc.) and that they were abandoned.*

Phase 5: abandonment. *This phase of chaîne opératoire is conceptual. If one adopts the life histories approach, then rather than strive toward survival as all organic matter does, lithic implements 'die' at all stages of the life cycle. In this sense, the lithic assemblage is comprised entirely of Phase 5. Therefore, too much import should not be placed on this phase, with the most effective study of raw material economy gauging the amount of 'life' experienced before 'death.'*

These phases, and their subsuming headings and sub-headings, comprise the framework outlined by Geneste (1985: 177-182) that is broadly followed in this research. As discussed, lithic assemblages can be seen to represent complete or incomplete 'life' stages within this framework. Empirical studies of *chaîne opératoire* can therefore signify the lithic activities occurring at a site and, when correlated with the distribution of raw materials, can indicate technological provisioning, economic zonation, as well as land-use organisation such as mobility and settlement systems (Geneste 1985; Kuhn 1993, 1995; Inizan *et al*. 1995; Turq 1999).

For instance, as discussed in Section 2.3.1, Geneste (1985, 1989) has observed that truncated reduction sequences are observed, i.e. the latter phases of the production system, in sites located at greater distances from their raw material sources, typically in the semi-local to exotic economic zones. In contrast, sites provisioned with raw materials from the local zone showed the breadth of the production system and a more expensive attitude toward lithic production, as seen through a lower frequency of retouch and higher rates of discard in the early operational sequences. In a site where truncated reduction sequences are observed, but are represented by the first phases of production, one may expect to see these sites located at a raw material source (quarrying), or activities where lithic blanks or supports or perhaps cores were pre-formed and transported elsewhere. It is within such sites that one may find greater frequencies of entames, larger cortical flakes, and broken raw material blocks and rough cores, indicative of Phase 0 and perhaps Phase 1.

These correlations between reduction sequences and distances have been repeatedly observed for the Middle Palaeolithic record, particularly in France (e.g. Geneste 1988, 1990, 1991; Geneste and Rigaud 1989; Turq 1990a, 1992, 2005; Féblot-Augustins 1993, 1997a, 1997b; Simonnet 1999; Fernandes and Raynal 2006; Wilson 2007s, 2011; Fernandes *et al.* 2008; Browne and Wilson 2011). The intensity of research in France may in part be due to the abundance of flints and the extensive knowledge of its distribution and quality based on these decades of geo-archaeological research (Figure 2.2); these data have provided extensive archives that can be, and have been, utilised by researchers interested in the organisation of technology and settlement (e.g. Daujeard and Moncel 2010; Moncel and Daujeard 2012).

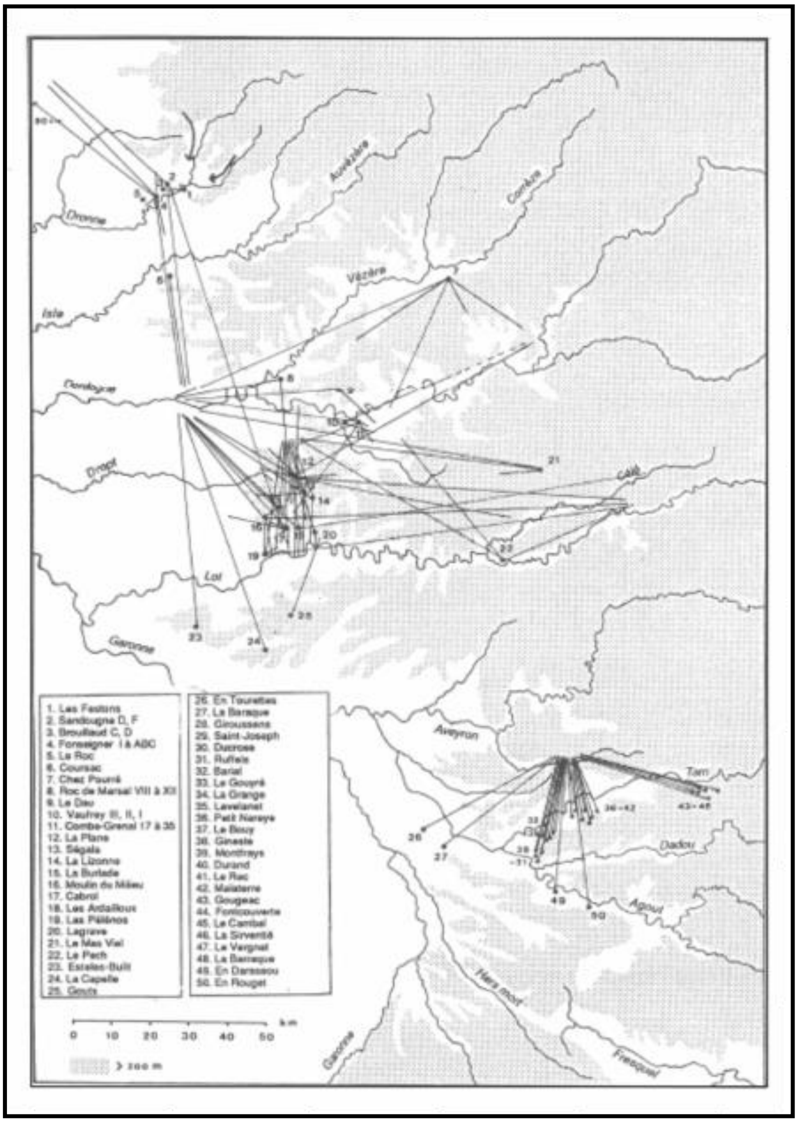

Figure 2.2: The extensive known distribution of raw lithic materials in France, from Féblot-Augustins (1997a: Fig's 38 and 39). Note the Euclidean delineation of material movement, and the lack of topographic consideration in determining distances.

These correlations have also been observed across Italy, indicating a widespread consistency in the local, semi-local, and exotic economic zonations in the late Neanderthal populations. In the Italian peninsula, raw materials have been regionally studied and variably recorded (e.g. Kuhn 1995; Porraz 2005; Longo *et al.* 2006; Arzarello *et al.* 2007; Porraz and Negrino 2008; Spinapolice 2008, 2009, 2012; Longo and Giunti 2010); however, the scale of these surveys and the compiled dataset of known raw material sources in no way rivals that of France.

In Salento, Puglia, Spinapolice (2008, 2009, 2012) linked Mousterian site lithic artefacts with their established provenances through extensive lithic prospection and microscopic and macroscopic analyses. The data indicate that transfer distances across the landscape reflect primarily local and sub-local provisioning of poor quality limestone and siliceous limestone. *Meretrix chione* shells were also occasionally knapped, namely for the manufacture of lateral scraper-type implements (Spinapolice 2008, 2012); this phenomenon of working shells has also been observed elsewhere in Puglia, such as at Grotta dei Giganti (Cristiani and Spinapolice 2009; Spinapolice 2009), Grotta del Cavallo (Palma di Cesnola 1965, 1966; Messeri and Palma di Cesnola 1975-1976) and Grotta dell'Alto (Borzatti von Löwenstern 1966). High quality materials including jaspers were recovered from several of the sites; however, survey confirmed the *geological* absence of these in the Salento Peninsula. The nearest sources of flint and jasper at distances of 100-150km to the north therefore indicate the long-distance transfer of exotic materials through direct circulation or exchange (Spinapolice 2011). Spinapolice (2008) posits that the flat nature of the Puglian landscape would have facilitated such long distance movements between residential sites in northern Puglia, and movement to logistical sites in the south.

In Liguria, raw material economy studies incorporating lithic prospection further emphasise consideration of inter-regional analytical scales, in addition to the geological character (quality and abundance) and geographic features (in this case, a 'corridor' through which materials were carried) of the region under study (Porraz 2007; Porraz and Negrino 2008). The impact of these variables on raw material transfer distances may explain the long distance transport of lithic materials, extending beyond the typically-observed 100km range to reach over 200km. Although such distances are observed, lithic assemblages are typically dominated by local raw materials, for which complete reduction sequences are recovered. These findings are comparable to the findings from those Mousterian assemblages in France (e.g. Geneste 1985).

Acknowledging the bias toward sites bearing denser archaeological signatures, Porraz (2007) focussed on those sites with less dense lithic assemblages to better understand the settlement patterns and landscape organisation from two Neanderthal sites in different regions of Italy: Pié Lombard in Liguria, and Grotta del Broion in the Veneto. Both sites contain sparse archaeological records, and local LRM sources are absent. The truncated reduction sequences are interpreted to indicate the introduction of mobile toolkits to the sites, and imply short-term site use for task-specific purposes within a wider subsistence landscape.

In west-central Italy, Kuhn's (1991, 1993, 1995) ecological approach to techno-economic studies highlights the relationship between Neanderthal behaviour and environmental constraints from a perspective in line with the underlying framework of this research: lithic technology is a problem-solving, strategic behaviour for the management of costs and benefits of maintaining raw material supply and anticipating tool need. Kuhn considered raw material type (which, in west-central Italy, was restricted to small flint pebbles, fairly ubiquitously distributed across the landscape), reduction strategies, and tool types, in an attempt to identify Neanderthal ecology. Foraging strategies, mobility, and landscape use were thus determined by patterns of raw material management (Kuhn 1995).

Linking the lithic technological records of Mousterian sites to the distribution of raw materials in the landscape, Kuhn (1991) found that core reduction is linked to raw material availability, whereas the management and maintenance of lithic implements through retouch and reduction is the result of differential transport and settlement patterns. Correlating this variability with subsistence remains, Kuhn (1993) linked higher mobility and greater foraging range to increased rates of blank manufacture, and to greater frequencies of maintenance activities seen through retouch and resharpening. In contrast, sites showing evidence of long term occupation, through complete anatomical representation of faunal species (Stiner 1990-1991, 1993), are associated with reduced lithic maintenance activities and a higher frequency of local LRM.

Kuhn (1995) considered not only LRM quality and abundance, but additional technological variables such as retouched edge angle, number of usable edges, and the number of retouched edges, which are linked to LRM distribution and evidence for subsistence strategies. These data were incorporated into a cost-risk model in which the technological signatures of lithic assemblages can indicate settlement patterns and mobility strategies. Assemblages containing high amounts of end products and evidence of maintenance of tools, such as resharpening, can be perceived to represent short-term site use by hominins adhering to a provisioning of individuals strategy. A high frequency of local raw material blocks, cores, and cortex, conversely, indicating the early stages of *chaîne opératoire*, would probably indicate a more residential site, and a provisioned place. Kuhn (1995) noted, however, that apparent provisioning strategies were likely not so straight forward, and that hominids likely practiced both provisioning of individuals and provisioning of places in response to varying subsistence activities and mobility strategies; however, it is difficult to differentiate these strategies particularly in more dense assemblages, as each accumulate at different rates.

While raw material provenance is typically indeterminable in west-central Italy, limiting linkages between procurement distances and costs with observations of technological provisioning strategies, in regions where lithic materials can be more assuredly determined, such as in northeast Italy, these provisioning strategies can be further tested. Kuhn's interpretive framework, considering the economic choices of Neanderthals in response to the costs and risks of environmental constraints, has clearly demonstrated that the determination of raw material provenance and lithic transport is critical to site-level interpretations, as well as regional inferences of mobility strategies, settlement systems, and resource management.

In the study area in northeast Italy, limited lithic prospection has been carried out. Research in the eastern Monti Lessini pre-Alps has indicated a predominantly local procurement strategy by late Neanderthals in this region, through geological surveys that have focused on the distribution of LRM in the vicinity of Riparo Mezzena (Longo *et al.* 2006; Moncel *et al.* 2007) and Riparo Tagliente (Arzarello *et al.* 2007). Additional survey includes a 5km area of the southern Valpantena Valley (Longo and Giunti 2010). Rheological testing (Longo *et al.* 2006) of the Monti Lessini flint varieties indicates those characteristics that may have influenced procurement and technological choices (see Chapter 3, Section 3.4). As these flint types are distributed across the Monti Lessini, and to some extent in the sub-Alpine foothills, these data can be extrapolated to augment the data collected in this research.

Lithic Raw Material Character

The studies discussed above demonstrate that across the Mousterian landscape there is a repeated correlation observable between the distance to a raw material source and its frequency within an archaeological assemblage, falling in line with Geneste's (1985) economic zonations for the Aquitaine Basin. This demonstrates that Neanderthals most frequently provisioned places with local lithic raw materials that required less energy and time due to shorter distance coverage. Where sites indicate longer-distance transport of raw materials, these are often represented by truncated reduction sequences and increased frequencies of retouch. The latter imply the provisioning of individuals with mobile toolkits, which provided lithic implements and tool potential in anticipation of need and resource scarcity, and which minimised transport costs due to their reduced size and weight. Beyond the distance between a source and a site, however, other variables have been shown to impact the lithic assemblage, including the shape, abundance, and quality of raw materials. These can be seen as *attractiveness characteristics*, alluding back to the work of Wilson (2007a, 2007b), which, in addition to terrain features and the distribution of resource patches, can be positively linked to LRM provisioning and land-use strategies, exemplified by mobility and settlement patterns.

		Lithic Quality	
		High	**Low**
Lithic Abundance	**High**	Formal and informal tool production	Primarily informal tool production
	Low	Primarily formal tool production	Primarily informal tool production

Figure 2.3: Relationship between raw lithic material quality and tool production (after Andrefsky 1994: 30)

Brantingham and Kuhn (2001) note that the shape of the raw material source may have influenced procurement strategies because of its role in determining technological strategies. In looking at the productivity of Levallois cores on river cobbles, the edge length for steep-angled Levallois cores increased when flatter cobbles were utilised (although this also correlates to decreases in the number of tool blanks produced). Therefore, the selection of raw materials was a product of environmental constraints and technological aims, in which Levallois core technology served as a time-optimising strategy of minimising lithic debris and maximising the manufacture of blanks and tool potential (Kuhn 1995; Brantingham and Kuhn 2001). Brantingham and Kuhn (2001) argued that the low time and energy costs of Levallois core preparation may have enabled changes in mobility, where hominins were not bound to raw material sources: Levallois cores produced more blanks with morphologies that maximised the number of usable cutting edges. These variables are advantageously linked to high mobility (Kuhn 1994; Brantingham and Kuhn 2001). The influence of raw material abundance and quality has also been correlated to tool production (e.g. Kelly 1988; Andrefsky 1994; Turq 1989; Féblot-Augustins 1997a, 1997b). Higher quality and abundance are linked to both formal and informal tool production (*sensu* Andrefsky 1994), whereas lower quality and abundance are linked to mostly informal tool production (Fig 2.3). In a scenario where lithic quality is high but abundance is low, one would expect to see primarily formal tools. Disregarding the conceptualisation inherent in the notion of “formal” and “informal” tools, the relationship between lithic abundance and quality and technological production is important to consider in raw material economy studies. However, additional factors must be considered, including procurement strategies (direct or embedded), as well as environmental variables that impacted subsistence, including non-lithic resource distribution and character, as well as terrain, which would have imposed varying costs and constraints in mobility.

Therefore, numerous factors influenced Neanderthal technology, not only the distribution and quality (attractiveness) of LRM, but terrain and those other subsistence activities occurring in the landscape. However, these must be demonstrated to have influenced assemblage variability, as was demonstrated in Brantingham's (2003) neutral model of LRM procurement, which suggests that the variability that is interpreted as Neanderthal adaptive strategies in RMES cannot be qualitatively distinguished from chance encounters with stone resources based on randomly traversing a uniform environment. However, as will be demonstrated in this research, the lithic environments around each of the three study sites was not uniform, ranging from very dense (Grotta di Fumane), to devoid of LRM sources locally (Grotta del Broion). Grotta del Broion, then, in particular, presents an opportunity with which to test the relationship between Neanderthal adaptive strategies and demonstrate that lithic assemblages represent behaviours aimed at optimising tool potential whilst minimising procurement costs and risks.

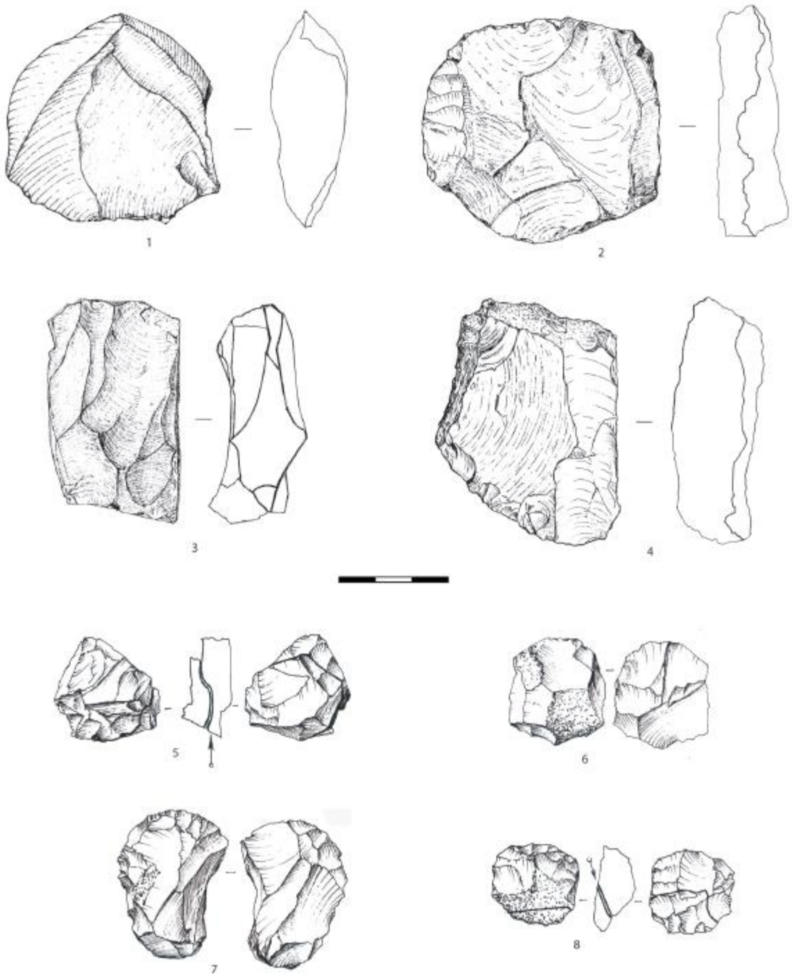

Figure 2.4: Cores in Scaglia Rossa flint from Monte Versa (no's 1-4) and Grotta Maggiore (5-8). Note the significantly smaller size of the cores from San Bernardino (Porraz and Peresani 2006: 6)

Therefore, the varied distribution of LRM in the study region, as well as differences in quality and accessibility, provide an apt environment within which to test such observations. For instance, the variable assemblages observed in a comparison of two sites in northeast Italy appear to indicate economising strategies. At the open air site of Monte Versa, which is located directly on a raw material outcrop, truncated reduction sequences represent the initial phases of production. Large tested raw material blocks were recovered, and retouched implements were lacking. Additionally, a high percentage of cores was observed, many large and discarded due to internal fracturing or manufacturing error. Together these observations signal a low level of parsimony that could be afforded by the abundance of high quality raw materials outcropping at the location (Peresani 2000-2001; Porraz and Peresani 2006). These findings are in contrast to the late Middle Palaeolithic cave sites in the area located further from LRM sources, but which used the same flint type as Monte Versa. For example, at Grotta Maggiore di San Bernardino, cores are less frequent and were recovered fully exhausted (Figure 2.4), indicating economic choices geared toward resource management and conservation (Porraz and Peresani 2006).

2.5 Summary: The Site in Context

Rather than a two-dimensional plane of ubiquitous resource distribution, the Middle Palaeolithic environment was a diverse, undulating, variably prolific landscape, in response to which Neanderthal organised their sites, activities, and mobility. The lithic assemblage, particularly its variability, is the most telling of Neanderthal ecological responses to environmental constraints.

The information provided by the lithic record in relation to a landscape archaeology approach is two-fold: observations of reduction sequences show transport and management behaviours, and the correlations of utilised materials with their sources and palaeoenvironmental reconstructions indicates settlement dynamics. Raw material variables including abundance and quality may be linked to site distribution and assemblage composition, following optimal foraging models that seek to address the costs and constraints of resource-scheduling. Techno-economic analyses that further consider evidence for management and maintenance through reduction and retouch of lithic implements further indicate provisioning strategies. These show correlations between sites that appear to be residential sites, or that show repeated use, depending on how one interprets the archaeological record, and a local proximity to raw material sources meeting these criteria (productive resource patches). Sites lacking in a local abundance, or that are in proximity to low quality resources, may contain assemblages that appear to record sporadic use of a locale, with truncated reduction sequences and greater levels of retouch and reviving activities.

Raw material economy studies of Neanderthal sites across Europe clearly demonstrate that across the Mousterian landscape there is a correlation between distances from a raw material source to a site, and its frequency, level of reduction, and management within a lithic assemblage. This correlation demonstrates that Neanderthals most frequently provisioned places with lithic materials that required less energy and time to transport. LRM from distances beyond the local zone were typically introduced in a reduced state, demonstrating truncated reduction sequences that imply the provisioning of individuals with mobile toolkits. Such toolkits provided lithic implements and tool potential of increased functionality in anticipation of technological needs and resource scarcity, and minimised transport costs due to their reduced size and weight. Attractiveness variables, including the quality, source abundance, and size of raw materials, also influenced the character of the lithic assemblage.

However, distance is frequently inaccurately perceived and measured in raw material economy studies: varied terrain incurred unique costs that would have influenced procurement strategies, leading to the hypothesis that distance does not necessarily correlated to costs, and mobility routes requiring less energy and time were likely preferred and more frequently exploited.

Chapter 3: *Literature Review of the Study Area*

3.1 The late Middle Palaeolithic of Northeast Italy: An Historical Overview of Research

Italy possesses a rich Palaeolithic past, including one of the oldest fossil hominin remains in Europe (Manzi *et al.* 2001); however, it was not until the 1960's that an intense archaeological focus on the Palaeolithic began. For the northeast, as in the rest of the country, Palaeolithic research was originally published as lengthy archaeological reports. A perusal of Italian journals (e.g. *Rivista di scienze preistoriche, Bullettino di paletnologia italiana, Bollettino del Museo Civico di Storia Naturale di Verona*) from this time period shows a large number of Palaeolithic publications alongside Mesolithic and Roman articles. In the study region, the Upper Palaeolithic and later sites, perhaps due to their greater visibility and more sensational archaeology of art and beads, have historically been more frequently published. Detailed excavations and analyses of Middle Palaeolithic sites were not as intensive or prolific; however, in light of the advancements in excavation techniques in the last few decades, greater varieties of materials are collected and retained, and a wider range of data synthesised (Peresani 2001). Research is more greatly focussed on cave sites, while open air sites from the late Middle Palaeolithic have been little documented. The varying visibility of cave versus open air sites is likely less significant of Neanderthal land use and more indicative of post-depositional actions (alluviation and modern construction) in masking or destroying open air locations, as opposed to the better preservation of, and thus greater research attention to, well-preserved cave sites.

As the significance of new finds, such as evidence of intentional feather removal by Neanderthals at Grotta di Fumane (Peresani *et al.* 2011a), to the 'Middle to Upper Palaeolithic Transition' has been recognised, international reports have become more frequent in recent years. Additionally, the recovery of an Uluzzian transitional industry, also from Fumane, has put northeast Italy on the archaeological map (Peresani *et al.* 2008). The Italian Middle Palaeolithic, once little known beyond the Alps and the Adriatic, is now at the forefront of Neanderthal discoveries.

The initial interest in the Italian Palaeolithic in the 1960's may correlate to the proximity and popularity of the work of French prehistorians. While reports on faunal assemblages or pollen counts were also published, and often in great detail (Italian journal publications, until perhaps within the last two decades, range between 60 and 80 pages), many of the publications from this time period focus on the lithic record. In Tuscany, researchers adhered to the Analytic Typology of Laplace (1966), publishing quantitative statistical data on the lithic assemblage, emphasising levels of retouch rather than pre-determined tool typologies. In the study region of northeast Italy, the Bordes method was applied to lithic assemblages, with Levallois Indices (IL) and type-lists reported; within this paradigm, 'type sites' were considered to represent the character of the region. For instance, the lithic industries of the study region are considered to be homogenous (Peretto 1992), and Riparo Tagliente was considered the site-type for the Middle Palaeolithic of the pre-Alps (Bartolomei *et al.* 1982) based on its Typical Mousterian rich in scrapers assemblage, and may still be (Peretto 1990; Fiore *et al.* 2004). However, as modern excavation techniques and analyses yield a greater breadth of information on Palaeolithic life, research must instead focus on the variability of *chaînes opératoires* within the lithic assemblages to elucidate the organisation and structure of Neanderthal land use and resource scheduling.

Assemblage diversity is seen not only in the lithic assemblages of these Mousterian sites, but in their overall archaeological assemblages that indicate diverse site use ranging from apparently intensely occupied and frequently inhabited (e.g. Grotta di Fumane, Riparo Tagliente) to locations indicating brief visitations (e.g. Caverna Generosa, Grotta del Broion), perhaps as task specific areas. For the three focal sites of this research, the influence of environmental variables, including climate, topography, and lithic raw material distribution and attractiveness can be seen to have influenced site formations and technological provisioning strategies. Through inter-site comparisons of the raw material economy observed at each of the three study sites, a better understanding of mobility, subsistence strategies, and settlement dynamics can be seen at the regional scale.

Section 3.2 will give a detailed description of the archaeological character of the study region, providing context for the discussion of the current state of knowledge and research on Neanderthal behaviour at the site level and on a regional scale during the late Middle Palaeolithic of Italy (Section 3.3). These discussions provide detailed overviews of the faunal, charcoal, and wood remains at the site-level. Section 3.4 will provide an in-depth look at the lithological characteristic of the study region, which will be linked to archaeological contexts through a report of the current state of lithic analyses undertaken in the study region. The summary of these data will provide a regional foundation of the current state of knowledge on Neanderthal raw material management, from which this thesis will be built.

3.2 The Archaeological Character of the Study Region

The Middle Palaeolithic record of northeast Italy is primarily composed of flaked stone and animal bone, with the occasional *Homo* fossil. These assemblages reveal a record of Neanderthal occupation in the study region spanning hundreds of thousands of years. The diverse topography and occupation over a long period of time makes the study region ideal for Neanderthal land-use studies.

The Palaeolithic archaeological record of the northeast of Italy begins in the late Lower Palaeolithic, primarily represented by open air sites, often at high altitudes (Mussi 1999;

Milliken 2001), which are typically stylistically dated and/or their temporal assignment is based on the likelihood that these were occupied during an interstadial event, due to their proximity to glacial limits (Milliken 2001) The Lower Palaeolithic of the region is typically represented by an Acheulean pebble industry, where choppers and occasional (but rare) handaxes have been recovered. Discoid industries have also been observed (Lanzinger 1990; Mussi 1999). It is interesting to note that Lower Palaeolithic archaeological remains have not been observed at any of the Middle Palaeolithic sites in the study region, indicating changing land use strategies over time, an observation that will be discussed further in the following paragraphs.

The known record of the entire Middle Palaeolithic of the region comprises around 60 sites, found in both caves and rock shelters and in open air (Peresani 2001). In the early Middle Palaeolithic particularly, open air sites containing Levallois Mousterian industries represent a good percentage of known occupations in the region. These are found at higher elevations in the Alps and pre-Alps (900-1800m asl). Due to post-depositional processes, faunal remains and features are not frequently preserved, and the remaining artefacts lack stratigraphic context (Peresani and Porraz 2004). Those recovered are represented by small lithic scatters (Fiore *et al.* 2004; Peresani 2009), characterised by a recurrent Levallois reduction strategies, although Discoidal strategies can be observed at some sites. Centripetal Levallois appears to have been preferred over either uni- or bidirectional modalities (Peresani 2001, 2010, 2012; Peresani and Porraz 2004; Porraz and Peresani 2006).

For the later Middle Palaeolithic, few open air sites are known in the study region. This may reflect archaeological visibility and presence in favour of sheltered sites over open-air sites, which were obscured or obliterated by glacial or fluvial action and Pleistocene and Holocene sediment cover (Fiore 2004; Peresani 2001). Of the identified late Middle Palaeolithic open air sites, the majority are surface finds from the sub-Alpine foothills in the Monti Berici and the Colli Euganei, situated at lower elevations in proximity to outcrops of LRM (Peresani and Porraz 2004; Duches *et al.* 2008; Duches and Peresani 2009; Peresani 2009, 2013). These assemblages typically contain Levallois artefacts and lack stratigraphic context, so temporal assignments of these sites are stylistic and therefore vague. An exception is the site of Monte Versa in the Colli Euganei, attributed to MOIS-4, where stone artefacts have been recovered within a palaeosol layer (Peresani 2000-2001, 2001b, 2013).

As the majority of the identified Middle Palaeolithic (e.g. Monte Versa, Colle Mattara, Casa Ambrosia) sites in the Colli Euganei are located in proximity to or are directly associated with LRM sources, these are interpreted as quarrying and lithic processing locations; this is supported by the tendency toward truncated *chaînes opératoires* representing the initial phases of raw material block testing and core removals, and the low frequency of retouched implements (Porraz and Peresani 2006; Duches *et al.* 2009; Duches and Peresani 2009;

Peresani 2013). The presence of Colli Euganei flints (20km south) in Monti Berici archaeological assemblages also indicates the importance of this landform as a flint source (Peresani 2009; Porraz and Peresani 2006). Due to the sparse nature of open air remains compared to the denser record of the cave and rock shelter sites of the region, the open air sites are considered to represent ancillary activity areas (Fiore *et al.* 2004; Peresani 2001).

Figure 3.1: Major late Middle Palaeolithic cave sites and the open air site of Monte Versa in the study region of northeast Italy (Basemap: Google Earth 2014).

There seems to shift in land-use strategies from the Lower Palaeolithic to the Middle Palaeolithic in the study region (Mussi 1999; Longo and Giunti 2010; Peresani 2010, 2011; Porraz and Peresani 2006). In the Lower Palaeolithic, there is skeletal evidence of hominid interaction with herbivores in open air locations, seemingly in strategic places where species would aggregate or come to die (Mussi 1999). In the late Middle Palaeolithic, sites are most frequently found in stratified cave and rock shelter localities with good preservation due to loess cover (Peresani 2011). Middle Palaeolithic open air sites generally contain only lithic implements: faunal and vegetation remains are generally not recovered, and were either not preserved or they were not introduced (Peresani 2001). Therefore, the records of the open air sites are potentially incomplete and represent a challenge in assessing settlement systems. Based on the faunal assemblages and pollen remains, the cave sites were situated in proximity to different biomes, with access to diverse geophysical and resource environments (including LRM) that would have facilitated residential-type occupations (Fiore *et al.* 2004; Peresani 2001; Moncel *et al.* 2007). A preference of site locations in proximity to diverse resources is suggested by the apparent absence of sites in areas where only a single biome could have been exploited, such as the Po Plain; beyond this geographic unit, the Monti Lessini pre-Alps and the sub-Alpine foothills both represented diverse environments due to shifts in elevation and altitude. The persistence of cave occupations in the late Middle Palaeolithic indicates that these locations played a significant role in Neanderthal lifeways, likely for shelter and protection, in keeping with a theory of a move to a more residential landscape strategy (Figure 3.1). The higher resolution of the cave site assemblages indicate the repeated, and often intense, use of many sites (multiple levels and high artefact counts), with diverse activities (e.g. knapping, butchery, hearths) occurring in a single occupation layer, further suggesting a move toward a more residential scheme of mobility.

Also included in the late Middle Palaeolithic of the study region are those cave sites where occupation appears to have been short term or activity specific. The assemblages of Grotta di Broion and Caverna Generosa are characterised by a low density lithic presence and an absence of human-accumulated faunal remains. The composition of these sites may indicate their function as short-term *locations* within a wider system of residential mobility (Peresani 2009).

There are some areas within the study region where archaeological sites attributed to the Palaeolithic appear to be entirely lacking. The lack of known archaeological sites on the Po Plain is likely largely to do with natural processes occurring both during and after the Pleistocene, as a result of glacial and alluvial action (Peresani 2001). While infill of loess is more thickly preserved in cave and rockshelter sites, weathered fluvial and Aeolian loess is recorded thinly distributed across the Po Plain (Cremaschi 1990). Therefore, potential sites could be buried under sediment and are thus not archaeologically visible, which presents a challenge in reconstructing settlement patterns. It is, however, essential to recognise their likely existence, as evidence of LRM transport from the Monti Lessini pre-Alps, across the Palaeolithic Venetian Po Plain, has been documented at sites in the Monti Berici and Colli Euganei (Peresani 2010; Peresani and Porraz 2004; Porraz and Peresani 2006). This concretely demonstrates movement across this apparently archaeologically-negative landscape (Figure 3.2).

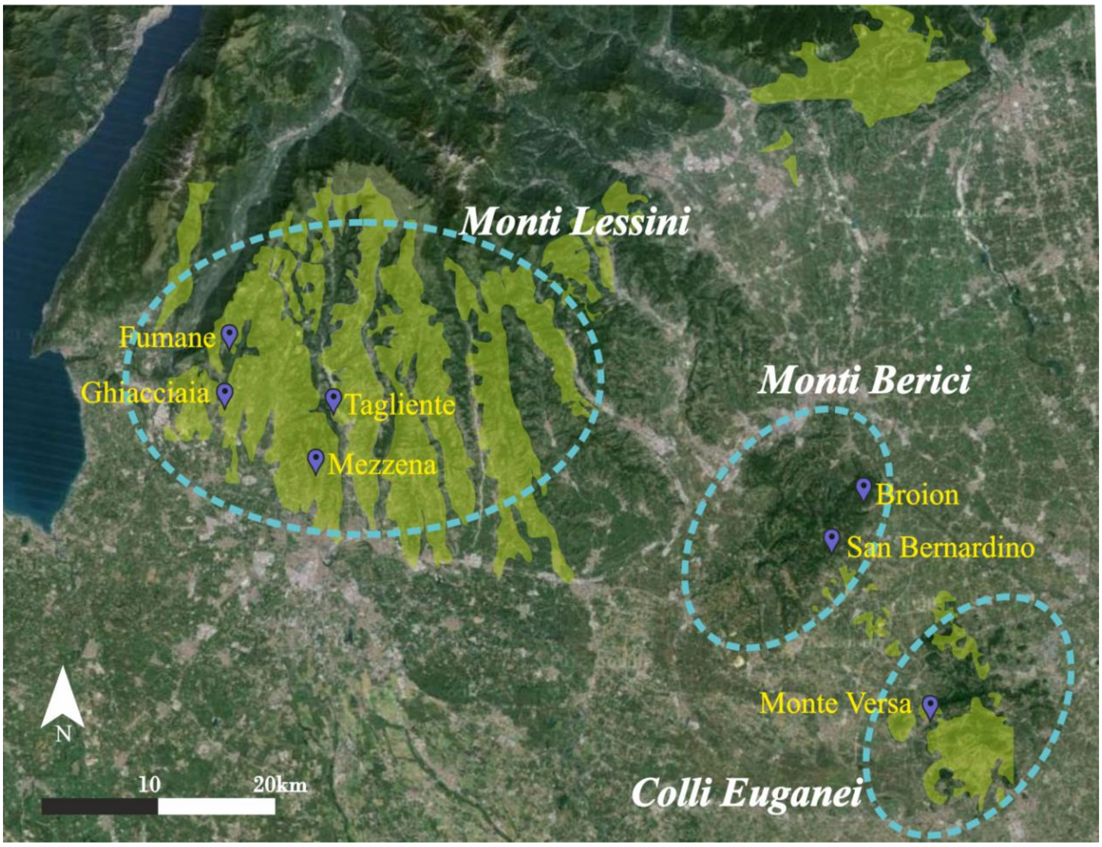

Figure 3.2: Late Middle Palaeolithic cave sites (and Monte Versa), and the geological distribution of flint potential (highlighted in yellow), with greater flint potential in the Monti Lessini (Basemap: GoogleMaps 2014; Lithological data: Carta Litostratigrafica del Veneto 2014).

There is also a scarcity of known archaeological sites on the Berici Plain, between the Monti Berici and Colli Euganei, despite that flint from the Colli Euganei has been recorded in Grotta Maggiore di San Bernardino and Grotta del Broion (Peresani 1995-1996; Peresani and Porraz 2004; Porraz and Peresani 2006), thus demonstrating its transport across the plain. It is probable that the sites recording the movement of these populations exist, but are currently unknown due to late Quaternary and Holocene sedimentation, modern building activity, and lack of archaeological survey. For instance, on the Pontinian Plain of west-central Italy, the Agro Pontino Survey (Voorrips *et al.* 1999; Holstrom *et al.* 2004) revealed numerous open air sites across a wide geographic area, implying that Mousterian life was not limited to the caves and rockshelters as typified by the current archaeological record. This is likely the case in northeast Italy, as well: indeed, numerous open air sites were revealed in recent systematic survey of the Colli Euganei regional park (Duches *et al.* 2008; Peresani 2013).

While cave sites in the study region during the Middle Palaeolithic seem to have been located in proximity to diverse biomes and geophysical contexts (Fiore *et al.* 2004; Moncel *et al.* 2007; Peresani 2001), this cannot be easily ascertained for the open air sites. Because these are of a low grain and organic matter was not preserved, their palaeoenvironments can not be accurately ascertained, and thus it is difficult link ecological conditions with site use across the entirety of the study area. Further, not enough is known about the whereabouts of *potential* open air sites in the Po Plain to determine local biomes; it is likely, however, based on its flat topography and local environmental indicators, that local conditions were uniform rather than varied. The cave sites, however, would have provided access to varied subsistence needs, including LRM, in keeping with a theory of home base (*sensu* Binford and Binford 1966) placement central to resources. However, mosaic environments were widespread in the pre-Alps and sub-Alpine foothills, largely due to topography, including elevation changes in the hills and mountains, and so such conditions were easily accessible. Interestingly, Grotta del Broion, which was situated in proximity to diverse biomes, but which was lacking in local LRM sources, contains only a scant lithic record; these conditions may signify the importance of lithic resource distribution in site function and settlement patterning in the late Middle Palaeolithic of the study region.

3.2.1 Summary of the archaeological character of the study region

While assemblage composition and the physical characteristics of the late Middle Palaeolithic record of northeast Italy are clearly diverse, some commonalities can be observed. In terms of the lithic record of those sites attributed to MOIS-3, nearly all lithic assemblages can be assigned to the Mousterian of Levallois facies, *sensu* Bordes (1953, 1961). The occasional use of Discoidal reduction sequences is also observed, typically in a subordinate role, with the exception of a few MOIS-3 levels at Grotta di Fumane (Peresani 1998, 2002), and thus holds significance for the study of provisioning strategies and environmental impacts on lithic manufacture, maintenance, and transport.

Archaeological sites attributed to the late Middle Palaeolithic tend to be located in caves, where preservation is good, and systematic excavations and studies are more frequent. Of the few known open air sites, little has been documented. In addition to the low visibility or destruction of such sites by post-depositional effects, there is a lack of pedestrian survey in the study region to identify and record such sites (Milliken 2001), and thus the locations and contents of open air sites have been acknowledged in only a few publications (Peresani 2001, 2010, 2013; Peresani and Porraz 2004).

3.3 Current State of Research

As previously discussed, archaeological studies of Middle Palaeolithic assemblages from the northeast Italy region have historically focussed on documentation of lithic tool typologies, typically using the Bordes Levallois typological framework. However, in the last two decades, lithic analyses have begun to also consider variables relating to raw material management and site activity, to illuminate the technological organisation of a landscape from an economic perspective. However, before such studies are discussed, it is critical to first discuss those aspects of the archaeological record that can contribute to our understanding of Neanderthal land use, mobility, and economic choices.

Faunal remains, charcoal, wood, and pollen remains provide additional and supporting indicators of the late Middle Palaeolithic palaeoenvironments, and will be discussed in Chapter 4. The following sections will consider these elements in the context of the complete surviving archaeological assemblage, indicating Neanderthal ecology at the site and regional level.

3.3.1 Faunal remains

Neanderthal remains

Few human remains have been recovered in the study area that can be attributed to Neanderthals. These remains are typically fragmentary and small in number, indicating that the human bones recovered can be attributed to carnivore action rather than burial practice (Mussi 2001). These have typically been taxonomically determined through morphological and morphometric analyses, although recent DNA and isotopic studies are shedding new light on the current record of human remains.

At the site of Riparo Tagliente, a phalanx and two teeth (an upper right molar, and an upper left canine) were recovered in MOIS-3 Mousterian levels 36 and 37 (Peresani 2009; Villa *et al.* 2001). At Grotta di Fumane, four human teeth have been recovered from across the MOIS-3 A levels. A deciduous molar (Fumane 1), recovered during the 1989 excavation of the level A11, has been attributed to a Neanderthal child around 11 years old (Giacobini 1992; Peresani 2011). Two deciduous molars (Fumane 4 and 5) were recovered from level A9 during the 2010-2011 excavation campaign; morphological and metric analyses indicate that they are potentially attributable to a single Neanderthal child based on their recovery within the same unit and their similar resorption stages. The age of this child, based on root morphology, is estimated at six years. From the Uluzzian level A3, a fragmented molar (Fumane 6) lacks morphological characteristics that can attribute it taxonomically to either Neanderthal or AMH (Benazzi *et al.* 2014b). Genetic and isotopic analyses have not been conducted on the human remains from Grotta di Fumane.

At Grotta Maggiore di San Bernardino, a distal hand phalanx and two teeth recovered from the upper Mousterian MOIS-3 Unit II were originally attributed to Neanderthal (Vacca and Alciati 2000). However, a recent re-evaluation of the Grotta Maggiore di San Bernardino remains raised uncertainties about their original taxonomic assignment (Benazzi *et al.* 2014a); the gracile hand phalanx did not fit within the size range of known Neanderthal remains, and morphometric analyses of the labiolingual breadth of specimen San Bernardino 5 (SB5) (a deciduous incisor) showed that it fell well within the modern human range (and far beyond

Neanderthal). To address these concerns, Benazzi *et al.* (2014a) conducted morphometric and isotopic analysis in addition to mtDNA analysis and radiocarbon dating on the third San Bernardino specimen, a lower third right molar (SB4). These analyses clearly demonstrated that SB4 belonged to a modern human, who lived around 440 cal BP, or AD 1420-1480. Based on these results, and the size and association of the other two remains within Unit II, Benazzi *et al.* (2014a) conclude that each of the remains likely belonged to medieval modern humans and not Neanderthals, and were deposited in the uppermost Mousterian levels due to post-depositional admixture.

A relatively substantial amount of hominid remains have been recovered from the late Mousterian MOIS-3 Level I (sub-layer Ib) at Riparo Mezzena. The human remains from this unit include an incomplete mandible, 11 skull pieces, and three fragmented sub-cranial parts. Morphological analysis indicates that these remains fall within the known Neanderthal spectrum in terms of skull thickness and mandibular characteristics (Giunti *et al.* 2008). Analyses and comparison of procured mtDNA with other known Neanderthal mtDNA sequences have confirmed the morphological determination of the Riparo di Mezzena remains to the Neanderthal species (Caramelli *et al.* 2006; Condemi *et al.* 2012). However, recent morphometric analyses of the recovered mandible also seem to demonstrate an AMH-like shape amongst the typically Neanderthal traits of the other Riparo Mezzena remains, which has led Condemi *et al.* (2013) to argue that the presence of a slight chin could indicate some interbreeding between Neanderthal and AMH in northeast Italy in the final Middle Palaeolithic. This possibility could be supported through a comparison of the absolute date from the underlying Unit III of Riparo Mezzena (40,380 to 38,840 cal BP) with those from the proto-Aurignacian level A2 at Grotta del Fumane (ranging from 38,720 to 41,400 cal BP), which indicates to the researchers that Neanderthal and AMH shared a contemporary presence in the Monti Lessini (Higham *et al.* 2009; Longo *et al.* 2012). Unrelated to Neanderthal/AMH overlap, but interesting, genetic research on the recovered Riparo di Mezzena mandible has also potentially demonstrated regional Neanderthal phenotypic traits of red hair and pale skin (Lalueza-Fox *et al.* 2007).

Herbivore remains

Within the study region, faunal remains have historically been reported as species inventories (Fiore *et al.* 2004), with an emphasis on gleaning climatological data so as to determine site chronologies within phases such as the Pleniglacial or Würm (e.g. Cassoli and Tagliacozzo 1994a, 1994b). Faunal remains have not typically been correlated with the broader associated archaeological assemblage (in particular the lithic record, a main focus of this study) to determine the breadth of site activities and to address off-site behaviours, such as mobility. However, the archaeozoological studies that have been conducted for the Middle Palaeolithic of the region have produced a wealth of data on hunted species, their demographic profiles (at death), and the methods with which the prey was transported and processed.

For instance, the work of Cassoli and Tagliacozzo (1994a) yields a considerable amount of data on the faunal remains from all of the Palaeolithic levels of Grotta Maggiore di San Bernardino, including detailed counts of species and their anatomic representations. Of the 14,349 specimens examined, most are highly fragmented, rendering species determination difficult; taxonomic assignment of the remains ranges between 10 and 15% across the sedimentary units. The determined species data are used to reconstruct the environmental conditions and climatological chronology of the site; Unit II, for example, based on the large number of roe deer and red deer, as well as some elk and wild boar, has been assigned to a humid, temperate-cold phase with woodlands, some Alpine grasslands, and limited marshy areas. Although the authors associate the underlying units with the late Middle Pleistocene (Units VIII-VI to MOIS-7, and Units VI-V to MOIS-6), they state difficulty in clearly assigning Unit II within this framework based on the macrofaunal remains.

Based on the estimated mortality ages of the ungulate species, Cassoli and Tagliacozzo (1994a) postulate that the faunal assemblages of Grotta Maggiore di San Bernardino resemble a hunter-gatherer profile rather than carnivore accumulation, but there is no direct explanation by the authors for the high degree of bone fragmentation observed, nor is there any mention of anthropic cutmarks on the faunal remains. However, later micro-morphological studies of the faunal assemblage confirm its primarily human accumulation, particularly in those levels with more dense archaeological signatures (II and VI), through the identification of cutmarks and striations made by stone tools (Malerba and Giacobini 1998a). Additionally, use-wear studies confirm that the striations on herbivore remains were made by anthropic action using stone tools (Lemorini *et al.* 2003; Picin *et al.* 2011): analyses on denticulates recovered in Units VIII through II show that these were used on soft/medium to medium/hard materials, such as animal skins or wood, indicating hide working and butchery (Picin *et al.* 2011).

The hunting strategies at Grotta Maggiore di San Bernardino appear to favour juvenile and adult ungulate species, and the most represented species include red deer, roe deer, and chamois (Cassoli and Tagliacozzo 1994a). Anthropogenic marks have been noted on the cervid remains, as well as the less prevalent elk (Peresani 2001). Bone fragmentation indicative of marrow processing has been observed, as has potential beaver processing (Malerba and Giacobini 1998a). Bird and fish remains have also been recovered, but these do not bear evidence of human action: the well-documented presence of carnivores and raptors likely explains their presence (Cassoli and Tagliacozzo 1994a).

The faunal records of the MOIS-3 A levels of Grotta di Fumane contain a diverse range of species, including herbivores, carnivores, rodents, and birds. As at Grotta Maggiore di San

Bernardino, faunal exploitation focussed on primarily adult and young adults (>90%) (Cassoli and Tagliacozzo 1994b). The most frequently recovered herbivore species are ungulates, particularly *cervidae*, which bear anthropogenic marks attributed to skinning and disarticulation, and shattered bones interpreted as marrow procurement activities (Peresani 2001; Bartolomei *et al.* 1992; Cassoli and Tagliacozzo 1994b). Horse and wild boar are rarely recovered, and their remains do not bear indicators of human activity (Peresani *et al.* 2011a; Fiore *et al.* 2004; Sala 1990). Recovered carnivore species, including fox, wolf, hyena, and cave bear, show evidence of human action related to skinning (Peresani *et al.* 2011a).

Interestingly, avifaunal remains from the late Mousterian levels A5 and A6, which include 22 distinct bird species from diverse environments, show evidence of anthropic action. 7% show evidence of disarticulation, skinning, and potentially feather-plucking, including on inedible species. Additionally, there is evidence for the intentional removal of a golden eagle talon from Mousterian level A12 (>46k cal years BP), which bears disarticulation striations (Peresani 2008; Romandini *et al.* 2014). These finds may indicate that Neanderthals were targeting birds for symbolic or social, rather than consumption purposes (Peresani 2011; Romandini *et al.* 2014). Additional evidence for social or symbolic action in the Mousterian A levels is seen in the Discoidal Mousterian level A9, where hematite traces are noted the concave external surface of a fossil marine shell, which may indicate its use as a personal object. The shell provenance is more than 100km, indicating long distance transport (Peresani *et al.* 2013b). These findings seem to indicate modern (cf. Mellars 2005) behaviours by late Neanderthals in northeast Italy.

The faunal remains from the A levels of Grotta di Fumane support sedimentological and anthracological data on local environmental conditions. The predominance of cervids indicates an expansion of forested conditions over Alpine grasslands in levels A11-A4 (with A13 and 12 being cooler and drier); however, the consistent presence of marmot, ibex, and some Alpine birds indicates either a local persistence of this biome (Cassoli and Tagliacozzo 1994b; Fiore *et al.* 2004; Peresani 2011; Peresani *et al.* 2011a, 2011b) or a foraging radius that included this environment. The animal species recovered from each level indicates the presence of diverse biomes around the site, which may have played a role in land-use strategies and settlement dynamics in the Monti Lessini as these would have provided access to a range of subsistence resources..

Similar faunal exploitations patterns are seen in the late Middle Palaeolithic (MOIS-3) levels of Riparo Tagliente (250m asl) in the Monti Lessini, a rockshelter site approximately 15km southeast of Grotta di Fumane. Around 20,000 large animal remains were analysed from across the Mousterian levels (54-31) of Riparo Tagliente. Due to the high degree of fragmentation of these remains, only 15% could be taxonomically identified in the lower Mousterian levels, a figure that decreases to 4% in the upper Mousterian levels (Alhaique *et al.* 2004; Thun

Hohenstein and Peretto 2005; Thun Hohenstein 2006). The majority of the bones were broken by human action (hence the difficulty in species assignment), probably for marrow extraction. As in other sites in the region (e.g. Grotta di Fumane, Grotta Maggiore di San Bernardino, Riparo Mezzena), the most frequently consumed animals were ungulates of adult and young adult age, predominantly deer, as well as ibex and chamois (e.g. Alhaique *et al.* 2004; Thun-Hohenstein 2006; Peresani 2011), which indicates a wooded environments around the site with the presence of some grasslands and Alpine conditions (Fiore *et al.* 2004).

While the severe bone breakage rendered the determination of the butchery processes at Riparo Tagliente difficult, good preservation of bone surfaces enabled the determination of various subsistence behaviours. The representation of anatomical parts indicates selective transport. As seen at Grotta di Fumane (Fiore *et al.* 2004), mid-sized herbivores such as roe deer were transported to, and processed complete, at the site (Aimar *et al.* 1997; Thun Hohenstein 2006). There is unique evidence at Riparo Tagliente, however, for the disarticulation and processing of larger ungulates, which were killed off-site, and then elements (typically limbs) were selectively transported back to the site (Thun Hohenstein 2006). Additionally, the presence of foetal or new-born remains within the assemblage indicates a spring season frequentation (May- June) of the site (Aimar *et al.* 1997; Thun Hohenstein and Peretto 2005; Thun Hohenstein 2006).

In addition to the herbivore species at Riparo Tagliente, the recovery of numerous marmot remains bearing marks attributed to skinning action may indicate that this species was targeted and processed for its pelts (Thun Hohenstein 2006), a phenomenon not often observed in the Middle Palaeolithic, where most human action on faunal remains is attributed to subsistence activities. Marmot remains have additionally been recovered in the Monti Lessini at Riparo Mezzena and Grotta di Fumane (Sala 1990), but these do not show signs of processing. In the Monti Berici, marmot remains have been recovered from Grotta del Broion and Grotta Maggiore di San Bernardino (Sala 1990; Fiore *et al.* 2004), and again there is no evidence of their processing. There are, however, as mentioned above, anthropic marks on beaver remains at Grotta Maggiore di San Bernardino, and morphological analyses indicate the possible targeting of these species for their pelts (Peresani 2009). While beaver has been observed elsewhere in the region (e.g. Grotta di Fumane) (Cassoli and Tagliacozzo 1994b), evidence for human processing has not been documented.

Little information is available for the late Mousterian MOIS-3 cave site Grotta della Ghiacciaia (250m asl), located just a few kilometres south of Grotta di Fumane in the Monti Lessini. The site, now located in a functioning quarry, is not currently under study. A small portion of the site was explored during an investigatory excavation in 1979-1980 (Sala 1990; Bertola *et al.* 1999), which revealed around 3.5m of archaeological sediments that have been divided into three stratigraphic units (Bertola *et al.* 1999). Each unit contained a low density of carnivore remains, and ungulate remains attributed to human action, with the exception of sterile basal Unit I. Unit II contained few ibex, roe deer, and bovine ungulate remains, as well carnivores including bear, wolf, and fox. These remains, in addition to sediment, pollen, and micromammal data, indicate a cold forested or open brush environment around the site. The upper Unit III contained predominantly ibex, in addition to bear, wolf, and fox, indicating climate degradation to a cold, steppic environment, which is in agreement with the loessic soil matrix (Bertola *et al.* 1999). Despite the presence of carnivores, the observed marks on the ungulate remains are attributed to complete exploitation solely by Neanderthals. Striations related to butchery and fragmentations related to bone breakage for marrow exploitation are observed only on the ungulate species (Bertola *et al.* 1999; Alhaique *et al.* 2004; Fiore *et al.* 2004).

The faunal remains at Grotta del Broion (135m asl) provide a different image of site activity, in which the low density of the archaeological record, as well as the absence of hearths or other indicators of longer occupations, indicate the short-term use of the site for activities that did not involve butchery or food consumption (Peresani 1995-96, 2001b, 2011b). The faunal record of Grotta del Broion, and in particular Unit ES2, also demonstrates the intensive use of the site by carnivores (discussed in greater detail in the following section). Whilst the bones of herbivore species have been recovered in the archaeological levels, these lack anthropic cut marks; rather, gnaw marks indicate a carnivore accumulation of predominantly red deer with limited chamois. More succinctly: there is no evidence for food provisioning by Neanderthals at Grotta del Broion (Peresani 2011), a situation which is unique in the study region, but which may be attributed to the use of the site as a carnivore den by bears and wolves (Sala 1980), in addition to the local dearth of lithic raw materials in the landscape (Peresani 1995-96, 2011b; Peresani and Porraz 2004). A similar scenario is observed at the high altitude site of Caverna Generosa**,** in the Lugano Alps on the western Italy/Switzerland border, where local raw lithic materials are also lacking, and the rich palaeontological assemblage recovered indicates the primary use of the cave by bears, with only a sporadic (six Mousterian lithics) Neanderthal presence (Bona *et al.* 2007).

Like Grotta del Broion and Caverna Generosa, the MOIS-3 site of Grotta del Rio Secco (580m asl), in the eastern Italian pre-Alps on the Pradis Plateau is located in an area devoid of local raw lithic materials. Also like the other sites in the region, Grotta del Rio Secco was situated in proximity to multiple environments, including open grassland, montane woodlands, and semi-closed forests (Peresani and Gurioli 2008; Peresani *et al.* 2009; Talamo *et al.* 2014). Carnivore remains, especially bears, are dominant in the Mousterian faunal assemblages. However, where a scarce anthropic presence and lack of human action on faunal remains are observed at Grotta del Broion and Caverna Generosa, the MOIS-3 Mousterian Units 7 through 5 of Grotta del Rio Secco demonstrate the frequent exploitation of herbivores by Neanderthals through burnt bone and cutmarks from stone tools; this is relatively atypical of a site dominated by carnivore remains and lacking a local raw material source (Peresani and Gurioli 2008; Peresani *et al.* 2009; Talamo *et al.* 2014). As observed at Grotta di Fumane, the presence of a raptor talon with disarticulation striae at Grotta del Rio Secco indicates the exploitation of bird remains for non-subsistence purposes (Romandini *et al.* 2014). Bird remains have been recovered from other sites in the study region, such as Grotta Maggiore di San Bernardino, but these do not show evidence of human intervention, and are thought to have accumulated naturally or through carnivore action (Cassoli and Tagliacozzo 1994a).

Carnivores, site use, and seasonality

While determining the frequented ecological niches of late Pleistocene carnivores is arguably problematic (cf. Stewart 2005), the presence of carnivores is well documented in the cave sites of northeast Italy. The role of carnivores as occupational deterrents for hominins has been theoretically addressed for the northeast of Italy. Mussi (2001a) compiled a dataset of around 200 sites (some strictly archaeozoological) in northeast and west-central Italy to evaluate the ratio of carnivore to lithic presence (taken as a direct proxy for human presence) in the Middle Palaeolithic. Comparing these regions, she observed a few direct correlations between species and occupation. For the northeast, she observed that where bear and lion species are found, lithic artefacts are less often recovered. Where medium-sized carnivores are documented, such as hyena and leopard, lithic materials are more frequently observed. She concluded that Neanderthal may have actively avoided larger carnivore species, but that encounters with medium-sized species would not have deterred occupation, perhaps because the groups were sufficiently prepared to defend or repel these animals.

The potential avoidance of larger-sized carnivore species by Neanderthals may have impacted site-use and settlement systems, and therefore, it is necessary to consider those location variables that may have been more or less suited to large carnivore presence (and Neanderthal sites). Clearly, cave sites are more appealing, on the basis on biological imperatives, such as hibernation and denning, to bears and lions. However, as most of the late Middle Palaeolithic archaeological sites in northeast Italy are found in caves, and in each of the sites in this research the presence of large, medium, and small carnivores is documented, can an avoidance of particular species in deference to others be determined? Based on the faunal records from the sites in the study region, we can postulated that Neanderthals may have indeed been more capable of driving away medium-sized carnivores than large-sized in order to claim a cave for themselves, as occupational intensity is statistically correlated with certain carnivore species (see below). It is also possible that Neanderthals may have actively avoided or frequented locations and thus interactions during certain times of the year, such as the winter (bear hibernation) or spring (hyena denning), a situation that is often unclear due to limited seasonal indicators.

As previously mentioned, carnivore remains are pervasive in the archaeological record of Grotta del Broion, and include lion, wild cat, wolf, hyena, and, predominantly, cave and brown bears. *Ursus spelaeus* (cave bear) remains dominate the faunal assemblages, indicating that the location was mostly used as a denning location, with only intermittent occupation by Mousterian populations, based on the low density lithic assemblages (Sala 1980; Peresani 2001, 2011; Peresani and Porraz 2004). As no evidence of food provisioning has been recovered from the site, the carnivores were likely responsible for the accumulation of the herbivore faunal remains recovered from the site (Peresani 2011).

At Grotta di Fumane, the presence of carnivores across the Mousterian A levels is consistent, but at a lesser degree than Grotta del Broion. The most commonly recovered species include wolf, hyena, and fox. Cave and brown bears, although not frequent, are regularly observed. The contribution of carnivores to the faunal assemblages is seen through gnaw marks and digested bits of bone (Peresani *et al.* 2011a). The wolf, bear, and fox remains also show evidence of human action (Cassoli and Tagliacozzo 1994b; Peresani *et al.* 2011a). The anthropic marks observed on the bear bones at Grotta di Fumane are attributed exclusively to skinning (Cassoli and Tagliacozzo 1994b; Peresani *et al.* 2011a), which indicates access to fresh remains for furs. The frequency of cutmarks made by lithic implements on ungulate remains, particularly in levels A6 and A5-A5+A6, however, demonstrate anthropic accumulation of these species; preliminary investigations into dental eruption and wear, as well as bone fusion, indicate that Grotta di Fumane was likely occupied in the spring through fall seasons, and was likely uninhabited in the winter months (Peresani *et al.* 2011b). This data indicates that the consistent presence of both Neanderthal and carnivores of medium to large size likely represents alternating occupations, potentially seasonal, where cave bear utilised the uninhabited cave in winter months for hibernation.

Cave and brown bear, whose remains are frequent in Mousterian Units 5 to 7 of Grotta del Rio Secco, are responsible for bite marks on ungulate remains, indicating a partial carnivore role in the formation of the faunal assemblage. However, the intensive use of the cave by humans in the same units may indicate an alternating use of the space amongst carnivore species (Talamo *et al.* 2014). Neanderthal use of the site was perhaps opportunistic or seasonal. Seasonality data for Neanderthal occupation have not yet been recovered, but traces of skinning, butchering, and fracturing of both cave and brown bear remains has been observed, which indicates the targeting of these species during hibernation (Romandini *et al.* 2013). However, cave bears often died during hibernation (Kurten 1968), so the potentially post-mortem exploitation of this species may have been opportunistic rather than strategic. Other recovered carnivores at Grotta del Rio Secco include wolves and foxes; these are recovered at low frequencies, and were likely not deterrents for occupation of the cave, based on their scarce presence and small-to-medium size (based on Mussi 2001a).

A low carnivore presence is recorded in the upper Mousterian levels of Riparo Tagliente, including wolves, bears, and fox: their role in the accumulation of the faunal assemblages appears to be quite limited, represented by scarce traces of gnaw and bite marks, which are slightly more frequent in the lower Mousterian levels 44-52 (Aimar *et al.* 2000; Alhaique *et al.* 2004; Thun Hohenstein and Peretto 2005). Microscopic analyses of the recovered herbivore remains (many with cutmarks and burning) indicate that these were accumulated and processed primarily through human action (Alhaique *et al.* 2004; Thun Hohenstein 2006). The recovered carnivore remains themselves do not bear traces of anthropic activity, which may indicate their use of the rockshelter following human occupation, possibly for hibernation. As previously discussed, the seasonality data of hunted fauna from Riparo Tagliente (pre- and neonatal remains as well as dental eruption in ungulates) indicates a spring/summer occupation (March through June) (Thun Hohenstein and Peretto 2005), which would coincide with an availability of the cave following a winter hibernation by bears; the presence of carnivore and archaeological remains in the Mousterian levels supports the alternating use of the site by Neanderthals and carnivores (Thun Hohenstein 2006), although this could represent yearly or many years rather than seasonal alternation.

At Grotta Maggiore di San Bernardino, carnivores are consistently present (Cassoli and Tagliacozzo 1994a; Peresani 2001), although in fluctuating frequencies, which appears to correspond with the intensity of human frequentation. For instance, bear remains, particularly cave bear, represent a significant portion of the faunal assemblages from Units IV (~31%) and V (45%), but indicators of Neanderthal presence are sporadic. These patterns are in keeping with Mussi's (2001a) observation of large carnivore avoidance by Neanderthals, if one assumes that bears had already staked claim. The percentage of bear remains is greatly reduced in the more anthropogenic Units II (~20%) and VI (~7%), and evidence of carnivore interactions with the faunal remains, including pits, punctures, and gnaw marks, are weakly signalled (Cassoli and Tagliacozzo 1994a). This evidence may indicate alternating use of the cave between carnivores and humans, although seasonality data from the Neanderthal occupations of the site are lacking to support this hypothesis.

Bone as tools

As well as a subsistence resource; fauna served as a raw material for the manufacture of tools. Retouchers made from predominantly ungulate long bones (although carnivore, particularly bear, bones were used as well) have been recovered from numerous late Middle Palaeolithic sites of the study region. At Grotta di Fumane, herbivore hind limb bones, particularly femurs, show conchoidal fractures and punctiform marks at the distal ends indicating their use as retouchers. Within level A6, from which 75% of Grotta di Fumane's bone tool industry was recovered, two retouchers were made from antler (Jéquier *et al.* 2012; Malerba and Giacobini 1998b); these are the only documented antler tools in the study region. The implements at Grotta di Fumane show an agreement between the consumed and hunted fauna and the bones used to make these tools, as the most commonly-utilised and hunted species were cervids (predominantly red deer) (Jéquier *et al*. 2012; Jéquier *et al*. 2013).

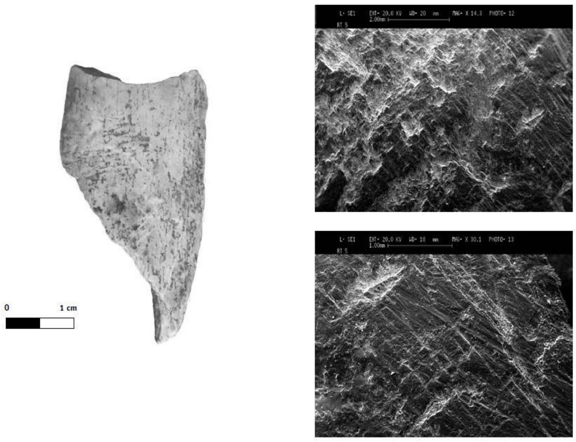

Figure 3.3: Bone retoucher recovered from late Mousterian level 42 of Riparo Tagliente. Image above right: microscopic view of cuts from tool use, showing striations from lithic tools; Image below right: striations from tool shaping (Thun Hohenstein 2006: 36).

At Grotta Maggiore di San Bernardino, herbivore long bones bear marks that indicate their functional use as retouchers. As at Grotta di Fumane, the retouchers were made from subsistence species represented in the zooarchaeological record, including red, roe, and giant deer (Malerba and Giacobini 1998b). Bone retouchers are also seen at Riparo Tagliente (Figure 3.3). Microscopic analyses of these bones show intensive scraping to shape the bone into a retoucher, overlaid with use-wear marks (Broglio *et al*. 2004; Thun Hohenstein 2006). Unfortunately, many of the species whose long bones were used to manufacture these bone tools are indeterminable, due to the high level of bone fragmentation observed at the site.

The use of bone as a raw material for tools is also interesting from an economic perspective: as LRM of good quality was widely available locally around Fumane, one could postulate that the bone tools served a technological and functional purpose, rather than economic strategy to maintain on-site tool needs.

3.3.2 Wood, charcoal, and anthracological analysis

The use of wood for fuel, tools, or other purposes is little documented in the study region, likely due to the biodegradable character of the resource, despite the very good preservation of the cave sites. Evidence for the use of wood as fuel has, however, been documented at numerous sites, where localised charcoal remains indicate that various arboreal species were burned as fuel in combustion structures. At Grotta di Fumane and Grotta Maggiore di San Bernardino, charcoal has been recovered from numerous archaeological levels (Peresani 1995-1996, 2001b, 2010; Peresani and Porraz 2004; Porraz and Peresani 2006). The late Mousterian level A6 of Grotta di Fumane yielded a very high number of combustion structures (n=21). Otherwise lacking in anthropogenic remains, Layer A5 contains a potentially stone-lined hearth (Figure 3.4). Anthracological analyses of the charcoals across the analysed layers A7 to A5 indicate a predominance of deciduous species, the most common being larch, with substantial representation of willow and ash (Peresani *et al.* 2011b; Basile *et al.* 2014). The anthracological analyses also demonstrate the reduction of deciduous species over time corresponding to the declining climate conditions of MOIS-3 (Basile *et al.* 2014)

Figure 3.4: Feature A5_SIII at Grotta di Fumane. Stones, potentially deliberately organised around a dense charcoal combustion structure with burnt and shattered faunal remains and lithic scatter (Peresani et al. 2011b: 137).

While the use of wood for tools such as hunting spears has been documented in the Palaeolithic (e.g. Schöningen, Abrić Romani), no evidence for wooden tool use has been observed in the study area. It is likely that such tools were utilised, however, based on the use-wear analysis of denticulates and other lithic tools at Fumane (Lemorini *et al.* 2003) and San Bernardino (Picin *et al.* 2011), which indicated their potential use in wood processing activities. Potential evidence of hafting of stone tools onto wooden shafts is seen in southern Italy, at the site of Oscurusciuto, where the Mousterian points bear impact fractures that seem to indicate their use as spear tips (Villa *et al.* 2009). Hafting activities have not been documented in northeast Italy, and there is currently no evidence of impact fractures on Mousterian, Levallois, or Discoidal pseudo-Levallois points.

3.4 Lithological Character of the Study Region

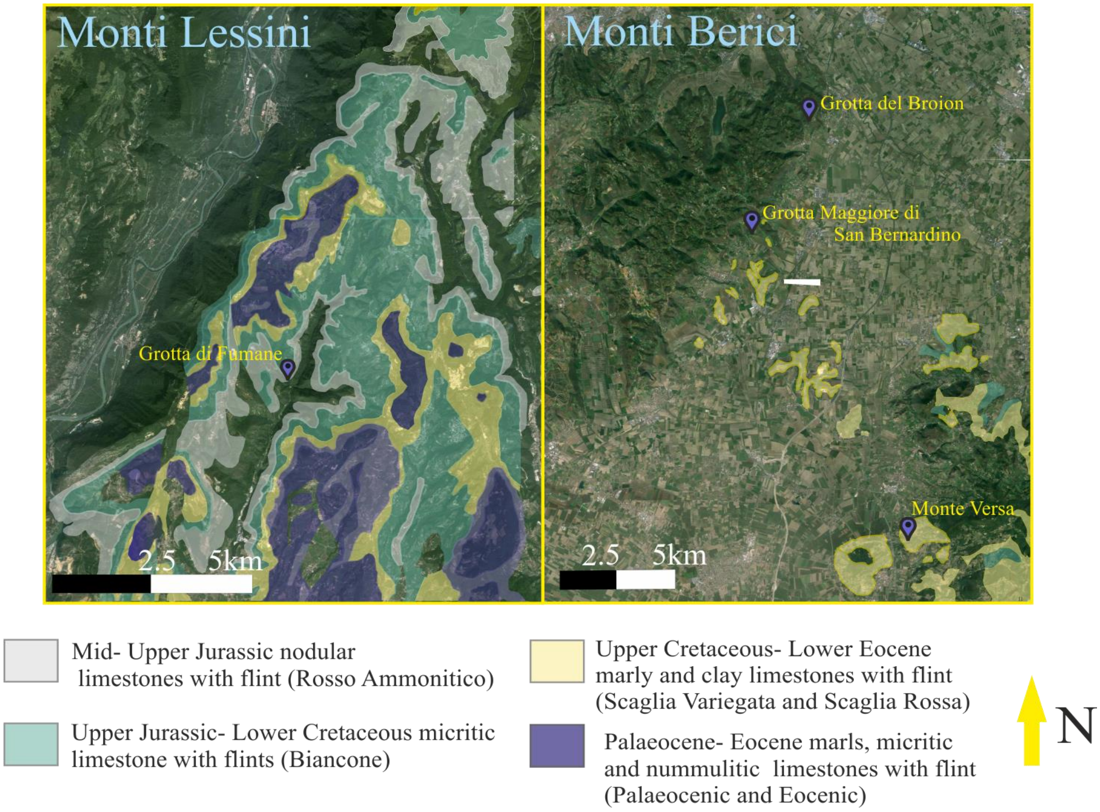

Figure 3.5: Geological formations with flint potential around Grotta di Fumane (left) and Grotta Maggiore di San Bernardino and Grotta del Broion (right). (Base map: Google Maps 2013; Geological data traced from Carta Litostratigrafica del Veneto (http://gisgeologia.regione.veneto.it/website/geol_250/viewer.htm))

As has been reiterated throughout this thesis, beyond technological studies at the site level, the distribution and character of lithic raw material are critical to interpreting Neanderthal ecology. The conclusion of this chapter will provide an overview of the current state of knowledge on the lithological character of the study region. Evidence of the exploitation of stone materials as tools and other implements is abundant in northeast Italy. The overwhelmingly predominant raw material utilised across each of the sites in this study is flint, which was available to past populations in various forms, quality, and accessibility. Flint is observed as blocks, nodules, and rounded cobbles, which are distributed unevenly across the landscape within Jurassic through Eocene geological strata (Figure 3.5) (Peresani 1995-1996; Bertola 1995, 2001; Longo *et al*. 2006; Arzarello *et al*. 2007; Giunti and Longo 2011).

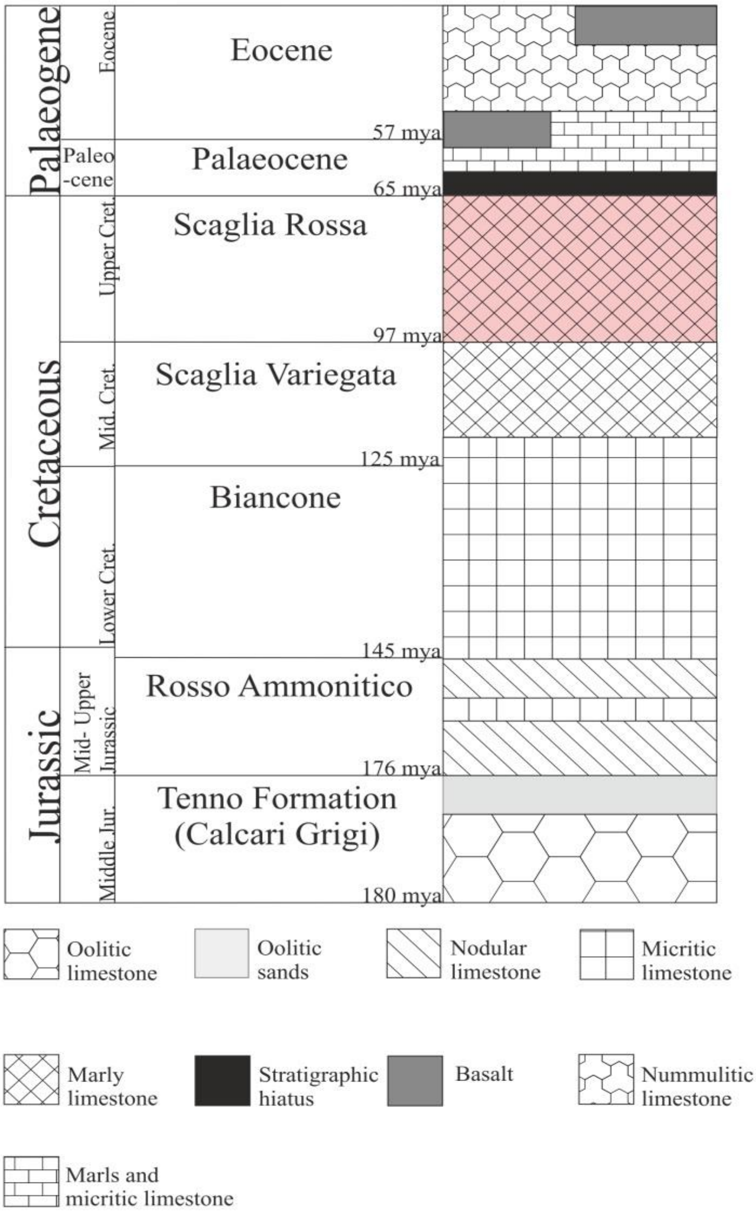

Figure 3.6: Geological strata of the Monti Lessini and Monti Berici containing the cryptocrystalline and microcrystalline flints discussed in text (after Pieri 1969; Cervato 1990; Longo *et al.* 2006)

The flint types and their distribution are fairly well known in the study region due to geological survey and complementary analyses of microfossils, geochemical composition, and microhardness (Bertola 1995-1996, 2001; Longo *et al*. 2006). Based on these analyses, the Jurassic through Tertiary (Palaeogene) strata of the study region have been determined to contain both cryptocrystalline and microcrystalline flints (Figure 3.6, 3.7; Appendix B) (Longo *et al*. 2006; Longo and Giunti 2010; Giunti and Longo 2011). The textural differentiation between these flints is related to the internal structure of the stone; cryptocrystalline flints have a finer texture, and demonstrate a more uniform fracturing reaction to percussive force than the microcrystalline varieties.

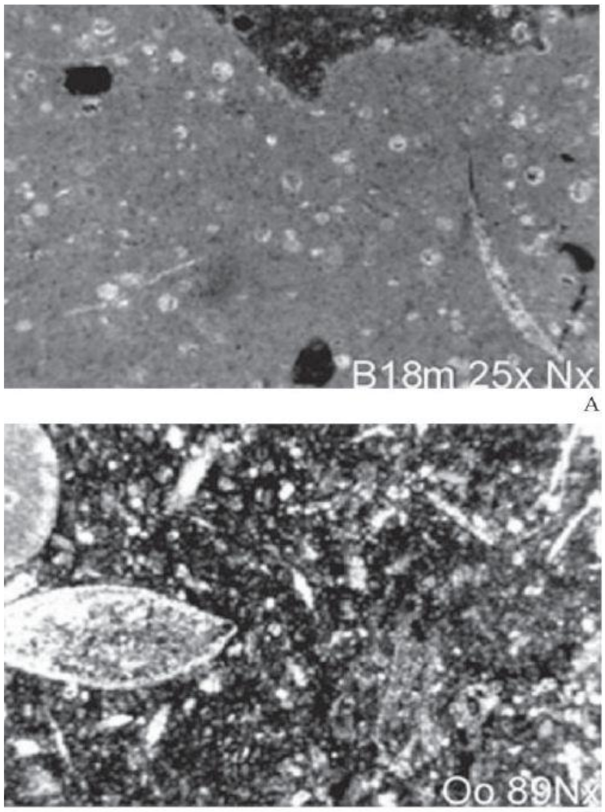

Figure 3.7: Microscopic images of the texture of cryptocrystalline (above) and microcrystalline (below) flints (Longo *et al.* 2006:214).

Cryptocrystalline flint, based on its higher quality and texture, is considered to be more suitable for knapping activities; the finer rheological characteristics may have influenced the technological operational chains of lithic production observed in the archaeological record. With a uniform response to percussion, these flints may be more suitable to the production of flakes and evolved retouch that require a greater degree of technical control. Experimental studies demonstrate that cryptocrystalline flints produce longer, thinner flakes: while the rheological properties of the microcrystalline flints are still considered to be good, these produce larger, thicker flakes (Longo and Giunti 2010). In the Valpantena River Valley of the Monti Lessini, cryptocrystalline materials were used for the production of laminar flakes in the Upper Palaeolithic assemblages, and comprised the majority of the late Mousterian lithic assemblages of Riparo Tagliente and Riparo Mezzena (Arzarello *et al.* 2008; Longo and Giunti 2010). Interestingly, the early Middle Palaeolithic Levallois and late Lower Palaeolithic Acheulean assemblages of the same region demonstrate a higher percentage of microcrystalline flint types. The authors postulate that the exploitation of the cryptocrystalline flints in the Upper Palaeolithic achieved technological aims that reflect a cognitive and behavioural adaptation to environmental pressures (Longo *et al*. 2006).

To examine these issues, it is critical to formulate an understanding of the distribution and quality of LRM specific to the study region, so as to observe the lithic archaeological record within a context of environmental variability. The following paragraphs will expand upon the previous section to describe the individual flint types of the study region and outline their geographic distribution.

3.4.1 Cryptocrystalline flints of the study region

As stated above, the cryptocrystalline flint types are characterised by their fine texture and uniform structure, which make them rheologically ideal for knapping techniques that require a higher level of control, and that produce longer, thinner flakes (Longo *et al*. 2006). While the cryptocrystalline flints respond better to retouching, they wear more quickly than microcrystalline, implying that Neanderthals would either have to resharpen existing implements, or replace old tools with new ones. Within the study region, the cryptocrystalline flints originate in micritic limestone and packstone formations, which are found abundantly in the western Venetian pre-Alps, and to a much lesser degree in the eastern Berici Hills. Scaglia Rossa, can also found intermittently in the Euganean Plain, as well as outcropping on Monte Versa in the Colli Euganei (Peresani 1995-96, 2001; Peresani and Porraz 2004; Porraz and Peresani 2006), where additional cryptocrystalline flint types have been identified, although in more limited quantities as compared to the Monti Lessini.

The finely-textured and homogenously-structured cryptocrystalline flints originate from limestone strata spanning the late Jurassic through to Cretaceous Eras, and include (from oldest to youngest) Rosso Ammonitico, Biancone (also referred to as Maiolica), Scaglia Variegata, and Scaglia Rossa, and Palaeocene varieties. Each is variously distributed in both primary and secondary positions in the Monti Lessini. In the sub-Alpine foothills, Scaglia Rossa is dominant, found only in distinct locations, and Scaglia Variegata, Biancone, and Rosso Ammonitico are sparsely distributed in the Colli Euganei (Peresani 2012; Porraz and Peresani 2006).

Biancone (Maiolica)

Gradually transitioning from the upper Jurassic strata, the early Cretaceous whitish-brown micritic limestone contains frequent nodules of high quality cryptocrystalline Biancone flint (Figure 3.8). The Biancone flints are generally reddish hued at the base of the formation, with colours ranging from red and pink (Bi-ros[1]) to reddish brown and yellow (gBi). Towards the top of the unit, the flint colours transition to grey and brownish nodules (Bi) (Bertola 2001). The Biancone flints, based on XRF, XRPD, and KNOOP microhardness tests are considered to

[1] An abbreviation for each flint type will be provided throughout the text, so as to simplify the discussion. Those used within this research are based on pre-established abbreviations already in publication (e.g. Peresani and Porraz 2004; Peresani 2012).

be the highest quality flint for knapping within the study region (Longo and Giunti 2010; Longo *et al.* 2006).

Figure 3.8: Nodular cryptocrystalline Biancone flint within a whitish brown micritic limestone matrix.

Biancone flints are the most geologically common in the western Venetian pre-Alps. This material is also the most utilised in the late Mousterian site records of the Monti Lessini, taking a dominant role in lithic production: for example, nearly 40% of the lithic materials from the final Mousterian occupational levels at the site of Riparo Mezzena, in the southwest of the Valpantena River Valley, are comprised of this flint type (Giunti and Longo 2011).

Scaglia Variegata

Gradually transitioning from the Bi, the Scaglia Variegata (SV) flints are found within early to middle Cretaceous whitish-grey marly and clayey limestone (Longo and Giunti 2010). The base of the unit contains flint nodules of grey-green colour (SV) (Bertola 2001). Like the Bi flints, the structure and excellent fracturing properties of this SV variety are conducive to knapping activities (Longo *et al*. 2006). At the top of the unit, the limestone becomes a whiter clayey marl, and nodules and slabs recovered here are a darker grey-black (nSV) with a lower rheological quality due to heavy fissuring (Longo and Giunti 2010; Peresani 2012).

In the Fumane Valley, outcrops of Scaglia Variegata are sporadically distributed within the Cretaceous strata, and their presence in the archaeological record is relatively marginal, likely sourced from stream and river beds (Bertola 2001; Porraz and Peresani 2006). The primary source of SV is not known to the east, in the Valpantena Valley (the location of Riparo Tagliente); however, nodules are abundant in streams and river beds (Arzarello *et al*. 2008). Primary and secondary sources of all varieties of SV flint are incredibly rare in the Monti Berici and Colli Euganei areas of the sub-Alpine foothills, and its archaeological presence is “négligeable” (Porraz and Peresani 2006: 2).

Scaglia Rossa

The Scaglia Rossa (SR) formation follows an abrupt change from the Scaglia Variegata to late Cretaceous red micritic and marly limestone. The cryptocrystalline SR flints have a distinctive matte appearance, and a fine to medium texture range (Longo *et al.* 2006). The internal structure of the stone is homogenous, although natural fractures are frequently observed. In the Monti Lessini, the predominant variety is a reddish-brown, but brownish-yellow and greenish varieties can also be observed (Bertola 1995-1996, 2001; Longo and Giunti 2010). Although the reddish brown colour of the SR is apparent in other cryptocrystalline flint types (Bi and SV), those occurrences are relatively infrequent. In this situation, examination of microfossils within the stone is necessary for confident identification of flint variety within the archaeological assemblages (Longo and Giunti 2010).

The upper Cretaceous outcrops containing SR plates and nodules are observed intermittently in the region in the Monti Lessini and Monti Berici, but nodules can be easily identified in secondary position in streambeds (Peresani 2012). After the Bi flints, SR is one of the most frequently exploited lithotype in the late Middle Palaeolithic record of the Monti Lessini. SR is the most frequently recovered lithic material type at the sites of Grotta Maggiore di San Bernardino and Grotta del Broion in the Monti Berici, where it makes up over 90% of the lithic assemblages (Porraz and Peresani 2004).

Palaeocene

The Palaeocenic (Peoc) flints are found in the lower Palaeogene Tertiary limestone strata that overlie the Upper Cretaceous limestone formation containing Scaglia Rossa flint. The Peoc flints are typically observed as nodules and plates of a dark grey-brown colour with a very fine cryptocrystalline texture. The Peoc flints possess excellent rheological characteristics, but despite their knapping potential, they are relatively rarely found within archaeological assemblages, and have thus not been much researched geologically. For instance, they are not mentioned in Bertola's (2001) or Longo *et al.*'s (2006) studies of the Monti Lessini flints. Further, despite its occasional presence in the archaeological record of Grotta di Fumane, its primary location(s) in the Fumane or Valpantena valleys has not been determined.

3.4.2 Microcrystalline flints of the study region

The microcrystalline flints have been demonstrated to have a coarser texture and more heterogeneous flaking properties than the cryptocrystalline varieties found in the western Venetian pre-Alps; however, their rheological characteristics are still quite good (Giunti and Longo 2011; Longo and Giunti 2010; Longo *et al*. 2006). As previously discussed, the use of this material may represent a technological choice by Palaeolithic knappers, to meet functional and/or economic needs (Longo *et al*. 2006).

Oolitic di San Vigilio

The Oolitic (Ool) flints of the San Vigilio formation are recovered from Jurassic limestone. The Ool flint within this formation is found as compact nodules around 20 centimetres in length with a microcrystalline texture lacking internal fractures. Its colour ranges from a whitish to rusty brown (Bertola 2001; Longo *et al.* 2006).

The San Viglio flint is recovered in the western Monti Lessini in primary and secondary positions at the base of the steep hillsides and within streambeds (Longo *et al*. 2006; Arzarello *et al*. 2007). Although the flint is locally abundant within the vicinity of sites in the Monti Lessini, it is inconsistently represented in the late Middle Palaeolithic record, and like the other microcrystalline flints, it plays a diminutive role to all cryptocrystalline types (Arzarello *et al.* 2007).

Rosso Ammonitico

The Rosso Ammonitico (RA) flint is primarily distributed in the Upper Jurassic marly limestone formations of the Venetian pre-Alps. Its presence is limitedly observed in the Colli Euganei sub-Alpine foothills (Peresani 1995-1996). Within the formation there are distinct units. The basal unit is pink to yellow micritic limestone with microfossils. Here, the microcrystalline RA flint, in the form of slabs and thin nodules, is present, although rare, and is considered good for knapping although inclusions and fractures are sometimes observed. The upper two units consist of red and grey limestone dense in radiolaria; flint nodules are red, rare, and are of poor quality for lithic production (Bertola 2001; Longo and Giunti 2010).

The RA flints are poorly represented within the lithic assemblages of the late Middle Palaeolithic, and often go unmentioned in the archaeological literature. For this reason, and in addition to its relative rarity compared to other microcrystalline varieties in the study region, Arzarello *et al.* (2008: 162) state that this flint type has “un faible intérêt archéologique” because of its low representation. However, as this LRM type is present, albeit in small quantities, in the lithic assemblages of the study region, consideration of this material as a viable knapping medium is warranted, and the economic, technological, and functional implications for its use will be considered.

Eocene

The base of the Eocene strata of the Tertiary formation yields Eocene (Eoc) flints from within marlstones and micritic limestone; these nodules are rare but finely textured, and whilst mostly light grey, the colours can range to olive, brown, and dark green (Bertola 2001; Peresani 2012).

Those of the light grey variety are seemingly similar to the Bi flint; however, the Eoc variety has a more fossiliferous and fractured cortex and a microcrystalline texture. The middle Eocene formation flints from nummulitic limestone are relatively scarce, and are of a coarse texture. These are fossiliferous, and colours are brown or grey (Bertola 2001; Arzarello *et al.* 2007).

The Eoc flints are infrequently observed in the late Middle Palaeolithic site record. For example, although they are found in the vicinity of Riparo Tagliente, where raw material exploitation is predominantly focussed on local flints found in secondary position in the Progno di Valpantena streambed immediately adjacent to the site, they are not observed within the lithic component of the Mousterian assemblage (Arzarello *et al*. 2007), indicating that these were actively selected against.

3.4.3 Linking lithic raw materials to the archaeological record

The flints of the study region are of varied quality and distribution, although most, such as the cryptocrystalline varieties, possess excellent knapping properties. As previously discussed regarding Bi in the Monti Lessini and SR in the Monti Berici, the introduced state of lithic raw materials at sites seems to be linked to the proximity and abundance of the resource. Comparisons of the Middle Palaeolithic lithic assemblages in the study area demonstrate some commonalities in terms of raw material choices and reduction strategies. Cryptocrystalline flint varieties are the most frequently recovered in the artefact records, and microcrystalline varieties are little represented. Further, although, as previously discussed, the predominant reduction strategy in the study area is the Levallois, with the notable exception of layer A8+A9 of Grotta di Fumane, there does not appear to be a difference between the LRM used in the manufacture of either the Levallois or Discoid, indicating a technological or functional rather than economic motivation in the use of one technique over the other (Peresani 2012).

The Levallois was typically manufactured from LRM blocks or nodules, primarily via recurrent unidirectional removals, followed later in the sequence by bidirectional, preferential, and centripetal action to further reduce the core (Figure 3.9) (Peresani 2001; Peresani and Porraz 2004): river and stream cobbles were also utilised, although to a lesser extent. The less frequent Discoid was accomplished through recurrent centripetal removals of the core face (Peresani 2008). Cores produced using both technologies in the study region are typically heavily reduced, and are often considered to be exhausted: for example, at Grotta Maggiore di San Bernardino, core dimensions measure 3x3x2cm (Peresani 1995-1996; Porraz and Peresani 2006).

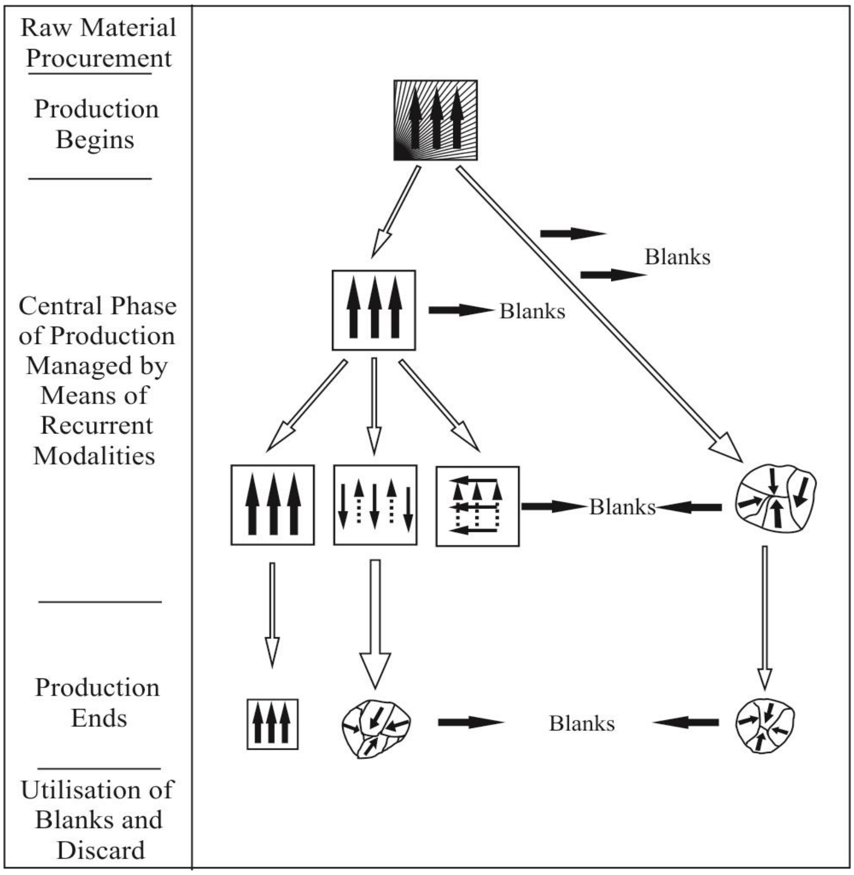

Figure 3.9: Schematic of typical Levallois reduction strategies observed in MOIS-3 Mousterian sites in the study region, showing initial unidirectional removals to produce blanks and an initial Levallois flake, followed by secondary unidirectional, bidirectional, or preferential removals, then centripetal reduction sequences (after Peresani 2001: 496).

Regarding the lithic reduction sequence, retouch, and artefact densities, the sites of the study region reveal distinct techno-economic signatures, indicating that lithic resource management correlates to LRM availability and character, as well as the energetic and time costs involved in its procurement: these ideas will be addressed later in this thesis.

The following section will provide an overview of the geographic distribution of LRM across the study region, and will briefly overview the techno-economic signatures of each study site in relation to these flints. Additional late Middle Palaeolithic sites will be discussed in a comparative role to outline a better understanding of the regional lithic character of the Veneto.

Monti Lessini (pre-Alps)

As discussed in reference to the LRM of the study region, the Monti Lessini contain the most abundant flint supply in the study region, with geological formations from the middle Jurassic through to the late Eocene. While Upper Pleistocene aeolian loess was widely dispersed in the pre-Alps, these deposits are generally thin and weathered (Cremaschi 1990). It is unlikely that sources of this material would be significantly buried. Therefore contemporary primary outcrops and secondary sources of raw lithic materials are largely comparable to the distributions encountered by Neanderthal populations.

Despite the abundance of the flint distribution in the Monti Lessini, the actual physical locations of raw lithic material outcrops and the distribution of secondary sources are patchily known. While lithological maps of northeast Italy are available, these identify only areas of flint *potential* within Jurassic, Cretaceous, and Tertiary strata. Limited geological survey in the Valpantena Valley, east of the Fumane Valley and the site of Grotta di Fumane, has identified some primary and secondary lithic outcrops (Longo *et al.* 2006; Longo and Giunti 2010); however, this work is not exhaustive, and the mapping of precise flint locations to the west around the site of Grotta di Fumane, in the Fumane Valley is lacking. It is uncommon for precise locations to be determined, much less recorded, despite the fact that these data are critical to determining sources of raw material procurement in the Palaeolithic.

At the study site Grotta di Fumane, both crypto- and microcrystalline flint varieties are widely available in secondary position in streambeds within a half a kilometre of the site and also in primary position in limestone outcrops within 5km of the site (Bertola 2001; Peresani 2012). Levallois industries were manufactured from a variety of flint types, although a preference for cryptocrystalline flints (especially Bi) is consistently observed (Peresani *et al.* 2008; Peresani 2010, 2011, 2012).

The dense archaeological assemblage of MOIS-4/MOIS-3 Level A11 represents the beginning of the final Mousterian sequence at Grotta di Fumane. Its lithic signature indicates the full Levallois reduction sequence of cryptocrystalline flint varieties that were available locally; microcrystalline flint was utilised to a significantly lesser extent (Peresani 2009, 2012). Scrapers are the most commonly-recovered lithic tool, with significantly fewer Levallois points, denticulates, and notches.

Of significant interest to techno-economic studies is the abrupt replacement of the dominant Levallois industry by Discoidal techniques, introduced in sub-units of level A10 and dominant in MOIS-3 level A8+A9 (Peresani 1998, 2002, 2003). The Discoidal tool assemblages consist of pseudo-Levallois points, triangular flakes made into simple or transverse scrapers, points, and denticulates, as well as utilised flakes. Techno-economic analyses suggest the method was used to create thicker flakes for multi-functional (non-specialised) tools (Lemorini *et al.* 2003; Peresani 2002, 2003). Functional analyses of use-wear patterns on the edges of the Discoid tools show evidence for the cutting and scraping of soft to medium-hard materials, such as hide or wood, but also potentially for whittling and engraving activities. Techno-functional analyses indicate that tools were not specialised, but were used ad hoc to accomplish occasional activities/ different uses (Lemorini *et al.* 2003); these were as successfully accomplished with Discoidal as well as with Levallois technologies as seen at Grotta Maggiore di San Bernardino

(Picin *et al.* 2011). Despite that the Discoidal technique is unique in these layers, it occurred seemingly independent of ecological variables, and A8+A9 contains an archaeological record showing occupational intensity comparable to A11 and A5-A6, with the utilisation of the same lithic types (Peresani, 1998, 2002, 2003).

Following the sterile level A7, the A5-6 complex records intense occupations of the site in the final Mousterian and the return of predominantly Levallois reduction sequences. Level A6 yields the highest amount of lithic artefacts of the complex, in addition to numerous faunal remains and hearths, which together indicate the intensive occupation of the cave. As observed in both Levallois level A11 and Discoid A8+A9, the final Mousterian A5-A6 unit, cryptocrystalline flints were most frequently exploited, particularly Bi, making up a significant portion of the industry (Peresani 2009, 2012). While the lithic record of A5-A5+A6 is more ephemeral than A6, as in each of the Levallois levels, initial unidirectional and bidirectional Levallois reduction sequences were followed by centripetal removals to fully exploit the core and create blades and flakes (Peresani 2009; 2011; 2012).

Despite the consistent exploitation of high quality cryptocrystalline flints, the varying frequencies of lithic materials recovered across the late Mousterian A levels of Grotta di Fumane, in addition to the exclusive Discoidal reduction sequences in level A8+A9, indicate that the site was somewhat differentially occupied throughout MOIS-3, although each indicates residential use of the cave. Rather than differential access to LRM, which were widely available locally in both primary and secondary position, the variability seen in the archaeological levels is likely a product of changing settlement dynamics and mobility in response to fluctuating ecological conditions, such as climate and vegetation.

The nearby site of Riparo Tagliente in the Valpantena Valley of the Monte Lessini at the base of Monte Tregnago has a similar MOIS-3 archaeological record to Grotta del Fumane, containing lithic and faunal remains and hearths that attest to repeated occupations (Thun Hohenstein and Peretto 2005; Thun Hohenstein 2006; Arzarello *et al.* 2007). The nearest source is a range of lithic varieties in secondary position in the streambed directly in front of the site, which are utilised nearly exclusively, with preference for cryptocrystalline varieties. Their modern representation (types and quality) in the Progno streambed is reflected in the archaeological record, indicating that these frequencies are unchanged (Arzarello and Peretto 2005; Arzarello *et al.* 2007). The Biancone flints have the highest incidences in the artefact assemblages, with Scaglia Rossa, Scaglia Variegata, and Oolitic flints, which today are found in smaller sized cobbles, being less well-represented (Arzarello *et al.* 2007; Longo and Giunti 2010; Giunti and Longo 2011).

The MOIS-3 Mousterian levels of Tagliente are divided into two units: the lower unit 1b, containing levels 52-44, and the upper unit 1a, containing 43-31. Unit 1b contains larger artefacts indicating full reduction sequences using variety of modalities, including centripetal Levallois, opportunistic, and core-on-flake (Peretto 1990; Arzarello and Peretto 2003). In Unit 1a, Levallois reduction through uni- and bidirectional modalities is observed, followed by centripetal removals to further reduce the core, as was observed in the Levallois assemblages of Grotta di Fumane. An increase in laminar production is also seen (Arzarello and Peretto 2005). Unit 1a also sees an increase in the knapping of Bi nodules from primary position a few kilometres from the site (Arzarello *et al.* 2007), indicating an expanded procurement range. These levels also contain the highest presence of cortex (Peretto 1990); based on the proximity of nodules to the site, this cortex likely indicates that cores were not shaped before they were introduced to the site. A technological study of Level 42 shows a high frequency of cortical products (33%), and refitting analysis shows that the entire *chaîne opératoire* from decortication to discard was carried out on site (Flores 2008). The representation of tool types is fairly consistent across the layers, most represented by simple convex scrapers. Denticulates and notches are quite rare (Arzarello and Peretto 2005). There is no change in the types of raw materials exploited across the units, with Biancone being the most widely utilised regardless of reduction strategies or exploited sources (Arzarello and Peretto 2005; Arzarello *et al.* 2007; Flores 2008).

The site of Riparo Mezzena (250m asl) is located in the Monti Lessini pre-Alps, not far from Riparo Tagliente and Grotta di Fumane. The rich faunal and lithic records of the Mezzena rockshelter indicate its repeated occupation for lithic production and subsistence activities (Giunti *et al.* 2008; Giunti and Longo 2011; Longo *et al.* 2012). Three Middle Palaeolithic archaeological strata have been identified, although upper Layer I demonstrates some admixture of the late Middle Palaeolithic with modern remains, as Bronze Age artefacts have been recovered along with Mousterian implements and Neanderthal remains. MOIS-3 Layers II and III contain numerous lithic and faunal remains as well as successive hearths, attributable to the repeated use of the site for multiple activities (Giunti and Longo 2010; Longo *et al.* 2012).

Lithic raw materials recovered from the site were available 5-15km from the site in primary and secondary positions, demonstrating a local and semi-local exploitation of flints at Riparo Mezzena. Again, a preference for cryptocrystalline flint (93%) from both primary and secondary deposits, including Bi, SV, and SR (Giunti and Longo 2008; Longo *et al.* 2012) is observed. These materials were exploited as cores and flake-cores. The low ratio of cortical flakes manufactured into end products suggests a tendency for materials to be reduced off-site and introduced as blanks. The industry is dominated by Levallois reduction sequences, typically recurrent unidirectional, as well as centripetal. A laminar Levallois industry is observed in Unit II. Discoidal reduction is observed throughout the units, in a minor role. The microcrystalline flints (predominantly Eoc) appear to have been introduced late in the reduction sequence, as the ratio of Levallois flakes to cortical artefacts and cores is high. In both microand cryptocrystalline flints, simple scrapers are best represented, followed by transverse and *déjeté* scrapers and Mousterian points (Giunti and Longo 2008, 2011).

Monti Berici and Colli Euganei (sub-Alpine foothills)

In the Monti Berici, the identification of flint sources is reliant on geological and lithological maps. These indicate that flint potential exists within the upper Cretaceous geological strata of the Berici foothills. Unlike the Monti Lessini, however, flint resources are much more sporadically distributed, and are of lesser quality and variety. The eastern ridges of the Monti Berici, including the San Pancrazio formation, 2km south of Grotta Maggiore di San Bernardino, provide a limited source of SR flint, which is of medium quality and contains some natural fractures (Bertola 1995-1996; Peresani 1995-1996; Porraz and Peresani 2006). Exogenous Eoc and Ool flints were procured from distances greater than 50km in the Monti Lessini, and higher-quality SV and Bi flints provenance from either the Monti Lessini up to 30km away, or 20+km to the south in the Colli Euganei, where these materials can be found in primary or secondary position in the lower-to-middle Cretaceous limestone formations (Bertola 1995-1996; Peresani 1995-96). Cretaceous flint (Bi, SV, and SR) in the Colli Euganei, and particularly the eastern sector, is the result of tectonic activity between the Eocene and Oligocene eras. These forces caused uplift that exposed blocks, nodules, and plates of cryptocrystalline flints, and shaped the landscape of the Colli Euganei, Monti Berici, and the hills between them on the Berici Plain (Duches *et al.* 2009).

The dense lithic assemblage of the early Middle Palaeolithic Unit VI (MOIS-6) of Grotta Maggiore di San Bernardino in the Monti Berici is primarily composed of local cryptocrystalline LRM, showing full reduction sequences (Peresani 1995-1996). The exogenous flints are more limited, and introduced to the site in an already-reduced stage, and cores in both local and non-local flints were abandoned when exhausted. These observations may reflect the limited access to high-quality flint materials within the most oft-exploited local range, and differences in site function in terms of activity and production objectives (Peresani 1995-1996, 2001; Porraz and Peresani 2006).

Units V and IV, formed during a cooler environmental phase that became drier with spreading steppic conditions over time, likely MOIS-5 (Cassoli and Tagliacozzo 1994a), contain lower-density artefact scatters that indicate sporadic use of the cave site by Neanderthals (Peresani 1995-1996). Retouched tools are of a higher frequency than the archaeologically rich Units VI and II, and cortical flakes, indicating initial reduction sequences, are lacking. Exogenous flint varieties are more evenly represented in these units, versus 40% and 21% frequencies in Units VI and II, respectively (Peresani 2001).

Unit II (MOIS-3), the focal level of this research, contains a scraper-rich Levallois Mousterian industry characterised by the use of Cretaceous cryptocrystalline flints, mostly for the manufacture of Levallois products. Reduction strategies are in agreement with those observed in Unit VI as well as elsewhere in the Veneto region: unidirectional recurrent Levallois, followed by a centripetal modality of further reducing a core, is the dominant reduction strategy. Cores were abandoned when fully exhausted (Peresani 1995-1996, 2001; Porraz and Peresani 2006). Another reduction strategy includes the use of large cortical flakes or blanks as cores, using a recurrent centripetal modality to produce flakes. Cortical flakes and Levallois flakes appear to have been preferred for tool blanks rather than by-products (Picin *et al.* 2011).

The most frequently provisioned and exploited LRM in Unit II is the abundant mid- to good quality local and semi-local SR flint. Higher quality exotic SR from the Euganean Hills is also observed, as are cryptocrystalline flints from the west-central Monti Lessini, 20-50+km distant (Peresani 1995-1996, 2001). Complete reduction sequences are observed on local blocks or nodules, but the exotic materials were reduced at some point before they were introduced to site as Levallois blanks or partially-exploited cores: the exotic flints also show more evidence for retouch (Peresani 1995-1996), indicating either the costs of their transport of differing technological aims.

Based on varying artefact densities and activities, including lithic production, animal butchery, and consumption across the Mousterian units of Grotta Maggiore di San Bernardino, site use appears to have differed over time. Occupational changes may reflect fluctuations in local environmental conditions, and reactive changes in settlement patterning. The short-term use of the site in Units V through III may be related to the cold and steppic conditions around the site as signalled in the pollen and microfaunal record. Evidence for on-site activities is reduced and lithic materials were introduced pre-formed or as blanks, with relatively higher proportions of exogenous materials. Additionally, carnivore presence is higher in these units than those showing more intensive site use (II and VI) (Cassoli and Tagliacozzo 1994a). The archaeological record of Units V through III seem to suggest the use of the site by provisioned individuals, possibly as a base camp within a residential scheme. The higher level of mobility demonstrated through the rate of exotic flints may perhaps be related to subsistence strategies within extended foraging ranges, in response to climatic influence on ecological contexts.

Units VI and Unit II indicate more intensive site use, and the higher percentage of local materials showing full reduction strategies may indicate a more residential use of the site. Decreased mobility was likely facilitated by the increased availability of vital subsistence resources due to climate amelioration, as temperate woodland environments are attested by sedimentological, faunal, and climate simulation data (Cassoli and Tagliacozzo 1994a; Peresani 1995-1996; Peresani and Porraz 1994; Porraz and Peresani 2006; Pini *et al.* 2010)

The Mousterian record of Grotta del Broion, ~5km as-the-crow-flies east of Grotta Maggiore di San Bernardino, spans the early to the late Middle Palaeolithic, and contains a total of only 511 lithics over more than 5m of sediments (Leonardi and Broglio1966; Porraz and Peresani 2006). The archaeological levels record short to very short occupations with limited activity size. Lithic raw materials are locally absent, and exotic lithic materials, introduced mostly as Levallois flakes and blanks and retouched implements, originated in the central Berici Plain, the Colli Euganei, and the Monti Lessini at distances ranging from 6 to 50km (Peresani 2001, 2009; Peresani and Porraz 2004; Porraz and Peresani 2006). Levallois (predominantly unidirectional with some bidirectional) reduction sequences are noted for each of these sources, but those from the exotic range show more evidence for retouch and re-working (70%) than the SR from the semi-local sources on the Berici Plain (45%) (Peresani and Porraz 2004).

The lithic assemblages of the MOIS-3 unit ES2 consist primarily of end-products and tools with a low representation of blanks and cores (Leonardi and Broglio 1966; Peresani and Porraz 2004). Reduction sequences are not complete, and the limited cores in the assemblage were introduced to site partially reduced (Peresani 2001). The lithic assemblages Grotta del Broion appear to indicate site use by individuals provisioned with personal gear and mobile toolkits. Limited flaking debris is documented, indicating that site activity was not focussed on lithic manufacture; rather, the maintenance of already existing tools was carried out, which is supported by the large percent of small flakes (<20mm) recovered (Peresani and Porraz 2004). Therefore, it seems that retouching activities for the management and preservation of the materials available occurred *in situ*. Overall, it seems that the low lithic density and absence of evidence for subsistence activities at Grotta del Broion can be interpreted as the product of repeated, short-term occupations, perhaps in response to the lack of a local LRM source and/or the ephemeral role of the site within a wider system of residential mobility (Peresani and Porraz 2004; Porraz and Peresani 2006).

Comparative northern Italian Mousterian sites outside the study area

The following MOIS-3-dated cave and open air sites in northern Italy provide comparative data for raw material economy studies in the study region.

The cave site of Caverna Generosa is situated at 1450m asl, on the Italian side of Monte Generosa in the western pre-Alps. Predominantly a cave bear den, containing over 30,000 ursine skeletal remains, the site also contains a sparse record of Mousterian occupation dated to MOIS-3. The low density of artefacts (one artefact per $27m^3$ of sediments) from across multiple levels of the site (n=6) indicates the repeated, but brief, use of the cave by Neanderthals (Bona *et al.* 2007). The lithic industry (introduced cortical blanks or semi-finished products) was made on radiolarite, a chert-like sedimentary stone, which can be found in the form of blocks in the Upper Jurassic Morbio limestone formations distributed around the

Monte Generoso, with the nearest source outcrops 3.5km and 9km to the south. Its poor knapping qualities are less than ideal for lithic manufacture. However, while higher quality flint blocks in Moltrasio limestone could be sourced in the walls of the cave itself, these appear to have either been ignored or overlooked, as there is no record of their exploitation at the site (Bona *et al.* 2007); however, it is possible this source was extracted and transported elsewhere, although there is no evidence to support that any testing or shaping occurred in the cave.

The high altitude of the site, the dominant carnivore presence, and the limited archaeological record each likely factored into the short-term use of Caverna Generosa by Neanderthals. Further, because of the repeated use of the cave by bears, and factoring in their extensive hibernation period, the potential time frame for occupation by humans of the site was limited, from the end of the spring to the beginning of autumn. Overall, Caverna Generosa seems to have served as temporary location where lithic manufacture was carried out elsewhere within a wider economic landscape (Bona *et al.* 2007).

Grotta del Rio Secco on the Pradis Plateau to the east of the study region contains evidence of repeated occupation of the site, including subsistence and lithic production activities. The lithic industry is represented by nearly complete *chaînes opératoires*, from the introduction of lightly-shaped cores to the manufacture and discard of retouched implements (Peresani *et al.* 2009; Talamo *et al.* 2014). Like the MOIS-3 sites of the study region, the lithic industry was mainly Levallois-focussed, characterised by recurrent unidirectional followed by centripetal removals to further produce blanks and flakes. The Discoidal technology is also observed to a lesser degree than the Levallois, and is represented by pseudo-Levallois points, *débordant* flakes, and a retouched flake (Talamo *et al.* 2014). The most represented lithic implements at Grotta del Rio Secco include scrapers, Levallois flakes, Levallois blades, and Discoidal flakes, which were manufactured from flint derived from secondary position in river deposits (Peresani *et al.* 2012). These secondary sources (cobbles and blocks from fluvial deposits) are situated a few kilometres from site (Peresani *et al.* 2009), while Jurassic through Eocenic geological flint-bearing strata are located at greater distances of 13 to 20km from the site.

Unlike previously discussed sites (Grotta del Broion and Caverna Generosa) located in flint-poor areas with a strong carnivore presence, Grotta del Rio Secco appears to have been repeatedly used for a range of maintenance activities, indicating its role as a home base. This may be due to the availability of secondary LRM sources, as well as the proximity of diverse resource environments. The unique character of the archaeological record, with evidence of faunal and possibly even carnivore exploitation, repeated occupations, and potentially the symbolic removal of a raptor talon (Romandini *et al.* 2014), indicates that the Pradis Plateau was likely attractive because of its proximity diverse geographic environments, such as the Venetian pre-Alps and the Friulian Plain (Peresani 2011).

Monte Avena (1450m asl) is an open air site located at an LRM source in the high altitudes of the Venetian Dolomites, a flint-rich area to the east of the Monti Lessini. Based on its location and the size and character of the lithic artefacts recovered, it may have served as a quarry site where blanks and tools were manufactured for use within a wider economic landscape (Lanzinger and Cremaschi 1988; Peresani 2000-2001). Unlike most Middle Palaeolithic open air sites of northern Italy, artefacts are preserved in intact palaeosols rather than as a surface scatter. Although several Mousterian implements have been recovered, investigations have primarily focused on the Aurignacian levels, which have yielded numerous lithic artefacts, including *Dufour* bladelets (Lanzinger 1984, 1990; Lanzinger and Cremaschi 1988). In the layers referable to MOIS-4 or MOIS-3 (based on stylistic dating), Levallois cores and flakes were recovered, as well as lightly-retouched tools derived from shaping Levallois or cortical blanks. No evidence of food provisioning or other activities has been noted.

The open air site of Monte Versa (135m asl) along the north-western slopes of the Colli Euganei and approximately 20km south of Grotta Maggiore di San Bernardino across the Berici Plain, contained more than 1000 Mousterian lithic artefacts, which were recovered from a reddish palaeosol. Although the site is attributed to MOIS-5e, based on the palaeosols and the anthropic frequentation of the location (Peresani 2000-2001; Peresani 2013), and are thus significantly older than the MOIS-3 levels under study, the signature of production activities at the site is relevant to the issue of Mousterian raw material management and mobility of northern Italy (Peresani 2000-2001, 2009).

The recovered lithic artefacts from Monte Versa are overwhelmingly made from the Scaglia Rossa flint outcropping in situ. Few products were introduced to Monte Versa from semi-local sources, which were likely from the Scaglia Rossa outcrops in the Berici Plain. The products manufactured in the Monte Versa flints indicate mostly the initial phases of lithic production, including cores and tested blocks: of the 1200 lithic artefacts manufactured from Scaglia Rossa, the in situ LRM type, 200 are cores (Peresani 2001). Cores were frequently abandoned due to imperfections in the stone. The on-site LRM source, truncated *chaîne opératoire* at the early phases of production, the relative scarcity of retouched implements, and a high rate of (large) cores and tested blocks signals Monte Versa's role as a quarrying and production location (Peresani 2000-2001). The flint was exploited to make predominantly elongated Levallois blanks, following a unidirectional recurrent technique, as is seen in MOIS-3 assemblages within the study region.

3.5 Chapter 3 Summary

Chapter 3 has provided a synopsis of the history of Palaeolithic research in the study region and an overview of the current state of archaeological research and the Mousterian character of the study region. In briefly detailing each site's contents, particular attention was paid to the lithic record, including the character and distribution of the exploited lithotypes. Regarding the lithic assemblages, Levallois was the dominant industry at all of the sites, and tended to adhere to a core reduction sequence of unidirectional removals, following later by centripetal removals for further blank removals. Discoid was always in a subordinate role when present, with the exception of level A8+A9 of Grotta di Fumane. A secondary *chaîne opératoire* of using flakes as cores was also frequently observed.

A preference for cryptocrystalline flint types was observed at each of the sites, and the distribution of LRM can be linked to the observed *chaîne opératoire* in site lithic assemblages: truncated reduction sequences representing the initial phases of reduction is correlated to the proximity of an LRM source (lithic extraction and testing), full reduction sequences are observed where local LRM are abundant, or an on-site LRM source has been provisioned, and truncated reduction sequences representing the later production stages of *chaîne opératoire* are observed where local, quality lithic resources are absent. These preliminary observations are in agreement with previous Neanderthal raw material economy studies (e.g. Geneste 1985, 1989; Turq 1992; Féblot-Augustins 1993, 1997a, 1997b).

Continuing on, Chapter 4 will provide an overview of the environmental character of northeast Italy, which will provide data on the off-site palaeolandscape that may have further impacted Neanderthal raw material economy.

Chapter 4: *The Palaeolithic Landscape of Northeast Italy*

4.1 Introduction

Stretching from Lago di Garda in the west to the Adriatic coast and bordered in the north and the southwest by the Alps and the Apennine mountain ranges, northeast Italy is a region of diverse landscapes and resources. This diversity, together with multiple palaeoenvironmental indicators and a rich archaeological record attributed to MOIS-3, create an ideal region for Neanderthal landscape and raw material economy studies. This chapter will describe in greater detail the physical and climatic environments of those landscapes that were exploited by Neanderthal populations, and which impacted the lithic assemblage variability that is seen between the sites of this region. The following section will provide an overview of each sub-region found within the confines of the study region, including the geological, topographical, and palaeoenvironmental variables that would have impacted Palaeolithic life. The Physical Palaeolandscape of Northeast Italy during MOIS-3

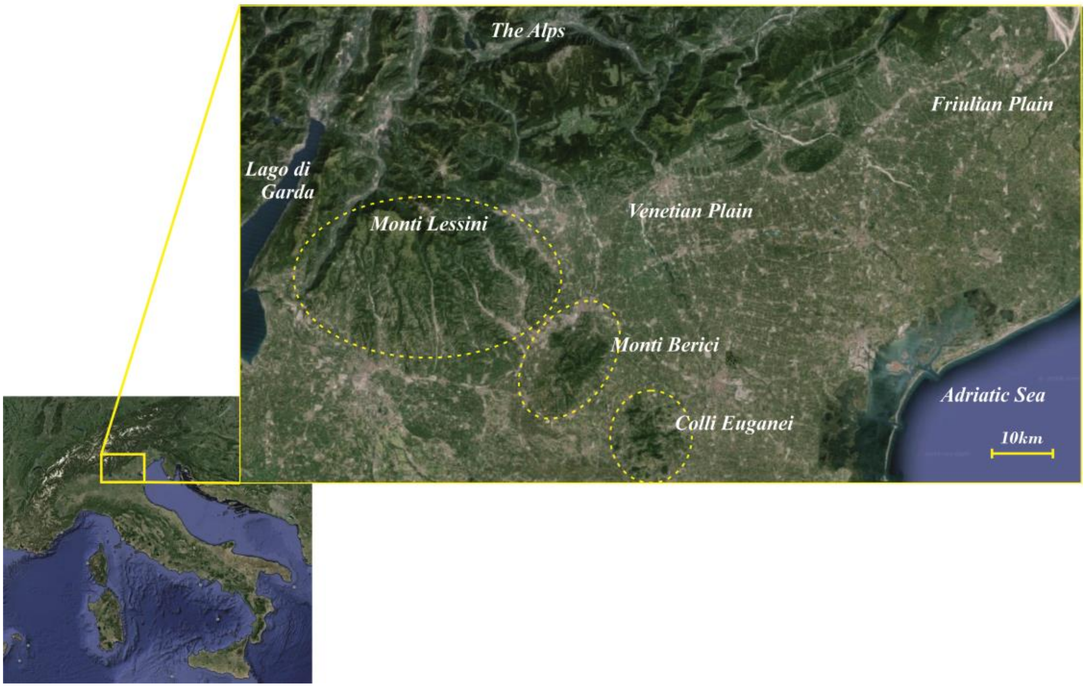

Figure 4.1: Satellite image of northeast Italy, showing major geographic sub-regions discussed in Chapter 4 (Basemap: Google Earth 2014).

This research is focused on what is commonly referred to in academic literature as 'northeast Italy.' While this thesis has referred, and will continue to refer, to the study region as such, the bounds of the project area are more narrowly located within the modern Veneto region. More specifically, the study region includes the southern Alps, the Monti Lessini pre-Alps, ranging from the eastern extent of Lago di Garda to the Valpantena Valley, the Po Plain extending from the pre-Alps margin to the sub-Alpine foothills, and the Monti Berici and the Colli Euganei (Figure 4.1).

The modern landscape of northeast Italy is similar to that of the late Pleistocene, in that the same geographic features: the Alps, pre-Alps, Po Plain, and the sub-Alpine foothills, existed then as today. This facilitates archaeological landscape studies, as major topographic reconstructions are unnecessary. However, it is acknowledged that the palaeolandscape has been somewhat impacted by glacial action, alluvial action, sea-level rise, and sedimentation deposits over time.

This discussion of the study region's palaeolandscape will be broken down into geographic units. This is to provide a clear environmental picture of each sub-region so that an understanding of the conditions in which each archaeological site was formed can be envisioned.

4.1.1 The Alps

The high peaks of the Alps run east-west, dividing Italy and central Europe. These peaks range from 3,000 to over 4,000 m asl, and are currently still partially covered with glaciers (Mussi 2001b). The Alps are bound to the Monti Lessini pre-Alps via steep valleys and the Lessini Plateau. During MOIS-3, the southern extent of the Alps was not glaciated (Peresani 2001), although the presence of steppic faunal species at MOIS-3 sites in the Monti Lessini pre-Alps (mostly open woodland at the time (Pini *et al.* 2010; Peresani 2009; Fiore *et al.* 2004)) shows that conditions at higher elevations were harsher than at lower elevations.

Though they appear to lack in archaeological sites during MOIS-3, the proximity of the Alps to known sites and their incomplete glaciation in this time means that they may have served as a resource zone for the late Neanderthals. Indeed, Alpine species, such as cut-marked Alpine chough recovered in the archaeological record of Grotta di Fumane, indicate Neanderthal forays into the mountainous zone (Peresani *et al.* 2011a). However, the immensity of these mountains would have impacted Palaeolithic life by forming a physical boundary for population movement, particularly during cold events when ice caps would have been significantly larger (Peresani 2009). Further, glacial action would have influenced settlement systems, as ice expansion and contraction impacted faunal and floral habitats, and thus the exploitation range of populations around the mountainous regions (Peresani 2001).

4.1.2 The Monti Lessini pre-Alps

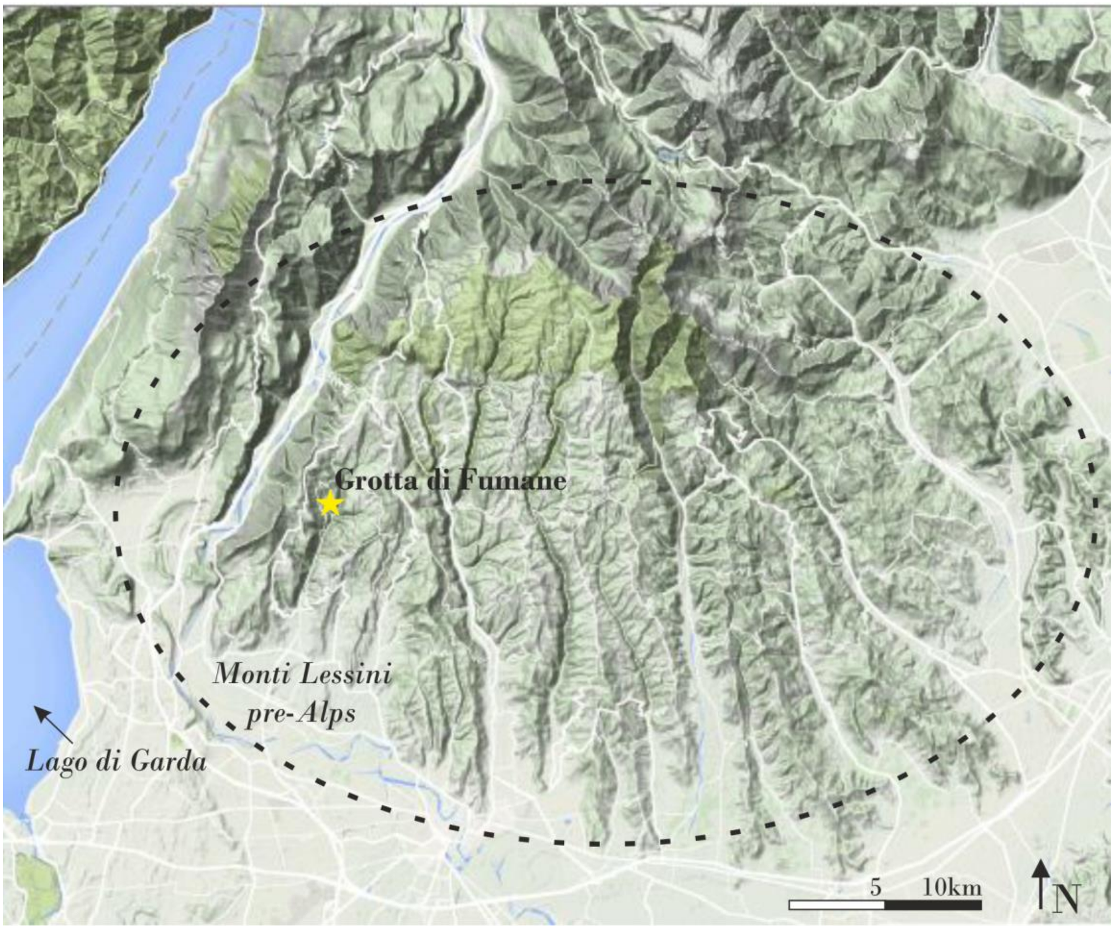

Figure 4.2: The Monti Lessini pre-Alps (Basemap: Google Maps 2014).

The Monti Lessini pre-Alps (Figure 4.2) are a discontinuous band of Alpine foothills and mountains that comprise the western basin of the Venetian pre-Alps. Stretching from east to west, this western basin is punctuated by large lakes and steep reliefs of glacial and tectonic origins that formed due to Palaeogene tectonic activity. During the Cenozoic era, marine transgression led to the formation of the pelagic sediments (Rasser *et al*. 2008) containing the flint-abundant strata of the region. In the Quaternary, continued tectonic uplift and subsidence led to intense sedimentation in the lower pre-Alps and Po Plain; however, these processes were mostly complete by the late Pleistocene (ibid.), when the area was inhabited by Neanderthal populations. During the late Pleistocene the Monti Lessini pre-Alps were not glaciated, although glacial action did lead to periglacial conditions, resulting in sedimentation in the form of aeolian deposits (Cremaschi *et al*. 1991; Castiglioni *et al*. 1990). Within caves, the thickness of loess deposits provides excellent preservation of archaeological materials (Peresani 2001, Cremaschi 1990). Aeolian sediments are also observed at the margins of the pre-Alps where they meet the Po Plain, and on karstic plateaus, such as the Lessini Plateau (Ferrara *et al*.

2004). However, the sedimentation is typically thin and weathered, and does not significantly hinder archaeological visibility (Cremaschi 1990).

4.1.3 The sub-Alpine foothills

The sub-Alpine foothills are comprised of two sets of hills: the Monti Berici and the Colli Euganei. Separated by approximately 20km by the Berici Plain, the hills are visible to each other under most weather conditions. Despite their proximity, however, each cluster was formed under different geological conditions.

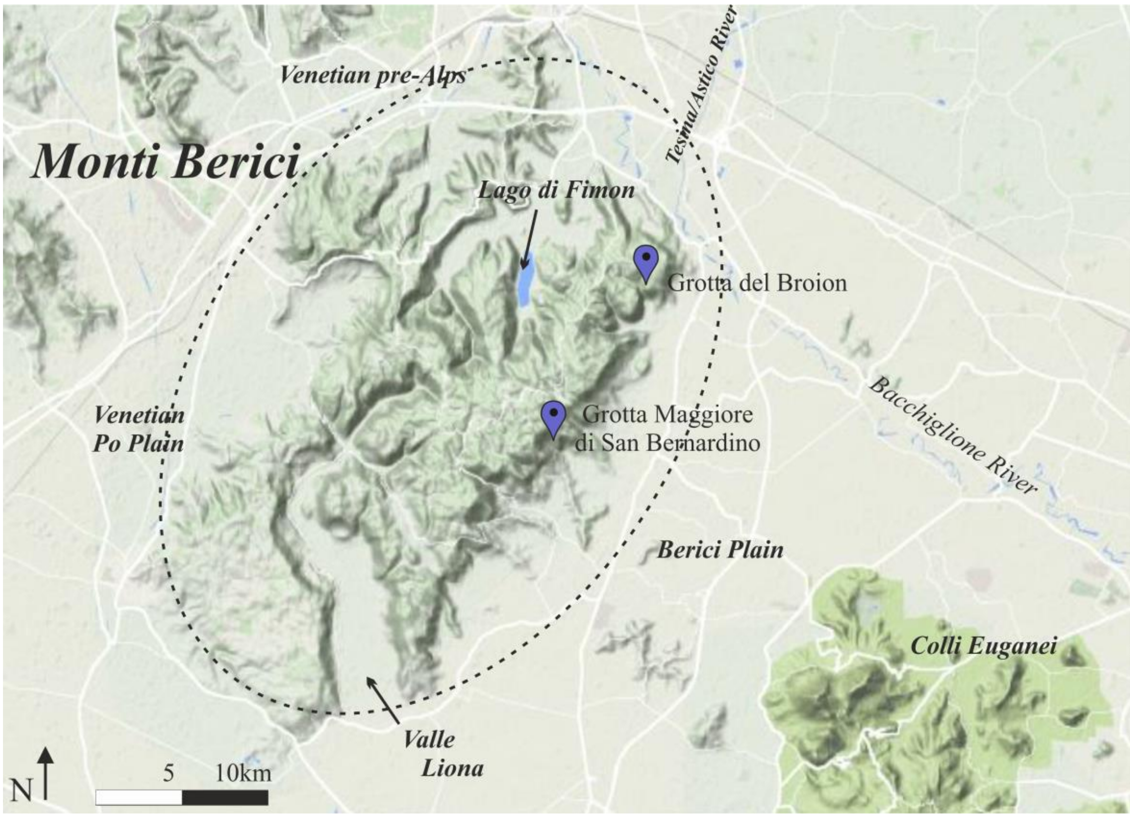

Figure 4.3: The Monti Berici, with associated geographic features and sites discussed in text (Basemap: Google Maps 2014)

The **Monti Berici** comprise a karst plateau formed by fluvial and tectonic activity. The original plateau was formed by tectonic uplift of Cretaceous limestone during the mid-Miocene era. Subsequent fluvial action by the ancient rivers Pozzola-Val Liona and Brendola incised large valleys such as the Valle Liona into the plateau (Figure 4.3). By the late Miocene, steep valleys were formed by tectonic and fluvial action around the plateau borders, their canyon-like slopes containing multiple caves and dolines. In the Pliocene, tectonic uplift raised the eastern foothills of the plateau, which today reach a maximum height of 444m asl (Sauro 2002).

The completion of the modern day appearance of the Monti Berici occurred in the Pleistocene, when the lower altitudes and gentle sloping of the western Berici plateau toward the plain were caused by limestone erosion (Sauro 2002). To the northeast, fluvial deposits from the Bacchiglione and Astico/Tesina rivers effectively dammed the eastern edge of the Monti Berici, enabling the Pleistocene formation of Lago di Fimon (Figure 4.6). This action also effectively created an inaccessible boundary at the eastern edge of the Monte Berici into the Po Plain and the Venetian pre-Alps (Pini *et al.* 2010). While the Monti Berici were not glaciated during the late Pleistocene, alpine glaciations did impact the landscape through periglacial conditions that led to sedimentation processes (Castiglioni *et al.* 1990). Quaternary loess deposits can be observed on the slopes of the Berici plateau and in the archaeological cave sites of the southern foothills (Cattani 1990; Sala 1990; Pini *et al.* 2010).

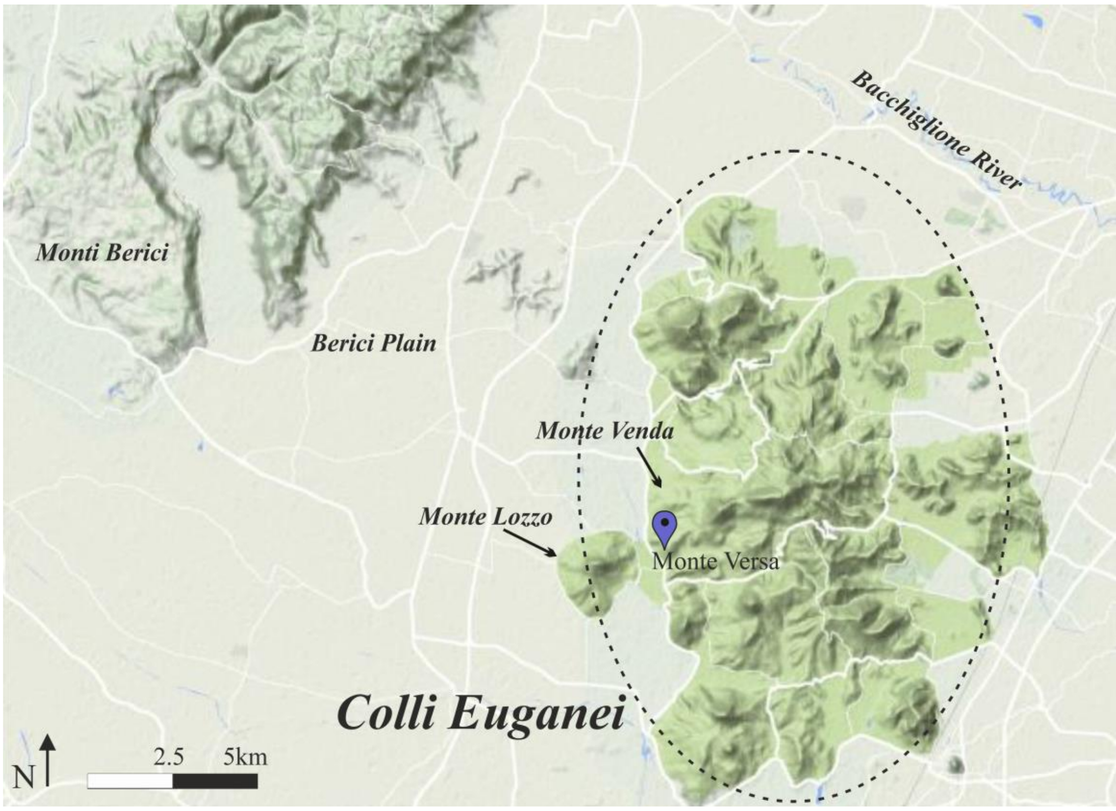

Figure 4.4: The Colli Euganei, with associated geographic features and sites discussed in text (Basemap: Google Maps 2014)

The **Colli Euganei** are a series of sub-Alpine foothills, located approximately 20km south of the Monti Berici, across the Berici Plain (Figure 4.4). Extending over hundreds of kilometres, the hills can be differentiated in terms of altitude and formational processes. The higher altitude peaks are cone-shaped and of volcanic origin, ranging from 400 to 601m asl at Monte Venda. The lower altitudinal hills are a more weathered limestone, creating a rolling landscape of peaks and valleys. The oldest geological unit of the hills dates to the late Jurassic, and is represented by the Rosso Ammonitico strata that are also observed in the Monte Lessini. This pelagic sedimentary unit has not, however, yielded significant knappable flints in the Colli Euganei.

As in the Monti Lessini, the overlying Cretaceous marly limestone units contain Biancone, Scaglia Variegata, and Scaglia Rossa flints. These units were exposed by tectonic activity during the Eocene, resulting in the additional deposition of basalts (Duches *et al.* 2008). Further volcanic activity in the upper Oligocene epoch further metamorphosed the landscape, and led also to the formation of other volcanic-origin silicate rocks such as rhyolite and latite. Limited Biancone and Scaglia Variegata, and more abundant Scaglia Rossa flint can be found unevenly distributed as lenses, nodules, and plates in Cretaceous strata (Peresani 1995-96; Peresani 2001; Duches *et al.* 2012). These flint sources have been recovered in open air Middle Palaeolithic sites in the Colli Euganei, such as at Monte Lozzo and Monte Versa, as well as across the Berici Plain in cave and open air sites (Peresani 2000-2001, 2013; Duches *et al.* 2008; Duches and Peresani 2009).

4.1.4 The Po Plain

To the south of the pre-Alps and the Monti Lessini, the Po Plain extends from the base of the pre-Alps to the Apennine Mountains, within which the Po River stretches some 652km into the Adriatic Sea, fed by pre-Alpine tributaries. Now very flat, the Po Plain was less so in the Middle Palaeolithic, before late Pleistocene deposits, a few metres thick, were deposited. While loess deposits are frequent, most commonly found along the southern pre-Alps/Po margin and the sub-Alpine foothills that emerge from the plain, these are typically thin and weathered (Cremaschi 1990).

The present-day plain was formed by multiple phases of sedimentation over what is now very deeply buried sections of the Alps and Apennine mountain ranges. These sediments formed at the base of the ancient Tethys Sea from compressive forces caused by the collision of African and Eurasian continents during the Mesozoic era (Ajassa *et al.* 1997).

At the north-western extent of the study region, Lago di Garda, formed by glacial action and extant during the Palaeolithic, borders the Po Plain and the Venetian Po Plain (Mussi 2001b). To the east, the Po Plain meets the Adriatic Sea. As sea levels varied during the late Pleistocene, this coastline ranged from approximately 40 to 120 meters below present-day levels, meaning that a large coastal zone would have been exposed (Bailey and Flemming 2008; Barron and Pollard 2002). The lowered MOIS-3 sea levels to the east of the study region during MOIS-3 largely ensured a more continental climate (Pini *et al.* 2010).

4.2 Climate and Vegetative Palaeolandscape of Northeast Italy During MOIS-3

MOIS-3 was a time of rapidly fluctuating climate, observed as stadial and interstadial events from a multitude of datasets. Pollen cores, palaeoclimate simulations, and site-level indicators of these past environmental conditions will each be discussed in greater detail in the following section to provide a better understanding of the climatic conditions experienced by Neanderthal populations during MOIS-3 in the study region.

4.2.1 Palaeoclimate reconstructions

Advances in palaeoclimate studies have led to more accurate means of reconstructing past environmental conditions. Climate and vegetation indicators from sediment cores and palaeoclimate simulations serve to provide complementary datasets to site-level indicators with which the past environments of northeast Italy can be reconstructed. The variability of these landscapes is crucial to develop an understanding of the scales of Palaeolithic mobility in response to the quality and distribution of targeted resources, as they represent the off-site environments encountered during subsistence and mobility activities.

Sedimentary and palynological studies

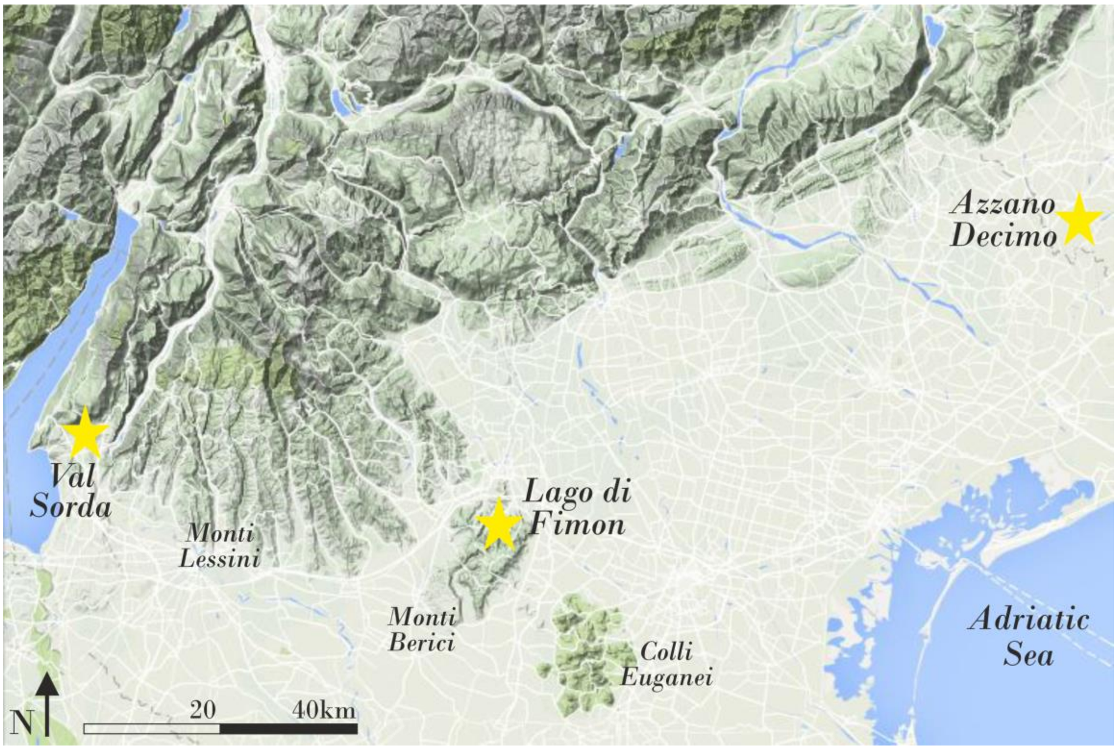

Figure 4.5: The northeast Italy sediment cores (represented by yellow stars) discussed in text (Basemap: Google Maps 2014).

In northeast Italy, continuous and detailed records of past environments are provided by sediment cores and profiles from three distinct locations- Lago di Fimon, Azzano Decimo, and Val Sorda (Figure 4.5). The palynological and sedimentary data gleaned from these cores enable a continuous and chronological overview of MOIS-3 climates and environments across the study region.

Lago di Fimon core

Figure 4.6: Modern-day Lago di Fimon (deep blue). Also indicated are the LGM Lago di Fimon (maximum extent outlined in dashed yellow), sediment cores (represented by white stars) and MOIS-3 archaeological sites discussed in text (Basemap: Google Earth 2014).

During the Pleistocene, the Adriatic coastline was significantly lower facilitating continental climates in the southern Alpine foreland, which are observed in the lacustrine cores from Lago di Fimon that provide a continuous view of climate and environmental conditions for the last 140ka. The lacustrine environment of Lago di Fimon, currently .67km^2, formed during the Eemian due to sedimentary damming from aggradation of the adjacent Venetian plain by fluvial outwash from the Bacchiglione, Astico, and Brenta Rivers at the northeastern boundary of the Monti Berici. Throughout MOIS-3, aggradation from external sources stopped, and lacustrine activity was limited to ephemeral ponds and marshlands that fluctuated within the Fimon basin in response to seasonally-impacted groundwater tables. By around 38ka, fluvioglacial aggradation resumed in the plain, and full lacustrine conditions began to resume in the Fimon Valley, leading to the lake's greatest extent in the Last Glacial Maximum (LGM) (Figure 4.6) (Pini *et al*. 2010; Monegato *et al.* 2011).

Three lacustrine sediment cores have been taken from Lago di Fimon: the Ponte Debba (Fimon PD), Torri di Arcugnano (Fimon TdA), and Fimon Lake core (Fimon FL). These recognise and date climate events throughout MOIS-3, which can be correlated with the archaeological chronology of the region. The cores, which are in agreement with one another and which have been correlated to global and Alpine climatostratigraphic sequences, indicate that at the onset of MOIS-3, the region was characterised by a mosaic environment of forest and steppe. Coniferous and deciduous species including pine and lime were dominant, comprising 50-70% of the pollen present, and indicating temperate conditions. Deciduous, broadleaf species (alder, lime, and oak) were continuous throughout MOIS-3, with alder in particular indicating moist environments, and larch, birch, and juniper further demonstrating a temperate, moist environment. Spruce and hardy herbaceous plants and shrubs are sporadically observed (Pini *et al.* 2010, Monegato *et al.* 2011).

These palynological results demonstrate a mixed woodland environment from the onset of MOIS-3, with persistent forestation (Monegato *et al.* 2011). The continuous presence of trees in the southern Alps foreland is due to moist conditions, explained by the North Atlantic Current, which carried warm water from the Mediterranean Sea northward into the Adriatic, resulting in enhanced cyclogenesis (Pini *et al.* 2010).

While tree presence was continuous, species variance and dominance throughout MOIS-3 is observed. A sharp decline in in arboreal pollen, dated to between 39,740 ± 1,300 and 36,600 ± 1,400 cal BP, is noted in the Lago di Fimon core, which correlates to the disappearance of lime and the expansion of larch. These data, as well as charcoal peaks in the core, indicate forest withdrawal within a cold and dry environment, and may indicate the sharp climate deterioration observable across the continent known as Heinrich Event 4 (Pini *et al.* 2010).

Azzano Decimo core

The Azzano Decimo pollen core, located on the Friulian plain, between the eastern Italian Alps and the Adriatic Sea, provides a continuous look at the climate and vegetation conditions of the southeast Alpine foreground for the last 215,000 years. The MOIS-3 chronology of the Azzano Decimo core is not as resolute as that of the Lago di Fimon core; patterns of climate oscillations between stadial and interstadial events are observed in the pollen record. Peat from the core was radiocarbon dated to provide a continuing chronological sequence from 21,025 ±

245 to 43,000 ± 3000 uncal BP (22,685- 23,890 cal BP to >41,373 cal BP (older dates exceed limits of radiocarbon calibration) (Pini *et al.* 2009).

Zones AZ 64-67 of the core correlate to MOIS-3. These demonstrate a predominance of forested environments, with fluctuating arboreal species prevalence. At what is presumed to be the onset of MOIS-3, the core indicates a dominance of pine and spruce forests in interstadial conditions. The most frequent tree species is pine, followed by birch. Spruce is present, although not strongly so. AZ65 represents stadial conditions following the interstadial onset of MOIS-3. Open conifer forests with spruce and birch stands were present, but open areas with herbaceous plants and grasses are also indicated. Pollen analysis from zone AZ 66 demonstrates a return to interstadial conditions and a return to a pine-spruce forest environment, where pine comprises up to 80% of the sample; the rest consists of spruce, birch, and herbaceous species. Zone AZ67 demonstrates an open pine forests, with stands of spruce, and increasing prevalence of steppic herbs and shrubs. Based on ^{14}C dating and correlation with ice core records, Zone AZ67 may correspond to the stadial conditions of Heinrich event 4 (Pini *et al.* 2009).

The results of the Azzano Decimo pollen analyses are in agreement with those findings of the Lago di Fimon core, demonstrating afforestation of the northeast Alpine foreground throughout MOIS-3, and relatively mild stadial conditions. Palynological results from a recent sediment core from Venice, Italy (ARS-S1) also demonstrates the continued persistence of arboreal vegetation until the end of MOIS-3, dominated by pine with spruce forests (Donnici *et al.* 2012). The pollen analysis also records a gap in the pollen record at 39,500 cal BP, which likely corresponds to the H4 stadial recorded in both the Azzano Decimo and Lago di Fimon pollen cores. Thus, the agreement observed between the sediment cores in the region enables a convincing record of climate and vegetation variables throughout MOIS-3.

Sedimentary data, in addition to the palynological studies at the site level, have indicated that vegetation productivity throughout MOIS-3 was high, although the abundance and distribution of species would have fluctuated in response to Dansgaard-Oeschger climate fluctuations. Despite this, in the Alpine fringe, and in the sub-Alpine foothills, arboreal pollens, as well as herbaceous species, are continuously documented for the late Middle Palaeolithic, indicating that these areas may have served as refugium during colder events.

Val Sorda core

The Val Sorda sediment sequence is situated on a south-facing slope on the eastern side of Lago di Garda. The 10 metre thick sediment profile begins at 210m asl and ranges to the top of Monte Moscal (427m asl), near the town of Affi in the Sorda Valley (Ferrara *et al.* 2004).

Pleniglacial palaeoclimate events were determined through mineralogical, magnetic, and particle size analyses, and indicate fluctuating climate conditions that are similar to those recorded across the Venetian plain by other authors (e.g. Accorsi *et al.* 1990; Cremaschi 1990; Cattani 1994). In the Val Sorda, periods of more humid and temperate conditions (MOIS-3) are interspersed between colder more steppic conditions (MOIS-4 and MOIS-2), with decreased arboreal pollen and pedogenesis resulting in loess accumulation (Ferrara *et al.* 2004). However, the pollen data of this western valley do not indicate the widespread afforestation recorded elsewhere in the study region, such as at in the sub-Alpine foothills at Lago di Fimon or Lago della Costa, where arboreal refugia throughout MOIS-3 and into the Last Glacial Maximum have been suggested (e.g. Paganelli 1996; Kaltenrieder *et al.* 2009; Pini *et al.* 2010). This may be the result of the proximity of this sedimentary sequence to the extant Lago di Garda and the open Po Plain, as well as the proximity of the Garda glacier, which reached (but never overtook) Monte Moscal in the early and late Pleniglacial, as evidenced through the presence of moraines in the Val Sorda (Accorsi *et al.* 1990; Ferrara *et al.* 2004).

Stage Three Project climate and vegetation simulations

The Stage Three Project began in 1995 at the University of Cambridge. From interdisciplinary perspectives, the aims of the project were to determine the climate of Europe during MOIS-3 and the effects of its severe oscillations on fauna and vegetation, as well as its impact on human behaviour as seen through the archaeological record (van Andel 2003). Using high resolution regional climate modelling, the project was able to conduct simulations of palaeoclimate and vegetation conditions for a typical warm Dansgaard/Oeschger (D/O) event, a typical cold D/O event, and the LGM at a generated regional climate grid (RegCM2) of 60 x 60km within a lower resolution global circulation model for those climate conditions experienced within MOIS-3 (Barron and Pollard 2002; Barron *et al.* 2003; van Andel 2003). Together, these modelled variables produced climate and vegetation models such as rainfall, snow depth, temperature, biomes, and vegetation productivity, which were each tested against independent datasets including geological and sedimentological evidence, fossil and macro-faunal data, and pollen records. The end results of The Stage Three Project are an expansive and freely accessible database of palaeoclimatic variables that can be selectively chosen to accommodate a point in space (for this research, an archaeological site) or time (warm or cold D/O event), with the option to select for those environmental variables that are relevant to the question being asked by a researcher.

Those palaeoclimate variables that are of the most relevance to this research include ground cover (vegetation, snow, ice), vegetation distributions (biome, plant types), and climate (temperature, wind, precipitation), as these would have impacted settlement systems. These climate variables will be further explained and the variables expounded upon in the Methodologies chapter.

The palaeoclimate of the study region as generated by The Stage Three Project indicates that the Venetian Plain was characterised by forest-steppe environments with highly productivity grass and herb species and sporadic stands of both coniferous and deciduous trees; these findings are generally in agreement with the site-level and sediment core findings (Cattani 1990; Huntley and Allen 2003; Huntley *et al.* 2003; Kaltenrieder *et al.* 2009; Pini *et al.* 2010). Persistent afforestation occurred in areas of arboreal refugium species throughout MOIS-3 and into the LGM, such as in the pre-Alps and the sub-Alpine foothills, where tree pollen in sediment cores reaches 50-70%, including mixed forests of deciduous and coniferous species (Pini *et al.* 2009, 2010). Further supporting these data are pollen data recovered from archaeological sites that clearly demonstrated the persistence of diverse tree species (Section 4.3.2*)*. The correlations between the Stage Three Project palaeoclimate simulations with external palaeoclimate indicators contribute to a confident reliance on the environmental data available for the study region during MOIS-3.

4.2.2 Site-level indicators

Within the study region, site-level macro- and microfaunal and vegetative remains, as well as sedimentological data yield palaeoenvironmental data that largely agrees with the data generated by external pollen and sediment cores and palaeoclimate simulations.

Macro-faunal remains

The faunal species presence and dominance informing on local biomes and prevalent environments in the study region are mainly represented by the bone remains of Neanderthal-exploited herbivores, carnivore/omnivore-accumulated herbivores, and, in cave sites, non-human carnivore/omnivore occupants, including hyena (*Crocuta crocuta)*, cave bear (*Ursus spelaeus)*, brown bear (*Ursus arctos*), lion (*Panthera leo)*, wolf (*Canis lupus)*, and fox (*Vulpes vulpes*).

While poor preservation at open air sites renders a low visibility of organic materials, Neanderthal-accumulated faunal remains are well represented in each of the cave sites of the study region. The exception is Grotta del Broion, where evidence of subsistence activities is lacking (Peresani 2010). The most commonly recovered anthropically-accumulated species are red deer (*Cervus elaphus*) and roe deer (C*apreolus capreolus*) (Peresani 2011a) supporting a palaeoenvironmental reconstruction in which forests and woodlands persisted throughout MOIS-3. The recovery of chamois (*Rupicapra rupicapra*), ibex (*Capra ibex*), and marmot

(*Marmota marmot*) at numerous sites (e.g. Grotta di Fumane (Peresani 2009), Riparo Tagliente (Arzarello *et al.* 2008), Grotta di Maggiore di San Bernardino (Cassoli and Tagliacozzo 1994a), and Riparo Mezzena (Longo *et al.* 2011)) in deference to cervids indicates that rocky slope alpine environments were present and exploited (Alhaique *et al.* 2004, Fiore *et al.* 2004). These findings are in agreement with sediment core findings (Ferraro *et al.* 2004; Pini *et al.* 2009, 2010, Monegato *et al.* 2011) and palaeoenvironmental reconstructions, which demonstrate shrub and steppe tundra at higher elevations (Huntley and Allen 2003). Aurochs (*Bos primigenius*) and giant deer (*Megaloceros giganteus*) indicating open woodlands and rocky slope environments have also been recovered, but their presence is relatively less common. Horse (*Equus caballus*), elk (*Alces alces)*, and wild boar (*Sus scrofa*) indicating open grasslands and marshlands (referred to regionally as *palude*) are more rarely recovered across the study region (Arzarello *et al.* 2004; Cassoli and Tagliacozzo 1984). At Grotta di Fumane, avifaunal species, including those considered inedible, bear marks of human action, potentially for the intentional removal of feathers, and indicate diverse local biomes, including woodland forests and rocky cliff faces (Peresani 2011).

The macro-faunal species recovered from site assemblages demonstrates that diverse spectrum of biomes and species was available to Palaeolithic populations during MOIS-3. The correlation of these environments with the hunted and consumed faunal species in site archaeological records demonstrates that Neanderthals had access to and were exploiting these multiple biomes, a pattern that is seen at nearly all (with the exception of Grotta del Broion) of the sites in this study. This may indicate that a site was occupied on locational merit, based on its geographic proximity to diverse environments.

Micro-faunal indicators

Micro-faunal remains at archaeological sites are a particularly effective way of determining immediate palaeoclimate conditions, as these species inhabited the immediate vicinity of the site and were not introduced by humans or non-human predators. Micro-faunal analyses have been conducted for numerous sites within the study region, and have provided additional support for pollen, sedimentary, macro-faunal, and palaeoclimate simulations of environment (Table 4.1). For instance, at Grotta del Broion, determined to have been located in mixed temperate forests in proximity to palude (marshlands), grasslands, and steppe conditions by other palaeoclimate indicators, the micro-fauna recovered serve to support these findings, with wood mouse (*Apodemus sylvaticus*) dominating the micro-faunal assemblage (Sala 1980; Peresani and Porraz 2004). At nearby Grotta Maggiore di San Bernardino, the presence of marmot, pine marten, and arctic hare in the late Mousterian Unit II reaffirms a predominantly woodland environment, in proximity to grasslands and Alpine steppe, where biome productivity fluctuated in response to climate oscillations throughout MOIS-3. Additionally, the presence of aquatic species, including beaver, fish, and wild boar signifies the nearby presence of fresh water lacustrine and palude environments (Cassoli and Tagliacozzo 1994a; Peresani 2001).

The microfaunal assemblage at Grotta di Fumane, including forest dormouse and wood mouse, supports the presence of forested environments in the vicinity of the site, and proximal humid conditions are signalled by water voles (Bartholomei *et al.* 1992). Similar environmental conditions with diverse biomes are signalled by the micro-fauna recovered from the MOIS-3 levels of Riparo Tagliente with cooler and more open grassland conditions recorded at the onset of MOIS-3 (layers 52-44) by *Dryomys bogdanovi* (Martino's vole) and *Microtus arvalis* (common vole), followed by climate amelioration and increased humidity as signalled by forest indicators *Glis glis* (edible dormouse) and the common shrew (Sala 1990).

Vegetation data

Because vegetation was likely a regular food and fuel source (e.g. Hardy 2010; Henry *et al.* 2011; Peresani *et al.* 2011b) for Neanderthal populations, it is also indicative of the resource character of exploited palaeoenvironments. However, due to the difficulty in identifying organic materials in the archaeological record, the importance of vegetative resources to past populations has not been wholly recognised or assessed.

New approaches to dietary study provide alternative prospects for observing plant consumption. Plant remains have been found in fossilised dental plaque from Neanderthals in modern day Belgium (Spy) and Iraq (Shanidar), which demonstrates that not only were plants being consumed, they were potentially being cooked (Henry *et al.* 2011). A fairly recent, albeit contentious, report claims the consumption of meat *and* plant remains from the recovery of Neanderthal-attributed coprolites from the site of El Salt in Spain. The coprolites contain coprostanol, bacteria-converted meat cholesterol specific to hominid digestive processes, as well as plant lipids (Sistiaga *et al.* 2014). These types of study have not, however, been conducted for northeast Italy, and the reconstruction of past environments at the site-level through vegetation remains is reliant on the preservation of pollen and charcoal.

Like plants for food, wood was also likely ubiquitously utilised for tools and fuel by Neanderthals, and gathering, processing, and consuming it would have played a large part in life beyond the site. Wooden hunting spears are known from around 400k years ago from Schöningen in Germany (Thieme 1997). At the site of Abric Romaní in Spain, casts in travertine of wooden tools have been recovered from levels dating to MOIS-3 (Vaquero *et al.* 2012). In Slovenia, approximately 200 km as-the-crow flies to the east of the study region, a deliberately shaped yew implement, interpreted as a Mousterian projectile point, was recovered from Ljubljanica River sediments; the wood has been AMS ^{14}C dated to 38,490 ± 330 BP (40,133- 41,063 cal BP) to > 43,970 cal BP (Gaspari *et al.* 2011). In the study region, wooden implements have yet to be discovered, and the presence and use of wood is observed only by the carbonised remains of hearths and isolated fires, which are regularly observed in the study region. These remains serve as valuable tools in reconstructing past environments: anthracological analyses of the charcoal remains from Grotta di Fumane, for example, demonstrated that larch was a locally abundant and regularly exploited resource (Basile *et al.* 2014).

The environmental conditions of the study region have also been reconstructed through pollen remains. For instance, the MOIS-3 Unit ES2 (layers N-I) of Grotta del Broion contains a rich palynological record of abundant arboreal and herbaceous species, which indicates a temperate and humid environment extending from the slopes of the Monti Berici into the surrounding Berici and Venetian Plains. A deciduous temperate forest biome dominated the local environment, and included hornbeam, hazel, Scots pine, ash, and lime species (Sala 1980; Cattani and Renault-Miskovsky 1983). The observed high presence of lime trees in Level I, dated to 46,400 ± 1500 uncal BP (>45,161 cal BP), appears to correlate with a spike of the same species observed in the Lago di Fimon sediment core (Pini *et al.* 2010), further establishing agreement of the archaeological record with palaeoenvironmental data. Grassland environments were also indicated by high pollen counts, as were herbaceous species that together indicate the presence of a steppic biome near the site. Aquatic plant species indicative of wetland conditions are additionally observed throughout the late Mousterian levels (Cattani and Renault-Miskovsky 1983). It is important to note that while the pollen recovery from the site and the subsequent analyses are presently around 30-35 years old (and therefore, questionable in light of modern advancements), the findings are in agreement with modern sedimentological analyses, and therefore, are a reliable and vast source of environmental data.

The findings from the late Mousterian levels at Grotta del Broion are in keeping with those of Grotta Maggiore di San Bernardino, where arboreal pollen from Unit II includes pine, hornbeam, hazel, and lime that support temperate and damp conditions with developed woodland environments in the Monti Berici during MOIS-3 (Cattani 1990; Peresani 2001). Anthracological analysis of the carbonised wood recovered from Unit II's combustion structures showed that deciduous species, including birch, willow, and alder were used as fuel (Peresani 2001). These palynological and anthracological palaeoclimate indicators are in agreement with the woodland species indicated by the site's faunal record (Cassoli and Tagliacozzo 1994a) and the palynological and climatic indicators in the lacustrine sediment cores from nearby Lago di Fimon (Pini *et al.* 2010). Further, the temperate and woodland conditions of Units II coincide with the a prolific archaeological assemblage, suggesting that the intensity of the cave's use may be related to the amelioration of climate conditions in MOIS-3 following colder and drier conditions in MOIS-4, shown by reduced pollen and species counts in Units V through III.

A consistent view of the MOIS-3 palaeoenvironment of the Monti Lessini is demonstrated by the vegetative remains recovered from Riparo Mezzena and Grotta di Fumane. At Riparo Mezzena, arboreal and grassland pollens from Mousterian layer III indicate a temperate and humid climate (Bartolomei 1980, cited in Giunti and Longo 2010), which is largely in agreement with the anthracological and (limited) pollen data from Grotta di Fumane that show continuous temperate continental climate conditions tending toward amelioration from the lower late Mousterian levels A11 to A5+A6. Evergreen species decrease in favour of deciduous broadleaved species over time, and in A5+A6, the strong presence of larch, which, as previously discussed, was used regularly as fuel, was demonstrated by high pollen counts (Basile *et al.* 2014). Deciduous species decrease into the Uluzzian level A4, indicating cooler and drier conditions (Bartolomei *et al.* 1992; Peresani *et al.* 2008; Jéquier *et al.* 2012).

Sediment data

In addition to floral and faunal remains, sedimentological data from sites in the study region inform on climatic conditions experienced in the immediate vicinity of a site during occupation. These site-level data support regional pollen core findings in demonstrating the persistence of a continental temperate environment with persistent woodland and steppe biomes throughout MOIS-3, with oscillations between colder stadial events.

At Grotta del Broion, the sedimentological data reflects the oscillating climate conditions reflected in the stadial and interstadial events recognised throughout MOIS-3 by global and regional indicators. The sediment data from late Mousterian Unit ES2 indicates a temperate and humid environment (Sala 1980), with some cryoclastic activity due to freeze-thaw conditions and loess sedimentation by aeolian sediments from the surrounding plain (Cremaschi 1990; Peresani and Porraz 2004). This determination is in agreement with the macro- and micro-fauna recovered from this unit, in addition to local lacustrine sediment cores (Pini *et al.* 2010, Monegato *et al.* 2011) and pollen data (Cattani and Renault-Miskovsky 1982-1983, 1989) that support a productive mixed forest environment, with the additional presence of grassland and palude environments (Peresani and Porraz 2004; Pini *et al.* 2010).

Similar climate oscillations spanning from the Eemian through the late Middle Palaeolithic are also observed from the sediment records of Units VI and II from Grotta Maggiore di San Bernardino. These indicate fluctuations between cooler and drier conditions and temperate humid climates; it is within the latter conditions, which correlates to MOIS-3, that woodlands were the most developed, as also evidenced by the pollen and faunal records (Cattani and Renault-Miskovsky 1989, Peresani 1995-1996, 2001b).

Climate oscillations are additionally recorded in the late Mousterian sites of the Monti Lessini pre-Alps. At Grotta di Fumane, the lower layers A13-A12 of the late Mousterian sequence Unit A contain cryoclastic breccia and colluvial sands, indicating a cold and humid environment. A move toward a more moist and temperate environment is seen in levels A11-A10, which also contain a large amount of organic material and a dense archaeological record that indicates a predominantly coniferous forested environment (Peresani *et al.* 2011a) Alternating cooler and dryer with more temperate and humid environments are recorded in sediments of the final Mousterian levels A9 to A5, where aeolian sedimentation is observed (Peresani *et al.* 2009). At Riparo Tagliente, the lower late Mousterian levels 52-44 (early MOIS-3) contain colluvial sediments coming from the erosion of soils immediately outside of the rock shelter, and thick breccia at the back of the shelter, all indicating a continental climate with cold and humid winters and dryer summers (Castiglioni 1990; Bartolomei *et al.* 1984). In the upper MOIS-3 Mousterian levels, layers 44-40 are characterised by climate deterioration, where cryoclastic activity caused the collapse of portions of the rockshelter's walls and roof. The aeolian sedimentation within these levels supports external climate indicators of local steppic conditions with sparse woodlands (Bartolomei *et al.* 1984; Castiglioni 1990). The final Mousterian levels record alternations between dry periglacial conditions indicated by loess and more humid glacial conditions indicated by small pebbles (Castiglioni 1990; Arzarello *et al.* 2007).

4.3 Summary

Comparisons of multiple datasets (pollen and sediment cores, site level floral, faunal, and sedimentological data, and palaeoclimate simulations) have shown an agreement in the general character of the palaeoclimate in the study region. Climate conditions, even in colder oscillations, were not severe (e.g. Cassoli and Tagliacozzo 1994; Fiore *et al.* 2004; Pini *et al.* 2009, 2010; Monegato *et al.* 2011; Peresani 2010), and were generally milder than northern continental Europe during MOIS-3.

On the Po/Venetian Plain, limited open forests with xerophytic shrub and grassland steppe environments prevailed during MOIS-3, with arboreal species and forest types fluctuating in response to climate oscillations (Sala 1990; Pini *et al.* 2009). Despite a trend toward consistently cool and drier conditions, persistent afforestation throughout MOIS-3 at middle altitudes such as in the sub-Alpine foothills and pre-Alps of the study region is demonstrated in pollen cores and in site-level pollen records, as well as by the consistent recovery of woodland species as hunted and consumed faunal from within the archaeological levels. Additionally, it seems that the Monti Berici and southernmost pre-Alps may have served as refugium for arboreal species during colder stadial events throughout MOIS-3 and into the LGM (Kaltenrieder *et al.* 2009; Pini *et al.* 2010). The late Mousterian sites in the region tend toward middle altitude forest conditions, in proximity to lower altitude steppe grasslands and higher altitude open alpine conditions, which are each demonstrated in the pollen and faunal assemblages recovered (Peresani 2010). These climate conditions and biomes are in agreement with those determined by palaeoclimate simulations (Barron and Pollard 2002; Barron *et al.* 2003; Huntley and Allen 2003; Huntley *et al.* 2003). While locations in proximity to diverse biomes were widespread in the pre-Alps and sub-Alpine foothills, that large, sheltered caves with access to such varied environments were regularly selected for use may reflect ecological choices in Neanderthal settlement systems to meet resource needs

Site	Level	MOIS	Sediments	Pollen (P) and Charcoal (C) Species	Carnivores/ Omnivores	Herbivores	Micromammals
Broion	ES2 (H-N1)	MOIS-3	Thermoclastic breccias and aeolian silts	**P**- Hop hornbeam, maple, grasses, wormwood, chicory, cattail, crowfoot, willow herb (**C & P**) ash, oak, lime, hazel, alder	Cave bear*, wildcat, hyaena, European badger, pine marten, grey wolf	Wild boar, red deer*, elk, aurochs, chamois	Wood mouse*, field vole, forest vole, dormouse, water vole, common shrew
San Bernardino	Unit II (B1)	MOIS-3	medium sized rocks in a sandy-silt matrix with organic material	P-Scots/ dwarf mountain pine, lime, ash, hazel, hornbeam, Aster family, grasses, daisy family, herbaceous plants (tubuliflorae) **C**- birch, willow, alder	Cave bear*, bear sp., beaver, marmot, red fox, lynx, wildcat, grey wolf, Eurasian hare, European polecat, leopard,	Roe deer*, red deer, elk, wild boar, deer sp., chamois, aurochs, ibex, giant deer	*No published data available*
Fumane	A13-A12	MOIS-4/3	Frost shattered breccias, colluvial sands; high sand content	**C & P**-Scots pine/ dwar mountain pine; **P**- lime, hazel Artemisia, Brassicaceae, grasses, Tubuliflorae, Rosaceae, Filipendula	Bear sp.*, cave bear, red fox, grey wolf, marmot, hare	Red deer*, chamois, ibex, roe deer, giant deer, bovidae sp.	Birch mouse, common shrew, water vole, pygmy shrew, European mole, common vole
Fumane	A11	MOIS-4/3	Frost shattered breccias, colluvial sands, plus **aeolian** matrix	**C**- Scots pine/ dwarf mountain pine*, birch, larch **P**- no data	Red fox*, brown bear, bear sp., cave bear, marmot, hyaena	Roe deer*, red deer, ibex, chamois, giant deer, bovidae sp.	Birch mouse, common shrew, water vole, pygmy shrew, European mole, common vole
Fumane	A10	MOIS-3	Frost shattered breccias, colluvial sands, plus **aeolian** matrix	**C**- birch, larch, Scots pine/ dwarf mountain pine **P**- no data	Red fox*, cave bear, brown bear, marmot, hyaena	Roe deer*, red deer, ibex, chamois, giant deer, bovid, horse	Birch mouse, common shrew, forest dormouse, wood mouse, water vole, bank vole
Fumane	A8+A9	MOIS-3	Frost shattered breccias, colluvial sands, aeolian matrix	**C**-Larch*, Scots pine/dwarf mountain pine; **P- too few**	Marmot*, grey wolf, brown bear, hyaena	Roe deer*, red deer, ibex, chamois, giant deer, bovid, boar	Birch mouse, common shrew, forest dormouse, wood mouse, water vole, bank vole
Fumane	A7	MOIS-3	STERILE level with clayey-loamy matrix	**C**-Larch* **P**- no data	Cave bear*	Roe deer*, red deer, ibex, chamois, giant deer, bovid	Birch mouse, common shrew, forest dormouse, wood mouse, water vole, bank vole, pygmy shrew, European mole
Fumane	A6, A5-A5+6	MOIS-3	Frost-shattered breccias, colluvial sands, plus **aeolian** matrix. Dense organic matter.	**C**-Larix*, broadleafed species; **P- too few (A5)**	Red fox*, brown bear, grey wolf	Red deer*, ibex, roe deer, chamois, giant deer, elk, bison sp.	Birch mouse, common shrew, forest dormouse, wood mouse, water vole, bank vole, pygmy shrew, European mole

Table 4.1: Faunal data: Broion- Sala 1980; Bernardino- Cassoli and Tagliacozzo 1994. Fumane- Bartholomei *et al.* 1992; Peresani 2011. Sediment data: Broion-Sala 1980. Bernardino- Peresani 1995-1996. Fumane- Bartholomei *et al.* 1992. Pollen data: Broion- Cattani and Renault-Miskovsky 1983, 1989. Bernardino-Cattani and Renault-Miskovsky 1989. Fumane- Bartholomei *et al.* 1992. * denotes most frequent species (NISP).

Chapter 5: *Methodologies*

5.1 Overview of Methodologies

To address the questions asked in this research:

- *To what extent did the character and distribution of lithic raw materials in the landscape influence the organisation of technology that is observable in the lithic artefact record?*
- *What was the impact of terrain on technological provisioning strategies and site formation?*
- *What was the role of technological provisioning within the wider sphere of Neanderthal ecology, including land-use patterns and resource scheduling?*
- *Through inter- and intra-site comparatives of Neanderthal raw material economy, can we begin to better understand mobility, subsistence strategies, and settlement dynamics at a regional scale?*

The methodologies of this research were undertaken in five distinct phases: I: palaeoenvironmental reconstructions; II: techno-economic analysis; III: lithic prospection, IV: terrain modelling, and V: data syntheses. Together, these provided a multi-disciplinary and expansive dataset from which observations and hypotheses on Neanderthal ecology can be made. This chapter will provide detailed descriptions of the application of these key methodologies to the study of Neanderthal land-use and resource scheduling in northeast Italy during MOIS-3.

5.2 Phase I: Palaeoenvironmental Reconstructions

To better understand the environmental constraints on Neanderthal ecology and to consider raw material economy within the wider realm of subsistence strategies, reconstructions of the palaeoenvironment including climate, vegetation, and faunal and vegetative resources are critical. To address this issue, the following approaches were undertaken and synthesised to compile a secure and reinforced model of the palaeoenvironmental conditions specific to each study site and its surrounding landscape: assessment of site-level climate and environmental indicators, study and comparison of pollen sequences from sediment cores, and palaeoclimate simulations of regional climate and environmental variables derived from The Stage Three Project (Table 5.1).

Phase I: Palaeoenvironmental Analyses	Site-level climatic and environmental indicators
Phase I: Palaeoenvironmental Analyses	Off-site climatic and environmental indicators
Phase I: Palaeoenvironmental Analyses	Palaeoclimate simulations

Table 5.1: Methodologies of Phase I.

Site-level palaeoenvironmental indicators of climate and environment were derived from faunal, pollen, and anthracological remains, in addition to sedimentological indicators. These served to indicate both conditions immediate to the site as well as exploited environments.

Faunal data was acquired from site publications, with a focus on species representation in terms of their percent of a faunal assemblage, calculated from their minimum number of individuals (MNI). These data were utilised to determine exploited resource niches, based on information on the known behaviours and ecologies of modern correlate species in the study region, referencing Fiore *et al.* 2004 (see Table 2.1). For this research, the merit of these determinations is considered to outweigh doubts on the relatability of considering modern species' behaviours as analogous with their Palaeolithic predecessors (e.g. Stewart 2005). Micro-mammal species and MNI served to indicate immediate site environments for the archaeological levels from which they were recovered (assuming a lack of evidence for burrowing, and thus, intrusion).

Site-level pollen analyses, where available in relevant literature, provided data on arboreal, shrub, and herbaceous species, and were considered to indicate the vegetative conditions immediate to each cave site. These data included vegetative species presence. Anthracological analyses of carbonised plant remains yielded arboreal species presence, and were interpreted as an anthropically-exploited fuel resource, indicating Neanderthal movement within specific resource patches in the off-site environment. Sedimentological analyses at the site-level were available at the general level from site-related literature, and were interpreted to indicate cold/warm and humid/dry climate conditions to support and reinforce other site-level palaeoenvironmental indicators.

Off-site palynological frequencies, temperature, and humidity data yielded from the high resolution **regional pollen sequences** in northeast Italy (Section 4.2.1) will be assessed from publication data and incorporated into regional analyses of MOIS-3 palaeoenvironmental conditions. These data will include vegetative species presence and climate indicators.

Palaeoclimate simulation data was gathered from The Stage Three Project's global and regional models of environmental conditions and vegetation models, whose databases are available online from an anonymous FTP through the University of Cambridge, Department of Earth Sciences' website (Barron *et al.* 2003-present). As the site-level and sediment core evidence suggests that the environment of northeast Italy during MOIS-3 did not tend toward severe conditions (e.g. Cassoli and Tagliacozzo 1994; Fiore *et al.* 2004; Pini *et al.* 2009, 2010; Peresani 2010; Monegato *et al.* 2011), even during colder climate oscillations, data collection focussed on the warm and cold-type events simulations, excluding LGM extreme cold-type simulations.

To begin, the WGS84 latitude and longitude coordinates of each site (acquired during pedestrian survey associated with lithic prospection) were converted into a coordinate system that aligned with The Stage Three Project regional RegCr2m model on a Lambert Conformal Projection grid. This was accomplished by using the Lambwin-converter, which is a software programme downloadable from The Stage Three Project website (the generated coordinates will henceforth be referred to as "Lambwin coordinates"). When each site's original WGS84 coordinates were typed into the programme, four sets of Lambwin coordinates, of varying statistical weight, were generated (Figure 5.1). The nearest neighbour, or highest weighted, converted coordinates, were tested against site level palaeoenvironmental indicators to determine if the simulated conditions meet those of the archaeological record. However, for each site, all four of the generated Lambwin coordinates were considered when recording climate and vegetation simulation data from The Stage Three Project, as these are considered to represent proximal diverse environmental conditions.

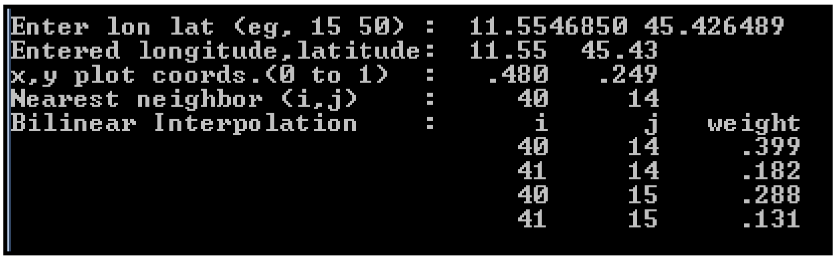

Figure 5.1: Projected coordinates yielded by the Lambwin software. Example: four weighted, potential coordinates for Grotta Maggiore di San Bernardino.

As each set of Lambwin coordinates corresponds to a grid square (60x60km) on the Lambert Conformal Projection grid of the Stage Three Project model, and the study sites' coordinates comprise three (west-east) by two (north-south) grid squares, with overlap among the different sites, the projected area covered by the palaeoenvironmental reconstructions in these methodologies is 180x120km. At 60x60km, the resolution of Lambert Conformal Projection grid is low, and therefore locationally-specific conditions and nuances cannot be assumed. However, these simulations provide data on regional climatic trends, which can be supported or refuted by the archaeological and regional sediment core environmental reconstructions.

The Lambwin coordinates were utilised in acquiring locationally-specific palaeoenvironmental reconstruction data from The Stage Three Project's online database. The ten variables selected to represent the most immediate and influential climatic impacts on environmental conditions, faunal and vegetative productivity and distribution, ground cover (surface costs), and limitations to LRM access (visibility of source, acquisition impediments) are outlined in Table 5.2. These include the following that were generated by Biome 3.5 vegetation modelling (Huntley and Allen 2002). Net primary productivity data (npp) data was available as an integer, representing grams carbon per square meter over a year (gC/m2/yr): the higher the number, the more productive the vegetative environment of a biome. However, as discussed in Section 2.3.1, net primary productivity does not necessarily relate to Neanderthal settlement choices or subsistence strategies; rather, it serves as a useful tool to highlight ecological variability.

The net primary productivity of plant functional types (npppft) was again based on gC/m2/yr, indicated by the npp of each of the potential pfts (typically, four to five of the 13 potential pfts were simulated for each projected Lambwin coordinate). Like npp, npppft demonstrated the character and variability of each site's ecological environs, and indicated the presence of biome types. Potential biome types (Table 5.3b) were generated for each site's four projected Lambwin coordinates, based on the composition of predicted pfts falling in between (for a discussion of the vegetative compositions of each pft type and biome, see Huntley and Allen 2003: 85), and the npppft of these biomes thus is particularly useful in assessing Neanderthal ecology. Leaf area index (lai) was available as a single integer representing the maximum seasonal leaf area index in a square meter

Palaeosimulation Variables for Warm and Cold-Type Events	
Biome (biome_cold and biome_warm)	Wind chill (ºC) (chill)
Net primary productivity of plant functional types (npppft)	Snow (days per annum) (snowd)
Dominant plant functional type (dompft)	Snow height (cm) (snowh)
Net primary productivity (npp)	Precipitation amount (mm per day) (precip)
Temperature (ºC) (surface air temperature, ~2m height) (ts2)	Relative Humidity (% humidity/month) (relhum)

Table 5.2: Palaeoclimate simulation variables for which data was acquired from The Stage Three Project.

PFT Code	Plant Functional Types
1	Tropical evergreen
2	Tropical raingreen
3	Temperate broadleaved evergreen
4	Temperate summergreen
5	Temperate evergreen conifer
6	Boreal evergreen
7	Boreal deciduous
8	Temperate grass
9	Tropical/warm temperate grass
10	Desert woody plant type C3/C4
11	Tundra shrub
12	Cold herbaceous
13	Lichen/forb

Biome Code	Biome Types
0	Sea
1	Tropical evergreen forest
2	Tropical semi-deciduous forest
3	Tropical deciduous forest/woodland
4	Temperate broadleaf evergreen forest
5	Temperate deciduous forest
6	Temperate conifer forest
7	Warm mixed forest
8	Cool mixed forest
9	Cold mixed forest
10	Evergreen taiga/montane forest
11	Deciduous taiga/montane forest
12	Tropical savanna
13	Temperate sclerophyll woodlane
14	Temperate woodland
15	Tropical grassland
16	Temperate grassland
17	Desert: shrubland and steppe
18	Steppe tundra
19	Shrub tundra
20	Dwarf shrub tundra
21	Prostrate shrub tundra
22	Cushion forb lichen moss tundra
23	Barren
24	Ice and snow

Table 5.3: (a, left) PFTs in Biome 3.5; (b, right) Biome types in Biome 3.5. After Allen and Huntley 2002

5.2.1 Phase I summary

Regional MOIS-3 palaeoenvironmental reconstructions considered site-level environmental indicators, including fauna, pollen, sedimentological, and anthracological remains, which highlighted the distribution of resource patches exploited by Neanderthal populations. Off-site palaeoenvironmental indicators included sediment cores from terrestrial and lacustrine settings that provided detailed records of the oscillating climates and environments of MOIS-3 within a high-resolution chronological framework. Palaeoclimate simulations of variables such as precipitation, net primary productivity, biomes, and temperature for simulated warm and cold-type events were determined through The Stage Three Project's online databases. These data served to reinforce and support other palaeoenvironmental indicators of the Neanderthal landscape.

5.3 Phase II: Techno-Economic Analyses

Phase II: Techno-economic analyses	Determine lithotypes and frequencies
	Cortical analyses
	Technological categories and *chaîne opératoire*
	Bordes type and retouch

Table 5.4: Methodologies of Phase II.

5.3.1 Data foundations and limitations

Techno-economic analyses were conducted on the MOIS-3 levels A8+A9, A6, and A5-A5+6 of Grotta di Fumane, Unit II of Grotta Maggiore di San Bernardino, and ES2 of Grotta del Broion. The lithic artefact and analysis data utilised in the techno-economic analyses of this research was provided by their principal investigator and analyst, Professor M. Peresani of the University of Ferrara, where the assemblages are housed in the Department of Biology and Evolution. Additional lithic data yielded by the lithic analyses , conducted under the tutelage of M. Peresani, for the Masters theses of L. Centi (Biancone, level A5+A6, 2012-2013), D. Delpiano (level A8+A9, 2013-2014) and E. di Taranto (Scaglia Rossa, level A5+A6, 2009-2001) were provided by M. Peresani. Because of the consistency in analysis methods, adhering to Bordes' (1963) type list for the Mousterian, Boëda's (1993) methods for the Discoid, and Peresani's consistent lithotype analysis, these datasets are reliably comparable and inter-observer error is not assumed to be significant.

Considering the archaeological levels of the three study sites, data for a total of 19,184 lithic artefacts was provided (Table 5.5). As this research is largely focused on linking site-level lithotypes with LRM distribution in the landscape, all instances of indeterminate (due to burning or patination) flint types in the lithic analyses (n=1,941) were excluded from this analyses, yielding a total of 18,183 lithic artefacts considered in this research. The lithic data from Grotta del Broion and Grotta Maggiore di San Bernardino represent the total number of lithic artefacts recovered and analysed, as excavations at these sites are not active. The lithic data from Grotta di Fumane represents up-to-date lithic analysis through 2013 for all lithotypes, with the exception of the Scaglia Rossa from levels A5-A5+A6 and A6, for which data on this lithotype is available through 2010, and as a single unit, A5+A6. Because it was not possible to consider Scaglia Rossa as a component of levels A6 and A5-A5+A6 individually, this research analysed it as a singular entity; through this method, the results of the Scaglia Rossa techno-economic analyses could be compared to the other lithotypes in the levels comprising unit A5+A6 and to the SR data from level A8+A9 as well.

Site	Level	Dates	Lithic Artefact Total	Lithic Artefacts Analysed
Grotta di Fumane	A8+A9	**A9**: 14C BP: 36,450±400, 42,750±700 BP, or 38,309 to 45,734 cal BP (Peresani *et al*. 2008); **A9**: ESR BP: 46,000±7,000 (Peresani 2008)	8860	7969
Grotta di Fumane	A6	ESR BP: 38,000±6000 (Peresani *et al.* 2008)	3227	3204
Grotta di Fumane	A5-A5+A6	**A5**: ESR ky BP: 38,000±6000; TL ky BP 50,000±8000 (Peresani *et al.* 2008); ABOx-SC 14C BP 40,150 ± 350; 41650 ± 650, or 41,162-44,379 cal BP (Higham *et al.* 2009). **A5+A6**: ABOx-SC 14C BP 40,460 ± 360, or 41,362 to 42,804 cal BP (Higham et al. 2009)	2832	2809
Grotta di Fumane	Unit A5+A6	(Scaglia Rossa only)	917	917
Gr. Maggiore di S. Bernardino	Unit II	ESR U/Th BP: (bone) 35,000±4,000 to 38,000 ±5,000; (tooth) 49,000 ± 5,000 54,000 ± 5,000 (Gruppioni 2004); 14C BP >40, 000, or >41,982 cal BP (Alciati and Vacca 2000)	3192	3192
Grotta del Broion	ES2 (Layers N1 to H)	**Layer Ib**: 14C BP: 46,400 ±1500, or >45,161 cal BP(Vogel and Waterbolk 1967); 14C BP: **Layer I**: 40,600 ± 1270, OR 40,431 to 45,092 cal BP (Leonardi and Broglio 1966)	96	92

Table 5.5: Sites, archaeological levels, dates, and counts of analysed lithic artefacts included in this research. Note that 'lithic artefact total' includes indeterminate lithotypes, whereas 'lithic artefacts analysed' does not.

Sub-lithotype data (e.g. Scaglia Variegata black (nSV)), which facilitate linking lithic artefacts with the distribution of LRM sources in the landscape, was provided by Prof M. Peresani for all assemblages with the exception of Level A8+A9 of Grotta di Fumane, where only assignments of major lithotypes has been made. This research interprets the lithotype assignments in A8+A9 to represent the breadth of lithic raw materials procured by the Grotta di Fumane Neanderthals.

5.3.2 Data collation

The lithic artefact data from each individual site and level were collated to create a master database. This collation served to unify diverse data sources and enable accurate cross-referencing of the numerous site assemblages and lithotype analyses conducted by Prof M. Peresani and his students, which were recorded using different terminologies and coding. The unification of the lithic data simplified the act of techno-economic analysis through the application of uniform technological nomenclatures, analytic categories, and data coding.

The following variables acquired from the aforementioned lithic analyses data were considered most informative of Neanderthal techno-economy: lithic techno-culture, technological phase of *chaîne opératoire,* Bordes tool type, retouch and use-wear, lithotype, LRM source and form, and cortex. These variables were generally available for each of the considered MOIS-3 archaeological levels from the three study sites (Table 5.6), and were provided as data by Prof M. Peresani.

	Fumane A8+A9	Fumane A6	Fumane A5-A5+A6	Bernardino Unit II	Broion ES 2
Techno-culture	✓	✓	✓	✓	✓
Technological category of *chaîne opératoire*	✓	✓	✓	✓	✓
Bordes type	✓	✓	✓	✓	✓
Retouch	✓	✓	✓	✓	✓
Use-wear	✓	✓	✓		✓
Lithotype/sub-lithotype	✓	✓	✓	✓	✓
Cortical analyses (LRM source and form)	Sample (16.4%)	21%	21%	✓	✓

Table 5.6: Techno-economic data provided by Professor M. Peresani from the University of Ferrara, Ferrara, Italy. Blank categories indicate that this data was lacking or limited by small sample size (less than 5%).

Techno-culture was determined based on the observed lithic artefact types, following the analytic framework of Bordes (1953, 1961) for the Levallois assemblages, supplemented by Boëda (1993) for the Discoid. The **technological categories** of *chaîne opératoire* were based on the lithic artefact categorisation proposed by Geneste (1985, Figure 5.2) and observed within the late Mousterian levels. **Bordes tool types** (Table 5.7) were gathered from the available lithic analyses data for the tools in each of the late Mousterian levels in the study group with the exception of the SR assemblages in A6 and A5-A5+A6, where this data was not available. Data on **retouch** and **traces of use** were available from the lithic analyses data provided by M. Peresani for all of the archaeological levels of Grotta di Fumane and Grotta del Broion, with the exception of the SR assemblages from A6 and A5-A5+A6 of Fumane, where this data was not available; for Unit II of Grotta Maggiore di San Bernardino, this data was gleaned from published reports (Peresani 1995-1996). The number of retouched edges were determined based on the morphology of the determined Bordes tool type (e.g. double scraper= two retouched edges). **Lithotype** data was available for all artefacts in each of the late Mousterian levels of the three sites; when lithotype assignment was not possible due to burning or intense patination, the artefacts were categorised as 'indeterminate': these were excluded from this research. Finally, as discussed above, sub-lithotypes assignments were available for all of the archaeological levels, with the exception of A8+A9, which were interpreted such that these were not utilised by Neanderthal populations.

Lithotype analyses further included **cortical analyses**, which not only identified cortex presence and percent of lithic artefacts, but also provided data on the original acquisition provenance, from either a primary outcrop or a secondary source (fluvial, palaeosols, older patinated artefact), as well as form (cobble, block, plate, or nodule). LRM source was determined by rough, smoothed or rolled cortex, and patinas. From Grotta di Fumane, M. Peresani provided cortical analyses data for analysed samples of the cortical pieces from levels A5-A5+6, A6, and A8+9. For Grotta del Broion, facilitated by the small assemblage size (total determinable lithic artefacts in site: n = 506; ES2: n=96), LRM form was determined when possible for all cortical pieces. Cortical analyses were limited from Grotta Maggiore di San Bernardino; this data has been gleaned from publication data on the techno-economic analyses of the site's Mousterian levels (Peresani 1995-1996). From this publication, data of the form of the procured raw material does not directly correlate to individual artefacts, however, but to lithotype categories. Therefore, general observations on provisioning strategies could be made, but these were irrespective of technological categories.

5.3.3 Further techno-economic analyses

This research conducted the following analyses to expand the informational potential of the available techno-economic data. These include the **adaptation** of Geneste's (1985) technological categories framework, the **conversion of technological phases** from originally highly-divisive analyses to fit within this framework, and the **determination of *chaîne opératoire* phases.**

This research adheres to the technological categories and phases of *chaîne opératoire* outlined by Geneste (1985). However, the production sequences observed in the assemblages of the late Mousterian assemblages from northeast Italy differed from those studied by Geneste in France, and therefore it was necessary to adapt the list of technical products and by-products to suit the lithic character of the studied assemblages of research (Figure 5.2).

5.3.4 Phase II summary

Techno-economic analysis of the lithic archaeological assemblages identified lithotypes, their frequencies, and their procurement from primary or secondary sources as determined by cortical analyses. Additional lithic analyses determined *chaîne opératoire* phases, as well as retouch and use-wear frequencies and tool types.

Technological Categories and Phases of Chaîne Opératoire (after Geneste 1985)

Reference Type	Nomenclature- technological categories	Adapted technological categories	Phase
0	Tested or rough raw material block	Tested or rough raw material block	0
1	Decortication flake, entame with cortex >50%	Decortication flake, entame with cortex >50%	
2	Flake with residual cortex (<50%) and cortical striking platform flake and blade	Flake with residual cortex (<50%) and cortical striking platform flake and blade	1
3	Natural backed knife	Natural backed knife	
4	Ordinary flakes and points, and flakes from reviving the striking platform	Ordinary flakes and points, and flakes from reviving the striking platform	2A
5	Ordinary blade	Ordinary blade	
6	Atypical Levallois flakes and blades, pseudo-Levallois and déjeté flakes	Atypical Levallois flakes and blades, pseudo-Levallois and déjeté flakes, *flaking accidents	
7	Levallois flake	Levallois flake	
8	Levallois blade	Levallois blade	
9	Levallois point	Levallois point	
10	Pseudo-Levallois point	Pseudo-Levallois point	
11	Discoidal core	Discoidal core	2B
12	Diverse core types	Diverse core types	
13	Levallois flake or point core	Levallois flake or point core	
14	Levallois blade core	Levallois blade core	
15	Levallois débordant	Levallois *or Discoid débordant	
16	Core or blade edge, crested flake	Core or blade edge, crested flake	
17	Core fragment	Core fragment	2C
18	Core on flake and Kombewa type	Core on flake and Kombewa type	
19	Thinning on flake, not retouched	Thinning on flake, not retouched	
20	Kombewa flake	Kombewa flake	
21	Indeterminable flake fragments without cortex	*21a Indeterminable flake fragments with cortex	
22	Biface thinning flake	*21b Indeterminable flake fragments without cortex	
23	Retouch flake	Retouch flake	3
24	Debris > 30mm with or without cortex	Debris > 30mm with or without cortex	Diverse
25	Debris <30mm with or without cortex	Debris <30mm with or without cortex	
26	Small diverse flakes and fragments 10-30mm	Small diverse flakes and fragments *all sizes	
*27		Debris without cortex (size not recorded)	
*28		Debris with cortex (size not recorded)	
*29		Debris with/without cortex (size and cortex not recorded)	

Figure 5.2: Adaptation (right) of Geneste's (1985) original technological categories and phases (left) to represent the MOIS-3 Levallois and Discoidal assemblages of northeast Italy. Changes are denoted by an asterisk and light grey text.

Bordes' standard type-list of tools for the Lower and Middle Palaeolithic					
1	Typical Levallois flake	21	Déjeté scraper	41	Mousterian tranchet
2	Atypical Levallois flake	22	Transverse scraper, straight	42	Notch
3	Levallois point	23	Transverse scraper, convex	43	Denticulate
4	Retouched Levallois point	24	Transverse scraper, concave	44	Bec burinante alterne'
5	Pseudo-Levallois point	25	Scraper on bulbar face	45	Retouch on bulbar surface
6	Mousterian point	26	Scraper with abrupt retouch	46-47	Abrupt, thick, alternate retouch
7	Elongated Mousterian point	27	Scraper with thinned back	48-49	Abrupt, thin, alternate retouch
8	Limace	28	Scraper with bifacial retouch	50	Bifacial retouch
9	Simple straight scraper	29	Scraper with alternate retouch	51	Tayac point
10	Simple convex scraper	30	Typical end-scraper	52	Notched triangle
11	Simple concave scraper	31	Atypical end-scraper	53	Pseudo-microburin
12	Double straight scraper	32	Typical burin	54	End notch
13	Double convex scraper	33	Atypical burin	55	Hachoir
14	Double concave scraper	34	Typical piercer	56	Plane
15	Double biconvex scraper	35	Atypical piercer	57	Tanged point
16	Double biconcave scraper	36	Typical backed knife	58	Tanged tool
17	Double convex/concave scraper	37	Atypical backed knife	59	Chopper
18	Convergent scraper, straight	38	Natural backed knife	60	Inverse chopper
19	Convergent scraper, convex	39	Raclette	61	Chopping tool
20	Convergent scraper, concave	40	Truncated flake	62	Diverse
				63	Bifacial leaf point

Table 5.7: Bordes (1963, modified 1984) numeric list of tool types for Lower and Middle Palaeolithic used in the lithic analyses of each of the study sites of this research

5.4 Phase III: Lithic Prospection

Phase III: Lithic Prospection	Identify LRM source locations
	Document LRM sources
	Assess LRM source attractiveness characteristics
	Attractiveness value AQ (excluding *cost of terrain*)

Table 5.8: Methodologies of Phase III.

As has been demonstrated in the discussions in Chapters 1 and 2, lithic prospection to identify lithic raw material sources in the landscape is critical to raw material economy studies. To this aim, geological and lithological maps were sourced online from the Istituto Superiore per la Protezione e la Ricerca Ambientale's (ISPRA) geological portal via the GeoMapViewer and Carta Geologica d'Italia alla scala 1:100.000, Regione del Veneto's Carta Litostratigrafica del Veneto, and Piano Regionale Attività di Cava (Carta Geologica della provincial di Verona 1982) (Appendix A). These served only to indicate geological formations with flint potential, as they do not indicate *actual* (primary or secondary) locations of LRM. Nor do these maps indicate primary or secondary source form (e.g. nodule or plate), size, quality, accessibility, or abundance. Therefore, it was necessary that **lithic prospection** was conducted to determine the precise distribution of LRM and their associated attributes in the landscape of northeast Italy. The identified flint sources were linked to the archaeological assemblages of the sites based on the determination of these lithotypes in their lithic records; geochemical and microscopic analyses of the chemical compositions and microfossils linking the lithic artefacts to landscape sources were not conducted for this research, as neither the time nor the means were within the scope of this thesis.

The following discussion of the lithic prospection methodologies will be divided into two sections: **field methods** and **attractiveness.**

5.4.1 Field methods

Lithic prospection was carried out via **pedestrian survey** over two seasons, in the early spring to limit the concealment of lithic sources by vegetation growth. Survey was restricted to a 5km, Euclidean-derived radius around each site (Figure 5.3). The areal limitations of the survey tested the current paradigm of the 5km 'local' foraging, or economic range, theoretically proposed by Binford (1982) and observed by Geneste (1985, 1988), Turq (1989, 1992), and Féblot-Augustins (1993, 1997a, 1997b), and which does not account for real distances and physical terrain, nor quantitatively determine the impact of LRM *attractiveness* (*sensu* Wilson 2007a, 2007b) on raw material economy.

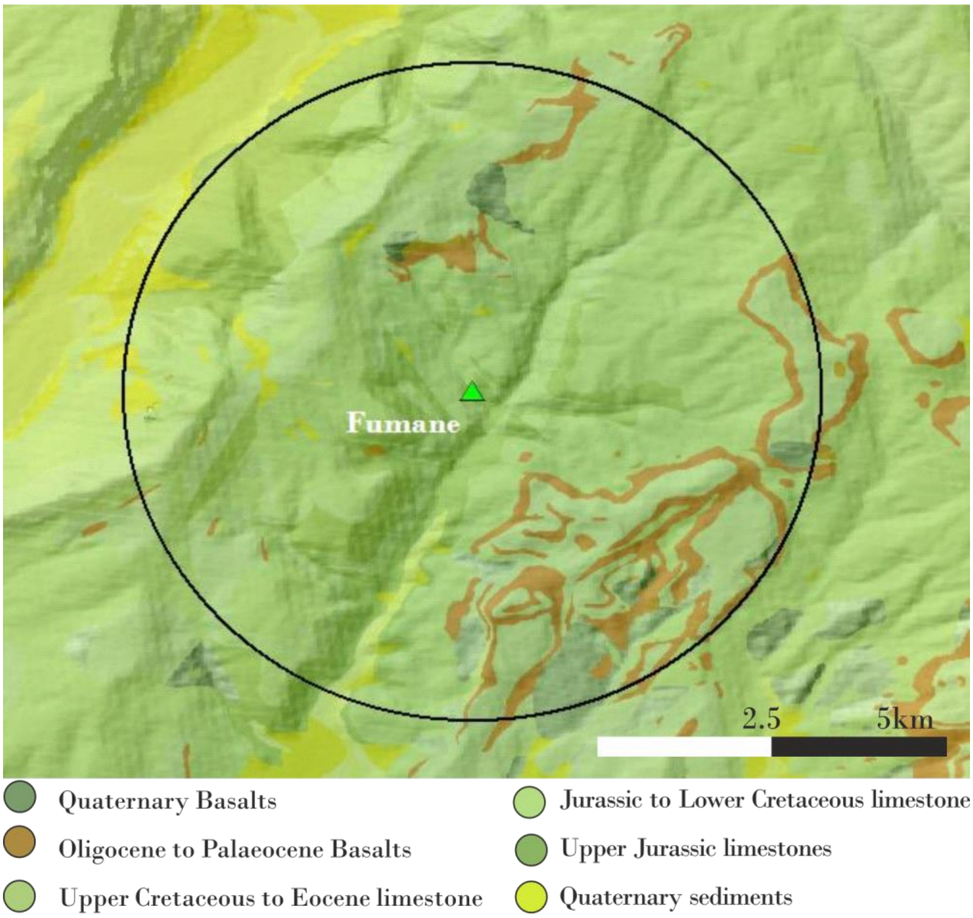

Figure 5.3: 5km buffer zone (local economic zonation) around Grotta di Fumane. Terrain features overlaid with lithological map including geological formations potentially bearing flint.

Pedestrian survey was carried out on foot. The 5km buffer zones around each site were systematically explored according to the LRM potential indicated by the flint-bearing geological formations (late Jurassic through Tertiary) shown on the lithological maps[2] (Appendix A). Additionally, geographic features, particularly streambeds, where secondary LRM sources are prevalently found, were surveyed. The lithic prospection was limited to visual surveillance; penetrative sampling of the landscape was problematic for many reasons, including time and permissions, and so was not considered a viable research technique.

Flint types were identified based on their characteristics, as outlined in Appendix B. Beyond the identification of LRM sources, pedestrian survey further tested the assumption that flint materials were ubiquitously distributed and of equal quality. To quantitatively demonstrate this variability, lithic prospection relied upon documentation of numerous variables for each identified raw material source: **photographs**, **geographic coordinates**, **elevation**, **sampling**, and **assessment** and recording of '**attractiveness**' characteristics.

Reference **photographs** were taken using a Canon Ixus handheld digital camera. These photographs were labelled and assigned to photo database corresponding to site (see Appendix. C). **GPS waypoint coordinates** and elevation in metres above sea level (m asl) were taken at each located source using a handheld Garmin eTrex. Waypoints and elevations were taken standing at the primary sources of raw material. **Samples** were taken from approximately 25% of both primary and secondary identified LRM sources to serve as post-survey reference types. These were individually bagged and labelled, and given a Munsell colour code to be assessed against those codes observed within archaeological lithic assemblages.

Attractiveness

The *attractiveness* (*sensu* Wilson 2007a, 2007b) of a lithic raw material source refers to the sum of its unique variables, including quality, abundance, and size, that indicate its knapping value. The field assessments of LRM attractiveness were not assumed to be directly applicable to the experiences and opinions of Neanderthals on raw material quality and access: rather, these served as data to be quantitatively assessed alongside additional factors that may have impacted attractiveness: energetic and time costs, which are too often excluded from raw material economy studies.

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[2] When land marked as 'private property' was encountered during survey, permission to enter was enquired before investigation. When land was marked as 'no trespassing,' it was not entered, and was omitted from the survey. Those properties not investigated are indicated in Chapter 6, Figure 6.7.

To this end, a source's **attractiveness** was determined as a quantifiable quotient (**Attractiveness Quotient- AQ)**, derived from an equation based on the work of Wilson (2007a, 2007b) and Browne and Wilson (2011):

$$A = \frac{(quality)(extentofsource)(100)}{(difficulty\ ofterrain)(Costofextraction)} \times \frac{size}{scarcity}$$

Equation 5.1: Attractiveness equation from Wilson 2007b: 397.

Quality (0-16): Based on homogeneity, texture, internal structure:

0: very poor (extremely friable, not fully silicified, heavily fractured)

1: poor (contains numerous internal fractures; very course texture)

2: fair (some nodules/blocks/plates contain internal fracturing, course texture)

4: good (reduced internal fracturing, fully silicified, medium-to-fine texture, most nodules of knappable quality)

8: very good (lack of internal fracturing, fine texture, fully silicified)

16: excellent (not used in study area; represents obsidian-like high quality, very fine textured)

Whilst the determination of **quality** was subjective, it was based on a relative scale and in relation to previous studies of the study region's flint's rheological characteristics (Bertola 1995-1996, 2001; Longo *et al.* 2006): for instance, Biancone flint has excellent knapping potential, with a fine texture. However, due to formational processes or the outcrop's position within the geological strata, even flint generally considered excellent may vary according to source. While KNOOP hardness tests, mineralogical analyses, and fracture tests were not within the scope of this research due to the time and expenses necessary, visual and textural inspections served to support or refute assessments of the quality made by previous researchers for each raw material source, and thus was an effective means of assessment.

Extent of Source (1-4): based on the diameter of a source in metres, as determined through pacing. The extent of the source is broken down into a size scale:

1: *small* <10m

2: *medium* 10-50m

3: *extensive*: 50-100m

4: very extensive: >100m

Difficulty of Terrain (units of cost): To determine the difficulty of terrain, the costs of the least-cost pathways from each source to site as determined in ArcGIS were factored into the Attractiveness Equation. These units of cost represent the energetic expenditures (in kcal) of each least-cost path required to cover terrain; these have been factored to exclude extreme slopes (>56º) and to select shortest-time routes. A more in-depth discussion of the determination of least-cost pathways can be found in Section 5.5.

However, to fully demonstrate the impact of terrain, and to show how an LRM source could be perceived as very attractive when terrain costs are not considered, these cost units were not initially factored into the attractiveness equation (substituted with ‘1’). Following the determination of source-to-site least-cost paths in the terrain modelling analyses, these cost units were re-factored into the equation, quantitatively demonstrating the impact of terrain on source attractiveness.

“100”: The multiple ‘100’ was applied to the equation to eradicate confusing decimal points from the AQs (Wilson 2007b) when re-figuring the attractiveness of LRM sources accounting for the energetic costs of the modelled least-cost paths (see Section 5.5), which did produce very small quotients. However, the multiple “100” was omitted from the attractiveness equation that did not factor terrain costs, as, rather than eradicate decimal points it garnered sums that were too large, reaching the opposite end of the overly-complicated spectrum. The omission or utilisation of this multiple did not hinder comparisons between the two derived AQs.

Cost of Extraction: Cost of extraction refers to the difficulty or the ease of removing flint from its primary or secondary source, either from the surface or loose (easiest), to the extraction of a block/plate/nodule from an outcrop or soil using force (hard). For this research, the cost of extraction was not ranked, as to do so would be subjective, not knowing what means by which Neanderthals were acquiring flint, but also likely inaccurate, as nodules that are now perceived as loose, and thus easy to procure, may have been more difficult to extract in MOIS-3. Therefore, for both primary and secondary identified LRM sources, this variable was uniformly input as ‘1,’ which thus did not impact the final quotient.

Size: Size was recorded on a quantitative scale, following those dimensions outlined by Browne and Wilson (2011), which agree with what is observed in the study region of this thesis. The quantitative scale records the dominant size range of LRM from an outcrop or secondary source.

1: small (0-5cm)

2: medium (6-15cm)

3: large (16-30cm)

4: very large (>35cm)

Size was determined in the field using a handheld ruler, at the largest extent of a nodule/block/plate, and at a sample rate of 10%. These measurements were averaged for use in the attractiveness equation.

Scarcity: Scarcity, referring to the abundance or lack thereof of a lithic source, is the inverse of size in the Attractiveness Equation. Scarcity is ranked on a scale of 1 to 4, where one is the most abundant, and 4 is the scarcest.

1: Very abundant (>50% of source surface contains potential flint)

2: Abundant (25- 50% of source)

3: Medium (5-25% of surface)

4: Scarce (<5% of surface)

For outcrops, scarcity was determinable via visual inspection. For secondary sources such as streambeds and soils, which can be quite extensive in size, scarcity was determined through a sampling method. For streambeds containing flint, flints prevalence was recorded within a sampled square meter, at 1km intervals.

5.4.2 Phase III summary

Lithic prospection identified primary and secondary sources of LRM within a 5km radius of each site, and determined the attractiveness of these sources based on quality, source extent, size, and abundance. LRM attractiveness equations produced quantitative data to be linked to observations of technological provisioning and Neanderthal raw material economy in the Mousterian assemblages under study.

5.5 Phase IV: Terrain Modelling

Phase IV: Terrain Modelling
Visualise topography and lithology
Model hypothetical mobility routes
Determine energetic costs of least-cost paths
Create temporal buffers

Table 5.9: Methodologies of Phase IV.

The overarching goal of terrain modelling consisted of the visualisation and modelling of the landscape of the study region using geographic information systems (GIS), in order to create mobility distances and routes from which cost in terms of distance, energy, and time, can be generated and compared to one another and LRM attractiveness. While this modelling is heuristic and does not represent the actual costs of Neanderthal mobility, as due to innumerable reasons, these cannot be known; it provides a well thought-out model from which hypotheses on mobility, LRM procurement strategies, technological provisioning, and settlement patterning can be assessed at a regional scale to highlight Neanderthal ecology.

Terrain modelling was accomplished through four individual aims, outlined in Table 5.9.

Terrain modelling was carried out in the software programme ArcMap, a facet of the ArcGIS desktop suite, version 10.2.2 (ESRI 2014). Terrain data was modelled using a NASA Shuttle Radar Topography Mission (SRTM) (Farr *et al.* 2007) one arc-second DEM, which was acquired from the USGS and NASA's Land Processes Distributed Active Archive Center (LP DAAC). The DEM raster utilised a WGS84, UTM zone 32 (Northern Hemisphere) spatial reference, with linear units in metres. The 1-arc sec DEM represents the highest resolution raster map available for Italy, with cell sizes of 26.67m, each of which represent data for 3D elevations (elevation surface) for terrain modelling. Movement across these cells can be measured to indicate not only distance, but travel and time costs to generate a cost surface from which least-cost anisotropic movement between two points in space- in this research the identified LRM sources and sites- can be modelled.

The following paragraphs outline the methodologies undertaken in ArcMap using the DEM of the study region to accomplish the aforementioned four aims of terrain modelling.

Topography was visualised by running the Hillshade function (Spatial Analyst Tools→ Surface→ Hillshade) on the acquired DEM of the study region. Slope and relief were modelled by running the Slope function (Spatial Analyst Tools→ Surface→ Slope). Landscape changes, including late Quaternary and Holocene sedimentation processes as determined through relevant literature, were considered, although 3D modelling of any changes was not possible using this software. **Lithological modelling** of the landscape was accomplished by overlaying a lithological data layer to the DEM that indicated the distribution of geological flint potential; this data was accessed through the ArcGIS server, and provided by the Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA).

The WGS84 latitude and longitude coordinates of the identified primary LRM sources, along with the coordinates of each study site, were plotted within the visualised landscape. Secondary palaeosols sources and the tested 1x1m streambed areas were also plotted. The latter (streambed) sources were not, however, subjected to distance and least-cost path analyses, as their continuity and ubiquity mean that they could be accessed from any number of routes or points in the landscape, making their procurement costs indeterminable.

To model movement in the palaeolandscape and test the impact of terrain on Neanderthal raw material economy, **hypothetical mobility routes**, representing potential one-way (non-return), source-to-site routes were created; the source-to-site methodology yielded the same routes as modelling site-to-source distances, but served as a more time-effective method of analysis. Therefore, the modelled mobility is based on direct resource procurement, rather than embedded procurement. This approach was adopted for two reasons: one) because other subsistence resources cannot be as accurately reconstructed as LRM, and because we cannot presume to hypothesise on the factors and choices influencing the resource scheduling involved in embedded procurement, and two) one-way, direct procurement is a heuristic approach to terrain modelling that that yields quantitative and comparative data.

The hypothetical mobility routes were conducted individually for the three study sites. The modelled routes included:

- 2D straight line distance (planar)
- 3D straight line distance
- Least-cost paths

The 2D straight-line routes from each identified, plotted LRM source within a site's 5km buffer zone to its respective site were derived using the Point Distance function (Analysis Tools→Proximity→Point Distance), which generated distances in metres between points on a planar scale (WGS84 coordinate system). The distances of the 2D straight-line routes were used as comparisons against the 3D straight-line routes and the least-cost paths to test the efficacy of this method of delineating distances in archaeological contexts.

3D straight-line distances from each identified, plotted LRM source to its respective site were manually drawn using the 'Interpolate Line' function from the 3D Analyst Toolbar, which utilises the functional terrain surface to create distances that account for topography and changes in elevations. The paths and distances of the 3D straight-line routes were generated to test the feasibility of assuming and modelling straight-line mobility routes over varied topography.

Least-cost paths (LCP) were modelled in ArcMap to represent the easiest route from point A (LRM source) to point B (site), reflecting direct procurement routes and factoring in varied terrain. LCPs were not generated to LRM sources of poor quality, which were considered unsuitable to knapping. Least-cost path costs were based on distance, movement up and down slopes, as well as energy expenditures.

As outlined above, the direct procurement routes generated by the LCP analyses were not assumed to reflect all Neanderthal mobility patterns in the past, but provided a heuristic approach to determining the easiest, least-costly means of lithic resource acquisition. The quantifiable data outputs of these LCPs enabled comparisons between the identified LRM sources in the landscape with their representation in the lithic archaeological assemblages, from which observations of mobility and procurement strategies in response to environmental variability could be made.

Cost surfaces (from which least-cost paths were derived) were created following a two-step process, the first concerned with generating slopes from which vertical (up and down) movement costs could be determined, and the second involving defining surface costs based on the metabolic energy expenditures of moving over these slopes, incorporating decreased walking velocities with slope rise and decline.

Slope was generated two times for the DEM, once by degrees, and once by percent grade; the two instances of slope were to meet the functional needs of the energetic expenditure equations outlined below. Both generated slopes were reclassified (Spatial Analyst Tools→ Reclass→ Reclassify) into 10 classes, to allow the slope values to be weighted (Spatial Analyst Tools→ Overlay→ Weighted Overlay), with lower slopes having a higher weight in the forthcoming analyses than steeper slopes. Slopes greater than 56º (150%) were restricted from the analyses in this step, as these were considered to be too steep for realistic mobility; this restriction is more generous than that proposed by Wilson (2007a, 2007b) of 60%. The product of these methods thus far was a cost surface representing the slope costs of the off-site landscape, and two outputs to be used in the forthcoming energetic equations, “Weighted_Slope_in_Degrees” and “Weighted_Slope_in_Percent.”

While ArcMap was capable of determining LCP distances based on the changes of elevation and slope as determined by the values of the input DEM raster of the study area and the above slope functions, the determination of energy costs had to be incorporated into the analysis using the Raster Calculator tool (Spatial Analyst Tools→ Map Algebra→ Raster Calculator). To this end, the following formula, created by Pandolf *et al.* (1977) based on the testing of human movements carrying loads, and modified by van Leusen (1999) to account for the symmetry of energetic costs occurring after 6º (10%) slope, was incorporated into the least-cost path analyses:

$$M = 1.5W + 2.0(W+L)(L/W)^2 + N(W+L)(1.5V^2 + 0.35V * abs(G+6))$$

Equation 5.2: Formula for determining energetic expenditure in metabolic watts (Pandolf et al. 1977, modified by van Leusen 1999)

In the equation, ‘M’ is the metabolic energetic expenditure rate in watts of the travelled route, accounting for weight in kilograms (W), load carried in kilograms (L), terrain friction (N), velocity, or walking speed in metres/second (V), and slope covered in percent (G).

Weight was input as 75kg and carried load was 3kg. Weight was approximated from current paradigms on Neanderthal male physiology (Froehle and Churchill 2009), and load weight represented a subjective estimate weight of stone or wood. While these figures cannot be perceived to accurately represent the typical Neanderthal or carried load, as physical fitness, age, sex, and activity are not accounted for, the accuracy of these values was irrelevant to the outputs of this formula, as the energy costs of these routes needed only to be comparable to one another. Although vegetation, scree, and countless other variables likely impacted terrain friction, these were likely varied across the landscape, and also could not be accurately recreated. Therefore, terrain (N) was input as ‘1.0,’ which represented a constant value that would not impact the output.

$$V = 6e^{-3.5|s+0.05|}$$

Equation 5.3: Tobler's Hiking Formula for determining walking velocity (Tobler 1993)

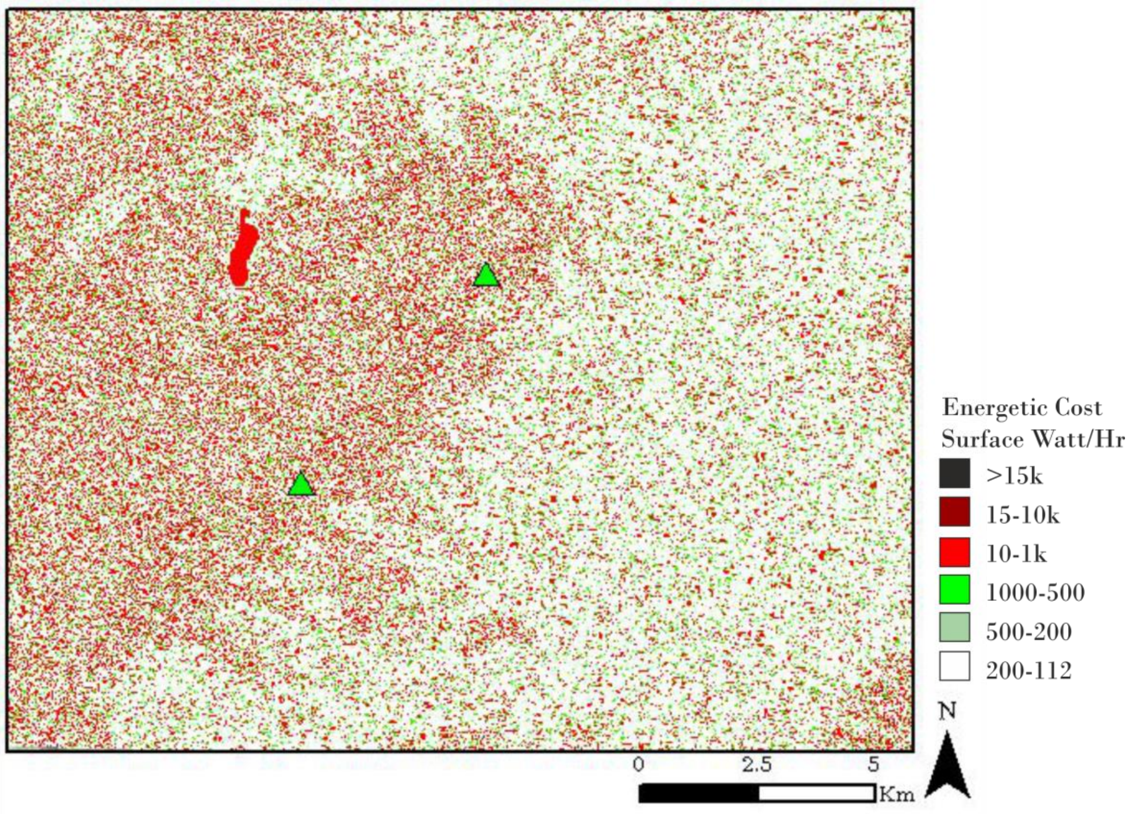


Figure 5.4: Generated energetic cost surface for Grotta Maggiore di San Bernardino and Grotta del Broion, demonstrating lower costs on the Berici Plain (white and light green)

To determine velocity for input in Pandolf's *et al.*'s (1977) equation, Tobler's (1993) hiking equation, where V equals walking speed in km/hour, 'S' equals slope in degrees , and '*e*' is the logarithmic base (Equation 5.3), was separately calculated in Raster Calculator (output→ "Velocity" using the following software-friendly formula: **6 * *Exp*(- 3.5 * *Abs*(*Tan*(*"Weighted_Slope_in_Degrees"*) + 0.05))**. This calculation resulted in a cost surface with values of "0-4.88km/hr" for each of the sites. These represent walking speeds dependent on slope, which were determined using Tobler's Hiking Function over other hiking-time calculators such as Naismith's Rule, due to its applicability to diverse terrain, rather than specific topography: Naismith's Rule, for example, is applicable only to Class 1 hikes (simple hiking, based on the Yosemite National Forest classes of climbing difficulty). Tobler's Hiking Function has been criticised in modelling human mobility costs (c.f. Pingel 2010), because the outputs underestimate declining speeds with extreme downward slope, generated routes are energetically sub-optimal as time is emphasised, and because the energetic as well as time costs are not factored. However, despite these issues, Tobler's hiking function was utilised by this research as the generated LCPs are not interpreted as definitive data on Neanderthal mobility, but rather, as estimates of hypothetical direct procurement that can be compared to one another.

Further, regarding the issue of walking speeds, this has been addressed in the LCP modelling by the modification to Pandolf's (1977) equation by van Leusen (1999), as described above.

With both the weighted slope functions and the velocity functions run, the energetic expenditure formula was entered into the Raster Calculator (Equation 5.4), resulting in a cost surface, with kilocalorie (kcal) costs based on the energetic expenditures of moving in the landscape based on walking speeds over distances and variable slopes (Figure 5.4).

(1.5 * 75) + (2.0 * (75 + 3) * *Square* ((3 / 75))) + (1.0 * (75 + 3) * (*Square* ((1.5 * *"Velocity"*)) + (.35 * *"Velocity"*) * *Abs* ((*"WeightedSlopeinPercent"*) + 6))))

Equation 5.4: Pandolf *et al.*'s (1977) metabolic energy expenditure equation, modified by van Leusen (1999) in Raster Calculator terminology, with variables inputted

Following the creation of energetic cost surfaces with weighted slopes, the next step in the creation of least-cost paths required *path distances* to be generated (Spatial Analyst Toolbox→ Distance→ Path Distance), representing the costs of moving from each cell in the cost surface raster (area of the landscape) to a specific point on the map, which, for this research, is the archaeological site. The generated energetic cost surface was input as the *cost surface*, and the original 1-arc second DEM was utilised as the surface raster to define elevations and distance, which were also utilised in the *Vertical Factor Parameters* to determine if travel movement was level, up, or down slope.

The outputs of the Path Distance analysis ("path_distance" and "path_distance_backlink") were then entered into the Cost Path function (Spatial Analyst Toolbox→ Distance→ Cost Path), to generate the least-cost paths from each LRM source to the site in focus. From the generated LCPs, a total route cost was acquired from the *Attributes Table*. This figure in watts was converted to kcal, which provided a smaller and more manageable figure that is also more familiar and thus easier to comprehend. To determine the distances of these generated routes, each least-cost path was converted from its original raster type to a *polyline* (Conversion Tools→ From Raster→ Raster to Polyline), and distance in kilometres was retrieved from the generated polyline's Attribute Table.

Once cost units in kcals for each LCP were determined, these were individually factored into the Attractiveness Equation as the *difficulty of terrain* variable, and the AQs of each LRM source were refigured, to be compared to one another and to the original AQ, omitting *difficulty of terrain.* As discussed in Phase III, lithic prospection methodologies, the variable "100" was refigured into the attractiveness equation to yield comparable results that avoided confusingly small numbers.

The final terrain modelling procedure in this research was the creation of **temporal catchments** around each site based on hiking time over slopes (anisotropic) rather than 2D Euclidean (isotropic) space, to represent the area of land that could be covered on foot within a set amount of time. This was accomplished by running a new *Path Distance* function, where the cost raster was the "Weighted_Slope_in_Degrees" previously generated from the DEM, and the DEM itself represented the surface raster and the surface of the *Vertical factor parameters*. Also input in the *Vertical factor parameters* was Tobler's Hiking Function equation in table format (acquired online from an ArcGIS-affiliated website (Yanchar 2015)), which computed the walking distances that could be covered of moving up and down the generated slopes in a set amount of time (hours). The result of this path distance analysis was a temporal distance output raster ("Temporal_Cost_Surface").

To visualise the temporal landscape, the output time distance raster was multiplied by '60' in the Raster Calculator (Spatial Analyst Tools→ Map Algebra→ Raster Calculator) to convert the raster to minutes ("Temporal_Cost_Surface * 60). The next step involved creating spatial contours (Spatial Analyst Tools→ Surface→ Contour) based on hourly intervals (*contour interval* = 60). Because of the limitations of terrain, these temporal catchments were expected to be quite different from the Euclidean-derived, planar catchments, and represent a novel perspective of approaching Neanderthal mobility that can be tested against previous delineations of economic zonation. To determine the area of the temporal buffers, each generated hourly interval was individually selected, and the selection was saved as a new layer on the map. These were then converted to a raster (Conversion Tools→ From Polyline→ To Raster), *surface information* was added (3D Analyst Tools→ Functional Surface→ Add Surface Information), and then *surface volume* (3D Analyst Tools→ Functional Surface→ Surface Volume) was determined.

5.5.1 Phase IV summary

Terrain modelling visualised topography and demonstrated the potential impact of terrain and LRM distribution on Neanderthal land-use strategies. Hypothetical mobility routes served to highlight the non-planar nature of Palaeolithic lifeways, and provided a means of testing the plausibility of using Euclidean distances to test LRM transport, and Neanderthal mobility, generally. Least-cost paths generated hypothetical one-way, direct procurement mobility routes that provided quantitatively comparable distance and energetic costs; these will be statistically assessed against the sites together and in pairwise comparisons using SPSS statistical tools in in Section 7.3.4 These methodologies enabled linkages between sites and resource distribution from a three-dimensional perspective that considered the impact of terrain on Neanderthal ecology. Creating temporal buffers enabled a four-dimensional perspective of the palaeolandscape. Terrain modelling introduced an element of realism to assessing the various costs and constraints of mobility on Neanderthal landscape, from which perceptions of economic zonation, land-use organisation and resource scheduling can be reconsidered.

5.6 Data Processing: Syntheses of Methodological Phases

The following section covers those methodologies aimed at synthesising the data acquired in Phases I-IV. To visualise data syntheses, each phase of research has been schematized (Figure 5.5). The following discussion of these methodologies will detail (and simplify) each step of data correlations by referring to datasets as analytic units (A-D).

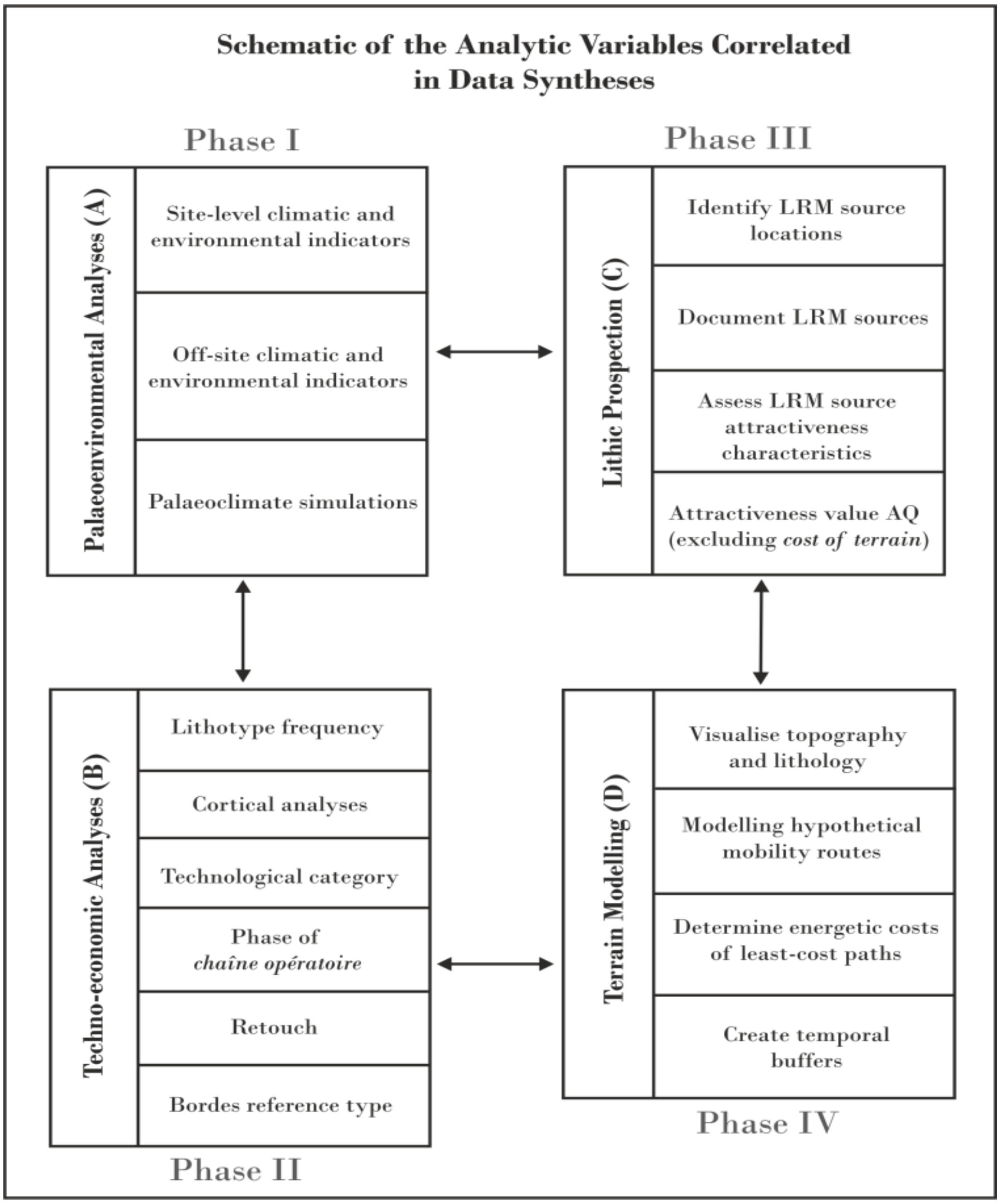


Figure 5.5: Visual schematic of data syntheses.

5.6.1 Linking lithics to the landscape (B and C)

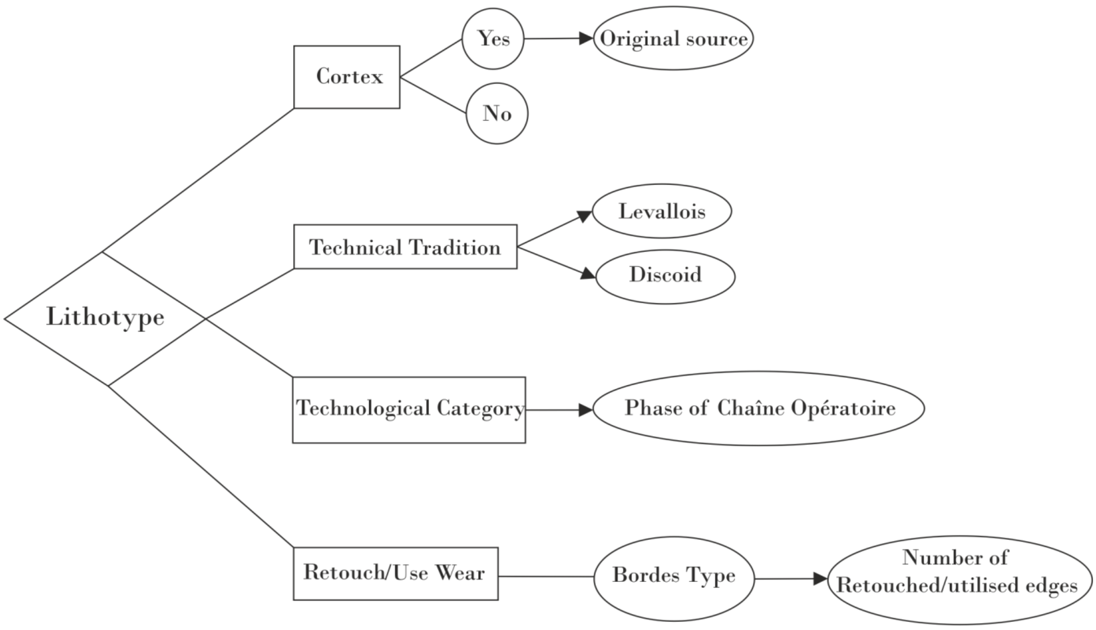


Figure 5.6: Schematic of techno-economic data syntheses.

The represented lithotypes within the studied assemblages were correlated with their associated techno-economic data (B), to indicate differences or similarities in *chaîne opératoire*, and to demonstrate maintenance and management strategies informing on techno-economic choices (Figure 5.6). These findings were then linked to the distribution and quality of the utilised LRM identified in the landscape (C) to highlight its impact on technological choices made by Neanderthals in procurement strategies and in the management and maintenance of these lithotypes at the site level.

5.6.2 Determining the impact of the palaeoenvironment on settlement dynamics and subsistence strategies (A, B, C)

Palaeoenvironmental analyses (A) were correlated to the distribution of sites and the identified primary and secondary LRM sources (C) that were utilised in the archaeological assemblages (B); these correlations placed both the sites and the LRM sources within their ecological contexts, so that inferences on raw material economy, mobility, and economic zonation could be viewed within the wider sphere of subsistence strategies and settlement systems.

5.6.3 Linking lithic prospection and terrain modelling (C, D) to the techno-economic record (B)

Lithic prospection (C) was linked to terrain modelling (D) through the determination of hypothetical mobility routes from LRM sources to their respective sites, whose distances and temporal distances were compared to the frequencies of lithotypes in the lithic assemblages. The energetic costs (kcal) of the LCPs were factored into each LRM source's attractiveness equation (as *terrain difficulty* was omitted from the attractiveness equation in Phase III, lithic prospection). The attractiveness equation for each LRM source was then re-figured, and the new AQs were determined. These AQs were then considered against the previous AQ determinations, and LRM source attractiveness was thus re-evaluated. To determine if an LRM source's attractiveness was linked to its representation in the site lithic assemblages, the observed *chaîne opératoire* and frequencies of retouch of each lithotype (B) were linked to the new AQs and to source distance, as well. These data addressed the impact of the differential distribution and quality of LRM sources in the landscape on Neanderthal provisioning strategies.

Additionally, statistical analyses of the terrain modelling cost outputs were conducted to quantify the distribution and significance of the generated values. This was done using both one-way and two-way ANOVA tests (based on normality and equal variances criteria) in IBM SPSS Statistics 22. These methods supported independed data of different sample sizes.

5.7 Methodologies Summary

The methodologies undertaken in this research incorporated an interdisciplinary approach to examining the impact of environmental variability on Neanderthal raw material economy, mobility, and settlement dynamics. Phase I focussed on utilising site-level archaeological data in addition to regional pollen sequences and palaeoclimate simulations to provide a cross-referenced reconstruction of the climate and resource distributions of the MOIS-3 off-site landscape. Phase II, techno-economic analyses, utilised lithological and cortical analyses to determine potential procurement areas in the off-site landscape. Techno-economic analyses further utilised lithic analysis variables such as reduction sequences, *chaîne opératoire* phases, and retouch to indicate technological provisioning strategies and procurement strategies. Phase III, lithic prospection, identified primary and secondary LRM sources within a Euclidean-drawn 5km buffer zone around each site. Lithic prospection therefore served to identify potential flint procurement locales to be linked with the lithic assemblage, and also yielded data for testing models of Euclidean-derived local economic zonation. Phase IV terrain modelling created hypothetical two-dimensional and three-dimensional straight-line mobility routes as well as least-cost paths for testing how distance and mobility are measured in archaeology. The least-cost path analyses further yielded comparative data on the energetic costs of procurement over three-dimensional terrain, and the concept of a temporal landscape was introduced via modelling of temporal buffer zones, or the areas that could be walked in the landscape in hourly increments. Following these analytical phases, data processing was undertaken to synthesise the multi-disciplinary data. This was accomplished by correlating the data outputs of the phases, and testing hypotheses of the impact environmental variability and terrain on the character of the lithic assemblages.

The results of this research will be presented in the following chapter, Chapter 6.

Chapter 6: *Results*

6.1 Introduction

This chapter will provide the results of the palaeoenvironmental reconstructions, techno-economic analyses, lithic prospection, and terrain modelling carried out for each of the three MOIS-3 sites in the study region, northeast Italy. These results demonstrate that the organisation of technology that is observable in the lithic artefact record was impacted by the character and distribution of LRM in the off-site landscape. Further, technological provisioning strategies were impacted by the costs and constraints of lithic procurement and mobility in variable terrain. Palaeoenvironmental variability was also shown to have contributed to Neanderthal site formation and land use patterns. Together, these data indicate that raw material economy can be perceived to represent Neanderthal ecological responses to the diversity of palaeolandscapes.

The results in this chapter will be detailed by site. For each site, the palaeoenvironmental reconstructions, providing an overview of the Neanderthal landscape, will precede the results of the techno-economic analyses, after which the results of the lithic prospection survey and terrain modelling will be presented.

6.2 Grotta di Fumane: Results

6.2.1 Grotta di Fumane: Palaeoenvironmental analyses

Level A8+A9

Level A8+A9 of Grotta di Fumane records the end of cold climate conditions, which began in the MOIS-4 BR levels and slowly ameliorated from levels A12 through A10. Improving conditions, including increased temperature and moisture, were indicated by breccias and a steady decrease in the predominance of pine and caprids. Cool to cold conditions were signalled in the sediments of A8+A9, which included frost-shattered breccias and colluvial sands, with an aeolian matrix. While these sediments contained some organic matter and preserved a diverse faunal assemblage, pollen remains were limited, due to leaching processes (Cattani and Renault-Miskovsky 1986; Bartolomei *et al.* 1992). The limited pollen remains recovered in level A8+A9 included arboreal species, pine (*Pinus sylvestris/mugo*) and larch (*Larix*), typical of coniferous montane forests. Carbonised wood remains were frequent, and anthracological analyses supported palynological findings in verifying the presence of pine and larch. Spruce and birch were also identified, and the environmental picture of Fumane was broadened to position larch on the hill slopes around Grotta di Fumane and spruce on the valley floors below the site, likely alongside the numerous streams that dissect the local topography (Basile *et al.* 2014).

The faunal assemblage of level A8+A9 contained an NMI of 72 (NISP 1259) mostly adult species from diverse ecological niches (Romandini *et al.* 2014), which is in agreement with the palynological and anthracological indicators of both open and closed forests. The most hunted ungulates from the site were forest species (red deer (39.3%) and roe deer (22.3%)). Open forests were signalled by giant deer (6.2%) and bison (~3.5%) (Romandini *et al.*2014). Alpine grassland (marmot, chamois) and rocky slope (ibex, Alpine chough) species were exploited to a lesser degree (12%) (Cassoli and Tagliacozzo 1991; Romandini *et al.* 2014); these environments were likely located at the higher elevations and slopes leading down from the Lessini Plateau. The presence of wetland areas near the site was weakly signalled by elk (1.4%) and wild boar (0.2%). The microfaunal assemblage, including birch mouse, common shrew, forest dormouse, wood mouse, water vole, and bank vole, supported forest dominance in the vicinity of the site, nearby water sources, and the extension of the tree line from the valley floor to at least to the elevation of the cave (Bartholomei *et al.* 1992).

The Val Sorda sediment core (Ferrara *et al*. 2004) from the eastern border of Lago di Garda contained silty loess that confirmed site-based determinations of cold conditions in level A8+A9. The core contained pollens of grasses and *Cichoriaceae*, and limited arboreal pine and birch species, with oak occasionally signalling warmer climate oscillations. Overall, the Val Sorda core demonstrated an open steppic environment at the intersection of the western Monti Lessini and the Po Plain during MOIS-3. While the determination of cold conditions were in agreement with site-level environmental indicators, a more humid and forested environment was otherwise observed in level A8+A9; these differences may be explained by the greater proximity of the core sediment to the flatter, more open surroundings of the ancient Lago di Garda and the Po Plain, in contrast to the more enclosed conditions of the Monti Lessini.

Palaeoclimate simulation data from The Stage Three Project was generated for warm and cold-type events, to see which conditions most resembled the site level palaeoenvironmental indicators. Palaeoclimate simulation data predicted two biomes for the generated coordinates of Grotta di Fumane: evergreen taiga/montane forests (Biome 10), predicted at 86.2%, and temperate deciduous forests (Biome 5), predicted at only 13.7%. The plant functional types (pfts) within the evergreen taiga/montane forest biome included arboreal species: pine, spruce, larch, fir, birch, and willow, in agreement with numerous species represented in the palynological and anthracological record of A8+A9. The pfts within the temperate deciduous forest biome included the same arboreal species as the evergreen taiga/montane forest biome, as well as coniferous species cedar and yew. Open conditions in both biomes were little indicated, but included heath and grasses, which may correspond to the open Alpine conditions on the Lessini Plateau.

The simulated net primary productivity of the pfts (npppft) showed that the representation of boreal evergreen trees, boreal deciduous trees, and temperate evergreen conifers were relatively productive in both the simulated warm and cold-type events, with cold-type events being slightly more productive (Table 6.1). In both events, however, temperate grasses and woody desert plants were of limited productivity. The net primary productivity (npp) of the deciduous temperate summergreen trees pft, represented only in the temperate deciduous biome, was the highest of all simulated pfts in both biomes; however, the presence of deciduous forests near the site was not indicated at the site level, indicating that the presence of the temperate deciduous biome either occurred at a significant distance from the site, or that it was quite limited in size, which is likely, given the cold conditions of level A8+A9.

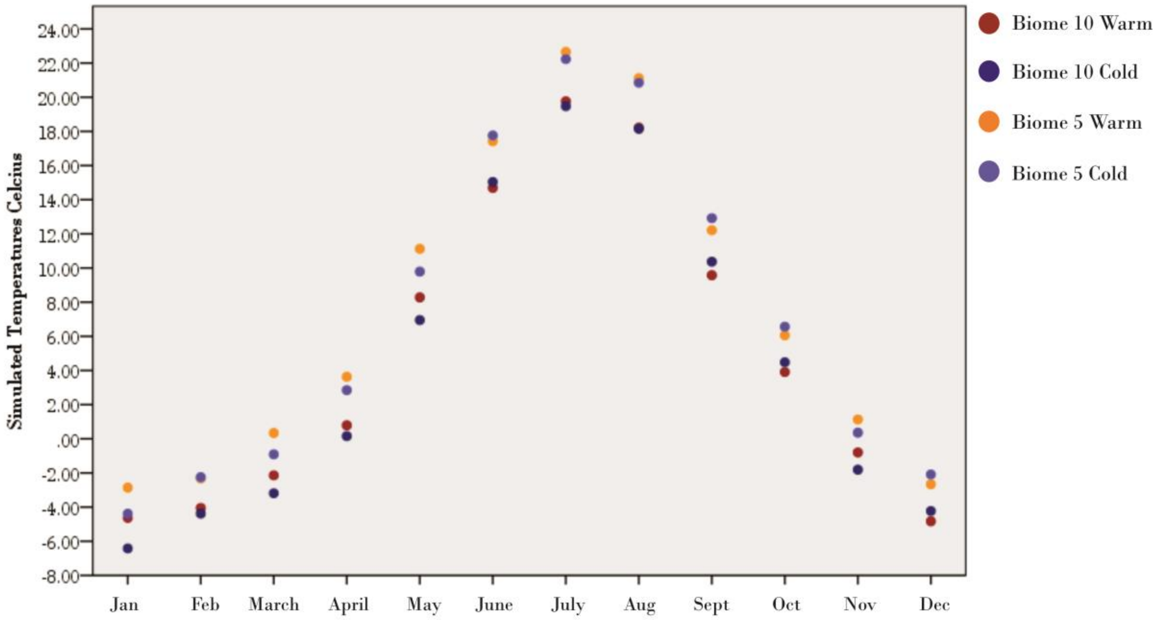
	Warm-type Event				Cold-type Event			
lambwin coordinates	**40, 15**	**39, 15**	**39, 14**	**40, 14**	**40, 15**	**39, 15**	**39, 14**	**40, 14**
PFT	**Biome 10**	**Biome 10**	**Biome 10**	**Biome 5**	**Biome 10**	**Biome 10**	**Biome 10**	**Biome 5**
Temperate summer-green				444.00				434.00
Temperate evergreen conifer			290.00	354.00			281.00	347.00
Boreal Evergreen	178.00	232.00	348.00	393.00	184.00	239.00	342.00	381.00
Boreal Deciduous	167.00	225.00	335.00	390.00	175.00	233.00	324.00	377.00
Temperate Grass	46.00	107.00	255.00	317.00	47.00	114.00	254.00	310.00
Desert woody plant type, C3/C4		49.00	98.00	114.00		51.00	98.00	111.00
LAI	1.93	1.93	2.24	2.71	1.93	1.93	2.24	2.71

Net Primary Productivity of Plant Functional Types, Biomes 10 and 5

Table 6.1: Net primary productivity of plant functional types in Biomes 10, evergreen taiga/montane forest, and Biome 5, temperate deciduous forest, for simulated MOIS-3 warm and cold type events.

The productivity of the biomes was supported by leaf area index (lai) simulations, which showed that the temperate deciduous biome had a higher lai than the evergreen taiga/montane forest biome (2.71 vs 2.03, respectively), which agrees with the net primary productivity simulations. The lai did not vary between both warm and cold-type simulations, likely indicating that the environment was consistently vegetated throughout MOIS-3, although by different plant species. For A8+A9, these were the colder coniferous arboreal species and grasses, observed in the site-level findings, and supporting the dominance of the evergreen taiga/montane forest biome, Biome 10, in proximity to the site.

Temperature simulations supported that the conditions in which A8+A9 was formed were cold, with sub-freezing temperatures occurring in November through March in warm-type climate events and November through April in cold-type events (Figure 6.1a). However, summer conditions appear to have been consistently temperate in both warm and cold-type events. For both predicted biomes, the coldest temperatures occurred in January, and the warmest in July. Temperatures in Biome 10 were colder than those of Biome 5 in both climate events. Wind chill simulations showed significantly reduced temperatures, particularly between autumn and spring, in both warm and cold-type climate simulations (Figure 6.1b).



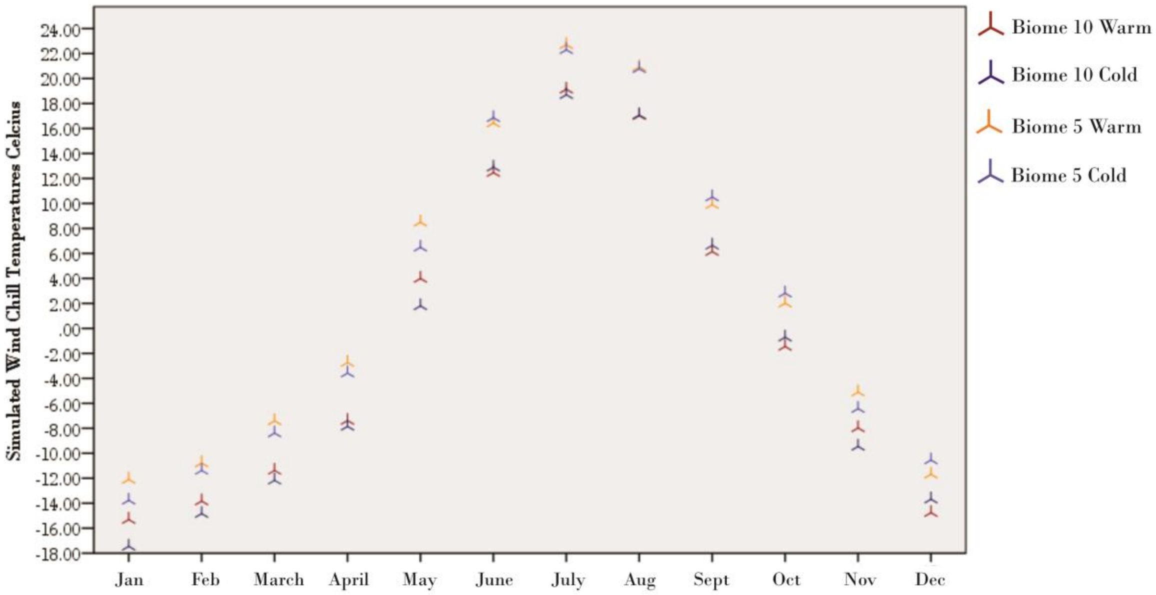


Figure 6.1: a) Distribution of simulated monthly temperatures for Biomes 10 and 5 at Grotta di Fumane (showing both warm and cold type climate simulations). b) Monthly wind chill temperatures compared to temperatures for Biomes 10 and 5 during both warm and cold type events.

In terms of snow days per year (Table 6.2), the palaeoclimate simulations did not differ significantly between the warm (174 days) and cold-type events (157 days) for Biome 10. However, there was a significant difference between warm (167 days) and cold (101 days) simulations in the temperate forest biome, which indicated more arid conditions in these environments during colder climate oscillations. Snow height simulations showed that depths exceeding 10cm occurred 5 months out of the year in Biome 10, in agreement with the sub-freezing temperatures in these months, and that depth reached 60cm (warm event) and 80cm (cold event) in the snowiest month, January. In contrast, in Biome 5 snow depth was significantly less for both warm and, particularly, cold type events, which further supports more arid conditions in Biome 5 during colder climate oscillations, in contrast to the evergreen taiga/montane forests, which appear to have been consistently humid.

	Grotta di Fumane, Snow Height, cm per month			
	Warm Event		Cold Event	
Month	**Biome 10**	**Biome 5**	**Biome 10**	**Biome 5**
JAN	40.62	18.31	13.63	44.89
FEB	61.98	24.16	14.70	56.20
MAR	45.06	2.54	8.45	51.30
APR	32.71	0.39	0.59	37.00
MAY	1.77	0.00	0.00	4.20
JUNE	0.00	0.00	0.00	0.00
JULY	0.00	0.00	0.00	0.00
AUG	0.00	0.00	0.00	0.00
SEPT	0.00	0.00	0.00	0.00
OCT	0.16	0.08	0.00	0.18
NOV	2.94	0.57	0.68	5.55
DEC	17.55	7.87	5.01	21.73

Table 6.2: Monthly snow height(cm) simulations for both warm and cold type events in Biomes 10 (averaged) and Biome 5.

Precipitation simulations showed wetter winters and drier summers for both biomes and climate events, and drier conditions in Biome 5 in cold type events in agreement with the simulations of snow days and height (Figure 6.2). These data further corresponded with the relative humidity simulations, which showed that the summer months were the least humid, in the mid-40s and lower-50s percentile range, and the winter months were the most humid, in the 80th percentile range; these data pertain to both biomes *and* both warm and cold type events, and is in contrast to those indicators of more arid conditions in Biome 5 during cold oscillations.

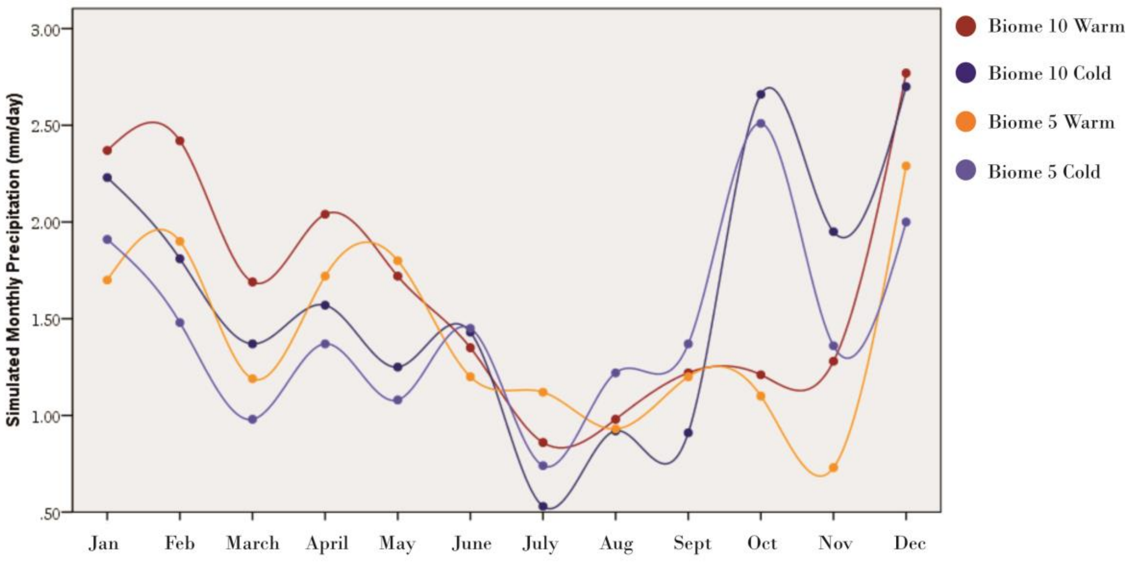


Figure 6.2: Simulated monthly precipitation for both biomes and simulated climate events.

Unit A5-A6 (levels A5-A5+A6 and A6)

Although occupational intensities appear to have varied between levels A5-A5+A6 and A6, the palaeoenvironmental indicators recorded within these levels, including sediments, vegetation data, and faunal records, were comparable, and indicated continuing climate amelioration from level A8+A9. Because of the comparability of these assemblages, their palaeoenvironmental reconstructions were analysed jointly as unit A5-A6.

Pollen remains, like in level A8+A9, were scarce, but those recovered indicated that larch was the prevalent arboreal species (Peresani *et al.* 2008). The breccias of unit A5-A6 indicated humid environments, and the rich organic component observed in the sediments recorded intense Neanderthal site use. Wood charcoals were abundant from numerous combustion structures (A6, n=21 and A5-A5+A6=7) (Peresani *et al.* 2011b), and anthracological analyses of these remains supported palynological findings in verifying the dominance of larch in proximity to the site. These analyses further identified numerous broadleaved deciduous trees, including willow, ash, birch, and maple (Maspero 1998-1999). The anthracological findings therefore supported sedimentological and pollen indicators of climate amelioration and shifting local environments around Grotta di Fumane from level A8+A9 to A6. Level A6 marks the disappearance of pine in favour of the broadleaved arboreal species; while larch remained a feature of the forested hillsides, the forests of the valley floors became dominated by deciduous rather than spruce forests, which persisted into the Uluzzian level A4.

The faunal assemblages of A5-A5+A6 (NISP 116) and A6 (NISP 248) contained species from diverse ecological niches, which agreed with the palynological and anthracological analyses in indicating both open and closed forests. A5-A5+A6 contained a higher carnivore component, dominated by red fox, which was possibly related to the relatively less intense occupation of the site by Neanderthals as signalled by lower lithic densities and less hearths. Dominant montane forest environments were signalled by hunted red deer remains in both levels, at 52% of A6 and 60% of A5-A5+A6 (Peresani *et al.* 2011b); these percentages were a significant increase from level A8+A9, supporting the expansion of forests throughout MOIS-3. Other forest species included roe deer, which were more prevalent in A6 than A5-A5+A6 at 18% and 4.5%, respectively, and brown bear and black grouse.

Open forests, correlating likely to the spruce and broadleaved species on the valley floor, were signalled by the few remains of giant deer (NISP 2, both levels) and bison (NISP 2, A5-A5+A6 only). The evidence for open grassland and rocky slope conditions, including ibex and chamois, as well as Alpine chough and corncrake (Peresani *et al.* 2011a, 2011b) were comparable between A5-A6 at around 12%, indicating the persistence of these environments throughout MOIS-3, likely on the Lessini Plateau. Humid conditions were signified by limited elk and by the bird species water rail and the common moorhen (Peresani *et al.* 2011a). The microfaunal assemblage was comparable to A8+A9, but also included bank vole, pygmy shrew, and the European mole (Bartholomei *et al.* 1992), which showed the development of more forested and humid conditions.

As discussed in reference to level A8+A9, the loessic composition and low arboreal pollen presence of the Val Sorda sediment core indicated open steppic environments at the intersection of the western Monti Lessini and the Po Plain during MOIS-3 (Ferrara *et al.* 2004). These findings were in contrast to the continued forestation observed from level A8+A9 into levels A6 and A5-A5+A6. Again, the differences in these records were likely due to the distance of the core from Grotta di Fumane, 13km southwest as-the-crow-flies, and its proximity to the flatter landscapes of Lago di Garda and the Po Plain, which likely did support open grassland conditions with sparse tree presence.

Because the generated Lambwin coordinates for unit A5-A6 were the same as for A8+A9 in the palaeoclimate simulations, the acquired Stage Three Project data were identical, with evergreen taiga montane forests (Biome 10) more strongly predicted (86.2%) over temperate deciduous biomes (Biome 5, 13.8%), in both warm and cold-type climate events. However, based on the site-level indicators of climate amelioration, the dominance of deciduous trees, and the absence of pine species, it is likely that the warm-type simulations of temperate deciduous forests are more in line with the environments proximal to site in these levels. It was also evident in the pollen, anthracological, and faunal records that climates were temperate, and therefore, the following climate simulations were focussed on warm-type rather than cold-type simulated events.

Simulated net primary productivity of the plant functional types demonstrated that for warm-type events, temperate plant species were most productive in Biome 5 (Table 6.3). For Biome 10 (in a warm-type event), arboreal species were also the most productive, signifying the dominance of forest environments around the site. Limited grasslands and open Alpine conditions were simulated for both biomes; these likely occurred on the Lessini Plateau. The more limited presence of these environments was supported by the lower frequency of caprids in the hunted ungulate assemblage. As was reported for level A8+A9, the leaf area index (lai) was greater for the temperate deciduous biome versus the evergreen taiga/montane forest biome; while consistent for both warm and cold-type simulations, vegetation types likely varied, and for unit A5-A6 these would have included less cold, coniferous arboreal species and more temperate deciduous types.

		Net Primary Productivity of Plant Functional Types for Biomes 10 and 5			
		Warm-type Event			
PFT	**pftcode**	**40 15 (10)**	**39 15 (10)**	**40 14 (5)**	**39 14 (10)**
Temperate summer-green	4			444.00	
Temperate evergreen conifer	5			354.00	290.00
Boreal Evergreen	6	178.00	232.00	393.00	348.00
Boreal Deciduous	7	167.00	225.00	390.00	335.00
Temperate Grass	8	46.00	107.00	317.00	255.00
Desert woody plant type, C3/C4	10		49.00	114.00	98.00
LAI		1.93	1.93	2.71	2.24

Table 6.3: Net primary productivity of plant functional types for the generated Lambwin coordinates for warm-type event in Biomes 10, evergreen taiga/montane forest, and Biome 5, temperate deciduous forests

Because the temperature simulations yielded comparable data for both Biomes 10 and 5 for the simulated warm type events, these were averaged to demonstrate highs of 20.5ºC in July, and lows of -4.19ºC in January. Applying these methods also to the wind chill simulations, the averaged January temperatures wind chills of both biomes dropped to -18.34ºC (refer to figures 6.1a and 6.1b).

Considering snow days per year, the palaeoclimate simulations also did not differ significantly between the biomes in warm-type events, with 174 days per year in the evergreen taiga/montane forest biome and 157 days in the temperate deciduous biome. The aridity signalled by decreased snow days per year observed for Biome 5 during cold-type events were in contrast to the site-level evidence for moist environments, and therefore further supports the attribution of unit A5-A6 to a warm-type event. The warm-type simulations of snow cover (height in centimetres) were more varied between the biomes: Biome 10 showed accumulations reaching up to 60cm in February, but only 24.16cm Biome 5, in which snow depth exceeded 10cm in only two months of the year (Table 6.2). To be further considered is that these simulations do not account for snow drift, which means that snow depth could have exceeded the modelled predictions.

Monthly precipitation simulations were in agreement with the snow days and height simulations for warm-type events, with December through February representing the wettest months in Biome 10, and October through January in Biome 5 (Figure 6.2). In both biomes and climate event simulations, the summer months were the driest, which agreed with the relative humidity simulations showing that the summer months, and July in particular, had the lowest humidity, between the mid-40s and lower-50s percentile range, while winter humidity was in the 80s percentile range.

6.2.2 Grotta di Fumane: techno-economic analyses

Level A8+A9

Level A8+A9 of Grotta di Fumane, formed of level A9 plus sub-unit A8, which is the dispersal of the upper A9 sediments (Peresani *et al.* 2008), contained a substantial lithic assemblage featuring the exclusive use of Discoidal technology, unique amongst the other Levallois Mousterian levels of the site. This level contained 8,860 lithic implements, of which 891 were removed from analysis due to indeterminate lithotype, leaving a remainder of 7,969 analysed pieces.

Grotta di Fumane, Level A8+A9: Techno-economic results, N= 7,969									
Lithotype	Frequency	Percent of Assemblage	Techno-culture	Dominant CO Phase	Chaîne opératoire	Retouch %	% Cortical	Dominant LRM Source	Dominant LRM Form
BI	5,184	65.10	Discoid	2c	Complete	5.03	43.80	Fluvial	Cobble
SR	1,391	17.50	Discoid	2c	Complete	4.24	44.90	Outcrop	Block/plate
SV	966	12.10	Discoid	2c	Complete	7.66	41.00	Outcrop	Cobble
Eoc	246	3.10	Discoid	2c	Complete	7.32	24.40	Outcrop	Block/plate
Ool	149	1.87	Discoid	2c	Complete	7.38	28.20	Outcrop	Indet
RA	4	0.10	Discoid	0	Truncated	75.00	100.00	No Data	No Data
Alloch	29	0.50	Discoid	Indet	Indet	13.80	17.20	No Data	No Data
Total	**7,969**	**100%**							

Table 6.4: Simplified results of the techno-economic analyses of each lithotype in level A8+A9.

The majority of the lithotypes in the A8+A9 assemblage were cryptocrystalline flints, predominantly Biancone (65.1%), followed by Scaglia Rossa and Scaglia Variegata (Table 6.4). The microcrystalline flint varieties were significantly less represented, and Palaeocene flints were not observed. Sub-lithotypes (e.g. black Scaglia Variegata nSV) were not determined in the original analyses.

The presence of cortex in the A8+A9 assemblage was quite high, with the cryptocrystalline flints containing the largest frequency of cortical pieces; the lowered presence in the exotic flint (allochthonous) assemblage likely reflects the distances of these to the site, indicating the exploitation of these materials over distances exceeding 20km.

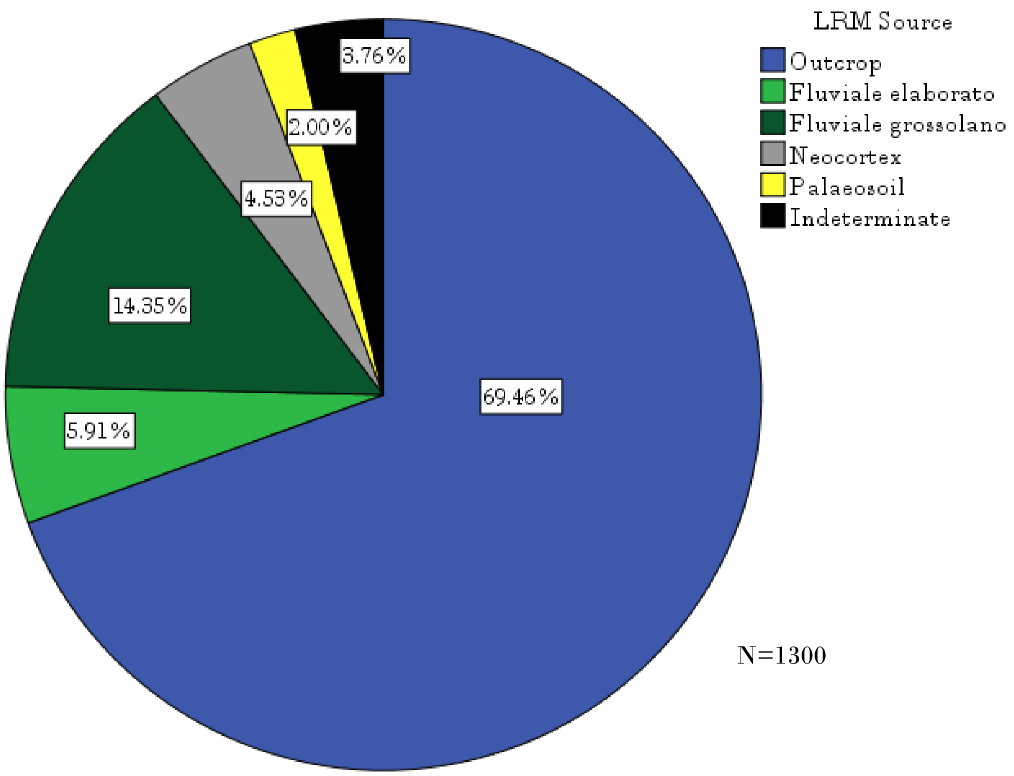


Figure 6.3: Cortical analyses results: A8+A9 LRM procurement sources for all analysed lithotypes

Cortical analyses demonstrated that the exploited flints were predominantly acquired as blocks, plates, and nodules from primary outcrops, with more limited exploitation of these forms from palaeosols, and as cobbles from streambed sources (Figure 6.3). The procurement of SR (89%), Eoc (82%), and Ool (91%) flints was predominantly from outcrops, with limited procurement from secondary sources (2.2%, 4%, 3%, respectively). The exception to these acquisition strategies was seen in the Bi and SV assemblages. Stream exploitation in SV was seen to be significant (19.5%) relative to outcrop exploitation (72.5%) in the analysed cortical sample. In the Bi sample, streambed procurement was the highest in the assemblage, at approximately equal that of outcrop exploitation (47% and 47.9%).

Also observed in the cortical analyses was the recycling of previous artefacts (as determined through double patination or *neocortex*). This was highest in the SR lithotype at 7%, and in the SV at 5.5%. Recycling was observed to a lesser degree in the Bi (2%), Eoc (2.1%), and Ool (0%) flints. Recycling appears to have been aimed at flake products, where cortical flakes, cortical fragments, and flake-cores were most represented for all of the lithotypes. Only two cores were recycled, both from the Bi flint; however, the distribution of technological products observed likely more reflects the analysed cortical sample rather than Neanderthal selection.

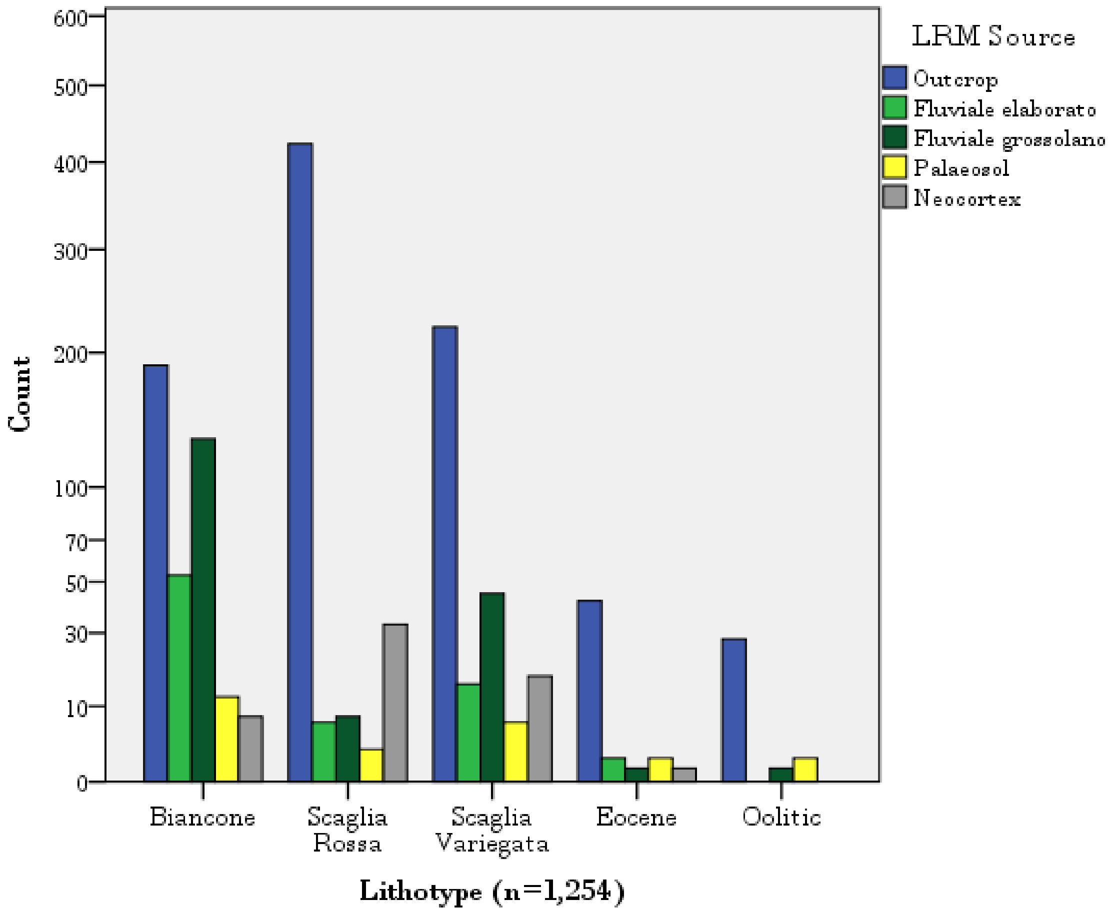


Figure 6.4: LRM procurement sources by sampled cortical lithotypes as determined in cortical analyses, indicating higher frequencies of fluvial source exploitation (greens) in Bi and SV, and higher incidences of recycling in SR and SV. Indeterminate LRM source (3.76% of analysed sample) not shown.

The Discoidal technological products in level A8+A9 demonstrated complete *chaînes opératoires* for all lithotypes, with the exception of RA, which was truncated at acquisition, and allochthonous flints, for which *chaîne opératoire* was indeterminate (Table 6.5). For all lithotypes, Phase 3 implements (retouching flakes) were not recorded during the initial analyses; it is likely that some of the smaller, unidentified flakes and fragments are attributable to this phase, as indeed, full production sequences and retouching are otherwise observed. The Diverse Phase, seen in all lithotypes except RA and the allochthonous flints, and mostly represented by shatter and undifferentiated flakes, could include Phase 3 retouching flakes.

Grotta di Fumane, Level A8+A9: Chaîne opératoire phases							
Lithotype	Phase 0	Phase 1	Phase 2a	Phase 2b	Phase 2c	Phase 3	Diverse
Bi	12.60	15.30	22.10	13.20	26.20	/	10.60
SR	11.36	13.90	18.80	12.60	31.60	0.22	11.60
SV	11.70	11.90	22.30	10.50	33.30	0.10	10.30
Eoc	3.70	6.90	24.00	14.20	34.20	/	16.70
Ool	4.70	5.40	18.80	9.40	55.70	/	6.00
Ra	50.00	/	25.00	0.00	25.00	/	/
Alloch	Indet	Indet	Indet	Indet	Indet	Indet	Indet

Table 6.5: Percentages of *chaînes opératoires* phases per lithotype in level A8+A9.

Phase 2, inclusive of its sub-phases, was the most represented in all lithotypes, demonstrating a uniformity in production aims toward the manufacture of flakes and pseudo-Levallois points (Table 6.6). Phase 2a, indicative of on-site core shaping and flake production activities, was well represented in all lithotypes (excluding non-analysed allocthonous flints), and included centripetal flakes and flaking accidents, as well as pseudo-Levallois points. Phase 2b, present in all lithotypes at around 10% or greater (with the exception of RA (absent) and allochthonous flints (not recorded)), was largely represented by débordant flakes (75%), along with Discoidal cores and crested core-edge flakes.

	Grotta di Fumane, level A8+A9: Technological categories by lithotype, n=7,969									
	Geneste Tech Category	Bi	SR	SV	Eoc	Ool	RA	Alloch	Tech Cat Total n	%
Phase 0	0	8	0	0	0	0			8	0.10
	1	643	158	113	9	7	2		932	11.70
Phase 1	2	794	193	115	17	8			1,127	14.14
Phase 2a	4	632	157	118	33	21			961	12.06
	6	333	67	58	9	6	1		474	5.95
	10	180	37	39	17	3			276	3.46
Phase 2b	11	102	32	18	4	1			157	1.97
	15	525	128	69	27	10			759	9.52
	16	58	15	14	4	3			94	1.18
Phase 2c	17	21	15	5					41	0.51
	18	158	42	36	5	5	1		247	3.10
	20	390	87	66	28	22			593	7.44
	21.1	410	141	83	16	14			664	8.33
	21.2	377	155	132	35	42			741	9.30
Phase 3	23		3	1					4	0.05
Diverse	26	552	161	99	41	9		29	891	11.18
	Lithotype Total	**5,183**	**1,391**	**966**	**245**	**151**	**4**	**29**	**7,969**	**100%**

Table 6.6: Level A8+A9 technological categories and *chaîne opératoire* phases by lithotype.

Phase 2c was the most represented phase of *chaîne opératoire* in level A8+A9, comprised mostly of cortical and non-cortical flake fragments, core fragments, flake-cores, and Kombewa flakes. The flake-cores were represented at equally low frequencies (ranging between 2-3%) in all major lithotypes, but the representation of Kombewa flakes was significantly higher in the

Eoc and Ool flints, at 11.38% and 14.75% respectively, versus 6-7% in Bi, SR, and SV. Overall, the strong representation of Phase 2c implements indicates that secondary production sequences featured in all lithotypes in the A8+A9 assemblage, but the prominence of these in Eoc and Ool may indicate technological strategies aimed at extending lithic use-life and functionality.

Acquisition, Phase 0, was dominated (99.1%) by flakes with greater than 50% cortex; only eight untested raw material blocks, exclusively Biancone, were recovered. Phase 0 was more highly represented in the local cryptocrystalline flints (Bi, SR, SV), nearly tripled that observed in the microcrystalline flint types (Eoc, Ool), indicating that the initial stages of acquisition and primary reduction sequences of these latter lithotypes occurred primarily off-site. The exception to the microcrystalline trend is the RA flint assemblage, for which Phase 0 represents half of the artefacts; however, this lithotype is very limited (n=4, or <0.1%), and therefore the two *entames* comprising this phase are not considered strongly indicative of any unusual *chaîne opératoire* profile, and rather may indicate an opportunistic procurement event of this LRM.

Phase 1, semi-cortical flakes, was represented in all lithotypes, with varying frequencies. For the cryptocrystalline flints, this phase was particularly well represented at around 12-15%. In conjunction with the relatively higher frequencies of Phase 0 in these lithotypes, it appears that these flints were introduced to and reduced on-site as blocks or minimally-reduced cores retaining cortex. Phase 1 in the microcrystalline flints was seen at half to a third of what was observed in the cryptocrystalline varieties; in conjunction with the low representation of Phase 0 implements and Phase 2b cores (Eoc 1.6% and Ool 0.7%) in these lithotypes, and the contrasting high frequency of Phase 2c implements indicative of secondary production sequences, the import of materials in the latter phases of production is further demonstrated.

Tools comprised 8.81% of the total A8+A9 lithic assemblage, of which 36.75% were non-retouched pseudo-Levallois points, typical of a Discoidal industry (Table 6.8). Per lithotype, SR presented the lowest percentage of tools overall (6.9%), followed by Bi (8.33%). Tool percentages were highest in the microcrystalline flints, particularly in the Eoc, reaching 14.23%. Within the individual lithotype tool assemblages, retouch frequencies varied, with again the lowest percentages of retouch in the SR and Bi tool assemblages, and the greatest retouch in the microcrystalline and allochthonous tools (Table 6.7). The exception to this was the Eoc flint tool assemblage, where tools are fairly evenly divided between non-retouched pseudo-Levallois points (48.57%) and retouched implements (51.43%).

Lithotype	Tools in lithotype assemblage %	% of Tools Retouched
Biancone	8.33	60.15
Scaglia Rossa	6.90	52.18
Scaglia Variegata	12.21	67.70
Eocene	14.23	51.44
Oolitic	9.39	78.57
Rosso Ammonitico	75.00	100.00
Allochthonous flints	13.79	100.00
Averaged %	**19.98**	**72.86**

Table 6.7: Tool representation in each lithotype of level A8+A9, and percentages of those tools that have been retouched

Of the retouched tools, those showing indeterminate retouch (Type 64, uncategorised retouch) were highly represented in all lithotypes, comprising ~30% of the overall level A8+A9 tool component. Implements with bulbar retouch (Type 45) and with thin retouch (Type 48) were also well represented, together reaching 14.5%; however, Bordes type-list numbers 45-50 have been interpreted as non-anthropic retouch caused by post-depositional effects (Mellars 1996). If this is the case in A8+A9, one must consider that retouch frequencies would be (mildly) lower across the different lithotypes.

Of the more standardised tool types, simple scrapers (Bordes Types 9-11) were most frequent (6.84%), and were best represented in the cryptocrystalline flints (89.36%). However, by lithotype, simple scrapers were most prevalent within the SR (11.6%) and Oolitic (21.53%) tool assemblages. Simple scrapers were less represented in the tool assemblages of the Eoc (~3%), Bi (5.78%), and SV (7.63%) flints. Scrapers with two retouched edges (including double, convergent, transverse, and déjeté scrapers together) comprised only 2.7% of the overall assemblage. These were represented in the lithotype tool assemblages at varied frequencies, at less than 3% of each with the exception of the Ool (7.14%) and limited RA assemblage (one double biconvex scraper equals 25% of the tool assemblage).

Blank preferences in the manufacture of retouched implements were not observed in any lithotype. The only exceptions are the two Mousterian points in SV flint, which were made exclusively on centripetal flakes. Simple scrapers were manufactured on a range of Discoidal products and sub-products ranging the full *chaînes opératoires*, including entirely cortical flakes, débordant flakes and flake fragments, as well as secondary *chaînes opératoires*, including flake-cores and Kombewa flakes. The same can be observed for the double scrapers, where products of both primary and secondary production sequences were utilised for their manufacture. These trends are further observed when considering the other tool types (end-scrapers, piercers, notches, and denticulates) recovered in the A8+A9 assemblage, including those implements with marginal retouch.

Grotta di Fumane Level A8+A9: Bordes Reference Types by Lithotype (n=7,969)

Lithotype and total frequency (Bordes Reference Type)	Bi (5,184)		SR (1,391)		SV (966)		Eoc (246)		Ool (149)		RA (4)		Alloch (29)		Total (7,969)	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
5	165	38.19	34	49.28	39	33.05	17	48.57	3	21.43					258	36.75
6					2	1.69									2	0.28
9	3	0.69			1	0.85	1	2.86	1	7.14					6	0.85
10	21	4.86	6	8.70	9	7.63	1	2.86	2	14.29					39	5.56
11	1	0.23	2	2.90											3	0.43
15	1	0.23							1	7.14			1	25.00	3	0.43
19					1	0.85									1	0.14
21	3	0.69	1	1.45											4	0.57
22	2	0.46			1	0.85	1	2.86							4	0.57
23	6	1.39													6	0.85
24	1	0.23													1	0.14
25	5	1.16			3	2.54	2	5.71			1	33.33			11	1.57
26					1	0.85									1	0.14
27	7		2	2.90	4	3.40									13	1.85
30	3	0.69			1	0.85									4	0.57
34					1	0.85									1	0.14
40	3	0.69													3	0.43
42	5	1.16	1	1.45	3	2.54									9	1.28
43	10	2.31	2	2.90	7	5.93									19	2.71
45	19	4.40	11	15.94	6	5.08			1	7.14					37	5.27
48	37	8.56	9	13.04	9	7.63	4	11.43	4	28.57	2	66.67			65	9.26
62	3	0.69	1	1.45	1	0.85	1	2.86					1	25.00	7	0.99
64	137	31.71	27	1.45	29	24.58	8	22.86	2	14.29			2	50.00	205	29.20
Total	**432**	**100%**	**96**	**100%**	**118**	**100%**	**35**	**100%**	**14**	**100%**	**3**	**100%**	**4**	**100%**	**702**	**100%**
% Lithotype	**8.33**		**6.9**		**12.21**		**14.23**		**9.39**		**75.00**		**13.79**		**8.81% all lithotypes**	

Table 6.8: Frequency of Bordian tool types by lithotype within the A8+A9 lithic assemblage.

Level A6

Level A6 of Grotta di Fumane contained a substantial Levallois lithic assemblage. 3,227 lithic artefacts were recovered from the level, of which 23 were excluded from analysis due to indeterminate lithotype, leaving a total of 3,204 lithic artefacts analysed.

As observed in level A8+A9, the dominant lithotypes in level A6 were the cryptocrystalline types Bi (67.38%), and SV (13.55%). Microcrystalline Eoc (6.21%) and Ool lithotypes (6.62%) were less represented (Table 6.9). The sub-lithotypes of Bi and SV were observed in minor frequencies. Whilst SR has been analysed separately, it represents the second-most utilised lithotype in the assemblage after Bi (see Unit A5+A6), and therefore each lithotype's overall frequency must be considered an over-estimate.

Grotta di Fumane, Layer A6: Techno-economic results, N=3,204									
Lithotype	**Frequency**	**Percent**	**Techno-culture**	**Dominant CO Phase**	**Chaîne opératoire**	**Retouch %**	**% cortical**	**Dominant LRM Source**	**Dominant LRM Form**
Bi	2,159	67.38	Levallois	2a	Complete	4.54	>34.51	Outcrop	Cobbles
Bei	16	0.50	Levallois	2a	Truncated	0.00	>12.50	Outcrop/ neocortex	Indet
Bib	36	1.12	Levallois	2a	Truncated	2.78	>22.22	Outcrop	Indet
Ros	5	0.16	Levallois	1	Truncated	20.00	>60.00	Fluvial	Cobbles
SV	434	13.55	Levallois	2a	Complete	8.06	>33.87	Outcrop	Blocks/ plates
nSV	85	2.65	Levallois	2a	Complete	7.06	>40.00	Outcrop	Blocks
mSV	32	1.00	Levallois	2a	Complete	0.00	>43.75	Outcrop	Blocks/ plates
Peoc	26	0.81	Levallois	2a	Truncated	11.54	>26.92	Outcrop	Blocks/ plates
Eoc	199	6.21	Levallois	2a	Complete	12.56	>27.14	Palaeosols	Nodules
Ool	212	6.62	Levallois	2c	Complete	4.72	>25.00	Palaeosols	Nodules
Total	**3,204**	**100%**							

Table 6.9: Level A6 techno-economic data by lithotype.

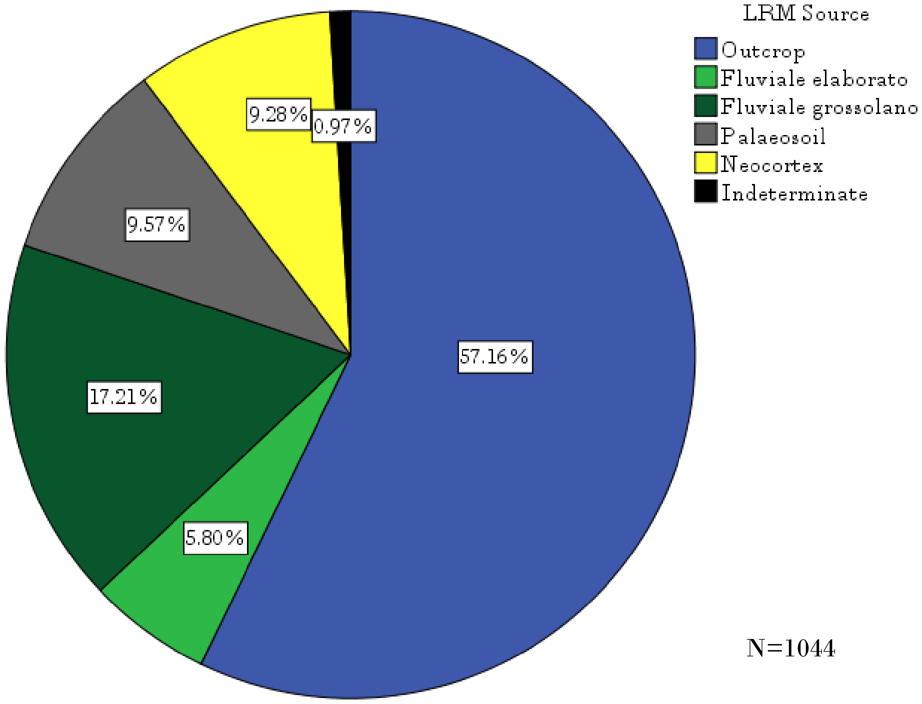


Figure 6.5: Distribution of LRM sources and forms identified in the cortical analyses of level A6.

Cortex presence varied amongst the lithotypes, with the cryptocrystalline varieties containing between 33% to 40% cortical pieces. This frequency is reduced in the microcrystalline and Peoc flint types, where cortical pieces were observed between 25 to 27%. Cortical analyses indicate that the exploited lithotypes were acquired predominantly from primary outcrops (57.16%) as nodules, blocks, plates, and undifferentiated block/plates (Figure 6.5). This represents a decrease in primary outcrop exploitation from level A8+A9, at 69.46%. Secondary source exploitation from streambed sources (23.01%) was comparable to A8+A9 (20.26%), but palaeosol exploitation increased from 4.35% to 9.57%. Recycling of older artefacts (as seen through patination, or neocortex) also increased relative to A8+A9, from 2% of the analysed sample to 9.28%, and is seen mostly in Bi.

The shifts in LRM source exploitation level from A8+A9 to A6 were most represented by the microcrystalline flints. These had been procured predominantly from primary outcrops in A8+A9; however, cortical analyses of level A6 do not show any outcrop exploitation in the Ool and Eoc flints (Figure 6.6). Ool flint procurement shifted to nearly exclusively palaeosol exploitation (97.02%), with limited (2.98%) fluvial procurement. Eoc flint procurement also shifted toward palaeosol sources (90%), with limited streambed (8%) and recycling (2%). As observed in level A8+A9, Bi and SV flints showed higher exploitations of streambed sources than the other assemblage lithotypes. However, in comparison to A8+A9, these frequencies were reduced, with Bi streambed exploitation observed at 29% as compared to 47%, and more than halved in SV, decreased from 19.5% to 8.6%. Biancone sub-lithotype Ros was procured exclusively from secondary fluvial sources; comprising less than 2% of the A6 assemblage, this may represent an opportunistic procurement event. Cortical analyses of the Peoc flint, which was not observed in A8+A9, demonstrated procurement predominantly from outcrops (71%), with lesser palaeosol (14.3%), and recycled contexts (14.3%); streambed exploitation of this lithotype was not observed. The recycling of the Peoc flints is interesting, as this lithotype is not observed in level A8+A9, and between the two anthropic levels, A7 is sterile. As there is no evidence for intensive digging of the cave floor by Neanderthal occupants, the recycled Peoc flint may have been procured from another site.

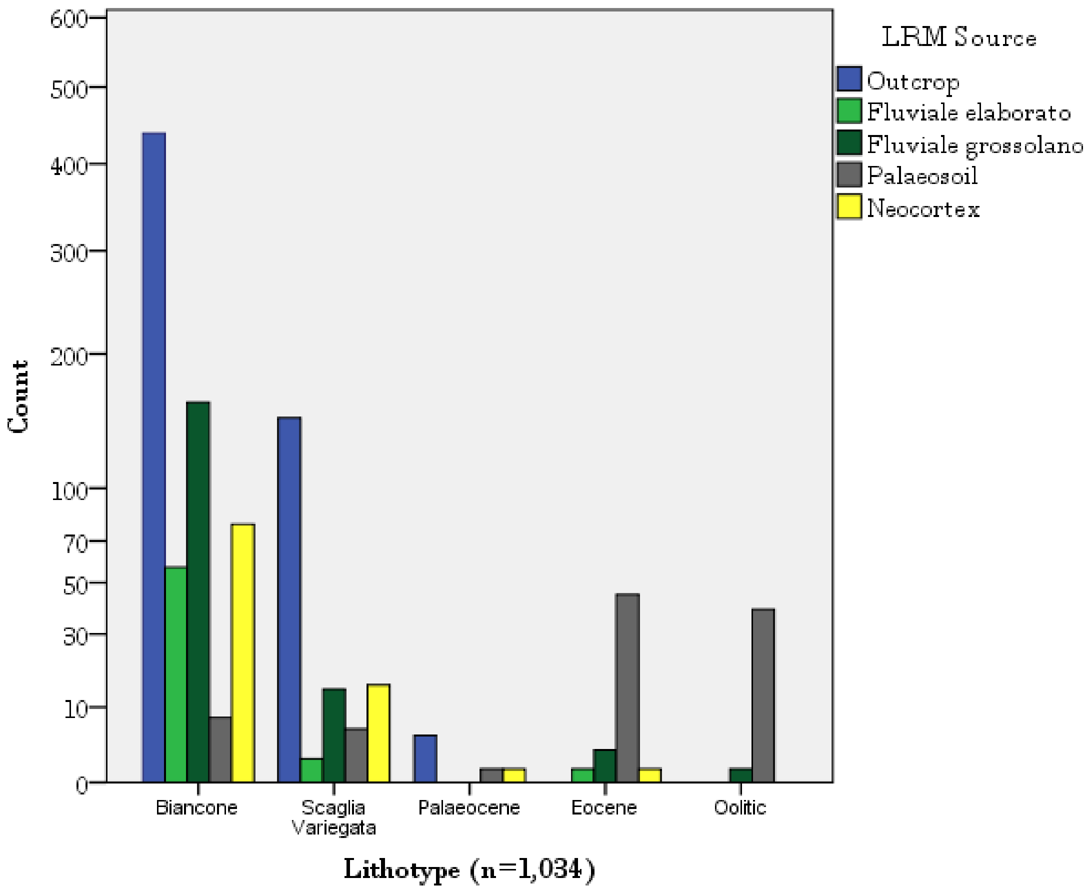


Figure 6.6: Exploited LRM sources per lithotype sample as determined through cortical analyses of level A6 (excluding indeterminate source, n= 10; 0.97%)

For all lithotypes, Levallois technologies dominated, and production sequences were initiated by unidirectional removals to shape the core and produce Levallois products and sub-products, regardless of LRM source or form (e.g. cobble vs. block). Continued production sequences featured centripetal removals to attain further implements from the core. Flakes-cores and Kombewa flakes representing secondary production sequences were limited in the A6 assemblage: these were not recorded in the Peoc and Bi ros sub-lithotype, and comprise only 1.48% of the Bi, 2.76% in SV, and 2% in Eoc flints. These sequences were best represented in the Ool (5.67%) flint and the Bi sub-lithotypes Bei (6.3%) and Bib (8.3%).

Unlike level A8+A9, Discoidal implements were limited in the A6 assemblage, and included a small number of cores (n=6; 6.93% of all cores, including flake-cores). Pseudo-Levallois points numbered 18 (0.56%) in the assemblage, and were predominantly manufactured from Biancone (n=10) flints, although these were also represented in Bib, Eoc, Ool (two each), SV, and nSV (1 each). Débordant flakes were observed in a very limited percent in Biancone flint (1.4%).

Grotta di Fumane, Level A6: Chaîne opératoire phases							
Lithotype	Phase 0	Phase 1	Phase 2a	Phase 2b	Phase 2c	Phase 3	Diverse
Bi	10.24	11.30	47.57	1.67	28.62	/	0.60
Bei	/	/	75.00	6.25	18.75	/	/
Bib	2.78	8.33	61.11	/	25.00	/	2.78
Ros	/	60.00	40.00	/	/	/	/
SV	7.60	8.99	52.07	2.53	27.88	/	0.92
nSV	5.88	12.94	51.76	3.53	24.71	/	1.18
mSV	12.50	12.50	59.38	6.25	9.38	/	/
Peoc	3.85	/	53.85	7.69	30.77	/	3.85
Eoc	4.02	9.05	57.29	2.01	26.63	/	1.01
Ool	1.89	4.25	40.09	0.94	52.36	/	0.47

Table 6.10: Percentage epresentations of *chaîne opératoire* phases for each lithotype in level A6.

The *chaînes opératoires* of level A6 were varyingly complete and truncated, largely in agreement with what was seen in level A8+A9: c*haînes opératoires* were complete in the more dominant cryptocrystalline flints types, and the microcrystalline flints showed the reduced presence of initial reduction sequences (Table 6.10). All of the lithotypes were most represented by products from Phase 2a, primary production sequences, as well as Phase 2c, indicating that secondary production sequences also occurred. Phase 2b was limited in the Bi flint (1.67%), and was represented mostly by Levallois cores (Table 6.11). The cryptocrystalline sub-lithotypes showed truncated (and varying) *chaîne opératoire* phases, which may be correlated to their minor representation in the assemblage and the possible opportunistic procurement of these flints.

	Grotta di Fumane, Level A6: Technological categories by lithotype, N=3,204												
	Geneste Tech Category	**Bi**	**Bei**	**Bib**	**Ros**	**SV**	**nSV**	**mSV**	**Peoc**	**Eoc**	**Ool**	**Tech Cat Total** n	%
Phase 0	0	1					1					2	0.06
	1	220		1		33	4	4	1	8	4	275	8.58
Phase 1	2	244		3	3	39	11	4		18	9	331	10.33
Phase 2a	4	673	8	14	2	133	25	10	5	51	45	966	30.15
	6	88	2	3		18	7	3		14	15	150	4.68
	7	256	2	3		74	11	6	9	47	23	431	13.45
	10	10		2		1	1			2	2	18	0.56
Phase 2b	11	3	1			2					1	7	0.22
	12	6				2	3	1		2		14	0.44
	13	35				9		1	2	1	1	49	1.53
	14	2				1				2		5	0.16
Phase 2c	17	13				2			1	1		17	0.53
	18	4				4					1	9	0.28
	20	28	1	3		8	1			4	11	56	1.75
	21.1	196		4		42	11	1	2	10	19	285	8.90
	21.2	367	2	2		62	9	2	5	37	80	566	17.67
Diverse	26	13		1		4	1		1	2	1	23	0.72
	Lithotype Total	**2,159**	**16**	**36**	**5**	**434**	**85**	**32**	**26**	**199**	**212**	**3,204**	**100%**

Table 6.11: Technological categories and *chaîne opératoire* phases by lithotype.

Phase 0 was relatively limited in the Eoc and Ool lithotypes at <5%, and was comprised only of flakes with greater than 50% cortex: no tested or rough raw material blocks were observed. The absence of raw material blocks in these lithotypes further supports that cores were shaped off-site and introduced to the site in a reduced state, as was indicated by the lower representation of cortical pieces in these lithotypes. This is further supported by the limited presence of Phase 2b cores within the A6 assemblage. While the Peoc flint also showed limited cortex and Phase 0 implements, as well as a complete lack of Phase 1, Phase 2b is best represented in this lithotype, comprised of two Levallois cores. While these finds indicate on-site core reduction, based on the small size of the Peoc assemblage (n=26), and considering that seven of these were shown to be recycled, this may indicate a single exploitation event.

Tools were well-represented overall in level A6 (18.13%; Table 6.13), at a higher rate than observed for A8+A9 (8.81%). This is largely due to the high frequencies of unretouched Levallois flakes in level A6, which dominated the tool assemblage, seen at 60% to 70% in all lithotypes. That unretouched Levallois flakes comprise 66.95% of the tools in level A6, in comparison to the unretouched pseudo-Levallois points in level A8+A9 (36.75%), may highlight technological differences in the Levallois and Discoidal industries, or differing technological aims. However, the representation of tools per lithotype was comparable between the levels, with 19.98% in A8+A9 and 21.51% in level A6 (Table 6.12). Retouch in the tool assemblages of A6 was significantly lower than in the Discoidal level A8+A9, at 30.54% versus 72.86%.

Lithotype	Tools in lithotype assemblage %	% of Tools Retouched
Bi	15.70	26.13
Bei	12.50	0.00
Bib	16.67	16.67
Ros	20.00	100.00
SV	22.35	31.96
nSV	20.00	35.29
mSV	18.75	0.00
Peoc	38.46	30.00
Eoc	34.17	36.76
Ool	16.51	28.58
Averaged %	**21.51**	**30.54**

Table 6.12: Tool representation in each lithotype of level A6 and percentages of those tools that have been retouched

The dominant cryptocrystalline flint types Bi and SV showed significantly less retouch both in their assemblages overall (4.54% and 8.06%, respectively) and within their tool assemblages 26.12%, 31.96%) than the limited Peoc (11.54%; 30.00%) and Eoc (14%; 36.76%) flints, which may indicate increased management of these latter flint types. Interestingly, reportedly non-local (Bertola 2001; Peresani 2012), microcrystalline Ool flint was retouched to a lesser degree, at 4.72% of its total assemblage, although retouch in its tool assemblage is significant at 28.58%. Regarding the little-represented sub-lithotypes, these show varying degrees of retouch in their total assemblages, from none (Bei) to 7.06% (nSV) to 20.00% (ros).

Considering those retouched tools in the lithic assemblage (Table 6.13), scrapers, as in A8+A9, were the dominant tool types. These were made almost exclusively in the cryptocrystalline flints: at 96.67%, this is even higher than the 89.36% observed in A8+A9. In the microcrystalline lithotypes, a single scraper with a thinned back was manufactured in Ool flint, and a double biconvex scraper and a scraper with a thinned back were made from Eoc flint. Including all lithotypes, simple scrapers were observed at a comparable percent (6.71%) to A8+A9 (6.84%), and double-edged scrapers were only slightly better represented at 4.47% (versus 2.7%). These findings indicate that, despite the differing technological industries between the levels, manufactured tool types were comparable. These findings support that in both A8+A9 and A6, retouch represented function and maintenance in response to blank shape, given the comparable exploitation of flint types despite their differing *chaînes opératoires*.

Of the dominant lithotypes, simple scrapers were best represented in the Bi (9.31%) and SV (9.27%) tool assemblages. Double scrapers were also highest in the Bi (6.19%) and SV (5.16%) tool assemblages. For the little represented sub-lithotypes where retouch was present, tools included double straight scrapers (Bib and nSV) and a simple convex scraper (nSV). Retouched Palaeocene tools consisted of a Mousterian point, a simple straight scraper, and a flake with marginal retouch. Although scrapers and formal tools were limited in the Eoc and Ool flints, numerous implements with uncategorised retouch were recorded (Type 64), at 29.41% and 22.86% of the tool assemblages, respectively.

Overall, the lithic assemblages of level A6 of Grotta di Fumane show comparable production strategies between the lithotypes, although differences in representative *chaînes opératoires* and degrees of retouch were observed, and may represent Neanderthal responses to LRM quality or acquisition costs. These points will be returned to when the assemblage is revisited following terrain modelling (Section 6.2.4).

Grotta di Fumane Level A6: Bordes Reference Types by Lithotype (*excluding SR) (n=3,204)

Bordes Reference Type

Lithotype and total frequency	Bi (2,159)		Bei (16)		Bib (36)		Ros (5)		SV (434)		nSV (85)		mSV (32)		Peoc (26)		Eoc (199)		Ool (212)		Total (3,204)	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
1	231	68.14	2	100	3	50.00			65	67.01	11	64.7	6	100	7	70.00	41	60.3	23	65.71	389	66.95
5	10	2.95			2	33.33			1	1.03							2	2.94	2	5.71	17	2.94
6	2	0.59							1	1.03					1	10.00					4	0.69
7									1	1.03											1	0.17
9	27	7.96							4	4.12											31	5.35
10	13	1.10					1	100.00	5	5.15	1	5.88									20	3.44
11	1	0.29																			1	0.17
12	8	2.36			1	16.67			3	3.1	2	11.76									14	2.41
15									1	1.03							1	1.47			2	0.34
18	8	2.36																			8	1.38
19	1	0.29																			1	0.17
22	4	1.18																			4	0.69
23									1	1.03											1	0.17
26	1	0.29																			1	0.17
27	1	0.29							1	1.03							1	1.47	1	2.86	4	0.69
29	1	0.29																			1	0.17
30									1	1.03											1	0.17
32	1	0.29																			1	0.17
42	5	1.47							1	1.03					1	10.00					7	1.2
43	7	2.06							1	1.03							1	1.47			9	1.55
45									3	3.1					1	10.00	2	2.94	1	2.86	7	1.2
64	18	5.31							8	8.25	3	17.65					20	29.41	8	22.86	57	9.81
Total	**339**	**100%**	**2**	**100%**	**6**	**100%**	**1**	**100%**	**97**	**100%**	**17**	**100%**	**6**	**100%**	**10**	**100%**	**68**	**100%**	**35**	**100%**	**581**	**100.00**
% Lithotype	**15.7**		**12.5**		**16.67**		**20.00**		**22.35**		**20.00**		**18.75**		**38.46**		**34.17**		**16.51**		**18.13% all lithotypes***	

Table 6.13: Frequencies and percentages of Bordian tool types in the A6 assemblage by lithotype.

Level A5-A5+A6

The substantial Levallois assemblage of Level A5-A5+A6 contained 2,832 lithic artefacts; 23 of these were excluded from analyses due to indeterminate lithotype, leaving a total of 2,809 pieces. Of these, Bi was dominant at 69.7%, followed by SV (11.18%), Eoc (7.19%), and Ool (4.38%) (Table 6.14). Despite its separate analysis, SR was well represented in this level, as the second-most represented lithotype; therefore, the lithotype percentages provided in Table 6.14 are over-estimations. Sub-lithotypes, as in level A6, were little represented.

Grotta di Fumane, Level A5-A5+A6: Techno-economic results, N=2,809									
Lithotype	**Frequency**	**Percent**	**Techno-culture**	**Dominant CO Phase**	**Chaîne Opératoire**	**Retouch %**	**% Cortical**	**Dominant LRM Source**	**Dominant LRM Form**
Bi	1,958	69.70	Levallois	2a	Complete	5.41	>40.45	Outcrop	Indet
Bei	12	0.43	Levallois	2a	Truncated	16.67	>33.33	Outcrop	Indet
Bib	42	1.50	Levallois	2a	Complete	7.14	>19.04	Outcrop	Cobble
Ros	2	0.07	Levallois	2a	Truncated	0.00	0.00	No cortex	No cortex
SV	314	11.18	Levallois	2a	Complete	8.60	>33.12	Outcrop	Block/plate
nSV	106	3.77	Levallois	2a	Complete	10.38	>33.01	Outcrop	Block, block/plate
mSV	25	0.89	Levallois	2a	Truncated	4.00	>52.00	Outcrop	Block/plate
Peoc	25	0.89	Levallois	2a	Truncated	12.00	>28.00	Outcrop	Indet
Eoc	202	7.19	Levallois	2a	Complete	7.90	>34.16	Palaeosol	Nodules
Ool	123	4.38	Levallois	2c	Truncated	9.76	>25.20	Palaeosol	Nodules
Total	**2,809**	**100**							

Table 6.14: Simplified results of the techno-economic analyses of level A5-A5+A6.

As observed in A8+A9 and A6, cortex presence was highest in Bi at >40%. In SV and Eoc, cortex at ~33% is comparable to what was observed in level A6. The Ool and Peoc flints showed more limited cortex presence at 25% and 28%, respectively; as in A8+A9 and A6, this is interpreted as the more frequent introduction of these flint types to the site in the later stages of reduction.

Cortical analyses demonstrated LRM sources were mostly exploited as nodules, blocks, and plates from outcrops (55.64%) (Figure 6.7). However, like level A6, and in contrast to A8+A9, both Eoc and Ool were mostly procured from of secondary palaeosol sources (90.32%), fluvial sources (9.67%), with no outcrop exploitation (Figure 6.8). Streambed procurement of Bi was comparable to A6 at 28.59%, and in SV was still significant at 6.99%, but less than Eoc (9.52%); only 3.7% of Ool and no Peoc was fluvially-sourced. Neocortex was observed at 10.44% of the A5-A5+A6 industry, and primarily in Bi (Fig. 6.8): this is comparable to the incidence of neocortex in A6 (9.28%), but is an increase of more than 200% from A6, where neocortex was also observed more equally across each lithotype.

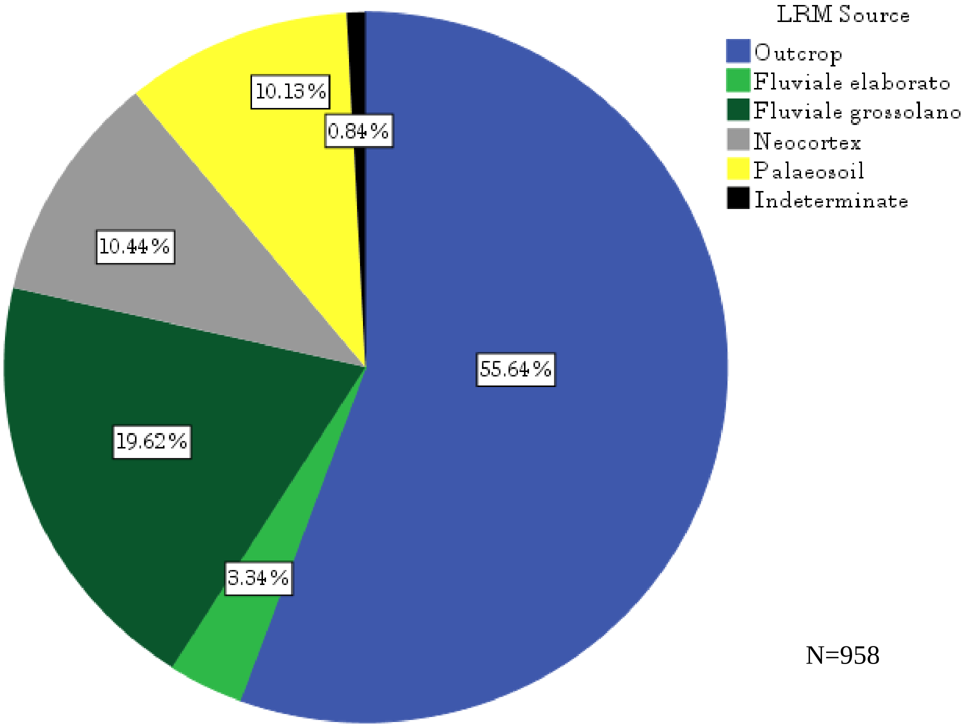


Figure 6.7: LRM sources exploited in A5-A5+A6 as determined by cortical analyses.

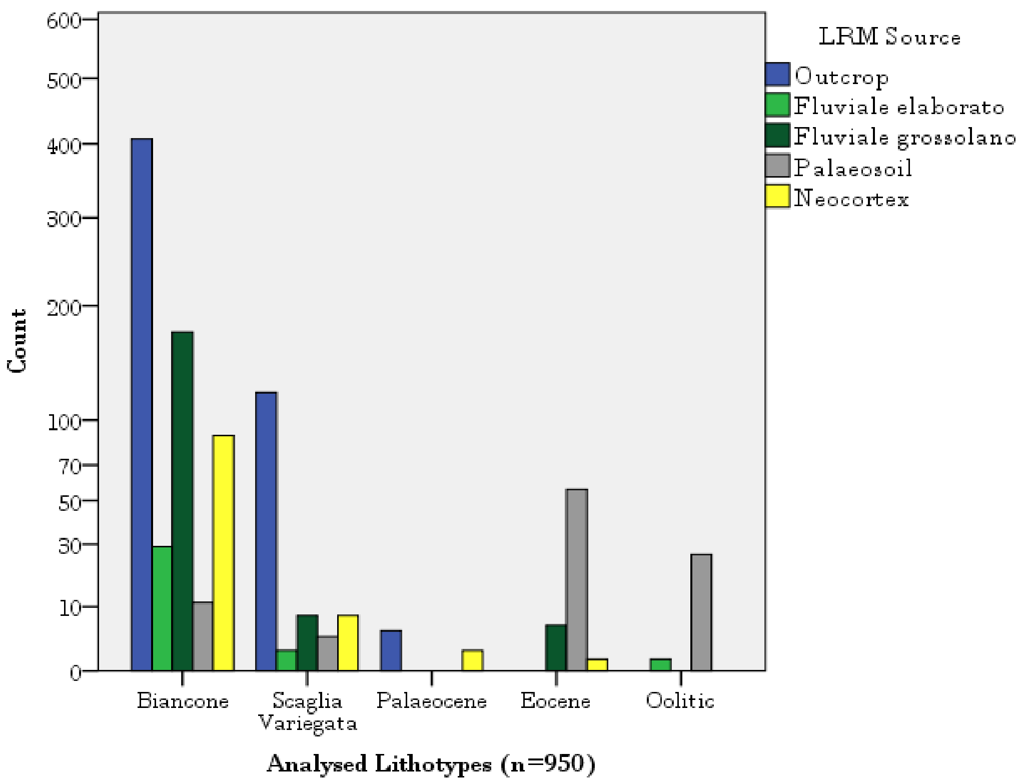


Figure 6.8: Exploited LRM sources for grouped lithotypes as determined by cortical analyses. Indeterminate source (n=8, 0.84%) not shown

Grotta di Fumane, Level A5-A5+A6: Chaîne opératoire phases							
Lithotype	Phase 0	Phase 1	Phase 2a	Phase 2b	Phase 2c	Phase 3	Diverse
Bi	8.12	12.21	44.89	1.74	32.74	/	0.31
Bei	16.67	8.33	75.00	/	/	/	/
Bib	4.76	2.38	59.52	2.38	30.95	/	/
Ros	/	/	100.00	/	/	/	/
SV	5.73	8.60	52.55	1.59	31.53	/	/
mSV	8.00	8.00	56.00	/	28.00	/	/
nSV	3.76	10.38	53.77	6.60	23.58	/	1.89
Peoc	8.00	8.00	56.00	/	28.00	/	/
Eoc	6.44	8.42	55.94	0.99	27.72	/	0.50
Ool	2.44	5.69	31.71	/	59.35	/	0.81

Table 6.15: Percentages of *chaîne opératoire* phases of the lithotypes in level A5-A5+A6.

Full Levallois *chaînes opératoires* were observed in each of the majorly represented lithotypes (Table 6.15). These indicated primary reduction sequences aimed at shaping cores (Phase 2b) to produce *entames* (Phase 0), semi-cortical flakes (Phase 1), Levallois flakes, and Levallois sub-products (Phase 2a) (Table 6.16). Secondary production sequences were indicated by Phase 2c products, including flake-cores, Kombewa flakes, and a significant number of non-cortical flake fragments. The full *chaînes opératoires* in the Bi and SV assemblages indicating on-site production sequences were supported by the elevated cortex presence in these assemblages, showing decortication and initial removals alongside debitage and cores. Although the cortex presence in the Eoc was comparable to that of the SV, the limited Phase 2b, represented by only a single flake-core, indicates that core reduction occurred off-site, and that cortical flakes rather than cores were introduced. In the Ool flint, with a truncated *chaîne opératoire*, Phase 2c was very highly represented at nearly 60%, indicating its conservation through intense on-site exploitation, but only one core fragment represents Phase 2b. While Phase 2b was lacking entirely from the Peoc assemblage, the initial phases of *chaînes opératoires* (Phases 0-2a) were well represented, indicating off-site core reduction and the transport of cortical flakes and core shaping flakes to the site. Levallois Phase 3 implements were not recorded for any of the lithotypes in the original analyses, but some of the smaller, unidentified flakes and fragments from Phases 2c and Diverse may represent retouch flakes, particularly where full reduction sequences and retouch were observed.

	Grotta di Fumane, Level A5-A5+A6: Technological categories by lithotype, N=2,809												
	Geneste Tech Category	**Bi**	**Bei**	**Bib**	**Ros**	**SV**	**nSV**	**mSV**	**Peoc**	**Eoc**	**Ool**	**Tech Cat Total n**	**%**
Phase 0	1	159	2	2		18	4	2	2	13	3	205	7.30
Phase 1	2	239	1	1		27	11	2	2	17	7	307	10.93
Phase 2a	4	572	8	15	1	97	35	10	4	57	17	816	29.05
	6	87		3		12	2	3	3	17	5	132	4.70
	7	207	1	7	1	54	18	1	7	39	14	349	12.42
	10	13				2	2				3	20	0.71
Phase 2b	11	2										2	0.07
	12	6				1	6			2		15	0.53
	13	28		1		3	1					33	1.17
	14	1				1						2	0.07
Phase 2c	17	14				1					1	16	0.57
	18	4				1			1	1		7	0.25
	20	31		1		4	2		2	9	7	56	1.99
	21.1	247		3		27	11	5	1	12	15	321	11.43
	21.2	342		9		66	12	2	3	34	50	518	18.44
Diverse	26	6					2			1	1	10	0.36
	Lithotype Total	**1,958**	**12**	**42**	**2**	**314**	**106**	**25**	**25**	**202**	**123**	**2,809**	**100%**

Table 6.16: Technological categories and *chaîne opératoire* phases.

As was observed for levels A8+A9 and A6, retouch was least prevalent in the dominant Bi lithotype (5.41%). Peoc was the most retouched (12%). Despite lower percentages of retouch in their total assemblages, Bi and SV showed the widest range of formal tools (within Bordes type-list) compared to the microcrystalline Ool and Eoc and the little-represented Peoc flints (Table 6.18). As in A6, tools percentages in the sub-lithotype assemblages were variable but typically higher than in the majorly represented lithotypes, ranging from 50% (Ros), 25.47% (nSV), and 25% (Bei) to 8% (mSV) (Table 6.17). Within these sub-lithotype assemblages, retouch was also varied; in the Bi ros assemblage (n=2), a single, non-retouch Levallois flake is recorded, and although only 8% of the mSV assemblage included tools, 50% of these were retouched. Along with the low frequencies of these sub-lithotypes in the assemblage their truncated *chaînes opératoires*, and higher tool percentages per lithotype (with the exception of mSV) may indicate that these lithotypes were opportunistically procured and reduced off-site, and were transported as personal gear.

Regarding tool assemblages, level A5-A5+A6 is comparable to A6, at 17.37% and 18.13, respectively: these values are significantly increased from A8+A9, where tools comprise 8.81% of the total lithic assemblage. As in A6, unretouched Levallois flakes dominated the tool assemblage of A5-A5+A6 at 61.48%. Across the lithotypes, simple scrapers were the dominant tool forms at 14.56%: this percentage is more than doubled what was observed for level A8+A9 and A6, perhaps indicating increased lithic management strategies in this final Mousterian level. Double scrapers in the A5-A5+A6 tool assemblage were comparable, however, to level A6 at 4.3%. As observed in A8+A9 and A6, both simple and double scrapers were nearly exclusively (98.55% and 95.24%, respectively) manufactured in cryptocrystalline flints (including sub-lithotypes). Implements with uncategorised retouch (category 64) were represented at 10.45% of the total tool assemblage, which is roughly comparable to A6 but only a third of what was observed in A8+A9. These tool types were most frequently observed in the Ool (38.46%) Eoc (26.92%), and Peoc (25%) tool assemblages. Other formal tool types in A5-A5+A6 included less represented Mousterian points (2.53%), notches (1.52%), and denticulates (2.02%).

Tool manufacture in all lithotypes occurred on a range of products from all *chaîne opératoire* phases, save Phase 2b. The tools in Bi, SV, and their sub-lithotypes were primarily made on cortical flakes and products from the primary reduction sequences (Phase 2a); Phase 2c products were utilised to a lesser extent. Phases 0 and 1 were not utilised for tools in the Peoc assemblage, and were subordinate to Phase 2a and 2c in the Eoc and Ool flints.

Lithotype	**Tools in lithotype assemblage %**	**% of Tools Retouched**
Bi	14.81	38.97
Bei	25.00	66.67
Bib	19.05	37.50
Ros	50.00	0.00
SV	21.97	34.78
nSV	25.47	40.74
mSV	8.00	50.00
Peoc	32.00	25.00
Eoc	25.74	30.77
Ool	21.14	53.85
Averaged %	**24.32**	**37.83**

Table 6.17: Tool representation in each lithotype of level A5-A5+A6 and percentages of those tools that have been retouched

Grotta di Fumane Level A5-A5+A6: Bordes Reference Types by Lithotype (*excluding SR)																						
Lithotype and total frequency	**Bi (1,958)**		**Bei (12)**		**Bib (42)**		**Ros (2)**		**SV (314)**		**nSV (106)**		**mSV (25)**		**Peoc (25)**		**Eoc (202)**		**Ool (123)**		**Total (2,809)**	
Bordes Reference Type	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
1	177	61.03	1	33.33	5	62.50	1	100.00	45	65.22	16	59.26	1	50.00	6	75.00	36	69.23	12	46.15	300	61.48
4																	1	1.92			1	0.21
5	11	3.79							2	2.89	2	7.41							3	11.54	18	3.69
6	2	0.69							3	4.34											5	1.02
8	2	0.69																			2	0.41
9	38	13.10	2	66.67	1	12.50			6	8.70	2	7.41	1	50.00							52	10.66
10	12	4.14			1	12.50			3	4.34	1	3.70							1	3.85	18	3.69
11	1	0.34																			1	0.21
12	5	1.72							1	1.45	1	3.70									7	1.43
15	1	0.34																			1	0.21
18	2	0.69							1	1.45											3	0.61
22	6	2.07							2	2.89	1	3.70									9	1.84
23																	1	1.92			1	0.21
25	1	0.34																			1	0.21
27	4	1.38																			4	0.82
29	1	0.34																			1	0.21
32	1	0.34																			1	0.21
40	1	0.34							1	1.45											2	0.41
42	2	0.69							1	1.45											3	0.61
43	4	1.38																			4	0.82
45	2	0.69									1	3.70									3	0.61
64	17	5.86			1	12.5			4	5.79	3	11.11			2	25.00	14	26.92	10	38.46	51	10.45
Total	**290**	**100%**	**3**	**100%**	**8**	**100%**	**1**	**100%**	**69**	**100%**	**27**	**100%**	**2**	**100%**	**8**	**100%**	**52**	**100%**	**26**	**100%**	**488**	**100%**
% Lithotype	**14.81**		**25.00**		**19.05**		**50.00**		**21.97**		**25.47**		**8.00**		**32.00**		**25.74**		**21.14**		**17.37% all lithotypes***	

Table 6.18: Bordian tool type frequencies and percentages by lithotype in level A5-A5+A6.

Unit A5+A6, Scaglia Rossa

The SR assemblage of levels A6 and A5-A5+A6 was analysed as a single unit, A5+A6, and therefore SR could not be analysed in the context of each level; however, it was majorly represented in both (di Taranto 2009-2010; Centi 2010-2011). This section will discuss the results of the techno-economic analysis of this lithotype, relating the results to the other lithotype assemblages A6 and A5-A5+A6, and making comparisons with the SR assemblage of A8+A9.

Grotta di Fumane, Unit A5+A6: Techno-economic results, N=917									
Lithotype	**Frequency**	**Percent**	**Techno-Culture**	**Dominant CO Phase**	**Chaîne opératoire**	**Retouch %**	**% cortical***	**Dominant LRM Source**	**Dominant LRM Form**
SR	917	100.00	Levallois	2a	Complete	5.13	>22.79	Outcrop	Nodules

Table 6.19: Simplified results of the techno-economic analyses of Scaglia Rossa.

917 SR lithic implements were analysed in unit A5+A6, >22.79% of which were cortical, a low figure compared to the other cryptocrystalline flints in levels A6 and A5-A5+6, and half this lithotype's cortical frequency in Discoidal level A8+A9 (Table 6.19). This low frequency is likely an underrepresentation due to analytic methods rather than manufacturing techniques: for the majority of flake fragments, cortical presence was not differentiated.

Cortical analyses indicated that SR was predominantly procured as blocks and nodules from primary outcrops (61%), which is a significant decrease from level A8+A9 (89%). Secondary blocks, plates, and nodules procured from palaeosols were much increased from A8+A9 (.2% to 16%), and rolled blocks and cobbles from secondary fluvial sources was a comparably low 1%.

Grotta di Fumane, Unit A5+A6, Scaglia Rossa: Chaîne opératoire phases							
Lithotype	Phase 0	Phase 1	Phase 2a	Phase 2b	Phase 2c	Phase 3	Diverse
SR	17.78	4.58	38.17	2.51	35.33	/	1.64

Table 6.20: *Chaînes opératoires* phases in Scaglia Rossa.

The SR assemblage showed full Levallois production sequences (Table 6.20). Secondary production sequences were seen in the extensive exploitation of cores, rather than flake-cores and Kombewa flakes, which were absent. Phase 2a and 2c were most represented at 38.17% and 35.33%, respectively (Table 6.21). Phase 0 (17.78%) was comprised entirely of flakes with >50% cortex; Phase 0 in SR is the highest across the MOIS-3 Grotta di Fumane assemblages, particularly considering that rough blocks in SR were not identified. Phase 1 was limited at <5%, as was Phase 2b, with more intense core reduction as compared to the other cryptocrystalline flint types (di Taranto 2009-2010). These findings indicate that, in addition to the on-site exploitation of SR cores, the Phase 0 cortical flakes may have been introduced to site following off-site removals: however, while evidence for the use of these as flake-cores is lacking, these were exclusively utilised for the manufacture of double scrapers. Phase 3, retouching flakes, were not recorded in the SR unit A5+A6 assemblage. As was noted for levels A8+A9 and A6, where retouching flakes were not recorded explicitly in the original technological analyses, it is likely that flakes from other production phases or the 'diverse' phase represent these implements, based on the observed retouch at 5.13%.

	Grotta di Fumane, Unit A5+A6: Technological categories by lithotype, N=917		
	Geneste Tech Category	**Scaglia Rossa**	**%**
Phase 0	1	163	17.78
Phase 1	2	42	4.59
Phase 2a	4	226	24.65
	7	124	13.52
Phase 2b	13	23	2.51
Phase 2c	21	312	34.02
	21.1	4	0.44
	21.2	8	8.7
Diverse	26	15	1.64
	Lithotype Total	**917**	**100%**

Table 6.21: *Chaîne opératoire* phases and technological categories in Scaglia Rossa, unit A5-A6.

At 5.13%, retouch in SR was comparable to the low retouch frequencies of SR in A8+A9 and Bi in A6 and A5-A5+A6. Phase 2a implements, including Levallois flakes (29.16%) and Levallois products (22.92%), were most retouched, followed by Phase 2c non-cortical flake fragments (16.67%). The least-represented technological categories with retouch were *entames* and cortical flake fragments. Overall, non-cortical pieces were more retouched than those retaining cortex (70% vs 30%); however, this may be an overestimation, based on the limited cortex recording in the original lithic analyses.

In the SR assemblage, 157 tools were identified, comprising 17.12% of the assemblage (Table 6.22). The majority of these were unretouched Levallois flakes (70.06%). Scrapers were the most frequent retouched tools in the tool assemblage, with simple (19.75%) prevailing over double types (2.55%). Simple scrapers were manufactured largely on Levallois flakes (41.94%), followed by Levallois sub-products (35.48%), semi-cortical flakes (16.13%) and cortical flake fragments (6.50%). Double scrapers were exclusively manufactured on Phase 0 cortical flakes; correlating this finding to the high representation of *entames* introduced to site, it is possible that the double scrapers were manufactured off-site. Notches (1.91%) and Levallois points (1.27%) were little represented. Tools with indeterminate retouching (Type 64) were observed at 4.46%, comparable to the SR tool assemblage of A8+A9 (1.45%), and significantly lower than observed in all of the other lithotypes in all levels. The indeterminate tools were manufactured exclusively on non-cortical flake fragments, indicating that activities involving marginal retouch may have focussed on this technological by-product.

	Grotta di Fumane Unit A5+A6, SR: Bordes Reference Types		
	Lithotype and total frequency	**SR (917)**	
		n	**%**
Bordes Type	1	110	70.06
	3	2	1.27
	9	31	19.75
	12	4	2.55
	42	3	1.91
	64	7	4.46
	Total	**157**	
	% Lithotype	**17.12**	

Table 6.22: Bordian tool types in Scaglia Rossa

6.2.3 Grotta di Fumane: Lithic prospection

During pedestrian survey of the Fumane landscape where lithic potential was indicated by geological maps, some areas were unable to be surveyed due to restricted access (private property, health and safety issues): these areas are outlined in Figure 6.9. However, despite these limitations, the survey covered significant ground and yielded substantial data on the lithic character of the Grotta di Fumane.

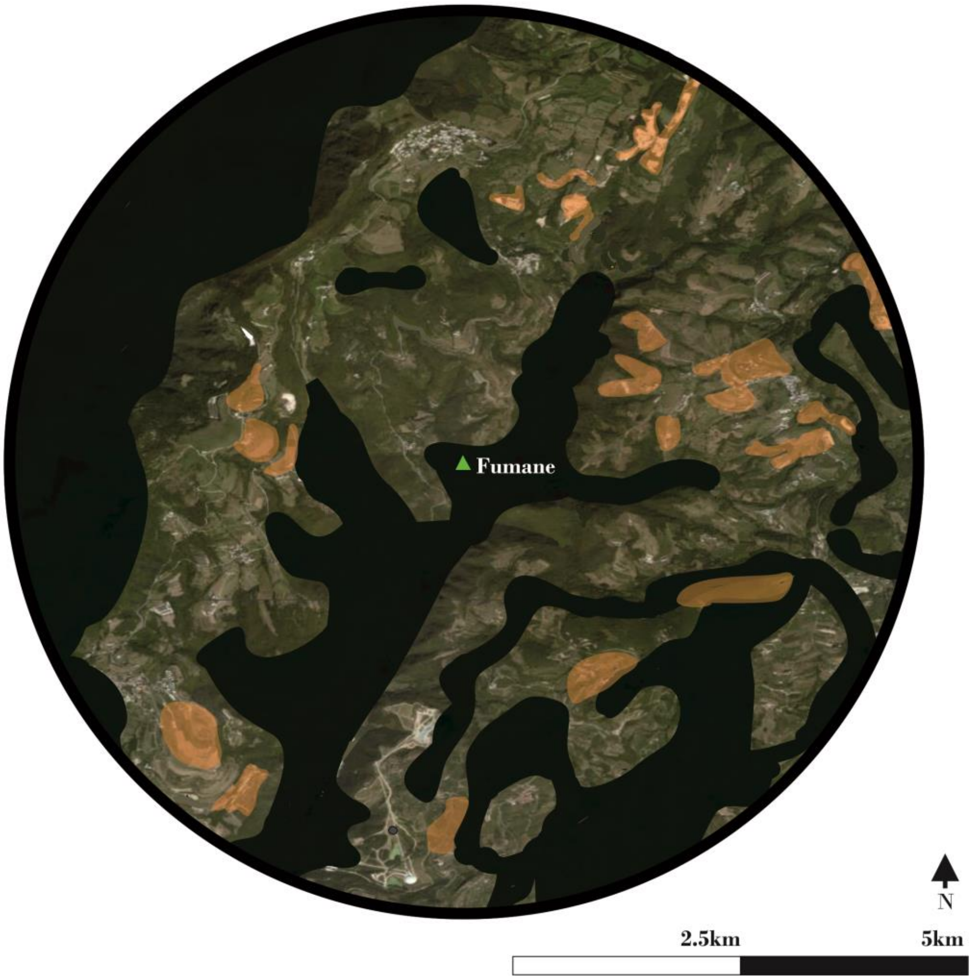


Figure 6.9: Areas not surveyed during lithic prospection. Dark areas represent non-flint bearing geological strata that were not surveyed (except streambeds), as indicated by the lithological map (Appendix A.1) of the study region. Orange indicates areas with flint potential that were not surveyed due to restricted access: private vineyards, farms, and quarries.

The results of the lithic prospection survey confirmed that the distribution of LRM around Grotta di Fumane was not ubiquitous: of the numerous potentially flint-bearing geological strata indicated by the lithological map, only some contained flint nodules, blocks, or plates. In contrast, secondary sources of LRM, which were not indicated on the lithological maps, were widely identified, predominantly in streambeds. Further, lithic prospection determined that the

LRM sources were not equally attractive in terms of quality, abundance, and size (Appendix D.1).

Primary lithic raw material sources

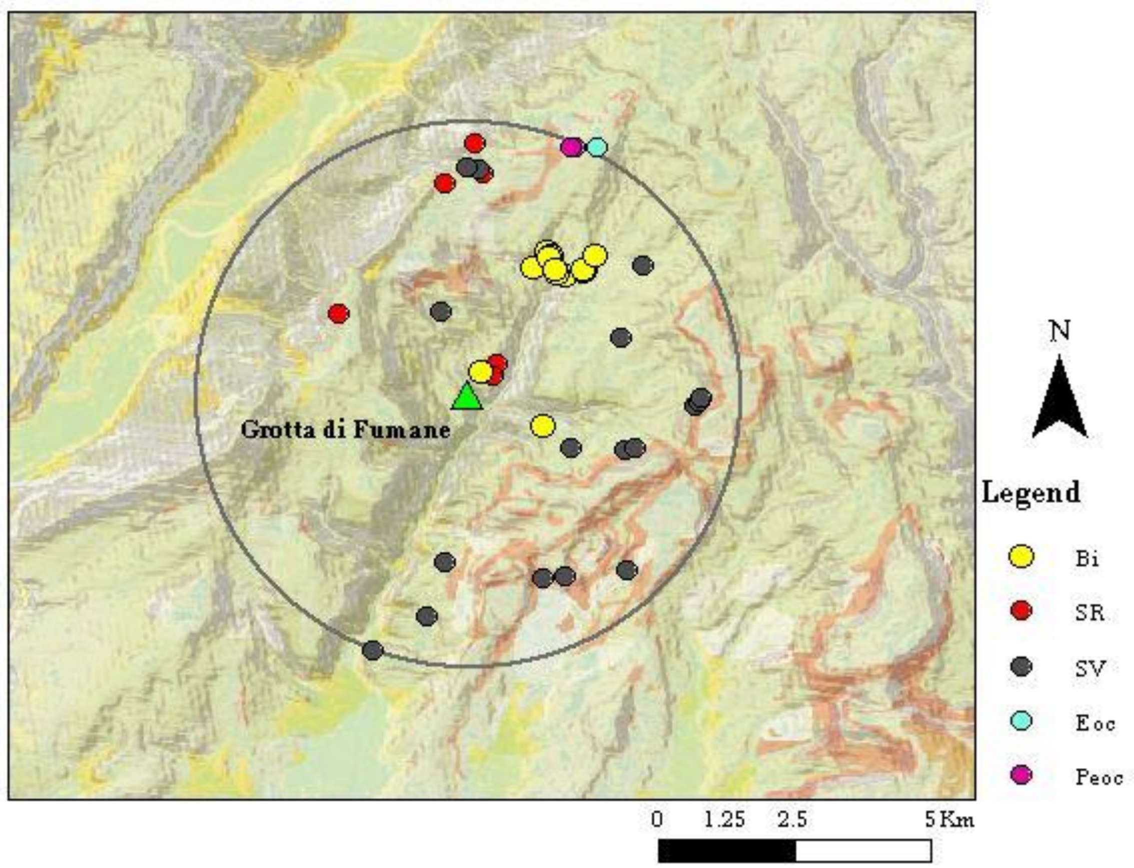


Figure 6.10: All primary flint outcrops identified during lithic prospection

A total of 39 primary LRM sources were identified during pedestrian survey (Figure 6.10; Appendix C.1). The identified primary sources outcropped in late Jurassic through Palaeocene geological formations that were mostly located on hill and mountain sides with slopes ranging from 20º to 90º cliff faces. The size ranges of these extents were found to be quite varied, from less than 10m in diameter to over 100m. Identified primary sources were largely cryptocrystalline flints (~95%), which corresponds with the frequency of these lithotypes in the assemblages of Grotta di Fumane.

Biancone (BI)

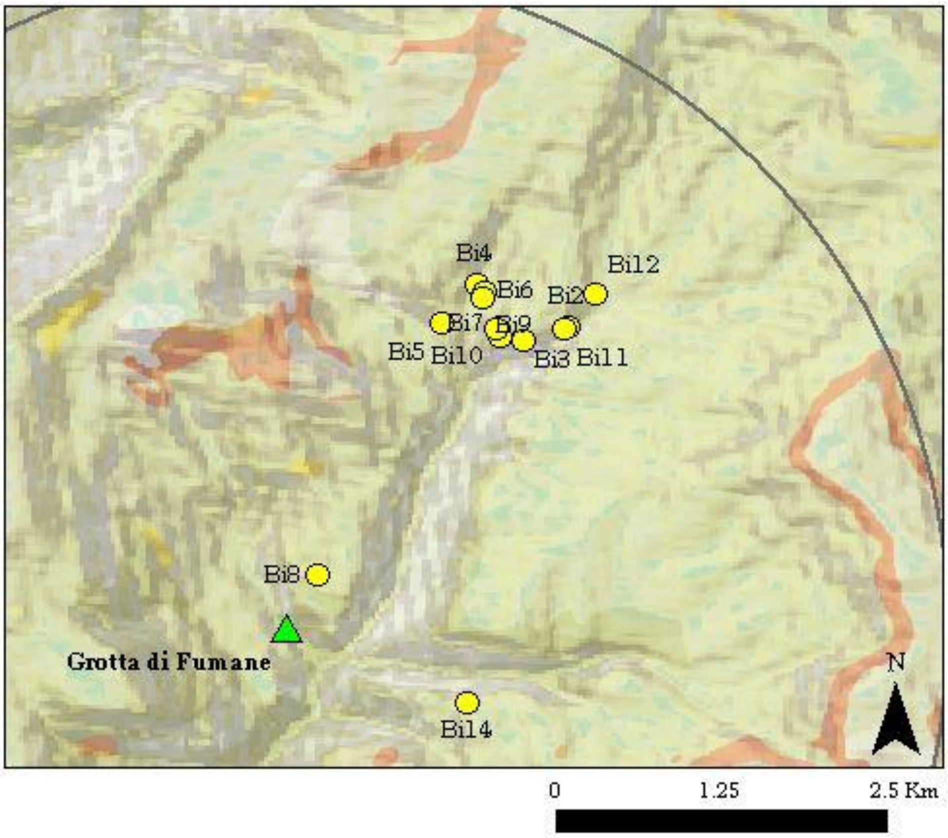
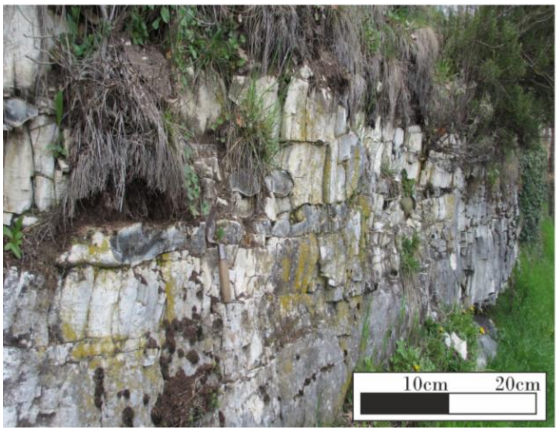


Figure 6.11: Primary sources of Biancone flint identified during lithic prospection.

A total of 13 primary sources containing plates, blocks, and nodules of Biancone flint were identified within a 5km radius of Fumane (Figure 6.11). These were mostly located within 1.5km of the site to the north and east, at elevations ranging from 340 to 640m asl. The colours of the identified Biancone flint included grey (BI) and beige/yellow (BEI) (Figure 6.12). Biancone white (Bib) and pink (Ros), which were recorded in the lithic assemblages of Grotta di Fumane, were not identified during this pedestrian survey. Due to the proximity and shared characteristics of some sources, identified Biancone outcrops were grouped into a single larger source. These include BI1, 2, and 11 (Bi Group A), Bi 3, 7, and 10 (Bi Group B), and Bi 4, 6, and 9 (Bi Group C).



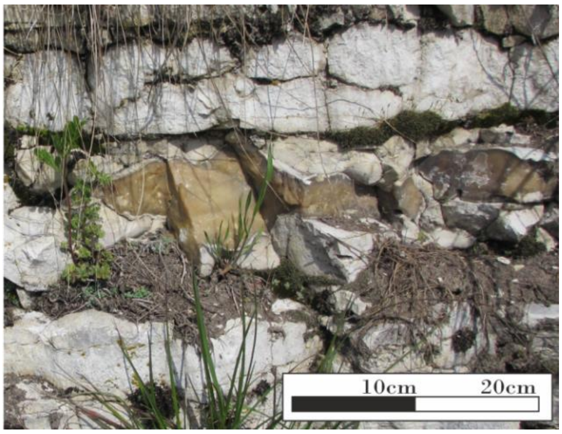


Figure 6.12: Primary outcrops of Biancone grey BI14 (left) and Biancone beige/caramel BI7 (right).

The determined attractiveness quotients of each of these sources based on their identified characteristics varied (see Table 6.23), with the most attractive primary source, BI14 (AQ 16), located approximately 1km, to the east of the site[3]. The primary source with the lowest attractiveness rating (AQ 1), BI8, was the highly fissured, beige Biancone, which was located nearest to the site at a distance of less than 500m.

Flint Source	Munsell Hue	Quality	Extent of Source	Difficulty of Terrain	Cost of Extraction	Size	Scarcity	Attractiveness Quotient (AQ)	Rank
BI1	10YR 7/8	4	1	TBD (1)	1	3	4	3	5
BI2	10YR 7/8	2	1	TBD (1)	1	3	3	2	6
BI3	7.5YR 4/6	4	1	TBD (1)	1	3	3	4	4
BI4	GL2 5/5PB	4	2	TBD (1)	1	4	3	10.67	3
BI5	10YR 6/2	4	2	TBD (1)	1	4	3	10.67	3
BI6	10YR 7/6	8	2	TBD (1)	1	3	4	12	2
BI7	10YR 7/6	8	2	TBD (1)	1	3	4	12	2
BI8	10YR 5/3	1	1	TBD (1)	1	3	3	1	7
BI9	GL2 4/5PB	2	1	TBD (1)	1	3	3	2	6
BI10	10YR 7/6	4	1	TBD (1)	1	3	4	3	5
BI11	10YR 7/6	2	1	TBD (1)	1	3	3	2	6
BI12	10YR 7/6	2	1	TBD (1)	1	3	3	2	6
BI14	7.5YR 5/1 to 5YR 5/1	4	4	TBD (1)	1	3	3	16	1

Table 6.23: Identified primary sources of Biancone flints, with attractiveness variables, save terrain difficulty.

[3] Euclidean-delineated, straight-lined distances are given in the Lithic Prospection Results, for later comparisons with least-cost path distances and hypothetical mobility route distances in Terrain Modelling Results.

Scaglia Rossa (SR)

A total of six primary outcrops of SR flint were identified within a 5km radius of Grotta di Fumane (Figure 6.13). The flints were observed as blocks and plates from upper Cretaceous geological strata, at elevations ranging from 510m to 865m asl and at distances 0.5km to 4.8km from the site. Only reddish-brown coloured SR was identified (2.5YR 4/4 to 5/4); this is in agreement with the representation of SR in the lithic assemblages of Grotta di Fumane.

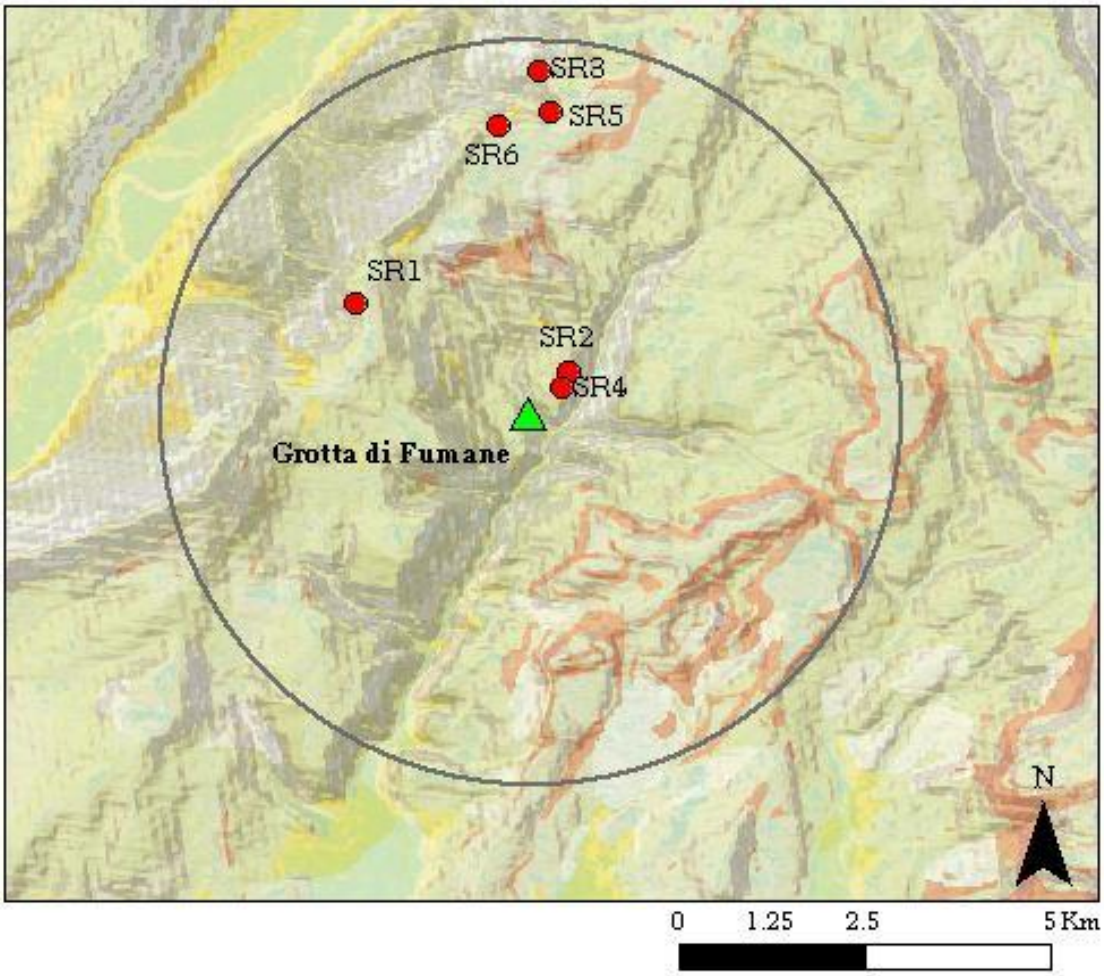


Figure 6.13: Primary SR outcrops identified during lithic prospection.

The attractiveness ratings of each of these sources varied significantly (Table 6.24). The least attractive sources, SR2 and SR4, both located within 500m of the site, had low AQs due to the extreme fissuring and incomplete silicification of most flint blocks (Figure 6.14a). The most attractive source, SR1, located west of the site, had an AQ of 16, based on the 'very extensive' source extent and the size and quality of the nodules, lacking internal fracturing (Figure 6.14b).

Flint Source	Munsell Hue	Quality	Extent of Source	Difficulty of Terrain	Cost of Extraction	Size	Scarcity	Attractiveness Quotient (AQ)	Rank
SR1	5YR 4/6	4	4	TBD (1)	1	3	3	16	1
SR2	5YR 5/8	1	1	TBD (1)	1	4	4	1	5
SR3	5YR 5/3	2	2	TBD (1)	1	2	4	2	4
SR4	5YR 5/8	1	1	TBD (1)	1	4	4	1	5
SR5	5YR 5/3	4	2	TBD (1)	1	2	4	4	3
SR6	5YR 4/6	8	1	TBD (1)	1	2	3	5.34	2

Table 6.24: Attractiveness variables and AQs of identified SR primary outcrops.

Figure 6.14: a) Poor quality outcrop SR4 with detail; b) good quality SR1 outcrop with large nodules and source extent.

Scaglia Variegata (SV)

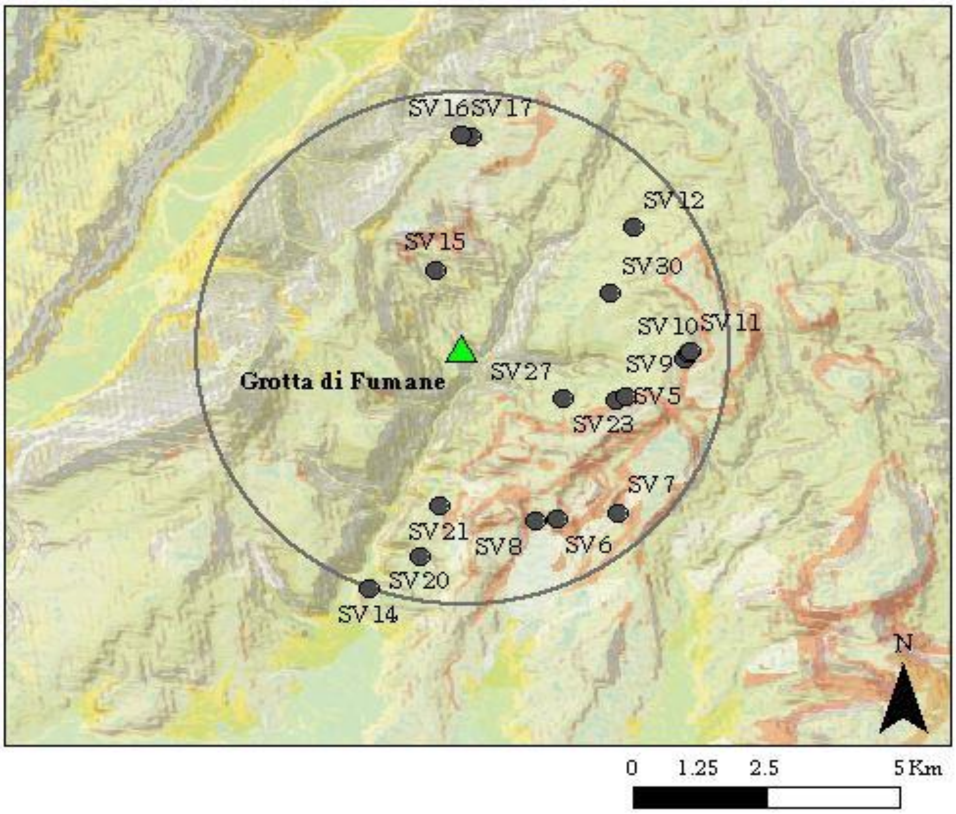


Figure 6.15: Primary SV sources identified during lithic prospection.

A total of 17 primary sources of SV including blocks, plates, and nodules of poor to good quality were identified. These were located at elevations ranging from around 300m asl in the south to over 800m asl near the northern margin of the Lessini Plateau (Figure 6.15). The colours of the identified SV flint included grey-green (SV) and black (nSV) (Figure 6.16). The chestnut brown SV (mSV) lithotype was not identified.

Figure 6.16: Black Scaglia variegata (nSV) nodule of poor quality.

The determined attractiveness of the SV primary sources was highly varied (Table 6.25), from the most attractive sources (AQ 5.33), SV12 and SV23, to the least attractive, SV14, which was a small outcrop of heavily fissured black SV (nSV) with an AQ of .67.

Flint Source	Munsell Hue	Quality	Extent of Source	Difficulty of Terrain	Cost of Extraction	Size	Scarcity	Attractiveness Quotient (AQ)	Rank
SV5	5YR 2.5/1 to 5YR 4/4	2	2	TBD (1)	1	2	3	2.67	4
SV6	5YR 5/2	2	2	TBD (1)	1	3	3	4	2
SV7	5YR 2.5/1	1	2	TBD (1)	1	2	4	1	8
SV8	5YR 2.5/1	1	2	TBD (1)	1	2	4	1	8
SV9	5YR 4/1 to 5YR 4/6	2	2	TBD (1)	1	2	4	2	5
SV10	5YR 4/1 to 5YR 4/6	2	2	TBD (1)	1	2	3	2.67	4
SV11	5YR 4/1 to 5YR 4/6	1	2	TBD (1)	1	2	3	1.34	7
SV12	10YR 4/1	4	2	TBD (1)	1	2	3	5.33	1
SV14	5Y 6/1 to 2.5YR 5/3	1	1	TBD (1)	1	2	3	0.67	9
SV15	10YR 2/1	4	2	TBD (1)	1	2	3	4	2
SV16	10YR 2/1	1	2	TBD (1)	1	3	3	2	5
SV17	10YR 5/6	1	2	TBD (1)	1	3	4	1.5	6
SV20	2.5Y 3/1	2	1	TBD (1)	1	2	3	1.34	7
SV21	2.5Y 3/1	1	4	TBD (1)	1	3	4	3	3
SV23	5YR 2.5/1 to 5YR 4/4	4	2	TBD (1)	1	2	3	5.33	1
SV27	5Y 2.5/1	1	2	TBD (1)	1	2	4	1	8
SV31	5Y 3/2	1	2	TBD (1)	1	2	2	2	5

Table 6.25: Attractiveness variables and AQs of the identified primary SV sources.

Palaeocene (Peoc)

Two primary outcrops containing nodules of Peoc flint were located during pedestrian survey for lithic prospection, at elevations ranging from 930m to 950m asl (Figure 6.17). These were located southwest of the town of Fosse, in proximity to one another, outcropping from the same eroding Tertiary geological strata (Figure 6.18a). The colour of these flint nodules was a medium greyish-brown (7.5YR 4/1 to 4/2), covered by a thin (~2mm) whitish-grey limestone cortex, and their quality was very good (Figure 6.18b).

The determined attractiveness of the sources ranked the same (AQ 32) (Table 6.26), Both Peoc1 and Peoc2 had large source extents, and contained numerous nodules of high quality cryptocrystalline flints: because these sources both represented different sections of the same large outcrop, they were analysed together as Peoc Group in the terrain analyses.

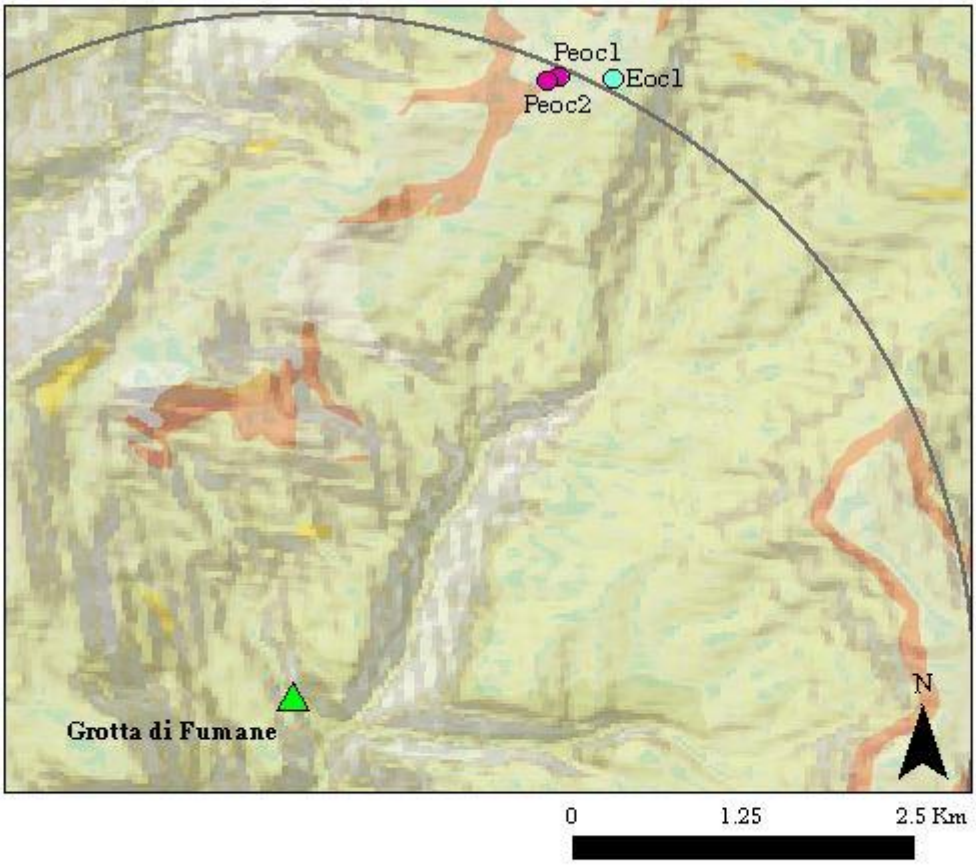


Figure 6.17: Palaeocene and Eocene outcrops identified during lithic prospection.

Figure 6.18: a) Degrading section of Palaeocene outcrop; b) Palaeocene nodule.

Flint Source	Munsell Hue	Quality	Extent of Source	Difficulty of Terrain	Cost of Extraction	Size	Scarcity	Attractiveness Quotient (AQ)	Rank
Peoc1	7.5YR 4/1 to 4/2	8	4	TBD (1)	1	3	3	32	1
Peoc2	7.5YR 4/1 to 4/2	8	4	TBD (1)	1	3	3	32	1

Table 6.26: Attractiveness variables of the Palaeocene outcrops.

Eocene (Eoc)

One primary outcrop of Eoc flint (Eoc1) was identified during lithic prospection (Figure 6.17). Located at ~930m asl, the light greyish-white blocks (Figure 6.19) were recovered from the Tertiary geological stratum, above the Peoc outcrops on the same landform southwest of the town of Fosse. Locating the brownish-grey Eoc flints purported to outcrop southeast of the Grotta di Fumane near the town of Marano (Bertola 2001) was unsuccessful: survey of the western edge of this Tertiary strata came up negative for flint. The AQ of the identified Eoc outcrop is 6 (Table 6.27), based on the lack of internal fissuring, the significant size of the blocks, fair quality, and small outcrop size.

Figure 6.19: Primary outcrop of Eocene flint (left), with close-up of Eocene block/plate (right).

Flint Source	Munsell Hue	Quality	Extent of Source	Difficulty of Terrain	Cost of Extraction	Size	Scarcity	Attractiveness Quotient (AQ)	Rank
Eoc1	GL1 8/1	2	1	TBD (1)	1	3	1	6	1

Table 6.27: Attractiveness variables and AQ of identified primary outcrop of Eocene flint.

Rosso Ammonitico (RA)

No primary sources of RA were identified during lithic prospection, despite observations that this flint outcrops locally around Grotta di Fumane (Bertola 2001; Peresani 2012).

Oolitic (Ool, Tenno Formation)

No primary sources of Ool flints were identified within a 5km radius of Grotta di Fumane. These results are in agreement with previous claims of its non-local provenance (Bertola 2001; Peresani 2012).

Secondary lithic raw material sources

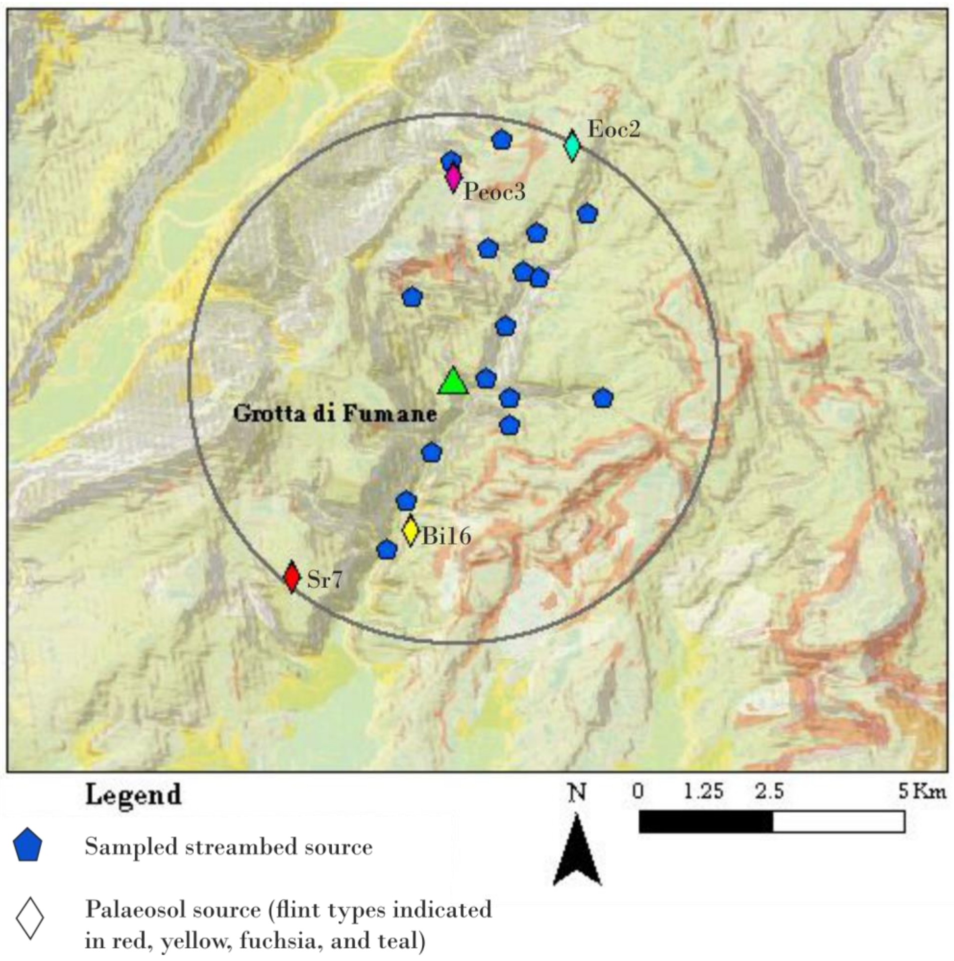


Figure 6.20: Secondary flint sources identified within the local 5km radius of Grotta di Fumane.

Secondary LRM sources were identified widely in the landscape around Grotta di Fumane; however, these were mostly limited to the streambeds and ravines that dissect the mountainous terrain (Figure 6.20; Appendix C.1). A detailed discussion of the secondary streambed sources will come after the following overview of the secondary palaeosol sources around Grotta di Fumane.

Palaeosols

Only four secondary sources of flint eroding from soils (likely from degraded outcrops) were identified (SR, BI, Peoc, Eoc). The characteristics of these sources varied significantly (Table 6.28).

Flint Source	Munsell Hue	Quality	Extent of Source	Difficulty of Terrain	Cost of Extraction	Size	Scarcity	Attractiveness Quotient (AQ)	Rank
SR7	5YR 5/8	4	4	TBD (1)	1	3	3	12	2
BI16	7.5YR 4/6	8	4	TBD (1)	1	4	3	42.67	1
Peoc3	7.5YR 4/1	8	1	TBD (1)	1	2	4	4	3
Eoc2	2.5Y 5/1	1	2	TBD (1)	1	3	4	1.5	4

Table 6.28: Attractiveness variables and AQ of secondary palaeosol flint sources.

The very extensive (>100m) palaeosol source of Bi (BI16) was located approximately 3km south of Grotta di Fumane, near Grotta della Ghiacciaia, and within the property boundaries of a modern quarry. While the yellow/caramel coloured (gBI) nodules (Figure 6.21a) were of very good quality and abundance (AQ 42.67), this flint type was not identified at Grotta di Fumane. SR (SR7) was found in loose soils approximately 4.3km to the south-southwest, which extended around 200m, although with low abundance (AQ 2). A solitary Peoc nodule (Peoc3) of very good quality was recovered from loose farm soils. The secondary source of Eoc flint (Eoc2) was represented by large, loose nodules of poor quality, with internal fractures and nummulitic cortex (Figure 6.21b), eroding from soils near primary outcrop Eoc1.

Figure 6.21: a (left), loose Bi blocks and nodules eroded from palaeosol source Bi16; b (right), Eoc nodule from eroded palaeosol source Eoc2.

Streambed sources

The results of the lithic prospection showed that, with the exception of RA and allochthonous flints, each of the lithotypes recovered in the studied assemblages of Grotta di Fumane could be recovered from secondary flint deposits in streambed sources (Appendix D.1, Table D.4). Within the 22 sampled $1m^2$ test areas, a range of cryptocrystalline and microcrystalline flint types were identified (Figure 6.22), and only 6 were negative for flint (see Table 6.29 at end of this section).

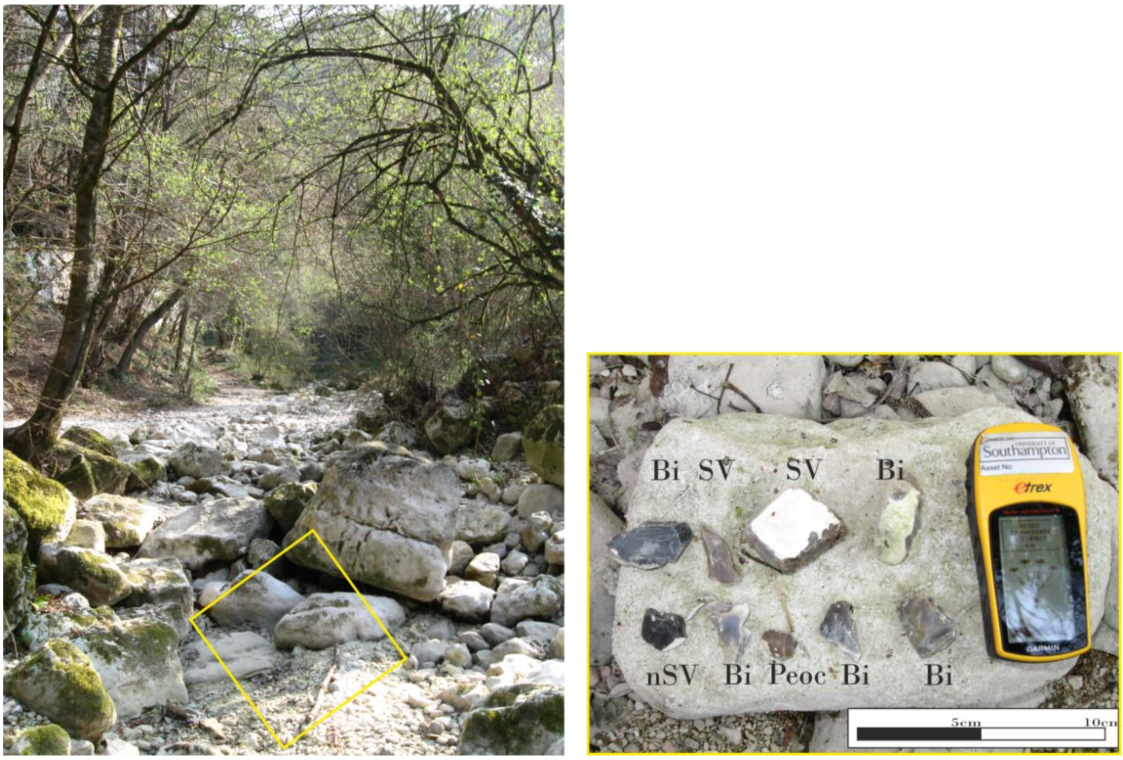


Figure 6.22: Streambed east of Fumane landform (left), with approximate location of sampled area SB1 outlined by yellow square; on right are those flint types identified within SB1.

Secondary sources of Bi flint were found in the form of nodules and blocks, primarily in streambeds and ravines, where it eroded from primary outcrops at higher elevations. Bi flints (Bi and Bei) were observed in nearly all of the ravines and streambeds around Grotta di Fumane, although in limited frequency, size, and quality (Figure 6.23).

Secondary sources of SR flint were identified only within two streambeds. A single, large nodule was identified approximately 2km north of Fumane; as no primary outcrops were identified at higher elevations around this stream, it is likely that the nodule eroded from sediments that may currently obscure SR visibility in this area of the landscape (Figure 6.24). SR was significantly more substantial in terms of quantity farther north in streambed test unit 20, as smaller rolled blocks.

Figure 6.23: Bi block/nodule in streambed east of the Fumane landform.

Figure 6.24: SR nodule found in streambed test area (SB16) north of Grotta di Fumane, next to small Eocene nodule (left). SV block, also identified, not pictured.

SV (SV, nSV) was identified in 50% of the sampled streambeds and ravines; its quality was generally poor to fair, and pieces ranged from very small up to 15cm. Peoc flint was found in SB1, and in three streambeds in the northern-most extent of the surveyed area. Observed Peoc nodules were of a medium size, good quality, and in a low frequency (<5% of sampled areas). Eoc flint was seen in four streambeds; each observed incidence was a single rolled nodule within the sampled metre, of poor to fair quality and small size. While Ool flint is reportedly non-local, outcropping 5km from Fumane at the top of the Valpantena and Adige Valleys according to literary reports (Bertola 2001; Peresani 2012), a streambed source of small nodules was identified in SB6. Although no associated primary outcrops were identified, it is possible that the nodules eroded from higher elevations in the cliffs that line the ravine, and thus were not visible during survey. That this flint type was not observed in the sampled areas downstream indicates that it is of low abundance in the Fumane region.

LRM Sources	Type	Form	Quality	Source Extent (m)	Size (cm)	Scarcity
SB1	Bi, SV, nSV, Peoc	Rolled blocks and nodules	4, 8	4	2	3
SB2	Bi, bei, SV, Eoc	Rolled blocks and nodules	0, 4, 8	4	2	3
SB3	Sv, Bei	Rolled blocks and nodules	4	4	2	3
SB4	Bi, Bei	Rolled blocks and nodules	4	4	2	4
SB5	Negative					
SB6	Sv, Bi, Bei, Ool	Rolled blocks and nodules	4	4	2	3
SB7	Negative					
SB8	Bi, Bei, SV, nSV	Rolled blocks and nodules	0, 4	4	3	3
SB9	Bi, SV	Rolled blocks and nodules	4	4	2	4
SB10	Bi, SV, nSV	Rolled blocks and nodules	0, 4	4	2	3
SB11	Bi, SV, nSV	Rolled blocks and nodules	0, 4	4	2	3
SB12	Negative					
SB13	Negative					
SB14	SV, nSV	Rolled blocks and nodules	0	4	2	4
SB15	Negative					
SB16	SR, SV, Eoc	Nodules	4	4	2	4
SB17	Eoc	Rolled nodules	0	4	2	4
SB18	Peoc, Eoc	Rolled nodules	0, 4	4	2	4
SB19	Peoc	Rolled nodules	8	4	2	4
SB20	SV, SR, Peoc	Rolled blocks and nodules	4, 8	4	2	3
SB21	Negative					
SB22	Negative					

Table 6.29: Results of the 1x1m² tested streambed areas

6.2.4 Grotta di Fumane: Terrain modelling

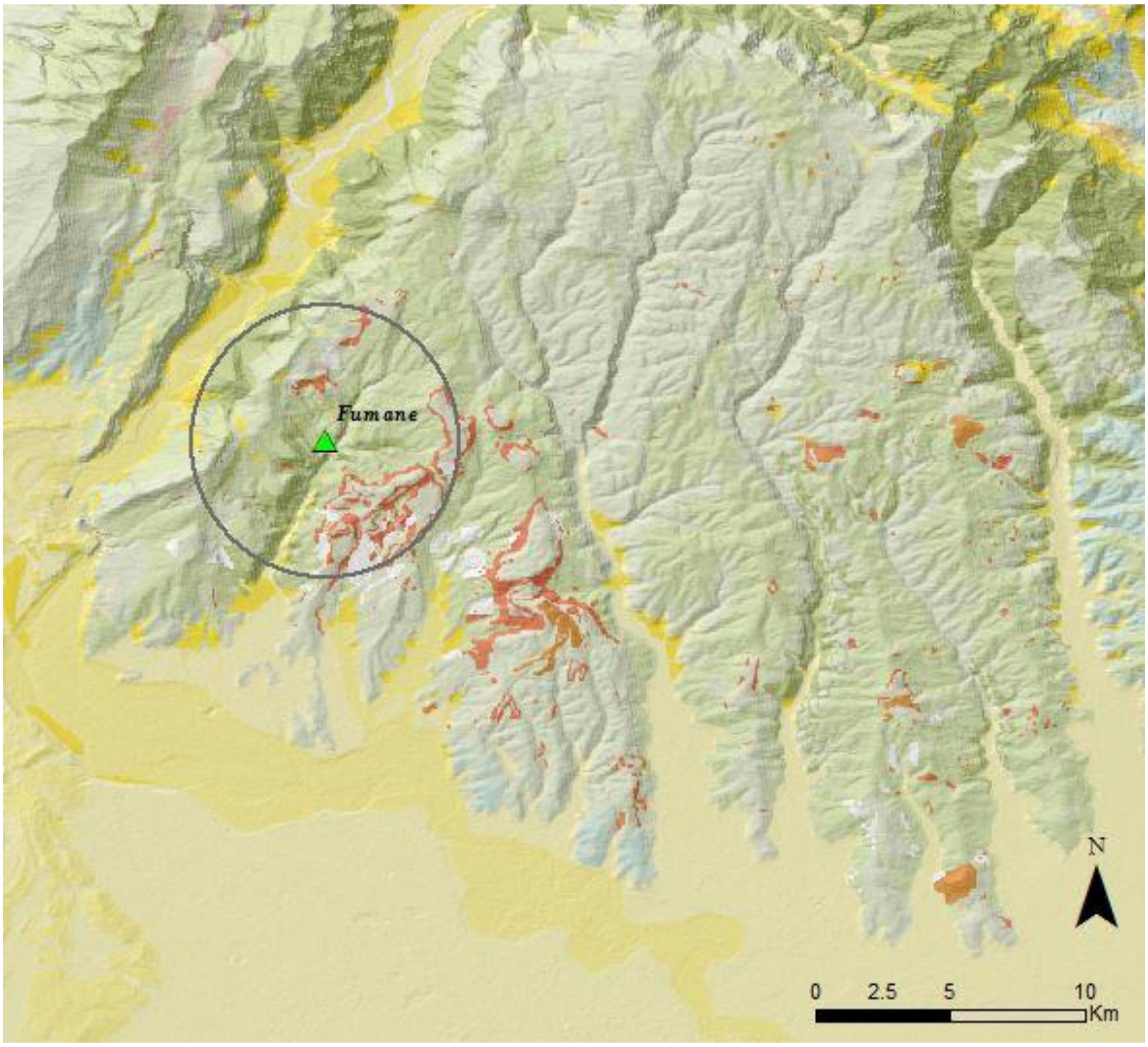


Figure 6.25: Visualisation of the terrain and lithology of the Monti Lessini and Grotta di Fumane. 5km Euclidean buffer zone shown.

Topographic and lithological visualisation highlighted the rugged terrain and flint potential of the Grotta di Fumane landscape (Figure 6.25). Considering the distribution of identified LRM sources in the landscape, primary sources were largely distributed along hillsides in lower elevations, palaeosols were largely found to the south, and fluvial sources of flints were widespread (Figure 6.26a). Even removing the LRMs identified as poor quality (Figure 6.26b), flint is still abundant and widespread in the landscape.

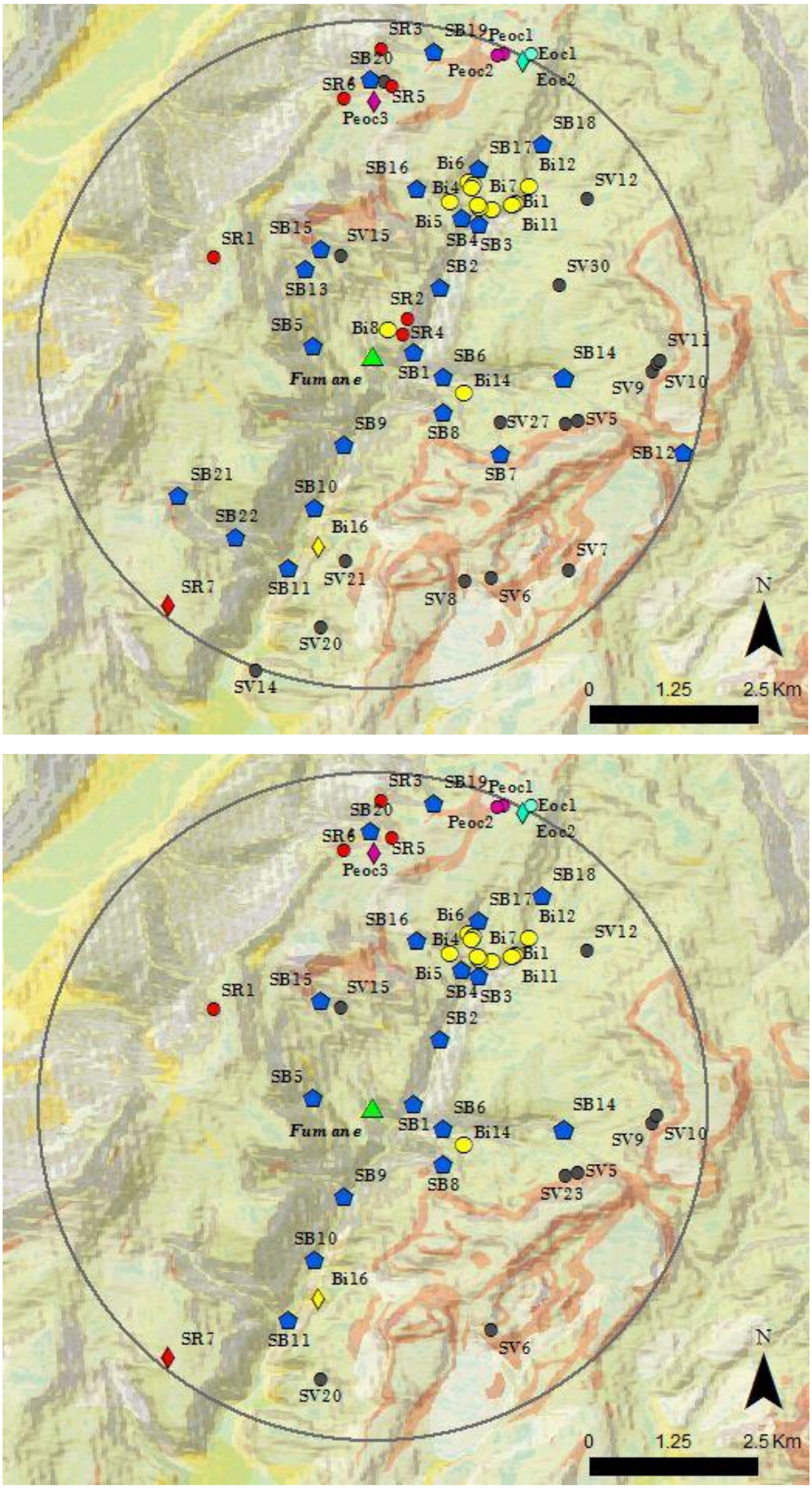


Figure 6.26: a) All primary and secondary flint sources identified during lithic prospection plotted on terrain map. Bi- yellow; SR- red; SV, grey; Eoc, teal, Peoc, fuchsia. Blue hexagon- streambed sources, diamond- palaeosol source. b) Identified LRM sources of ‘fair’ or higher quality.

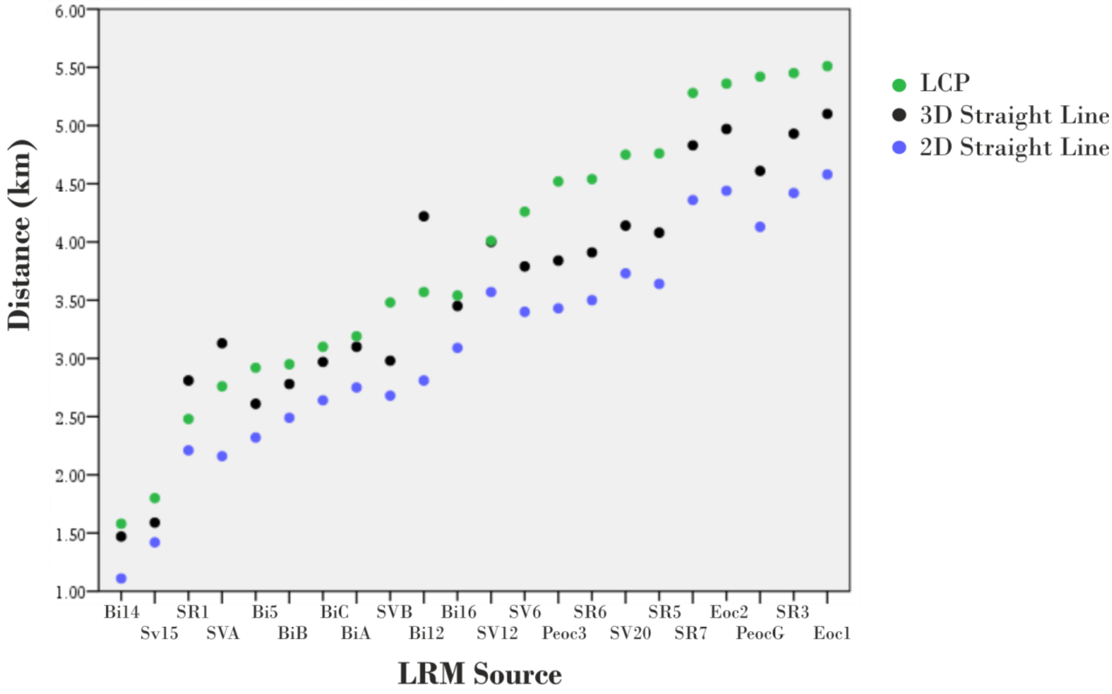


Figure 6.27: Comparative distances of the three hypothetical mobility routes to each identified LRM primary and palaeosol source.

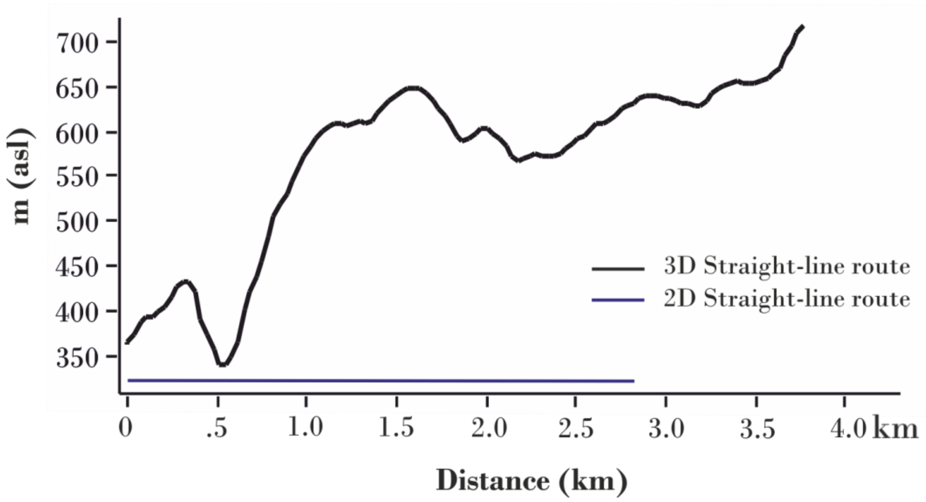


Figure 6.28: Comparison of the distances and elevations of the 3D (black) and 2D (blue) straight-line hypothetical mobility routes from Grotta di Fumane to SV Group B.

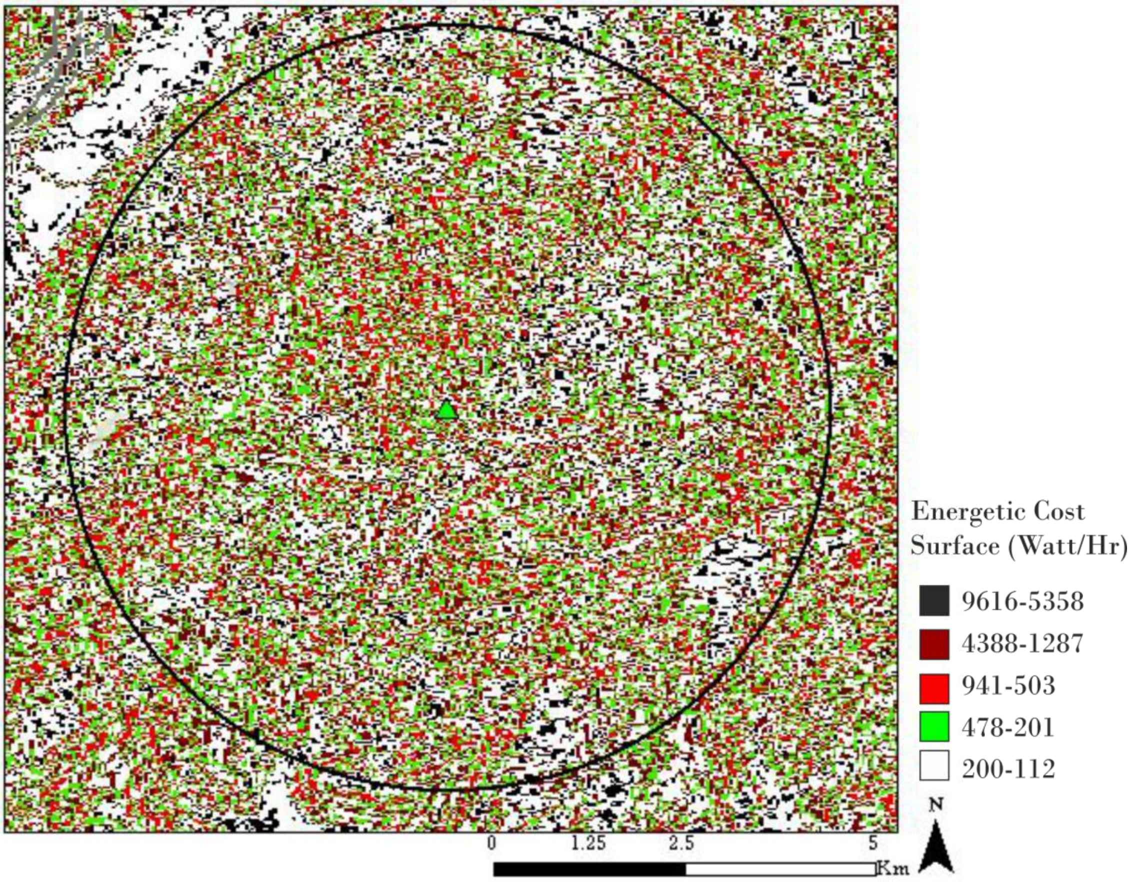


Figure 6.29: Energetic cost surfaces generated for Grotta di Fumane (Watt costs converted to kcal for analyses). Lower costs in white and green correspond to streams and hill

The results of the three source-to-site hypothetical mobility routes demonstrated that the various methodologies resulted in large discrepancies in distance measurements, over a kilometre in some cases (Figure 6.27). Comparing these distances (Appendix E.1), all projected 2D straight-line routes were found to be far shorter than both the 3D straight line distances and the least-cost path distances, showing that this method of delineating economic zonation is clearly inaccurate. The 3D straight-line routes, while of merit in that they considered topography, could not exclude terrain that was considered unnavigable, as exemplified by the route to LRM source SV Group B (SV9 and SV10) that incorporated slopes up to 70º (Figure 6.28). Further, inclusive of topography the 3D straight line distances, which theoretically represent shortest distances, often presented *longer* distances than the least-cost paths, and therefore, like 2D distances, do not represent viable means of determining Neanderthal mobility routes and economic zonation.

The preparation of cost surfaces for modelling least-cost paths demonstrated that the topography of the landscape would clearly impact travel speeds and energetic costs, with steeper slopes resulting in slower walking speeds and higher metabolic outputs (Figure 6.29).

The visualised cost surface indicates higher cost areas (white), which align to the steep slopes adjacent to streambeds and to vertical valley walls, and lower cost areas including reduced slopes and streambeds (grey to black), where less caloric energy was required, facilitating faster walking velocity.

The results of the least-cost path analyses in this costed terrain were winding routes, similar to natural human movement over uneven ground, with switchbacks employed to navigate physical movement impediments and reduce energy loads. The LCPs took advantage of natural corridors with lower slopes and steadier terrain, including streambeds and upland plateaus where secondary sources of flint occurred (Figure 6.30), and avoided steep slopes such as were encountered in the 3D straight-line routes (Figure 6.31).

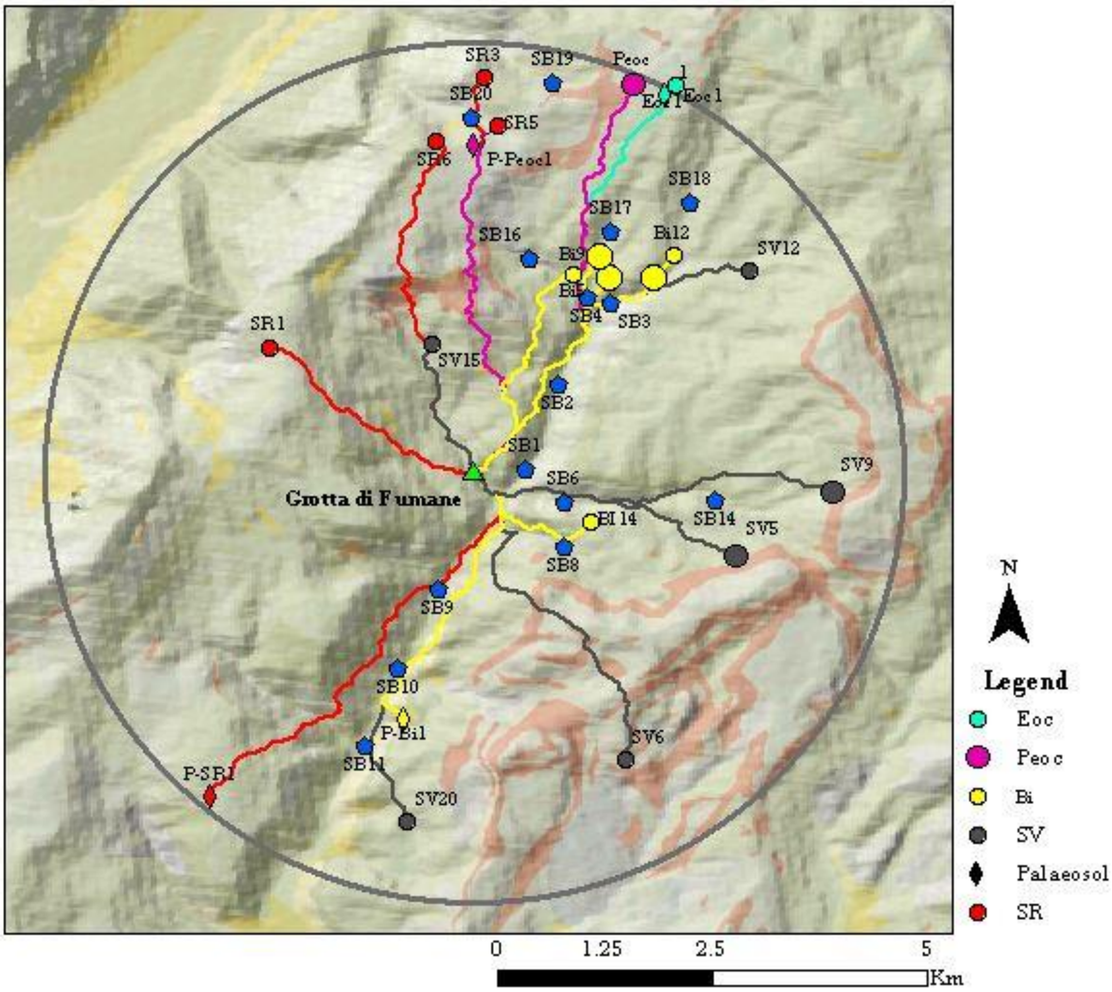


Figure 6.30: Source-to-site least-cost pathways. LCP route colours align with LRM colour coding.

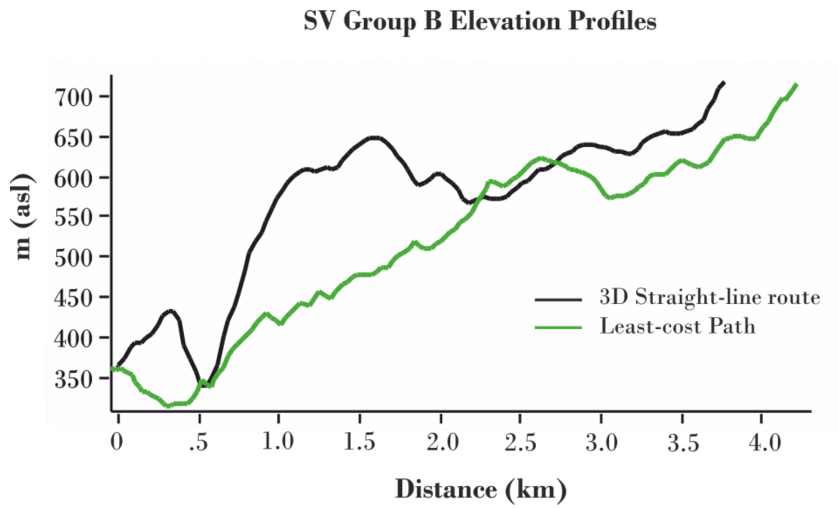


Figure 6.31: Comparative terrain incorporated in 3D straight-line routes vs. LCP hypothetical mobility routes for LRM source SV Group B.

The energetic costs of the LCPs varied according to distance and terrain (Appendix E.1). LCPs that incorporated higher slopes due to the nature of the landscape had higher energetic costs than routes of comparable distance, as well as some of shorter distances (Figure 6.32). In demonstrating that shorter distance routes can have higher energetic costs, these findings have direct implications for the impact of terrain on Neanderthal mobility.

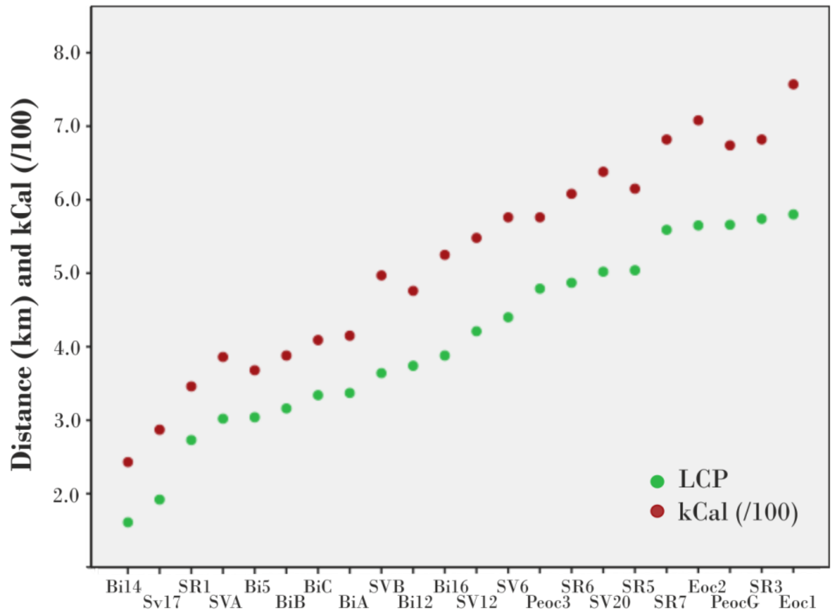


Figure 6.32: Comparison between LCP distance (green) and kcal (divided by 100 to enable graphic comparisons) expenditure (red). Note that the energetic expenditures are variably higher than the distances covered, indicating the impact of rugged topography.

Refiguring the attractiveness equations for each LRM source, factoring in the energetic costs (watts converted to kcal) as the previously null *terrain difficulty* variable, it became clear that the attractiveness of a source was significantly reduced when costs were higher (Figure 6.33; Appendix E.1). These results re-characterised the lithic landscape around Grotta di Fumane, as the energetic costs of procurement were shown to reduce flint attractiveness. For example, in the original equations not considering terrain difficulty, the Peoc flint sources had very high AQs (32); however, factoring in the energetic procurement costs, their attractiveness quotient dropped significantly (AQ 5.13). Bi14, more proximal to the site and following a significantly easier energetic route (199kcal vs. 624kcal for Peoc), although of only 'good' quality, became the most attractive primary LRM source (AQ 8.04). Palaeosol source Bi16, with large-sized, high quality nodules, also procurable at a relatively low energetic cost, remained the most attractive LRM source; however, the value of its AQ (9.72) did drop most significantly when terrain difficulty was re-factored into the equation, which clearly shows its impact on procurement choices.

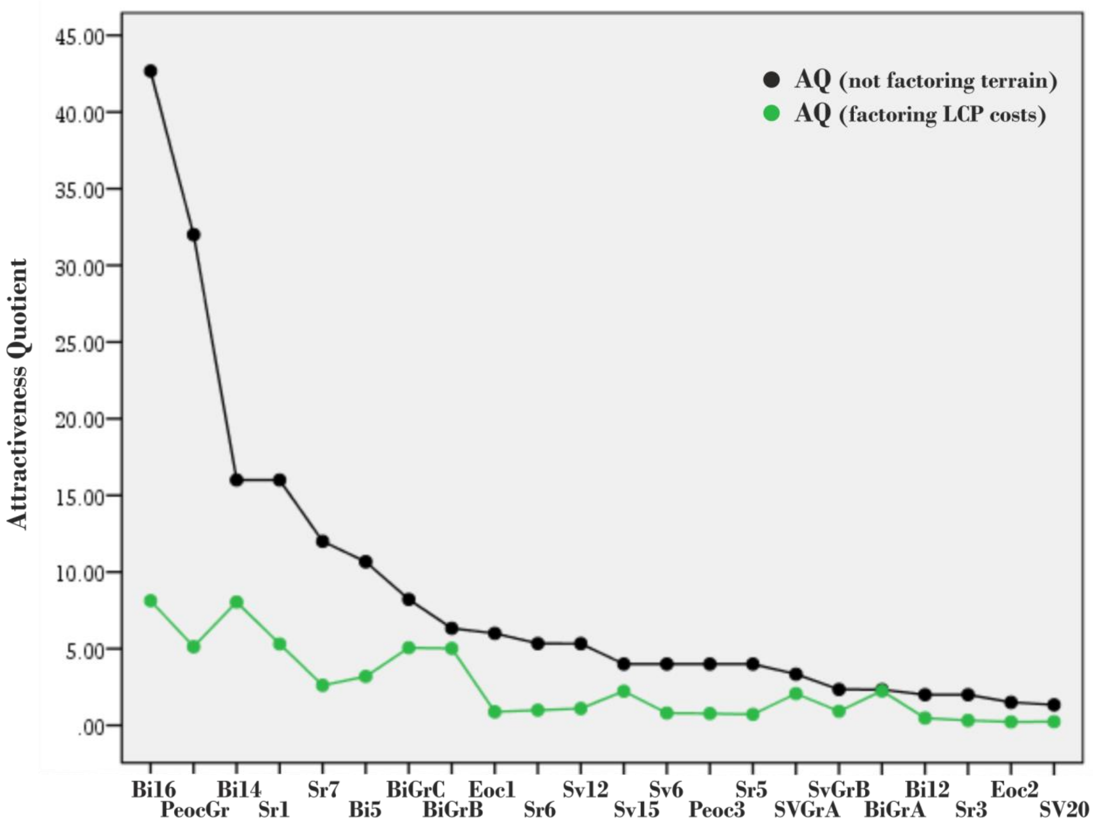


Figure 6.33: Comparison of Attractiveness Quotients, with black representing original AQs not factoring terrain difficulty, and green figuring energetic costs. .

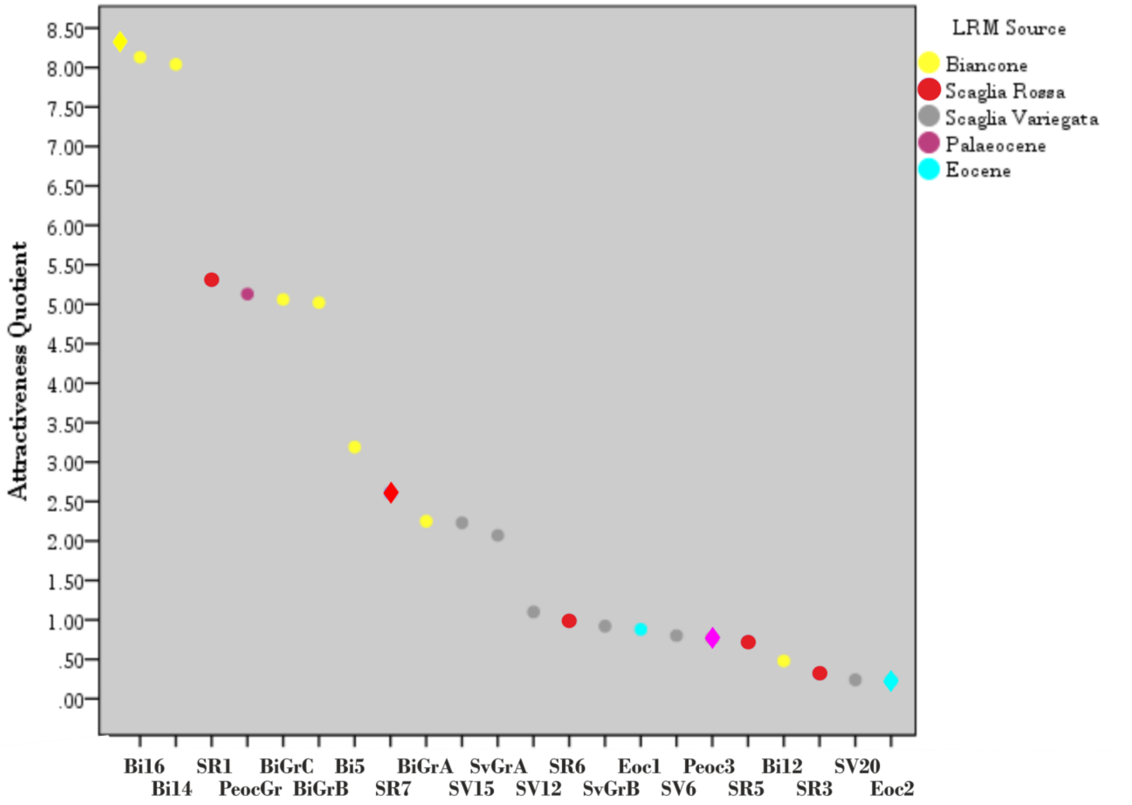


Figure 6.34: Re-figured attractiveness quotients factoring terrain difficulty, sorted by highest to lowest rank by LRM source and type. Diamond markers denote secondary palaeosol source.

Overall, Bi flints were the most attractive, followed by SV (Figure 6.34). While SR source SR1 was found to be highly attractive, sources SR3, 5, and 6 achieved low AQ rankings due to the impact of their distances from Grotta di Fumane (4.5-5.5km) and the energy costs incurred in their least-cost paths (~550-650kcal). The extensive and high quality primary outcrops of the Peoc group were highly ranked despite their distance and cost, but the secondary source, Peoc3, had a low AQ, based not only on the low source extent (one nodule), but also the high costs of procurement (4.52km, 522kcal). The Eoc flints ranked poorly based on the low quality of the LRM, as well as the distances and costs of these sources over 5km away and exceeding 650kcals.

The results of the temporal buffering, conducted for hourly increments of walking times, clearly demonstrated that the rugged terrain of the Monti Lessini cannot be delineated via concentric circles representing Euclidean distances (Figure 6.35). These results were also supported through pedestrian survey, where the time taken to hike the landscape roughly correlates to the temporal hiking buffers, although in pedestrian survey terrain friction resulted in slightly shorter distances covered. Therefore, like distance and energetic costs, the generated estimates of time should be considered to represent a minimum threshold.

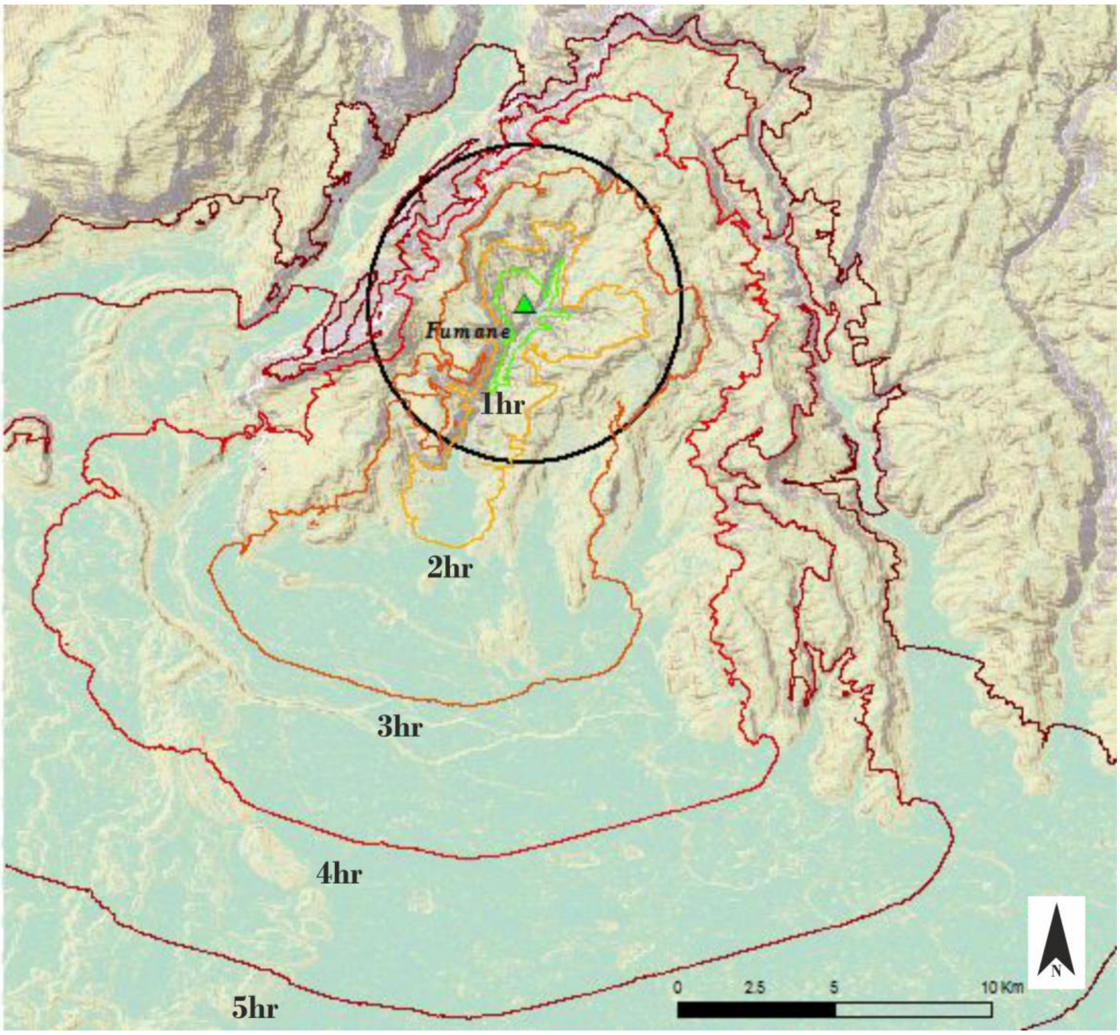


Figure 6.35: Temporal buffers of representing hourly increments of space around Grotta di Fumane.

The lines of the temporal buffers were amorphous, following the lines of slope, and showed that some of the identified LRM sources could be reached in shorter amounts of time based on topography (Figure 6.36, Appendix E.1). While only secondary streambed sources of flint could be recovered within an hour, Bi14, the most attractive primary flint source, in addition to the Bi flint groups, SV15, and SV Group A could be reached within 2 hours.

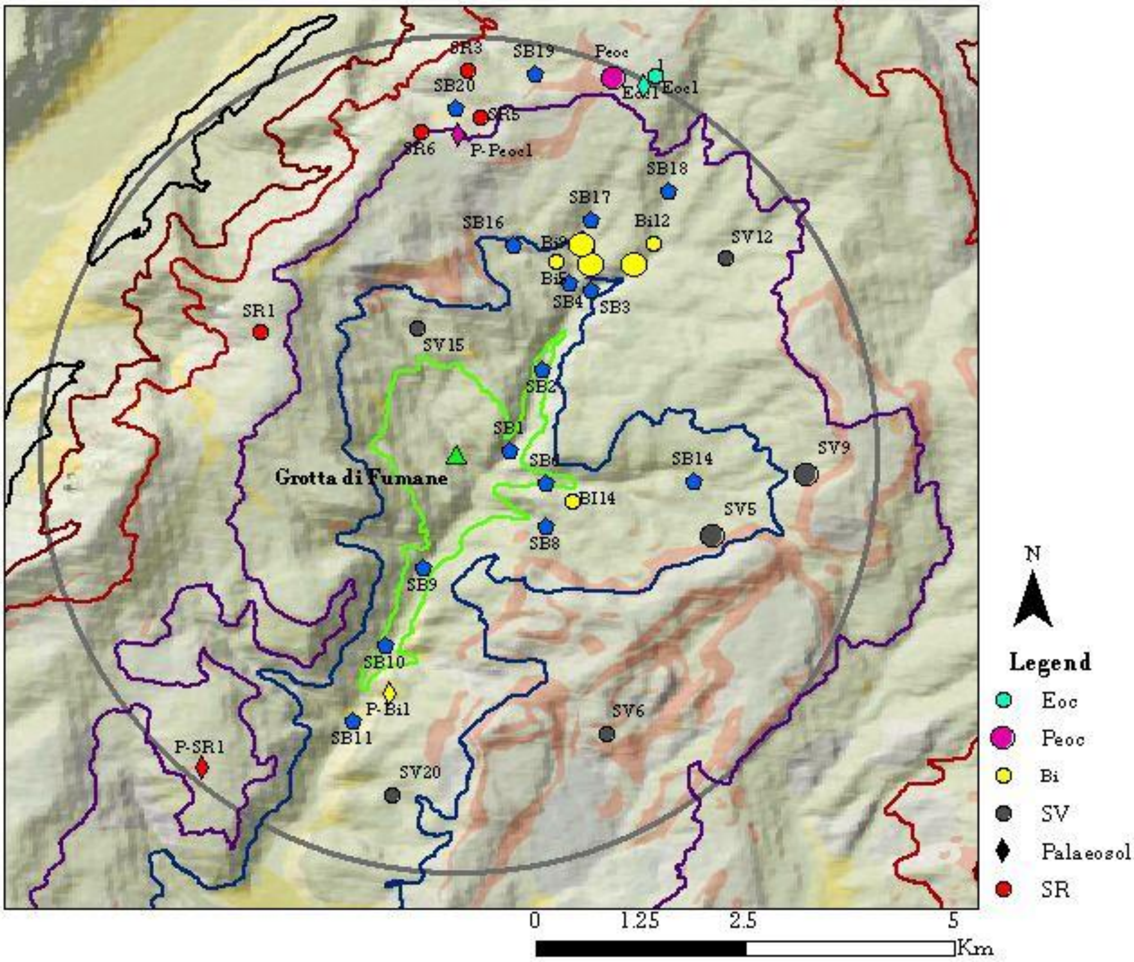


Figure 6.36: Hourly walking areas within the 5km Euclidean buffer zone, with the distribution of LRM sources. Green: 1 hour, Blue: 2 hour, Purple: 3 hour, Red: 4 hour, Deep Red: 5 hour.

Temporal Buffer	Area (km2)
1 hour	106.70
2 hour	177.84
3 hour	192.70
4 hour	391.25

Table 6.30: Areas of hourly temporal buffer zones.

The spatial areas of hourly temporal buffers were determined (Table 6.30). These quantitatively demonstrated that planar distances do not accurately represent a three-dimensional landscape. For instance, the 5km buffer drawn on a planar surface has an area of

78.54km^2, but the 1-hour temporal buffer, although appearing significantly smaller (in green in Figure 6.36), has a significantly larger surface area, 106.7km^2, due to the severity of the topography around Grotta di Fumane. This means that if the terrain of the 1-hour temporal buffer was stretched flat on a planar surface, its area would extend well beyond the 5km Euclidean buffer. Further, because of the ruggedness of the Monti Lessini terrain, the extent of the 5km buffer zone around Grotta di Fumane can be reached in variable amounts of time dependant on topography. In the east, six hours of walking would be required to reach the edge of the buffer zone. In contrast, to the south, the edge of the 5km buffer could be reached within two hours, with increased walking speeds facilitated by the natural corridor of the relatively flat Fumane Valley. These findings put the environment of Grotta di Fumane into a new perspective, in which, in conjunction with the results of the least-cost path analyses, hypotheses on Neanderthal mobility can be visualised in terms of time, distance, and energy.

Application of terrain modelling and lithic prospection results to the archaeological assemblages of Grotta di Fumane

Level A8+A9

A correlation between the lithotypes represented in level A8+A9 and the costs of their procurement from primary outcrops and palaeosources sources in the landscape was observed (Table 6.31). Bi, the nearest and least costly LRM, with the highest AQ, is by far the most dominant in the lithic assemblage at 65%, followed by SR and SV; these lithotypes were further the only primary sources identified within two hours walking distance of the site. Conversely, the more limited presence of the microcrystalline Eoc and Ool flints may be explained by their predominant procurement from primary outcrops, located at greater than 5km and 2.5hours from the site at significantly increased costs. While Ool and Eoc flints were observed in the streambeds proximal to Fumane, these sources were minimally exploited, perhaps due to low visibility or the reduced quality of rolled nodules.

LRM Type	Highest AQ	Avg. LCP Distance km	Avg. LCP Cost kcal	% in Assemblage	% Cortical	% Retouched	% Retouched with >1 Retouched Edge
Bi	8.13	2.97	367	65.10	43.80	5.03	5.99
SV	2.23	3.53	429	12.10	41.00	7.66	6.33
SR	5.31	4.5	526	17.50	44.90	4.24	3.23
Eoc	0.88	5.44	661	3.10	24.40	7.32	11.11
Ool				1.87	28.20	7.38	9.10

Table 6.31: Lithotypes in level A8+A9 and associated retouch, compared to LCP distances and costs to the identified primary and palaeosols LRM sources. An LCP to the Oolitic streambed source was not determined; the primary outcrops of this lithotype are purportedly >5km to the NE and NW.

Distances and costs also correlated to cortex and retouch frequencies, with the more proximal and least-costly cryptocrystalline flint types retaining higher cortical percentages, indicative of initial reduction sequences on site, and supported by higher percentages of Phases 0 and 1 and cores in these lithotypes. The cryptocrystalline flints also showed lower percentages of retouch, which agrees with shorter transport distance and a decreased need for maintenance, in contrast to the increased retouch and decreased cortex in Eoc and Ool. Overall, however, the frequency of retouch in these identified lithotypes can be considered relatively low as compared to the allochthonous (exotic) flints, with retouch at 13.8%. Further, distance and cost also correlated to the number of retouched edges observed in the lithotypes, with greater than one retouched edge doubled in Eoc than in the more proximal lithotypes, and 75% of the retouched implements in the allochthonous flints. Together, these data signify that, while more limited within the 5km range, retouch can be perceived to represent an economising strategy as a function of distance and cost.

The frequency of retouch on fluvial flint sources was similar to flints from outcrops (6.8% and 5.2%, respectively), which does not indicate a preference in material source for retouching activities. The correlations between proximity, cost, and lithotype frequencies seen in the primary outcrops and secondary sources were not observed for streambed sources, which are ultimately the most proximal and least costly LRM sources; however, with the exception of the Bi and SV, less than 5% of each assemblage lithotype was procured from these sources. Therefore, regarding cost, the apparent preference for flint from primary outcrops may be due instead to size, as rolled nodules and blocks from fluvial sources were of smaller dimension, and/or quality, as stream action can make flint more susceptible to internal fracturing.

Further, the dominant procurement of primary flint outcrops may also have been impacted by other subsistence activities taking place in the landscape, as based on palaeoenvironmental reconstructions and the identified distribution of LRM, overlap of exploited environments may have occurred. For instance, the distribution of open grassland environments and sparsely forested open environments, which were indicated by the palaeoclimate record and shown to be limitedly exploited (19.87%) by the hunted faunal assemblage, may overlap with those flint exposures on the Lessini Plateau, namely SR, Peoc, and Eoc types (20.6% of assemblage). Forested and wetland environments, dispersed at lower elevations on slopes and along the smaller streambeds dissecting the Fumane Valley, were shown to be the most exploited in the hunted ungulate assemblage (77.2%); the distribution of these environments corresponds to that of the most proximal primary and streambed sources of the well-represented (75.85%) Bi and SV flint. While other factors were clearly at play, namely rheological quality and source extent, it is interesting to note that the percentages of hunted species from each environment closely correlates to the percentages of those lithotypes in the assemblage that were distributed in those reconstructed environments.

That the cryptocrystalline lithotypes Bi and SV showed complete reduction sequences on flint from primary and secondary sources likely reflects its high quality as well as proximity and lower procurement costs as well. The procurement distances and costs of the microcrystalline Eoc and Ool from primary outcrops may have impacted the lower frequency of Phase I implements and the increase in secondary production sequences on flake-cores and Kombewa flakes as compared to the more proximal cryptocrystalline flints.

Unit A5-A6

In unit A5-A6, the terrain modelling results also found correlations between LCP distance and LRM procurement costs and each lithotype assemblage. The least-costly cryptocrystalline Bi, SV, and SR, within the two hour range, again showed the highest frequencies in the assemblages (Table 6.32), although SR, the most costly of these, indicates that cortical flakes were produced off-site and introduced to site. Although the streambed procurement in Bi and SV decreased from A8+A9 (43.94% to 28.81% and 21% to 7.66%, respectively), and thus greater distances and costs were incurred in these shifting procurement strategies, the acquisition of flints from primary outcrops still incurred the least costs over the other flint types. Eoc and Ool flints were significantly less represented than the cryptocrystalline flints, likely due to both the potentially increased costs of their procurement, if one hypothesises direct procurement, and/or their lower rheological qualities. As the cryptocrystalline Peoc flint is of high quality, its negligible representation in the A5-A6 assemblages cannot solely be a product of greater distances and costs, as these were comparable to those of Eoc; rather, it is more likely that the low frequencies of this lithotype in unit A5-A6 (and its total absence in A8+A9) can be explained by the low visibility of, or limited access to, its primary sources during MOIS-3, or by a Neanderthal preference for other flint types.

LRM Type	Highest AQ	Avg. LCP Distance km	Avg. LCP Cost kcal	% in Assemblage	% Cortical	% Retouched	% Retouched with >1 Retouched Edge
Bi	8.13	2.97	367	62.14	37.51	5.36	21.61
SV	2.23	3.53	429	14.63	35.00	8.53	26.10
SR	5.31	4.50	526	13.47	23.00*	5.13	34.04
Eoc	0.88	5.44	661	5.90	27.45	10.23	4.88
Peoc	5.13	4.73	573	0.75	30.65	11.77	25.00
Ool				25.10	4.72	0.00	0.00

Table 6.32: Lithotypes in Unit A5-A6 assemblages and associated retouch compared to LCP distances and costs. As non-streambed sources to Oolitic flints were not identified, LCP were not determined. *The data on this aspect of SR is incomplete, and thus cortical pieces were underrepresented.

Procurement costs also correlated to retouch frequencies, with Peoc and Eoc retouch double that of Bi. Higher cortical frequencies and full *chaînes opératoires* were observed on the cryptocrystalline flint types, indicating on-site initial reduction sequences of these lithotypes, supported by the strong presence of Phases 0 and 1 products and cores. Prior hypotheses that production sequences in Eoc and Ool flints occurred more frequently off-site, based on lower cortical frequencies and relatively limited Phase 0 and 1 implements, could be supported by the relatively greater distances and costs associated with their determined distribution in the landscape. These factors may also explain the truncated reduction sequences observed for the Peoc flint.

Increased procurement costs were not as strongly linked to retouched edges as compared to A8+A9, as such tools comprised a low percent of retouched Eoc implements. This may indicate shifting functional aims in unit A5-A6, where retouch appears to have been opportunistic, with over 70% or retouch resulting in indeterminate tool forms (Type 64).

The distribution of identified flint sources in unit A5-A6 also correlated to exploited environments as indicated by the hunted ungulate assemblages. Open Alpine grasslands and rocky slope environments on the Lessini Plateau represented 13.43% of the hunted ungulates and 13.64% of the lithic assemblage (Peoc, Eoc, Ool outcrops). Lower elevation forests and wetland conditions were represented by hunted ungulates at 84.9%, and by associated outcrops (Bi, SV, SR) at 86.16% of the assemblage. Despite the strong correlation between these variables, as was discussed for A8+A9, there were likely additional factors such as quality and nodule size influencing procurement choices; however, that these are observed in both levels to such a high degree increases the viability of these correlations.

6.2.5 Grotta di Fumane: results overview

Overall, the various indicators of palaeoclimate at and around Grotta di Fumane were largely in agreement, and demonstrated that level A8+A9 was formed during cool to cold climates that were dry but not exceedingly so. In levels A6 and A5-A5+A6, climatic amelioration and more temperate climates occurred, with an increase in temperate deciduous arboreal species and forest distribution. The reconstructions showed the site was located in proximity to forested, open forest, and Alpine grassland conditions throughout MOIS-3, and although the productivity and dominance of these shifted in response to climate oscillations, each would have provided access to diverse resources. In conjunction with the persistence of high winter precipitation rates and humidity, many months with sub-freezing temperatures, and extreme wind chills, conditions in the Monti Lessini during MOIS-3 winters were likely harsh, although somewhat less so in unit A5-A6, and thick snowfall may have limited Neanderthal mobility and their access to, and the visibility of, subsistence resources, including LRM.

Techno-economic analyses showed a move from Discoidal technologies in A8+A9 to Levallois in levels A6 and A5-A5+A6, with little change, however, in the flint types utilised. Changes in exploited LRM sources were, however, observed, with a move away from predominantly primary outcrop exploitation in the Eocene and Oolitic flints to palaeosol sources from A8+A9 to A5-A5+A6. Across the MOIS-3 levels, Biancone was the dominant lithotype, followed by cryptocrystalline varieties Scaglia Rossa and Scaglia Variegata. The full *chaînes opératoires*, higher cortical frequencies, and lesser retouch observed in these lithotypes indicated that lithic reduction sequences occurred on-site, and that exploitation attitudes were less concerned with maximising lithic potential than with technological aims. In contrast, the microcrystalline flints, which were much less represented, showed greater lithic management in increased retouch frequencies, particularly in the A8+A9 assemblage.

The results of the lithic prospection survey identified numerous primary and secondary sources of the lithotypes identified in the MOIS-3 assemblages of Grotta di Fumane, which were widely dispersed in the landscape, but of varied quality, abundance, and source extent. Linked to the results of the least-cost path modelling, the attractiveness of these sources was reconsidered, and correlations between lower energetic and time procurement costs and higher frequencies in site lithic assemblages, as well as full *chaînes opératoires*, higher degrees of cortex, and less retouch, were observed. In contrast, more costly LRM sources, including Eocene, Oolitic, and Palaeocene flints, located beyond a two hour hiking range, showed indicators of lithic management and maintenance over distance and time in the lithic record. As these variably showed full reduction sequences, although with some *chaîne opératoire* phases of limited representation, it is postulated that these flints within the Grotta di Fumane assemblage are associated with embedded procurement activities, in contrast to the more proximal and less costly Bi, SV, and SR flints, where greater use, full reduction sequences, and higher streambed procurements signal some direct procurement of these lithotypes.

Terrain modelling enabled visualisation and measuring of the landscape in such a way that hypothetical mobility routes from the identified LRM sources to Grotta di Fumane could be determined. These results demonstrated that the generation of least-cost paths, rather than 2D and 3D straight line routes, yielded more realistic patterns of human movement, and further showed that the costs of mobility were greatly impacted by terrain as well as distance. The creation of temporal buffers showed that the delineation of space in distance measurements is misleading, and that the distances that could be covered in a set amount of time were dependent on terrain.

6.3 Grotta Maggiore di San Bernardino Unit II: Results

6.3.1 Grotta Maggiore di San Bernardino: palaeoenvironmental reconstructions

Unit II of Grotta Maggiore di San Bernardino recorded temperate and humid environments, indicated by its sedimentary, palynological, and faunal record. These conditions were the continuation of climate amelioration, which began in the underlying Unit III following the cold steppic conditions recorded in the final Middle Pleistocene Unit IV. The sedimentary composition of Unit II recorded medium-sized rocks within brown, sandy loam sediments. Associated organic matter was considerable, and included charcoals from Neanderthal combustion structures (Peresani 1995-1996). Palynological remains, in contrast to Grotta di Fumane, were well preserved. Palynological analyses, conducted by Cattani and Renault-Miskovsky (1989), identified arboreal pollens at ~20% of the palynological record, including pine (either Scots pine or dwarf mountain pine), lime, hazel and ash, which together indicated the presence of coniferous and deciduous species in proximity to the site. Mixed forest environments were supported by anthracological analyses that showed the additional presence of birch, willow, and alder species. Herbaceous pollens were predominantly comprised of members of the Asteraceae (~32% of recovered pollen), Artemisia, and Graminaceae families; other meadow-type species, including Tubiflorae, pinks, and poppies, were represented in lesser amounts, and indicated the presence of open meadow environments (c.f. Cattani and Renault-Miskovsky 1989).

Faunal analyses conducted by Cassoli and Tagliacozzo (1994a) indicated the predominance of woodland environments, in contrast to the palynological data. Of the hunted ungulates, roe deer represented 25% of the recovered remains, followed by red deer at 12.6%. Rocky slope conditions were signalled to a much lesser degree, by chamois (4%) and ibex (1.2%). Open grassland species *Stephanorhinus sp.* was very limited in the faunal record at 0.2%. Open environments with sparse forests were weakly signalled by giant deer (0.3%) and aurochs (2.4%), and wetland environments were signalled by wild boar (5%), elk (9.2%), and beaver (4.2%); these may have been situated at the southern base of the Monti Berici where it meets the Berici Plain, and near Lago di Fimon. Carnivores other than bear (14.1%) were little represented, but included species red fox, leopard, wildcat, and polecat, whose ecological niches covered a range of habitats.

The Lago di Fimon Fimon-Ponte sulla Debba (FPD) sediment core analyses (Pini *et al.* 2010, Monegato *et al.* 2011) supported diverse environments and persistent forestation on the Berici landform throughout MOIS-3. Sedimentary unit FPD17, dated to 60,230 ± 400 cal BP (Pini *et al.* 2010), likely correlating to Greenland Interstadial 17 (59,400 ± 1,300 cal BP; Svensson *et al.* 2008; 60,200 ± 400, Sánchez Goñi *et al.* 2008), indicates open and closed mixed forest environments with wetlands that were dominated by spruce, pine, and birch pollens (50-75%). Mixed forests continued until just before 40ka, when in FPD17c, tentatively correlated to Heinrich event 4, a shift toward colder conditions are signalled by pine dominance and mountainous herbs (Pini *et al.* 2010)

Stage Three Project palaeoclimate reconstructions for the four projected Lambwin coordinates of Grotta Maggiore di San Bernardino were largely in agreement with the site-level faunal assemblage and the sediment core determinations of temperate and humid conditions during MOIS-3. As at Grotta di Fumane, evergreen taiga/montane forest (Biome 10) and the temperate deciduous forests (Biome 5) were predicted, at 58% and 42%, respectively, for both warm and cold events. Many of the Biome 10 species were represented in the palynological and anthracological record of Unit II, particularly pine and larch. The lime, hazel, ash, and hornbeam pfts of simulated Biome 5 were are also recorded in Unit II's pollen record. Temperate grasslands were less strongly predicted, which agrees with the faunal assemblage, indicating more limited alpine meadow environments, which were likely dispersed on the Berici Plateau. The simulation results therefore support the site level and sediment core indicators of mixed environments in the site's vicinity.

Net Primary Productivity of Plant Functional Types, Biomes 10 and 5

	Warm-type Event				Cold-type Event			
lambwin coordinates	**41, 15**	**40, 15**	**40, 14**	**41, 14**	**41, 15**	**40, 15**	**40, 14**	**41, 14**
PFT	**Biome 10**	**Biome 10**	**Biome 5**	**Biome 5**	**Biome 10**	**Biome 10**	**Biome 5**	**Biome 5**
Temperate summergreen			444.00	517.00			434.00	519.00
Temperate evergreen conifer			354.00	395.00			347.00	395.00
Boreal Evergreen	178.00	279.00	393.00	408.00	184.00	277.00	381.00	402.00
Boreal Deciduous	167.00	270.00	390.00	402.00	175.00	268.00	377.00	400.00
Temperate Grass	46.00	163.00	317.00	439.00	47.00	166.00	310.00	426.00
Desert woody plant type, C3/C4		74.00	114.00	146.00		76.00	111.00	143.00
LAI	1.93	2.24	2.71	2.71	1.93	1.93	2.71	2.86

Table 6.33: Simulated net primary productivity of plant functional types in Biomes 10 and 5 for warm and cold-type event, for all generated Lambwin coordinates.

The productivity simulations showed that arboreal species were comparably productive between both the warm and cold-type events. Temperate grasses and woody desert plants were consistently less productive than arboreal species (Table 6.33). That the deciduous arboreal species of Biome 5 pfts, represented in Unit II and in the Lago di Fimon core, were the most productive supports the persistence of mixed forest conditions near Bernardino throughout MOIS-3. This is further supported by the lack of variance in simulated leaf area indices for both simulated warm and cold type events.

Temperature simulations for both biomes support that the conditions in which Unit II was formed were cool (Figure 6.37), with sub-freezing temperatures occurring in November through March in Biome 10 and December through February in Biome 5 in warm-event simulations. Summer temperatures were slightly warmer in Biome 5, reaching the low 20º's in July. Wind chill significantly reduced temperatures, particularly in fall through spring, in both warm and cold-type climate simulations (Figure 6.38).

Climate simulations showed that Biome 10 was snowier than Biome 5, with two additional snowy months a year (159 vs. 93.5 days) in warm-type events, and nearly 2.5 months more (167 vs 98.5 days) in cold-type events. Snow depth exceeded 10cm for five months out of the year in Biome 10, reaching up to 55cm in the snowiest month, January, for both warm and cold-type events (Figure 6.39). While snow depth was also significant in Biome 5 for simulated warm-type events, a maximum snow height of only 12.2cm was simulated for February in the cold-type simulations. This data signalled more arid winter conditions, which are in contrast to the consistent site-level and sediment core indicators of humid conditions during the formation of Unit II.

Precipitation simulations showed marked seasonal shifts with wet winters and dry summers in warm events (Figure 6.40). These seasonal contrasts were not observed for cold events, with precipitation oscillating from month-to-month, although less extremely so in Biome 5. Relative humidity simulations were in greater agreement with the warm event precipitation and snow simulations, showing decreased humidity in the summer months and wet winters (Figure 6.41).

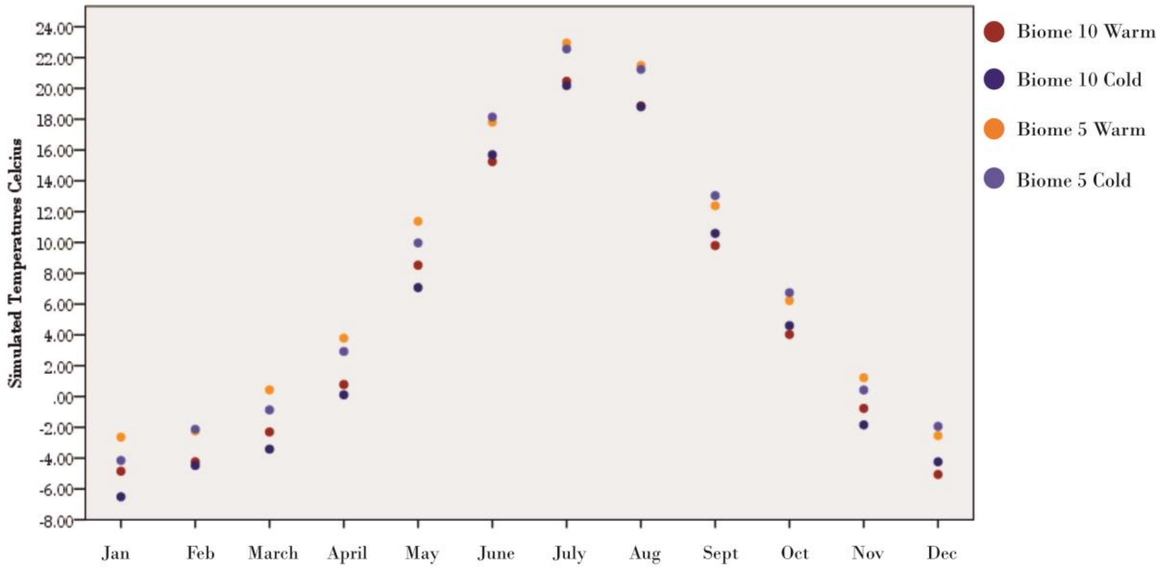


Figure 6.37: Monthly temperatures for Biomes 10 and 5 in both warm and cold type climate simulations.

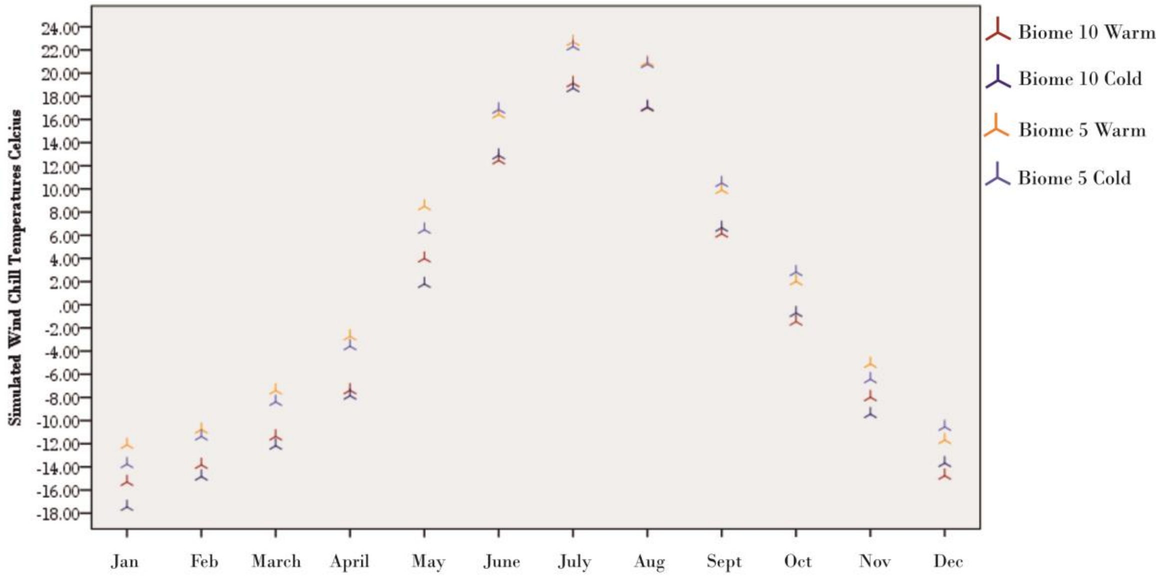


Figure 6.38: Simulated monthly wind chill temperatures for Biomes 10 and Biomes 5 for both warm and cold-type events

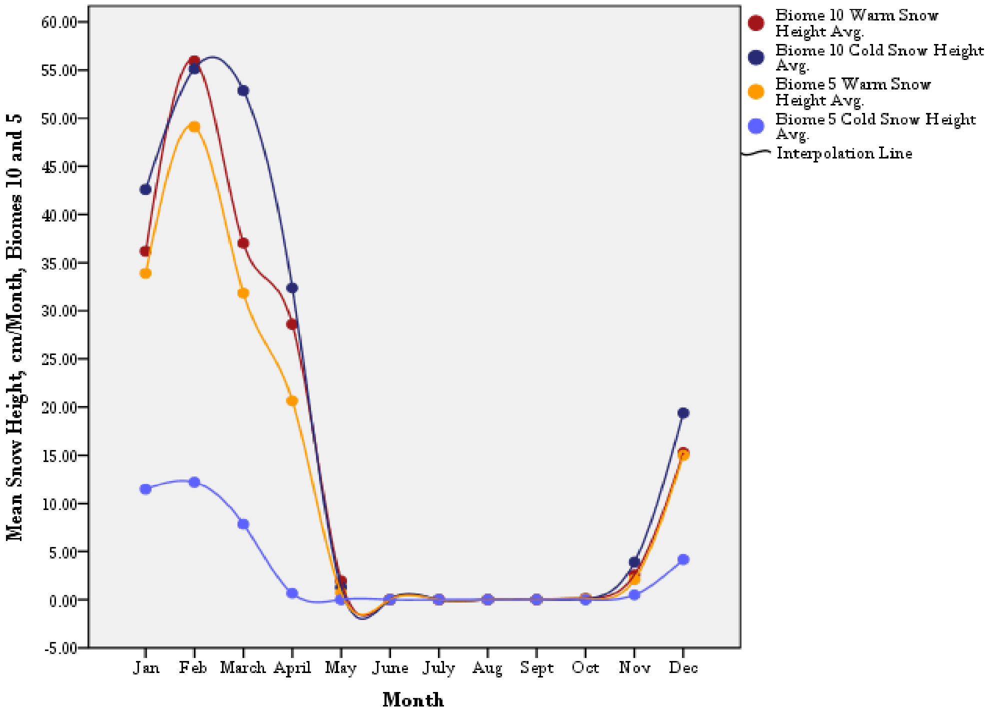


Figure 6.39: Simulated monthly snow height for Biomes 10 and 5 in warm and cold type climate events.

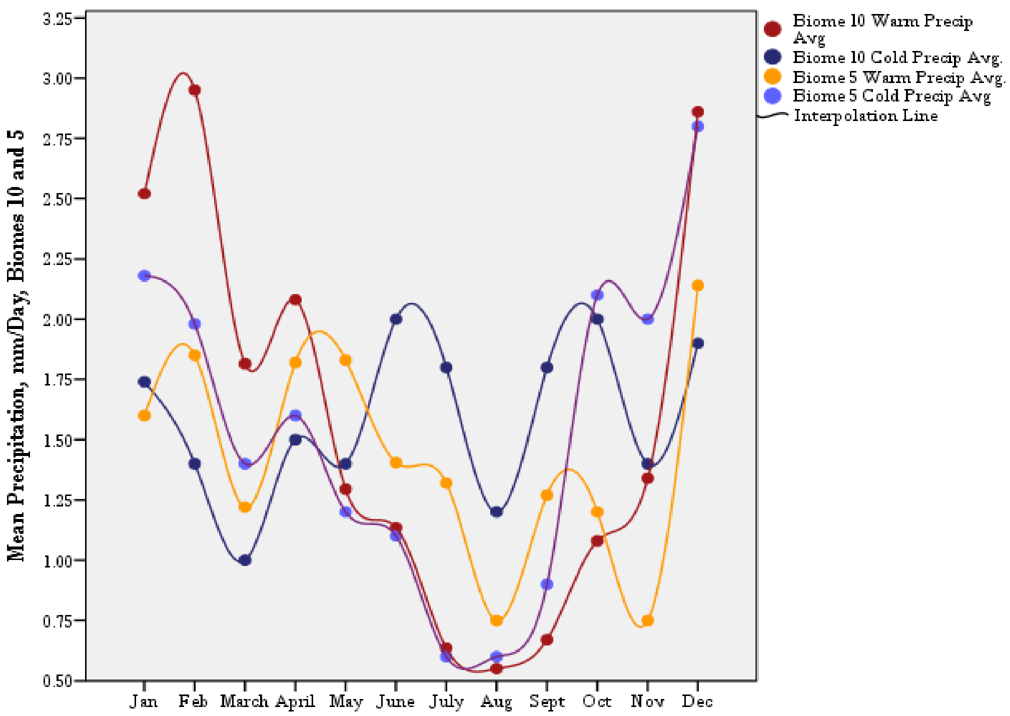


Figure 6.40: Simulated monthly precipitation for Biomes 10 and 5 in warm and cold type climate events, with near-monthly oscillations in the simulated warm-type events

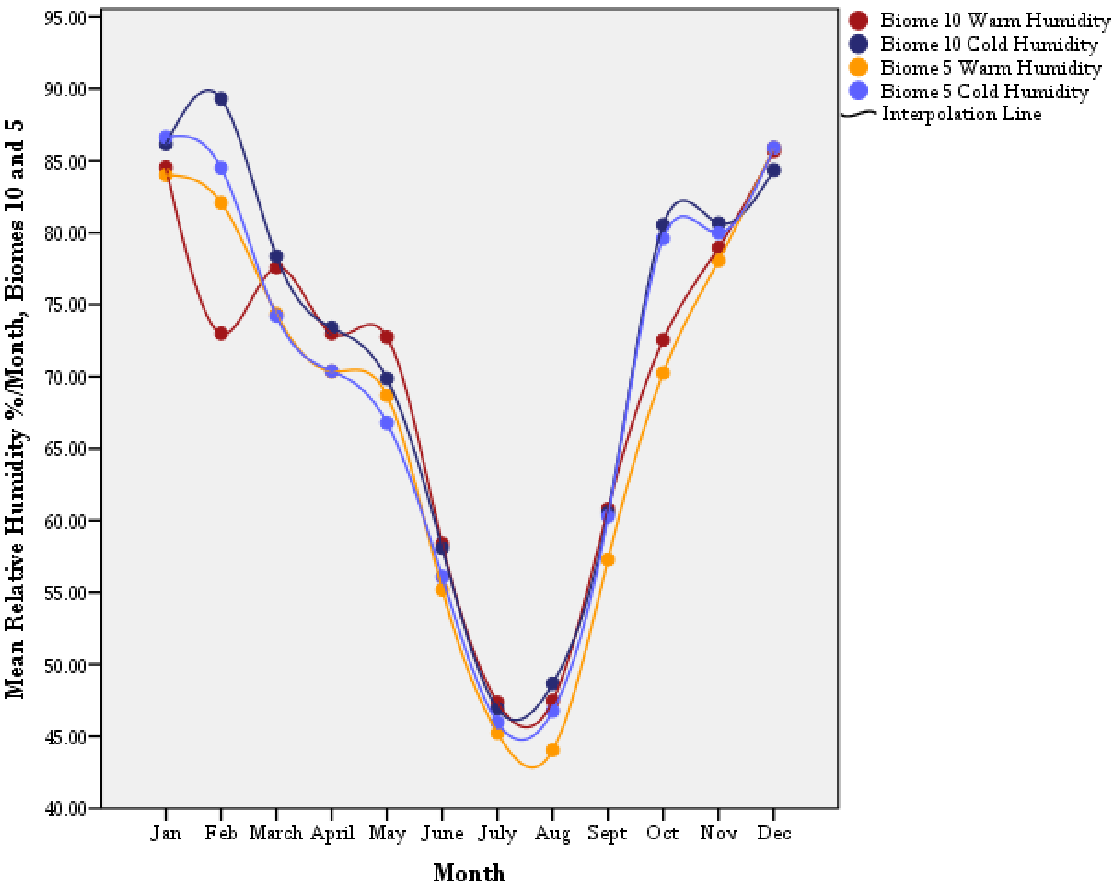


Figure 6.41: Simulated relative humidity per month.

6.3.2 Grotta Maggiore di San Bernardino: techno-economic analyses

The lithic assemblage of Unit II of Grotta Maggiore di San Bernardino contained 3,192 lithic implements, the entirety of the excavated unit, less debris smaller than 1.5cm; the lithic data for this analysis was collected from the published paper by Prof M. Peresani (1995-1996). The assemblage was dominated by the Scaglia Rossa flints (84.27%), which are reported to outcrop in a local to semi-local range around the site (Bertola 1995-1996; Peresani 1995-1996). The exotic cryptocrystalline flints (SGE) of the assemblage, Biancone and Scaglia Variegata, were analysed together as a single unit, though their potential sources include the Colli Euganei to the south (20+km) and the Monti Lessini in the north (30+km): these comprised 13.85% of the Unit II assemblage. The microcrystalline "AS" group (altre selce) included the Oolitic, Eocene, and Rosso Ammonitico flints of exotic provenance, purportedly the Monti Lessini at distances exceeding 50km (Peresani 1995-1996); these totalled 1.88% of the Unit II assemblage (Table 6.34).

Grotta Maggiore di San Bernardino, Unit II: Techno-economic results, N=3,192									
Lithotype	Frequency	Percent	Tradition	Dominant CO Phase	Chaîne opératoire	Retouch %	% cortical*	Dominant LRM Source	Dominant LRM Form
SR	2,690	84.27	Levallois	2c	Complete	10.26	42.92	Outcrop	Blocks and nodules
SGE	442	13.85	Levallois	2c	Complete	20.59	20.36	Outcrop	Lenses and nodules
AS	60	1.88	Levallois	2a	Complete	21.67	26.67	Outcrop	Nodules and lenses
Total	**3,192**	**100%**							

Table 6.34: Simplified techno-economic results of Unit II.

SR implements retained cortex at 42.92%, significantly more than observed for the AS flints at 26.67%, and more than double the SGE assemblage (20.36%). Cortical analyses indicated the dominant procurement of blocks, nodules, and plates from primary outcrops and from soils. The exploitation of secondary streambed sources was minor.

Full *chaînes opératoires* were observed in the SR flints (Table 6.35). Phase 2c was most represented, comprised mostly of non-cortical (60.7%) and cortical (34.61%) flakes; cores-on-flakes (2.55%) and Kombewa flakes (2.15%) were present in much lower frequencies (Table 6.36). Phase 2a included predominantly Levallois sub-products (62.94%) and flaking accidents (18.43%). Pseudo-Levallois points were seen at less than 10% of Phase 2a, indicating a limited, potentially Discoidal alternative reduction sequences. Six SR cores, officially categorised as 'undifferentiated,' were also suggested to be Discoidal, based on centripetal removals from both the striking platform and flaking surface; alternatively, these removals may be the result of secondary, or even tertiary, reduction sequences aimed at further reducing an originally Levallois core to maximise its lithic potential (Peresani 1995-1996). Phase 2b was represented at only 1.97% (28 Levallois cores and 25 undifferentiated cores). Phase 0 was comprised of only cortical flakes: no rough blocks were recovered. Phase 3, as at Grotta di Fumane, was not observed; however, it is likely that undifferentiated flakes and flake fragments from Phases 2c and Diverse represent this phase, given that 10% of the assemblage shows evidence of retouch. The dominance of Phases 2a and 2c products in SR indicates that two *chaînes opératoires* occurred on site: initial uni- and bidirectional Levallois removals from cores and secondary centripetal reduction sequences on these reduced cores or on cortical flakes. The frequency of secondary reduction sequences, the low frequency of Phase 2b cores and the exhausted state of these, indicates the intensive utilisation and lithic maximisation of this lithotype.

Gr. M. di San Bernardino Unit II: Chaîne opératoire phases							
Lithotype	Phase 0	Phase 1	Phase 2a	Phase 2b	Phase 2c	Phase 3	Diverse
SR	5.99	5.32	37.92	1.97	46.73	/	2.08
SGE	3.17	4.30	39.14	1.81	49.10	/	2.49
AS	11.67	5.00	55.00	1.67	23.33	/	3.33

Table 6.35: *Chaîne opératoire* phases of lithotypes.

	San Bernardino: Technological categories by lithotype, n=3192					
	Geneste Tech Category	**SR**	**SGE**	**AS**	**Total** n	%
Phase 0	0		1		1	0.03
	1	161	13	7	181	5.70
Phase 1	2	143	19	3	165	5.17
Phase 2a	4	642	126	24	792	24.81
	6	188	23	5	216	6.77
	7	172	22	3	197	6.17
	10	18	2	1	21	0.66
Phase 2b	12	25	5	1	31	0.97
	13	28	3		31	0.97
	17	27			27	0.85
Phase 2c	18	32			32	1.00
	21.1	435	34	1	470	14.72
	21.2	764	183	13	960	30.07
Diverse	26	56	11	2	69	2.16
Lithotype Total		**2691**	**441**	**60**	**3192**	**100%**

Table 6.36: *Chaîne opératoire* phases and technological categories in Unit II.

The SGE assemblage records full *chaînes opératoires*, but Phases 0 and 1 were less represented than in SR. Phase 2a implements included Levallois sub-products, Levallois flakes, and flaking accidents. Two pseudo-Levallois points comprise 8.33% of the SGE assemblage. Phase 2c was comprised only of non-cortical (84.33%) and cortical (15.67%) flakes; flake-cores and Kombewa flakes, unlike in SR, were not observed. The limited Phase 0 contained cortical flakes/*entames* and a single, untested flint block that was manufactured into a simple scraper. Of the eight SGE cores, three were Levallois and five were undifferentiated. The low frequency of cores in Phase 2b and the relatively high number of products from primary and secondary reduction sequences indicates the intense exploitation of these lithotypes on-site, which is further supported by the exhaustion of the cores and their discard at 20mm maximum length (Peresani 1995-1996).

The AS flint assemblage indicated full *chaînes opératoires*; however, AS, in its limited frequency, included three distinct flint types, which likely individually were represented by truncated reduction sequences. While difficult to test this hypothesis based on the low resolution of the data available, the representative phases of *chaînes opératoires* provide some clues. Phase 2b was very limited at 1.67%, represented by a single, undifferentiated core. The mostly Levallois sub-products of Phase 2a (55%) likely corresponded to the reduction of the identified core. Phase 0, however, likely represents personal gear from separate off-site manufacturing activities: 23.1% of the AS tools were manufactured on the *entames* and cortical flakes of this phase, which was more represented in AS (11.67%) than both SR (5.99%) and SGE (3.17%). While the flake fragments (mostly non-cortical) comprising Phase 2c indicate exhaustive exploitation strategies, likely in each flint type, flakes-cores and Kombewa flakes were not observed.

Observed retouch frequencies in each of the flint groups were the inverse of the cortex findings, where SR was significantly less retouched (10.37%) than the SGE (20.59%) and AS (21.67%) flints. Both the cryptocrystalline SGE and microcrystalline AS exotic flints also showed a greater intensity of retouch than the local and semi-local SR flints (Peresani 1995-1996). The correlation of low cortex in exotic materials, paired with the greater degree of retouch, seems to indicate a provisioning of individuals strategy in which mobile populations were transporting and maintaining personal gear over significant distances.

Scrapers, the most frequent tool form in SR, included simple types (27.9%) as well as those with more than one retouched edge: double, convergent, transversal, and déjeté scrapers (22.1%) (Table 6.37). Scrapers were very small, on average 10-62mm wide and 12-72mm long (Peresani 1995-1996). Denticulates were also significantly represented, at 12.68% of the retouched tools; use-wear analyses demonstrated these were utilised for working soft/medium to medium/hard materials, such as animal skins or wood (Picin *et al.* 2011). Implements with indeterminable retouch (Type 64) comprised 23.19% of the SR tool assemblage, while Mousterian points, an end-scraper and truncated flake, three burins, two typical piercers, and four raclettes, indicative of diverse on-site activities, comprised <5%.

While Levallois flakes were the predominant tool blank in the manufacture of simple scrapers in SR flint, double scrapers, when determinable, were manufactured on a range of blanks, from Phases 0-2a. Denticulates were also manufactured on a range of technical products, including cortical flakes, Levallois products and sub-products, and a core-edge flake. The Mousterian points were generally retouched to the extent that the original technical product could not be determined (62.5%); identified blanks included a semi-cortical flake, a Levallois flake, and a flaking accident. Notches were manufactured on Phase 2a implements, most predominantly on Levallois flakes (60%).

	Gr. M. di San Bernardino Unit II: Bordes Reference Types by Lithotype, N=3,192								
	Lithotype and total frequency	**SR (2,690)**		**SGE (442)**		**AS (60)**		**Total**	
		n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Bordes Reference Type	4			2	2.13			2	15.15
	6	8	2.90	2	2.13			10	0.51
	7			1	1.10	1	7.69	2	2.53
	8	2	0.72	1	1.10			3	1.01
	9	29	10.51	6	6.59			35	25.25
	10	26	9.42	5	5.49	3	23.08	34	9.09
	11	22	7.97	4	4.40			26	0.51
	12	4	1.45					4	
	13	3	1.09	3	3.30			6	3.54
	18	10	3.62	3	3.30			13	0.51
	19	9	3.26	3	3.30			12	1.52
	21	7	2.54	1	1.10	2	15.38	10	4.55
	22	14	5.07	3	3.30	1	7.69	18	0.51
	23	14	5.07	3	3.30			17	0.51
	30	1	0.36					1	
	32	3	1.09			1	7.69	4	
	34	2	0.72	1	1.10	1	7.69	4	2.02
	39	4	1.45	1	1.10			5	0.51
	40	1	0.36					1	
	42	5	1.81	1	1.10	1	7.69	7	0.51
	43	35	12.68	5	5.49			40	1.01
	45	12	4.35	1	1.10			13	1.52
	62	1	0.36					1	
	64	64	23.19	45	49.45	3	23.08	112	25.76
	Total	**276**	**100%**	**91**	**100%**	**13**	**100%**	**380**	**100%**
	% Lithotype	**10.26**		**20.59**		**21.67**		**11.90% of Unit II assemblage**	

Table 6.37: Bordian tool types by lithotype in Unit II.

A range of tool types in SGE were recorded, manufactured largely on non-cortical implements (71.43%). Simple scrapers (16.48% of the tool assemblage) were manufactured on a range of technological products, including flakes and flake fragments and Levallois flakes and sub-products. Scrapers with two or more retouched edges, including double, convergent, déjeté, and transversal types were comparably represented at 17.6%. While these were made on a similar range of blanks as the simple types, cortical pieces were less frequently utilised (37.50% vs. 66.70%); however, the absence of cortex could be explained by the retouching actions. Denticulates (5.49%), retouched Levallois points (2.13%), and Mousterian points (2.13%), were also observed, in addition to other diverse tool types, similar to the range seen in SR. While two-thirds of the denticulates were manufactured on Levallois flakes, perhaps indicating preferential blank selection, and indeterminate tool types (49.45%) were largely manufactured from non-cortical flake fragments (82.22%), other tool forms in the SGE assemblage were made on a range of implements.

The AS tool assemblage included three simple convex scrapers (23.08% of the tool assemblage), two déjeté scrapers (15.38%), and one of each of the following: elongated Mousterian point, transversal scraper, typical burin, typical piercer, and a notch. Indeterminate tool types were again well represented (23.08%), and were exclusively manufactured on non-cortical flake fragments. Despite the relatively low percentage of cortex in the AS assemblage, the frequency of retouch on cortical implements was higher in AS at 46.15% than in SGE (28.57%) and SR (28.99%), with retouch focussed on scraper manufacture. As on-site reduction sequences in AS were relatively limited, the high degree of retouch on cortical implements indicates that these represent transported implements.

6.3.3 Grotta Maggiore di San Bernardino: lithic prospection

The results of the pedestrian survey for lithic prospection reinforced what was indicated by the lithological maps of the region: the distribution of LRM around Grotta Maggiore di San Bernardino was limited to SR flint. Where flint potential was indicated by the lithological maps, only a limited number of outcrops with nodules, blocks, or plates, of variable quality and abundance were identified (Appendix D.2). Limited secondary SR sources, not indicated by lithological maps, were also identified. These findings clearly demonstrate the importance of lithic prospection in accurately determining the lithic character of the off-site landscape.

Primary lithic raw material sources

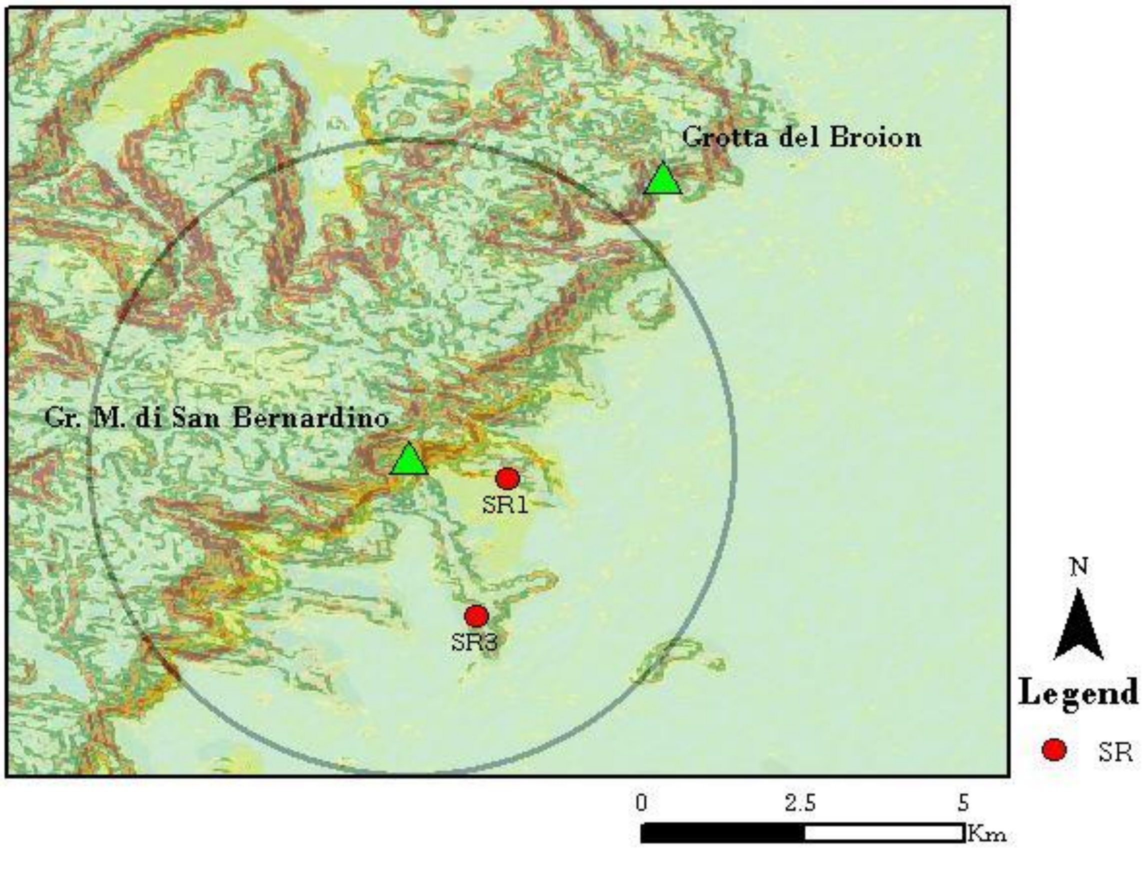


Figure 6.42: Primary SR sources identified within 5km of San Bernardino.

Only two primary LRM sources, SR1 and SR3, were identified during pedestrian survey within the 5km radius around Grotta Maggiore di San Bernardino (Figure 6.42; Appendix C.2). The identified SR primary sources outcropped as medium-sized nodules, plates, and blocks in late Cretaceous geological formations. The size ranges of these two source extents ranged from approximately 60m in diameter to over 150m. The colours of the identified SR flint were shades of pinkish red (10R 5/4 to 5/6), and the attractiveness of both sources were comparable, with the nearest source SR1 being somewhat less so due to its poor quality (see Table 6.38). SR3 contained some nodules of fair quality, but these outcrops mostly contained poor, partially silicified flint (Figure 6.43). The identified flint characteristics were in agreement with the cortical and techno-economic analyses results that demonstrated the SR flint was procured as blocks, nodules and plates from outcrops.

Flint Source	Munsell Hue	Quality	Extent of Source	Difficulty of Terrain	Cost of Extraction	Size	Scarcity	Attractiveness Quotient (AQ)	Rank
SR1	10R 5/6	1	4	TBD (1)	1	3	3	4	2
SR3	10R 5/4	2	3	TBD (1)	1	3	4	4.5	1

Table 6.38: Attractiveness variables of identified primary SR outcrops within 5km of San Bernardino.

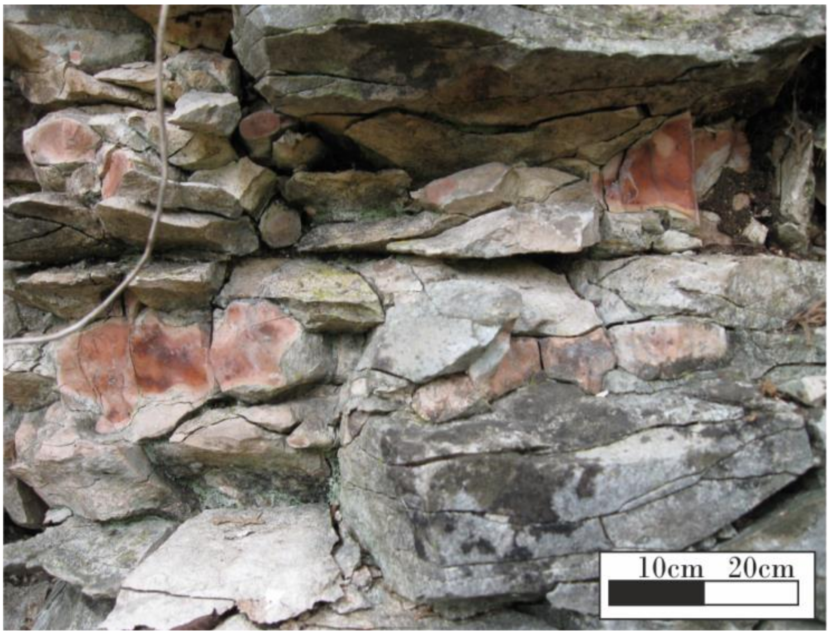


Figure 6.43: SR3 outcrop with fair quality nodules and unsilicified flint blocks.

Beyond the 5km radius to the south of Grotta Maggiore di San Bernardino, five additional primary flint sources were identified within distances of 6-7km, on slopes rising above the Monti Berici Plain (Figure 6.44). The reasons for this expansion in survey to the south were the visibility of these landforms across the Berici Plain and the lithological potential of their Cretaceous formations as indicated by geological maps. These outcrops contained mostly higher quality SR flints of a distinctively darker brownish-red colour (2.5YR 5/4 to 2.5YR 4/4) compared to the SR flints found within the 5km local radius.

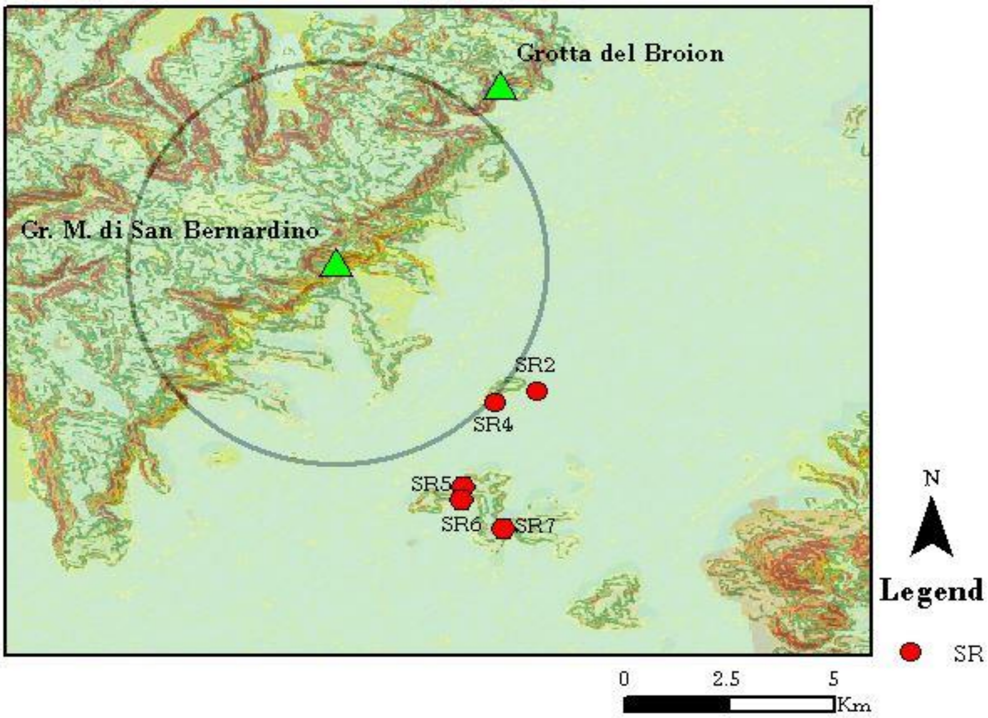


Figure 6.44: Primary SR outcrops identified beyond the 5km radius of San Bernardino.

Excluding the terrain difficulty variable, these sources were shown to be more attractive by the Attractiveness Equation than those outcropping with the 5km radius (Table 6.39). SR7 presented a very large outcropping containing large nodules (~40cm) of very good quality, despite that these were not abundant (Figure 6.45).

Flint Source	Munsell Hue	Quality	Extent of Source	Difficulty of Terrain	Cost of Extraction	Size	Scarcity	Attractiveness Quotient (AQ)	Rank
SR2	10R 5/6	4	4	TBD (1)	1	4	3	21.34	2
SR4	10R 5/4	4	4	TBD (1)	1	3	4	12	3
SR5	2.5YR 5/4	4	2	TBD (1)	1	2	4	4	4
SR6	2.5YR 4/4	4	4	TBD (1)	1	3	4	12	3
SR7	2.5YR 5/4	8	4	TBD (1)	1	4	4	32	1

Table 6.39: Attractiveness variables of SR outcrops found within a 5-7km radius of San Bernardino.

Figure 6.45: Large nodule at source SR7.

Secondary lithic raw material sources

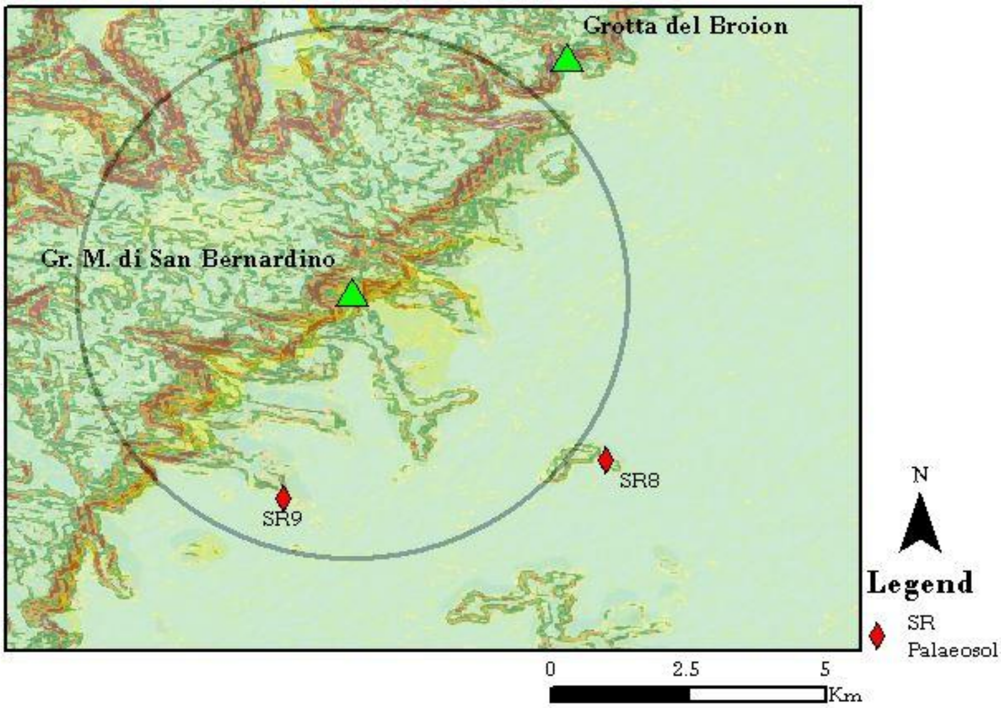


Figure 6.46: Secondary palaeosol sources of SR identified during lithic prospection.

Secondary sources of SR flints were identified in two locations within 5-6km of the site (Figure 6.46; Appendix C.2). Secondary source SR9 (AQ 4) was represented by surface finds of very small pieces of flint debris (~5cm), found at the base of a foothill extension of the Monti Berici (Table 6.40). Interestingly, lithic prospection of this landform identified no primary outcroppings of flint, which may indicate that sub-surface SR outcrops exist: whether or not these were accessible during MOIS-3, however, is indeterminable.

Flint Source	Munsell Hue	Quality	Extent of Source	Difficulty of Terrain	Cost of Extraction	Size	Scarcity	Attractiveness Quotient (AQ)	Rank
SR8	10R 5/4	4	4	TBD (1)	1	4	4	16	1
SR9	10R 5/4	4	4	TBD (1)	1	1	4	4	2

Table 6.40: Secondary palaeosol sources of SR identified during lithic prospection.

Secondary source SR8 (AQ 16) was found at the top of the Monticello landform, to the east of where primary source SR2 was identified. The good quality SR nodules were large, and the source was extensive (>100m) (Figure 6.47). As these nodules have been exposed due to modern quarrying it is difficult to say how accessible these may have been to Neanderthals during MOIS-3; however, based on the slopes of this landform, these were likely available as eroded, loose nodules.

Figure 6.47: Source SR8. Large image: view from SR8 on the Monticello landform, with the peaks of the Colli Euganei visible in the south. Inset: large SR nodule from SR8.

6.3.4 Grotta Maggiore di San Bernardino: terrain modelling

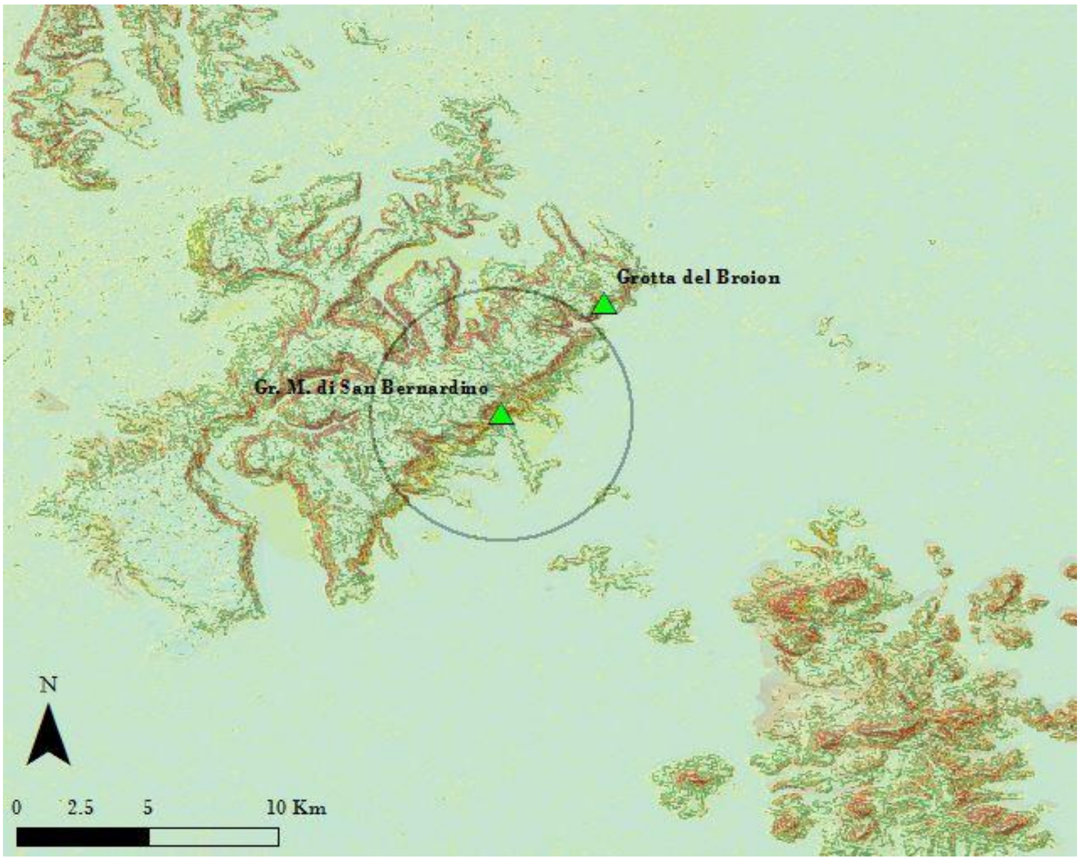


Figure 6.48: Visualisation of the Grotta Maggiore di San Bernardino landscape.

Grotta Maggiore di San Bernardino is situated on a steep south-west facing hill slope on the southern edge of the Monti Berici (Figure 6.48). Although the Monti Berici presented some areas of rugged terrain, overall the topography of the landscape was not as severe as the Monti Lessini. The primary and secondary SR flint sources identified during lithic prospection in the Monti Berici foothills and in the landforms rising from the Berici Plain can be observed on hillsides at elevations ranging from 25m to 45m asl. Compared to the modelled distribution of flint around Grotta di Fumane, the Bernardino lithological landscape was more limited and dispersed (Figure 6.49).

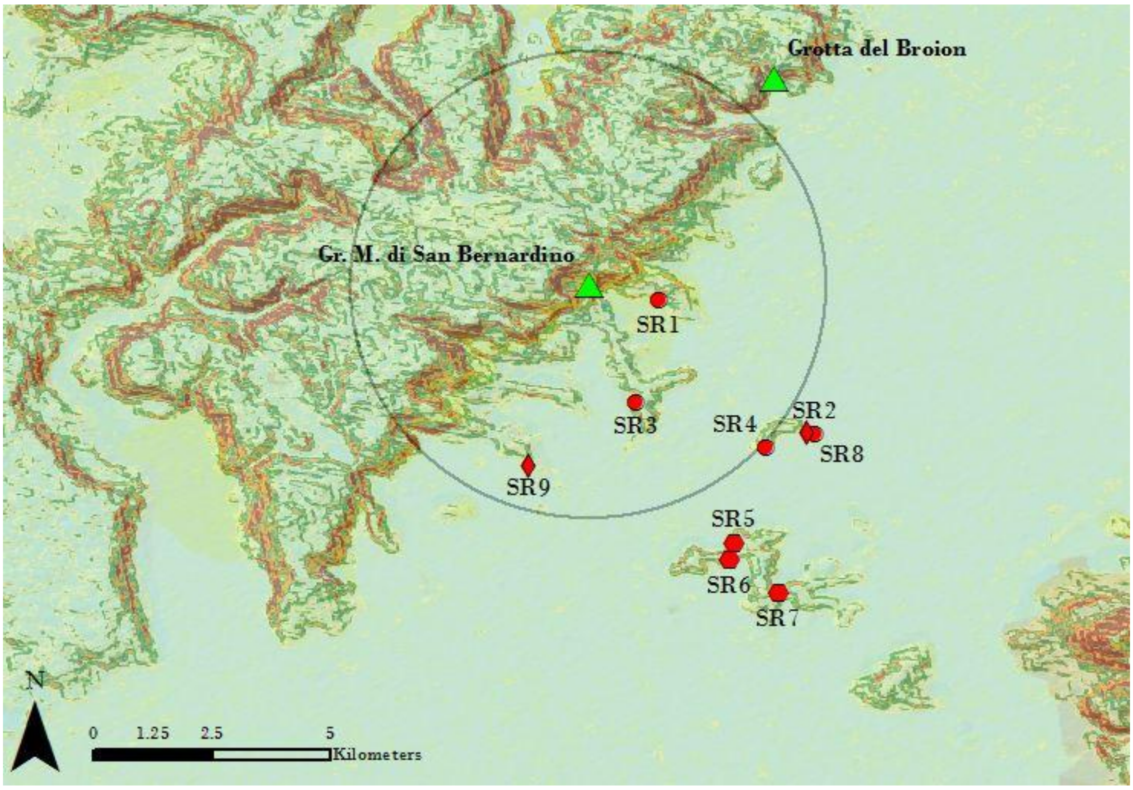


Figure 6.49: Distribution of primary (circle) and secondary palaeosol (diamond) sources of Scaglia Rossa flints identified during lithic prospections.

In modelling hypothetical mobility routes, the 2D straight line distances from Grotta Maggiore di San Bernardino to each identified flint source were again shorter than the 3D distances that accounted for topography (Table 6.41), as observed for Grotta di Fumane. The 3D distances rarely encountered slopes exceeding the modelling threshold of 56º, however, as the Monti Berici landscape represents less severe topography, particularly moving south, than that of the Monti Lessini. For this reason, and in contrast to the results of Grotta di Fumane, these routes were for the most part physically navigable; however, these are simplistic and do not consider those additional factors that would have impacted Neanderthal mobility strategies: energy and time.

	LRM Source	2D Distance	3D Distance	LCP Distance km	LCP Cost kcal	AQ
Primary outcrops <5km	SR3	1.01	2.69	1.32	299	1.51
Primary outcrops 5-7km	SR2	4.40	5.77	2.98	575	3.71
	SR4	2.43	5.11	4.88	480	2.50
	SR5	5.71	6.35	4.6	672	0.60
	SR6	5.95	6.60	6.44	709	1.69
	SR7	6.96	7.73	6.82	804	3.98
Palaeosols <5km	SR8	4.60	5.58	7.96	488	3.28
	SR9	3.66	4.07	4.42	462	0.87

Table 6.41: Comparative distances of hypothetical mobility routes distances and terrain difficulty.

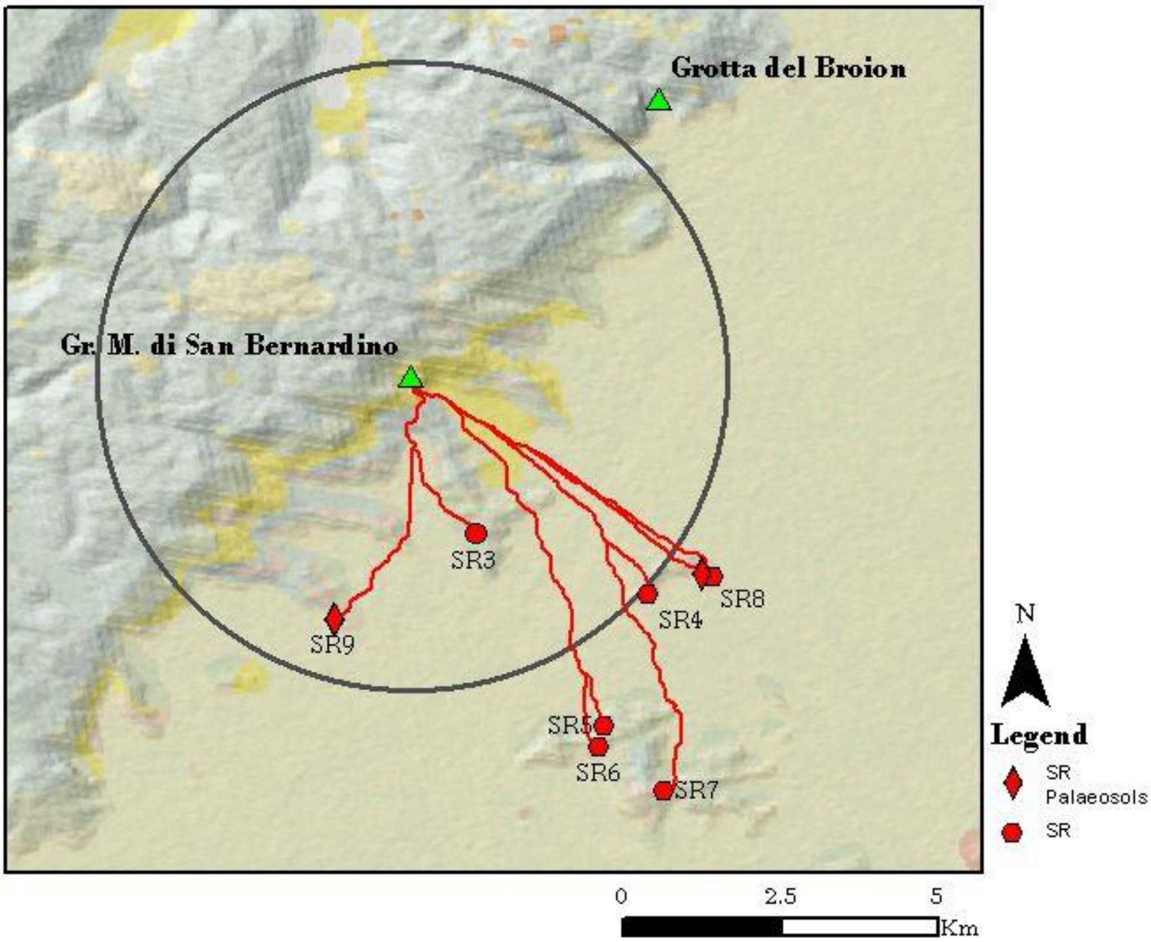


Figure 6.50: Modelled least-cost paths from each SR source to Grotta Maggiore di San Bernardino representing hypothetical mobility routes

The results of the LCP analyses were routes that largely followed the straightest possible route across the Berici Plain, and diverged to avoid steep slopes and higher energy costs along hilly terrain (Figure 6.50). All modelled routes came together at the base of the Monti Berici, where a natural least-cost corridor ascended the slopes. The energetic costs per kilometre of the LCPs were lower for all LCP routes as compared to Grotta di Fumane, demonstrating the relatively easier terrain of the Berici Plain, as demonstrated by the ratio of kcal to km (kcal/km). The relationship between topography and energetic costs in relation to distance is demonstrated in Figure 6.51

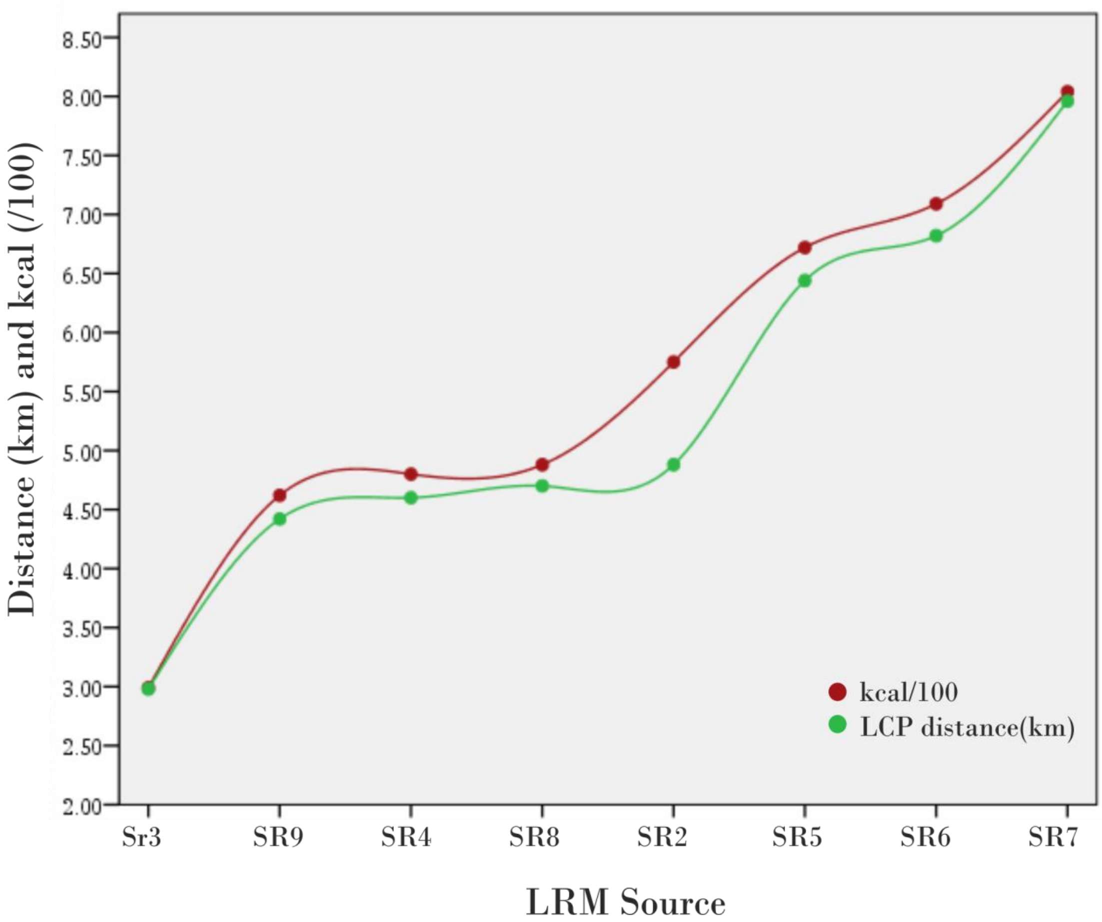


Figure 6.51: Relationship between energetic costs (k/cal divided by 100 for graphic comparisons) and LCP distance. Notice the closer alignment of these figures for Grotta Maggiore di San Bernardino than Grotta di Fumane (Fig 6.32).

Refiguring the attractiveness equations for each LRM source, factoring in the energetic costs of the LCPs as the previously omitted *terrain difficulty* variable, source attractiveness was decreased; however, in contrast to Grotta di Fumane, the attractive rankings of the new AQs for each LRM source did not change, as energetic costs were more closely linked to distance than rugged terrain (Figure 6.52; Appendix E.2). While the same sources (SR2, 7, and 8) retained their most attractive status, the AQ of SR7, the furthest and most costly LRM, decreased by over 90%.

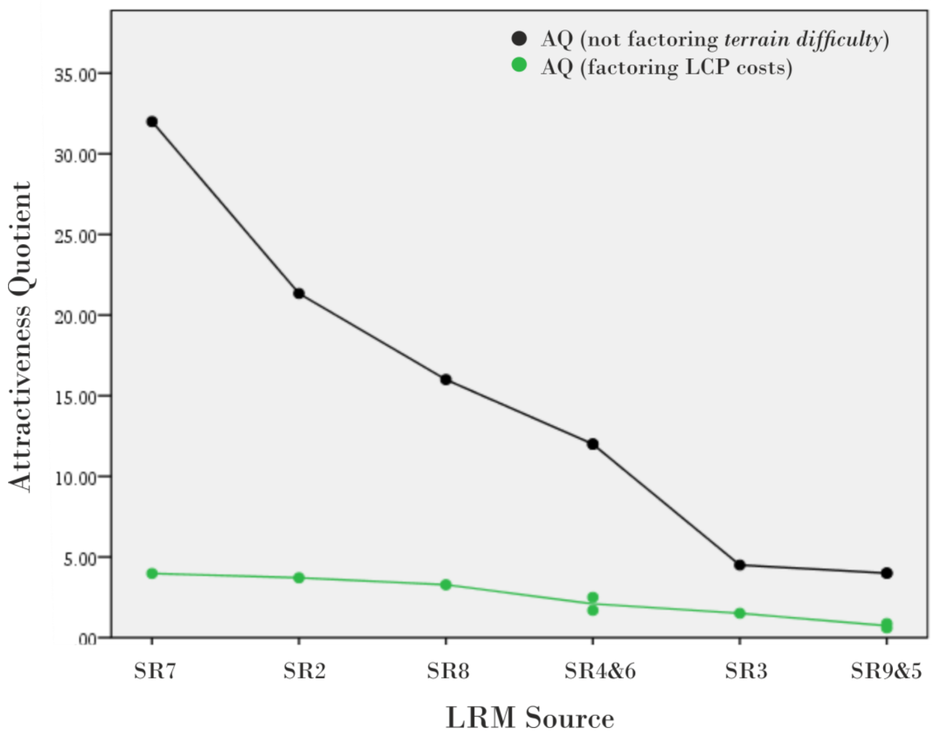


Figure 6.52: Comparison of original AQ (black) against re-calculated AQs factoring LCP path costs (terrain difficulty).

Determining temporal buffers in hourly walking increments showed that significantly increased distances could be covered over time in the gentler terrain of the Monti Berici landscape than the Monti Lessini (Figure 6.53). Further, the temporal buffer areas were significantly larger. For example, the one hour hiking radius around San Bernardino totalled 114 km2, compared to 106.7km^2 at Grotta di Fumane. These findings supported previous observations that terrain and mobility across it cannot be represented in Euclidean distances, and as shown in the comparison of temporal areas between San Bernardino and Fumane, the topography of each site imposes very different constraints on mobility. These findings reiterate that time as well as energetic costs must be factored into delineations of Neanderthal mobility, and the importance of considering these costs as dependent of each site's specific environmental contexts

While the lithic landscape of San Bernardino was less productive than Fumane, the number of LRM sources accessible within approximately 1.5hrs was greater, increased from one to five (Figure 6.54; Appendix E.2). The furthest source, SR7, could be reached in 2hrs 25minutes, which is roughly coincident with both Vita-Finzi and Higgs' (1970) and Binford's (1982) daily foraging radii. However, Binford's radius translated to 6km and Vita-Finzi and Higgs' to 10km, while the findings of this research indicate that a 2 hour walking distance south of San Bernardino equates to around 8km: the variations in these distances-to-time determinations clearly accentuates the importance of factoring in site-specific topography in landscape analyses.

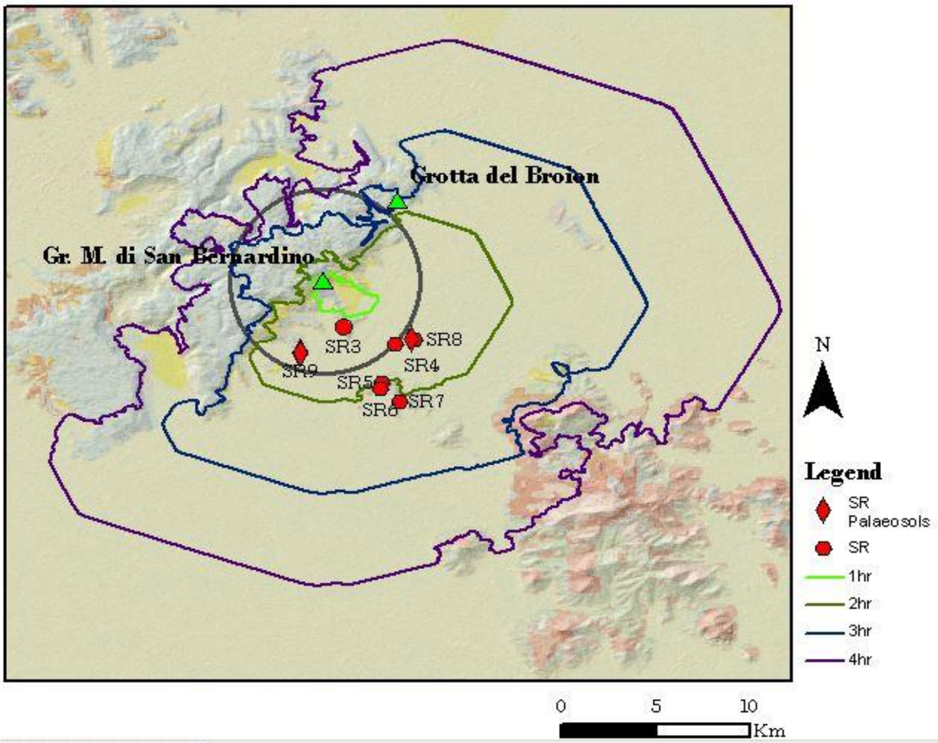


Figure 6.53: Temporal hiking buffers around Grotta Maggiore di San Bernardino. Note that the 2hr buffer extends beyond the Euclidean-derived

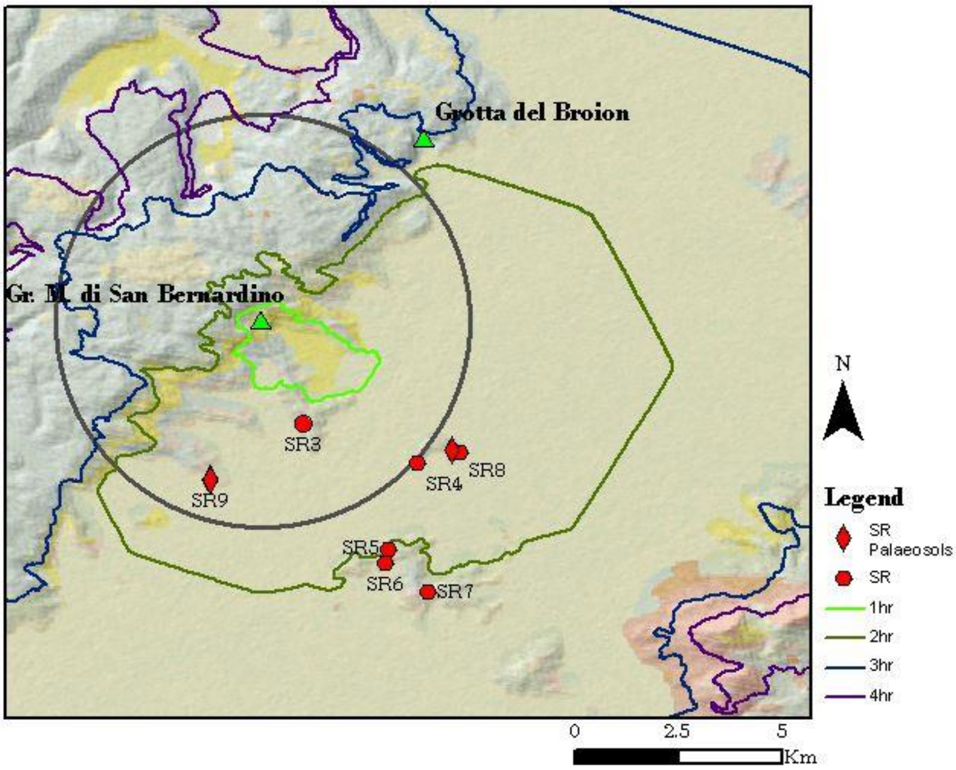


Figure 6.54: Closer view of the temporal buffers around Grotta Maggiore di San Bernardino, where steep terrain limits the one hour buffer

Applying terrain modelling and lithic prospection results to the lithic assemblage of Unit II

Linking LRM distribution and terrain modelling results to the Unit II lithic assemblage, the differences in the local and semi-local versus exotic materials can be perceived to represent differing technological provisioning strategies in response to procurement costs and mobility strategies.

While only SR flint was identified during lithic prospection, because of the wide distribution of this LRM over the landscape and its general uniformity in colour, it was difficult to determine from which source(s) the SR in the lithic assemblage of Unit II was procured. However, based on quality, the more distant sources were superior, and likely preferred by the Neanderthal occupants of San Bernardino, as the more proximal outcrops were variably productive and of lesser quality. Based on this hypothesis, Neanderthal were travelling extended distances to procure sources located at up to 8km to the south. These extended route distances would have, however, been facilitated by the reduced costs of travelling across the relatively flat Berici Plain. Therefore, it could be posited that based on the character of the lithological landscape and the relative ease of mobility, the local range at San Bernardino was extended to include these sources.

As observed at Fumane, there was a relationship between procurement costs, lithotype frequencies, and cortex, with SR, the most proximal flint source, being best represented in the assemblage and retaining around double the cortex of the exotic and less represented AS and SGE flints. Retouch in the SR flints was also only half of the more distant and costly SGE and AS flints, where increased retouch can be linked to the management and maintenance of these materials over both space and time.

Increased procurement and/or transport costs were also linked to the number of retouched edges observed in each lithotype. Of the retouched tools in SR, 22.91% show more than one retouched edge, which is comparable to the SR assemblages of unit A5-A6 at Grotta di Fumane. Retouched edge number was increased in the exogenous SGE (24.16%) and AS (30.77%) lithotypes. These findings, in conjunction with the overall higher retouch of the exotic flints, indicate that retouch was an economising strategy that served to meet the lithic needs of mobile Neanderthals.

As the lithic analyses of San Bernardino Unit II did not include cortical analyses to differentiate between secondary and primary source exploitation, it is difficult to say if either was preferred. However, based on the lithic prospection results, palaeosols source SR8 could have provided a procurement locale of significant attraction based on the quality and size of the available flint and the source extent. Further, unlike the streambed sources at Grotta di Fumane, the palaeosol sources did not appear to present any internal fissuring that would have dissuaded Neanderthals from its selection.

Unlike the conditions of Grotta di Fumane, where LRM sources were clearly distinct in their environmental contexts, the situation at Grotta Maggiore di San Bernardino is one such that at least two biomes would have to be passed through before reaching an LRM source: the forested biome in which the site was situated, and the open woodland of the Berici Plain. While landforms on which the identified SR flints outcropped were likely forested, and indeed, forest ungulates dominate the hunted assemblage (44%), the significant presence of wetland species (20%) as well as representatives of open forests and rocky slope conditions in the hunted faunal assemblage indicates that food subsistence was likely independent of lithic procurement. Indeed, the distances and costs of the higher quality, dark reddish-brown SR from 6-8km, while temporally within two hours and likely within a local *lithic procurement* foraging radius, would have been prohibitive for heavier faunal transport. In this scenario, embedded procurement incorporating flint acquisition would likely not be economical. Therefore, flint may have been directly procured, which may have contributed to the intensity of SR flint exploitation in Unit II, as was demonstrated though the exhaustion of the cores, secondary production sequences, and the small size of the recovered scrapers.

As discussed in the techno-economic analyses, while complete *chaînes opératoires* were observed on the allochthonous SGE and AS flints, these were likely a palimpsest of truncated reduction sequences in the diverse flint types that made up each group. In contrast, in the local and semi-local SR flint, complete reduction sequences are indisputable, and were supported by refittings (Peresani 1995-1996). Therefore, the completeness of *chaînes opératoires* appears to be linked to distance and costs.

6.3.5 Grotta Maggiore di San Bernardino, Unit II: results summary

Overall, the various indicators of palaeoclimate at and around Grotta Maggiore di San Bernardino were largely in agreement, and demonstrated that the MOIS-3 Unit II was formed during cool temperate and humid climates. The site was situated in proximity to predominantly mixed forests, with significant wetlands, open forests, and limited grasslands. Sub-freezing temperatures, made more severe by wind chill, and snowy conditions occurred in three to five months of the year. While precipitation reconstructions did not appear to be accurate, relative humidity simulations supported wet, humid winters and dry summers, where temperatures reached just over 20ºC. Colder and more open conditions at the end of MOIS-3, possibly correlating to Heinrich Event 4, are signalled in the Fimon sediment core; however, significant temperature and humidity drops were not indicated in the archaeological record. Overall, the palaeoenvironmental conditions at San Bernardino were largely comparable to those observed for Grotta di Fumane, although winters appear to have been milder with decreased snow conditions and slightly warmer temperatures.

Techno-economic analyses revealed differences in the procurement and maintenance of the SR flints versus the exotic flints, where full *chaînes opératoires* were observed on the local and semi-local SR flints, versus indicators of truncated *chaînes opératoires* in the SGE and AS flints from 20-50+km. The exotic flints also showed reduced cortex presence and an increase in retouch and retouched edges. In all material types, however, lithic exploitation appeared to have been aimed at maximising lithic potential, as cores were recovered fully exhausted and secondary reduction sequences occurred on even the SR flint.

Lithic prospection identified only two sources of poor to good quality SR flint within the local 5km radius, and just seven outcrops and two palaeosol sources of higher quality in the semi-local range, typically from the hillsides of the landforms rising from the Berici Plain. While these identified sources represent a viable lithological landscape for Neanderthal populations, its density and sustainability was much lower than was observed for Grotta di Fumane.

Terrain modelling demonstrated that, while the distances between the good and the high quality flints signified the difference between traditional delineations of local and semi-local foraging, the flat terrain of the Berici Plain facilitated relatively low costs and faster mobility speeds, where even the most distant (and higher quality) SR flints could be accessed within around a two hours foray. Based on these findings, and the representation of higher quality SR flints and their full *chaînes opératoires* in Unit II, the local lithic exploitation radius at San Bernardino likely extended to these more distant LRM outcrops, approximately 8km from the site. However, the costs and distances associated with the procurement of these flint sources would likely have exceeded economic thresholds for faunal procurement, and thus the acquisition of the more distant Scaglia Rossa sources likely involved direct procurement events.

6.4 Grotta del Broion ES2: Results

6.4.1 Grotta del Broion: palaeoenvironmental reconstructions

The sedimentary, palynological, and carnivore-accumulated faunal record of ES2 of Grotta del Broion recorded temperate and humid environments following colder and more arid open steppe conditions of the underlying unit ES3. The sedimentary composition of ES2 was dominated by aeolian sediments with evidence of cryoclastic activity and reddish-brown clays indicative of humid conditions (Sala 1980). The sedimentological indicators of cold conditions were, however, in contrast to the faunal and pollen data, which showed more temperate conditions. Palynological analyses of the numerous pollens recovered in ES2, conducted by Cattani and Renault-Miskovsky (1982-1983, 1989), indicated closed forests in proximity to the site, with deciduous hornbeam, willow, hazel, birch, lime, maple, and oak species outweighing pine. The strong presence of thermophilous species was supported by anthracological analyses (Cattani and Renault-Miskovsky 1989). The presence of grassland conditions were also signalled by herbaceous pollens, predominantly members of the Artemisia, pink, and Tubiflorae families.

The faunal assemblage of ES2 was dominated by carnivore remains, predominantly cave bear, and by carnivore-accumulated ungulates. An anthropic accumulation of faunal species was not recorded. Analyses by Sala (1980) demonstrated a diverse range of environments: in contrast to the palynological data, woodland species dominated the faunal assemblage at more than 60%, largely made up of red deer (25%). Roe deer were not identified, which is in contrast to both Fumane and Bernardino, and which indicates either a low presence of this species in the environment, or that roe deer represent a selected prey species by Neanderthals at the other sites. Rocky slope conditions were signalled by chamois (16%) and ibex (2.5%), and marmots were well represented at 18.4%. Open grassland species were not observed, despite that these were signalled in the pollen assemblage. Open environments with sparse forests were signalled by aurochs (5%), and wetland species included wild boar (2%) and elk (2.5%). The recovered carnivore species had wide ecological ranges, and included red fox, grey wolf (well represented), hyena, wildcat, weasels, and polecats. The diverse ecological contexts signalled by the pollen and faunal assemblages were supported by the micromammal assemblage, which included woodland and undergrowth species wood mouse, forest vole, and common shrew, the arboreal forest dormouse, and the grassland species field vole (Sala 1980).

The results of the nearby Lago di Fimon sediment core analyses (Pini *et al.* 2010, Monegato *et al.* 2011) supported diverse environments and persistent forestation on the Berici landform throughout MOIS-3. Open and closed forests environments were indicated by coniferous and deciduous arboreal pollens throughout MOIS-3, until more open conditions were signalled in the core that potentially corresponded to Heinrich Event 4. The wetland conditions of Lago di Fimon were also in agreement with the presence of the lacustrine pollen remains and wetland faunal species in ES2.

Because of its proximity to Grotta Maggiore di San Bernardino, the four projected Lambwin coordinates of Grotta del Broion were identical. Therefore, the only difference in the Stage Three Project palaeoclimate simulation data between the two sites was that the temperate deciduous biome, Biome 5, was more strongly predicted at Grotta del Broion (51%) than Grotta Maggiore di San Bernardino (42%). Because the generated palaeoclimate data for the sites were identical, the following discussion will focus primarily on how the data, reported in Section 6.3.1, relates to the site-level and Lago di Fimon palaeoenvironmental indicators.

The nearly equal prediction of the evergreen taiga/montane forest and temperate deciduous biomes was in agreement with the site-level and sediment core determinations of a predominantly mixed forested environment around Grotta del Broion during MOIS-3. Temperate grasses, signalled in both biomes to a lesser degree than arboreal species, likely corresponded to the Alpine meadow conditions of the Berici Plateau as indicated by the observed herbaceous meadow species pollens in ES2.

The high productivity of the arboreal pfts, particularly the temperate summergreen species of Biome 5 for both warm and cold-type climate simulations (Table 6.33) mirrors the pollen record of ES2. The low productivity of temperate grasses and woody desert plants may or may not be in agreement with the site pollen record; these pollens were well-represented in the site, but may be associated with the wind-blown deposits derived from the Berici Plain that were documented in the sedimentological record.

The greater productivity of Biome 5 was supported by simulated leaf area index (lai), which was greater in both warm and cold-type simulations than Biome 10. For both biomes, lai did not vary significantly between both warm and cold-type simulations, indicating that vegetation was consistent through MOIS-3; indeed, such conditions were recorded in the site-level data.

Temperature simulations support that the conditions in which ES2 was formed were temperate, with Biome 5 being warmer year round in both warm and cold-type events. Sub-freezing temperatures persisted longer in Biome 10 than Biome 5, particularly for the warm-type event, and summer temperatures were consistently mild in both warm and cold-type simulations. These findings were in agreement with the site-level indicators of temperate conditions at Broion during MOIS-3. Wind chill significantly reduced winter temperatures in both warm and cold-type climate simulations, reaching ultimate lows in January in cold-type simulations, with wind chill dropping temperatures in Biomes 10 and 5 to -17.46 ºC and -13.77 ºC, respectively.

There was little variation in the number of snow days per year between the warm and cold-type events, but a significant difference between the biomes, with Biome 10 having snow for 2 to 2.5 more months a year than Biome 5. Because the projected coordinates for ES2 of Grotta del Broion were evenly weighted for both biomes, it is difficult to ascertain which prediction is more in line with the actual palaeoclimate conditions of the site during Neanderthal occupation. The simulations of snow cover (cm/month) agreed with temperature simulations and snow days per year, showing that snow depth was deeper, and lasted longer, in Biome 10 than Biome 5 (Figure 6.39).

As was observed for San Bernardino, the precipitation simulations were quite varied by biome and warm and cold-type events, and were in contrast to the snow fall data and relative humidity simulations, which more clearly showed a significant decrease in humidity in the summer months, and contrasting high humidity in the winter. The agreement of the non-precipitation simulations therefore indicates that seasonal shifts in precipitation likely occurred, and the local environment of Grotta del Broion experienced wet winters and relatively dry summers.

6.4.2 Grotta del Broion ES2: techno-economic analysis

MOIS-3 ES2 of Grotta del Broion contained 96 lithic implements, including 4 of indeterminate lithotype, resulting in 92 analysed artefacts (Table 6.42). The assemblage was comprised mostly of SR flints (47.83%), followed by Bi (25%), and SV (19.57%). Eoc and Ool flints were little represented, at 4.35% and 3.26%, respectively.

Grotta del Broion ES2: Techno-economic results, N=92									
Lithotype	**Frequency**	**Percent**	**Techno-culture**	**Dominant CO Phase**	**Chaîne opératoire**	**Retouch %**	**% cortical***	**DominantLRM Source**	**Dominant LRM Form**
Bi	23	25.00	Levallois	2a	Truncated	43.48	8.70	Diverse	Nodules
SR	44	47.83	Levallois	2a	Truncated	40.91	29.55	Soils and eroded outcrops	Nodules and blocks
SV	18	19.57	Levallois	2a	Truncated	33.33	44.44	Eroded outcrops	Nodules and lenses
Eoc	4	4.35	Levallois	2a	Truncated	50.00	25.00	Soils	Nodules and blocks
Ool	3	3.26	Levallois	2a	Truncated	0.00	0.00	Indet	Nodules and blocks
Total	**92**	**100%**							

Table 6.42: Simplified techno-economic results of ES2.

Cortical analyses indicated that the exploited lithotypes in ES2 were procured from diverse source types, predominantly eroded primary outcrops and soils, as nodules and blocks. SR flint, which retained cortex at nearly 30%, was determined to have been sourced, based on flint colour and cortex, from two areas: to the west-southwest at San Pancrazio (San Bernardino source SR3) at around 5-7km, and more commonly (~66% of SR) from Monte Albettone (SR 5, 6, and 7) and southward to the Colli Euganei, at 10-20+km (Peresani and Porraz 2004). Bi, whose implements retained cortex at only 8.7%, was procured from between 20-30km from the vicinity of the Lessini pre-Alps and/or the Asiago region to the north. SV was procured from greater than 20km in the Lessini pre-Alps to the north and northwest and from the Colli Euganei to the south. Cortex was observed at a higher frequency (44.44%) in SV than SR, and was five times that observed in the Bi assemblage. Eoc and Ool flints were acquired exclusively from the western Monti Lessini pre-Alps, at distances exceeding 50km (Peresani and Porraz 2004). Cortex is seen in 25% of the Eoc implements, and is not represented in the Ool artefacts.

Truncated *chaînes opératoires* were observed in all of the recovered lithotypes, representing, however, different phases of reduction (Table 6.43). Bi was most represented by Phase 2a implements (69.57%), the majority of which were Levallois flakes (87.5%) (Table 6.44). Phase 0, cortical flakes, was significantly less represented, with no raw or tested blocks, and Phase 1 products were lacking. Phase 2b consisted of a single Levallois débordant flake, and Phase 2c was represented by both cortical and non-cortical flake fragments and a single Kombewa flake, although no flake-cores were identified.

Grotta del Broion ES2: Chaîne opératoire phases							
Lithotype	Phase 0	Phase 1	Phase 2a	Phase 2b	Phase 2c	Phase 3	Diverse
Bi	4.35	/	69.57	4.35	21.74	/	/
SR	9.09	/	63.64	2.27	20.45	4.55	/
SV	5.56	/	66.67	/	27.58	/	/
Eoc	25.00	/	50.00	25.00	/	/	/
Ool	/	/	100.00	/	/	/	/

Table 6.43: Percentages of *chaîne opératoire* phases in each of the ES2 lithotypes

	Grotta del Broion: Technological categories by lithotype, n=92							
	Geneste Tech Category	**Bi**	**SR**	**SV**	**Eoc**	**Ool**	**Tech Cat Total** n	%
Phase 0	1	1	4	1	1		7	7.61
Phase 2a	4	1	5	2			8	8.70
	6	1	6	2	1		10	10.87
	7	14	16	8	1	3	42	45.65
Phase 2b	8		1				1	1.09
	13		1		1		2	2.17
	15	1					1	1.09
Phase 2c	20	1	1				2	2.17
	21.1	1	1	1			3	3.26
	21.2	3	7	4			14	15.22
Diverse	26		2				2	2.17
	Lithotype Total	**23**	**44**	**18**	**4**	**3**	**92**	**100%**

Table 6.44: Technological categories and *chaîne opératoire* phases by lithotype in ES2.

In the dominant SR lithotype, Phase 0 implements (entirely cortical flakes and >50% cortical flakes) were double what was observed in the Bi assemblage, although Phase 1 was similarly absent. Phase 2a (63.64%) was most represented, with predominantly Levallois flakes (57.14%), as well as Levallois sub-products and a single Discoidal flake and Levallois blade flake. Phase 2b contained a single exhausted Levallois core, one of only two cores recovered in ES2. Phase 2c (20.45%) implements included non-cortical flake fragments (>75%), a cortical flake fragment, and a Kombewa flake; as in Bi, no flake-cores were identified, indicating that the Kombewa flake was manufactured off-site. Phase 3 retouching flakes (<20mm) made up less than 5% of the SR assemblage, and attest to on-site retouching activities.

In the truncated *chaînes opératoires* observed in the SV assemblage, Phases1, 2b, and 3 were entirely lacking. The representation of Phase 0 at 5.56% was comparable to the Bi assemblage. The dominant Phase 2a products included mostly Levallois flakes (66.67%), in addition to Levallois sub-products. Phase 2c (27.58%) included significantly more non-cortical than cortical flake fragments at a ratio of 4:1.

In the limited Eoc assemblage (n=4), truncated reduction sequences were observed, with a single cortical flake in Phase 0, a single Levallois core in Phase 2b, and a Levallois flake and an undifferentiated flake in Phase 2c. The Eoc assemblage may represent a mobile toolkit, where the core served to meet diverse potential lithic resource needs.

The Ool assemblage was comprised solely of three Levallois flakes, which, based on the lack of any other phases of production in this lithotype, must have been produced off-site and introduced to the site.

The frequency of tools in ES2 at Grotta del Broion (64.13% of the total assemblage) was significantly higher than observed in Unit II of Grotta Maggiore di San Bernardino (11.90%) and A8+A9 (8.81%), A6 (18.13%), A5-A5+A6 (17.37%), and SR A5+A6 (17.12%)of Grotta di Fumane.

In the Bi lithotype, tools (n=17) comprised 73.91% of the total assemblage, 77.78% of which were unretouched Levallois flakes (Table 6.45). The number of retouched tools amounted to nine (52.94% of the tools assemblage), of which 88.89% were scrapers. These included four simple straight scrapers (23.53% of the tool assemblage), one of which was manufactured from the above-mentioned cortical flake, and the remaining three were made on Levallois flakes. Two transversal scrapers represented 11.11% of the Bi tool assemblage, and were manufactured on a Levallois flake and Discoidal flake. Scrapers further included a single déjeté scraper and a scraper with alternate retouch, both of which were manufactured on Levallois flakes. Additionally, an implement with marginal retouch was recorded: overall, retouch in Bi occurred on 50% of the Levallois flakes and 33.33% of non-cortical flakes.

The SR assemblage included 18 retouched pieces (40.91%), manufactured on a range of technological products. 38.89% of these retouched implements were cortical, which is nearly quadruple that seen in Bi. Including unretouched Levallois flakes, which comprise 30.77% of the tool assemblage, nearly 60% of the SR assemblage consisted of Levallois tools. Of the retouched tools, the majority were flakes with marginal retouch (23.08%); these included a Kombewa flake, a Levallois flake, an atypical Levallois flake, a Levallois blade, and two backed flakes from Levallois production sequences. As observed for the Bi, scrapers made up the majority of the retouched tools (61.11%), with simple types occurring more frequently than those with two or more retouched edges. A single limace was also observed.

Grotta del Broion, ES2: Bordes Reference Types by Lithotype, N=92													
	Lithotype and total frequency	**Bi (23)**		**SR (44)**		**SV (18)**		**Eoc (4)**		**Ool (Tenno) (3)**		**Total (92)**	
		n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Bordes Reference Type	1	7	41.18	8	30.77	5	45.45			3	100	23	38.98
	2	1	5.88									1	1.69
	8			1	3.85							1	1.69
	9	4	23.53	6	23.08	1	9.09	1	50			12	20.34
	11			1	3.85							1	1.69
	12			1	3.85							1	1.69
	18			1	3.85	2	18.18					3	5.08
	21	1	5.88									1	1.69
	22	2	11.76	1	3.85							3	5.08
	27			1	3.85							1	1.69
	29	1	5.88									1	1.69
	48	1	5.88	6	23.08	3	27.27	1	50			11	18.64
	Total	**17**	**100%**	**26**	**100%**	**11**	**100%**	**2**	**100%**	**3**	**100%**	**59**	**100%**
	% Lithotype	**73.91%**		**59.09%**		**61.11%**		**50%**		**100%**		**64.13% of ES2 assemblage**	

Table 6.45: Bordian tool types by lithotype in the ES2 lithic assemblage.

Retouch occurred on 54.54% of the SV tools. As observed for the Bi and SR tool assemblages, Levallois flakes were well represented in SV tools (45.45%). Only a third of the retouched implements in the SV tool assemblage were cortical; this figure is comparable to the frequencies observed in SR (38.89%), but significantly less than in Bi (90.91%). Formal tools include a simple scraper, manufactured on a Levallois flake, and two convergent straight scrapers.

Considering the limited Eoc assemblage, retouch occurred on only two of the four total pieces, one of which was a cortical flake (Phase 0) with marginal retouch, and the other a Levallois flake (Phase 2a), which served as a blank in the manufacture of a simple scraper.

As previously mentioned, the limited Ool assemblage in ES2 was entirely comprised of tools. None of the three Levallois flakes were retouched or retained cortex; that the Ool flint is only represented by Levallois flakes may signify the role of these implements as preferred blanks within the Ool mobile toolkit.

6.4.3 Grotta del Broion: lithic prospection

The results of the pedestrian survey for lithic prospection reinforced what was indicated by the lithological maps of the region and what has been reported in relevant site literature: lithic raw material sources were lacking within the local 5km radius of Grotta del Broion. Lithic prospection within this radius did not identify a single primary or secondary source of flint, indicating that the lithic materials recovered from the site originated from greater distances. The nearest primary and secondary flint resources to Grotta del Broion were those identified during lithic prospection around Grotta Maggiore di San Bernardino (Table 6.46; Appendix C.2; Appendix D.3); these data indicate that the minimum (Euclidean) distance required to procure good quality flint was 7.5km.

Flint Source	Munsell Hue	Quality	Extent of Source	Difficulty of Terrain	Cost of Extraction	Size	Scarcity	Attractiveness Quotient (AQ)	Rank
SR1	10R 5/6	1	4	TBD (1)	1	3	3	4	6
SR2	10R 5/6	4	4	TBD (1)	1	4	3	21.34	2
SR3	10R 5/4	2	3	TBD (1)	1	3	4	4.5	5
SR4	10R 5/4	4	4	TBD (1)	1	3	4	12	4
SR5	2.5YR 5/4	4	2	TBD (1)	1	2	4	4	6
SR6	2.5YR 4/4	4	4	TBD (1)	1	3	4	12	4
SR7	2.5YR 5/4	8	4	TBD (1)	1	4	4	32	1
SR8	10R 5/4	4	4	TBD (1)	1	4	4	16	3
SR9	10R 5/4	4	4	TBD (1)	1	1	4	4	6

Table 6.46: Attractiveness variables and AQs of SR flints identified during lithic prospection. SR8 and SR9 are palaeosol sources.

6.4.4 Grotta del Broion: terrain modelling results

As no flint sources were identified within 5km of Grotta del Broion, terrain modelling was utilised to determine the minimum distances of hypothetical mobility routes including least-cost paths to those SR flints sources identified around Grotta Maggiore di San Bernardino (Figure 6.55). Determining the distances of the hypothetical mobility routes, the errors in utilising 2D measurements (substantially shorter distances) reinforced that this method of considering Neanderthal mobility is highly flawed (Table 6.47)

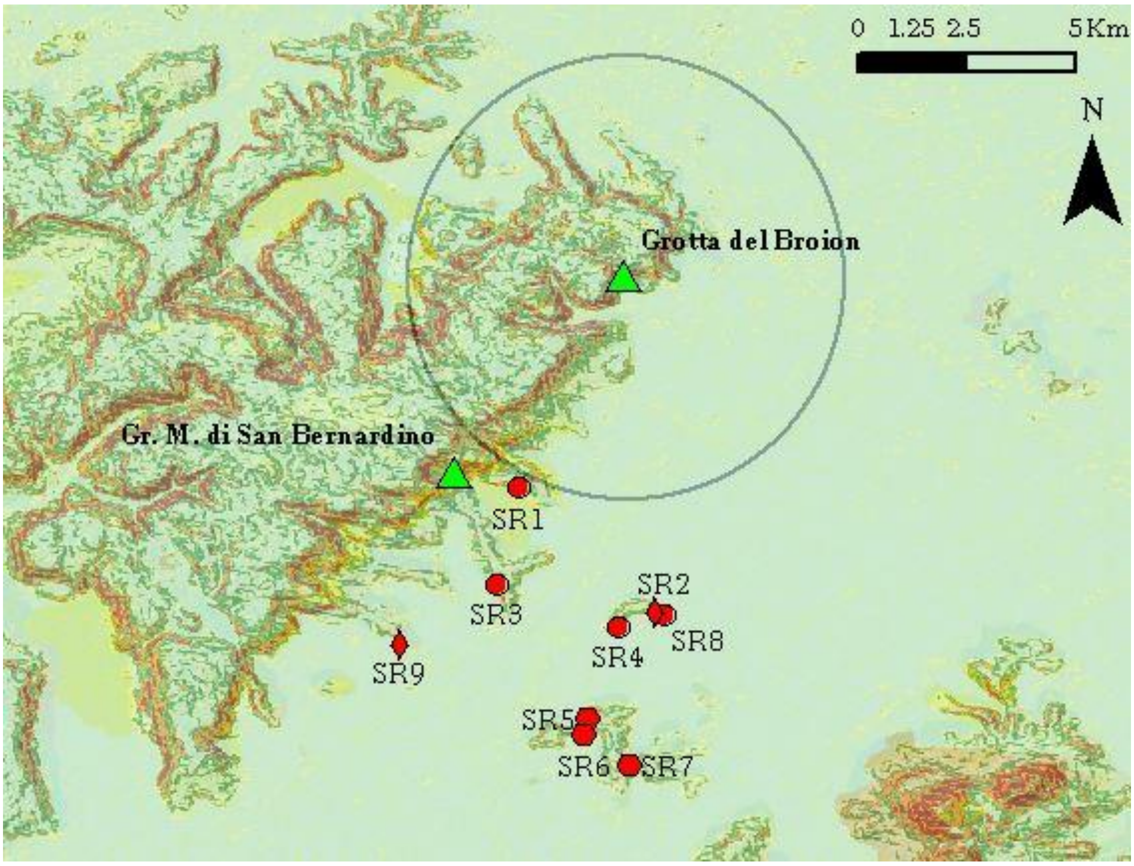


Figure 6.55: Terrain and distribution of identified SR flint in the landscape of Grotta del Broion.

LRM Source	2D Distance	3D Distance	LCPI Distance	LCPII Distance	LCPI Pathcost	LCPII PathCost
SR1	4.80	5.28	7.12	7.1	8089	8143
SR2	6.89	7.59	7.95	7.9	8905	8957
SR3	6.76	7.48	8.05	7.98	9876	9954
SR4	7.10	7.84	8.33	8.34	9694	9761
SR5	9.00	9.95	10.38	10.39	11292	11342
SR6	9.32	10.34	10.71	10.7	12275	12357
SR7	9.91	10.98	11.63	11.56	13132	13266
SR8	6.83	7.56	7.82	7.8	8627	8668
SR9	8.79	9.73	10.67	10.6	11575	11618

Table 6.47: Comparison of hypothetical mobility route distances and the kcal costs of the LCPs.

As observed for Grotta Maggiore di San Bernardino, the generated least-cost paths followed fairly direct routes across the Berici Plain, with small diversions to avoid elevated landforms (Figure 6.56). Upon reaching the hills containing the SR outcrops, the least-cost paths mimicked switchbacks up the slopes to reduce energetic costs.

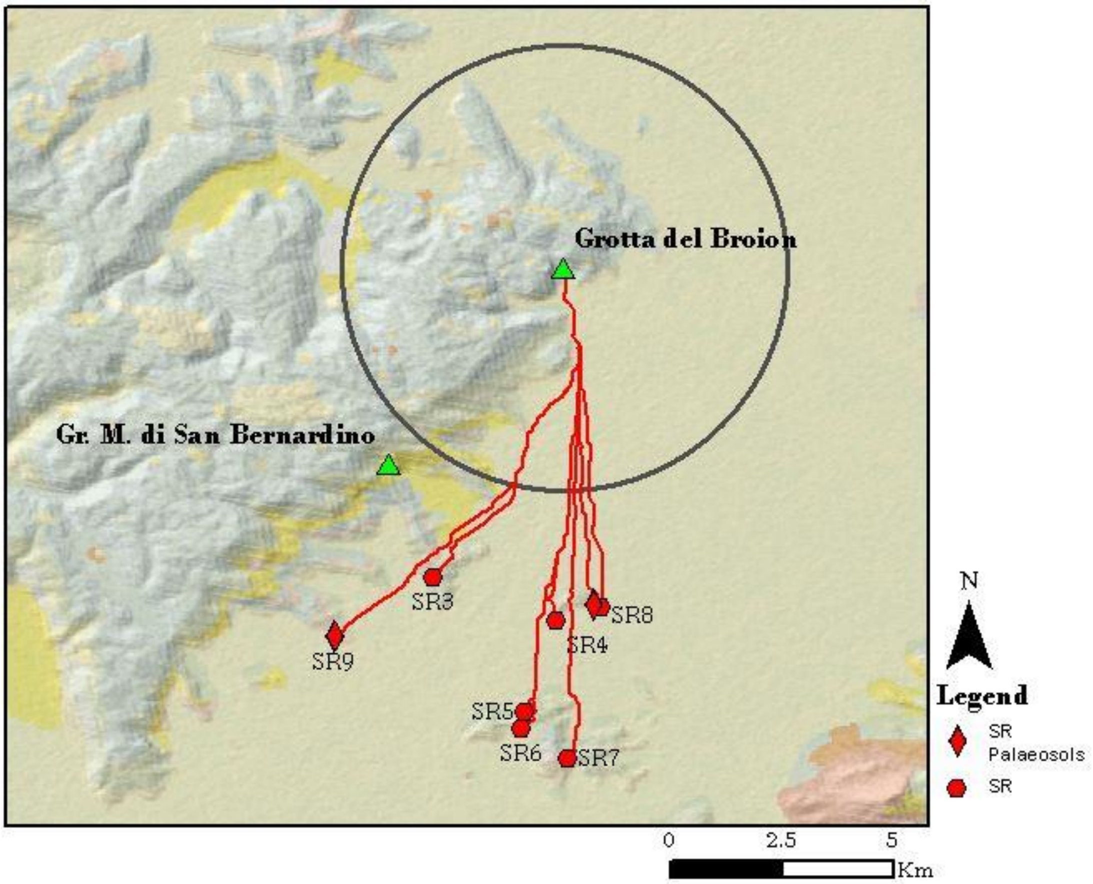


Figure 6.56: Least-cost paths to the primary and secondary sources of Scaglia Rossa identified during lithic prospection

An LCP was also generated from Grotta del Broion to Grotta Maggiore di San Bernardino; at 6.5km (and 716kcal), this route was significantly longer than the distance indicated by a 2D straight-line route (5.31km), reiterating the importance of considering the impact of terrain on mobility in a 3D landscape (Figure 6.57).

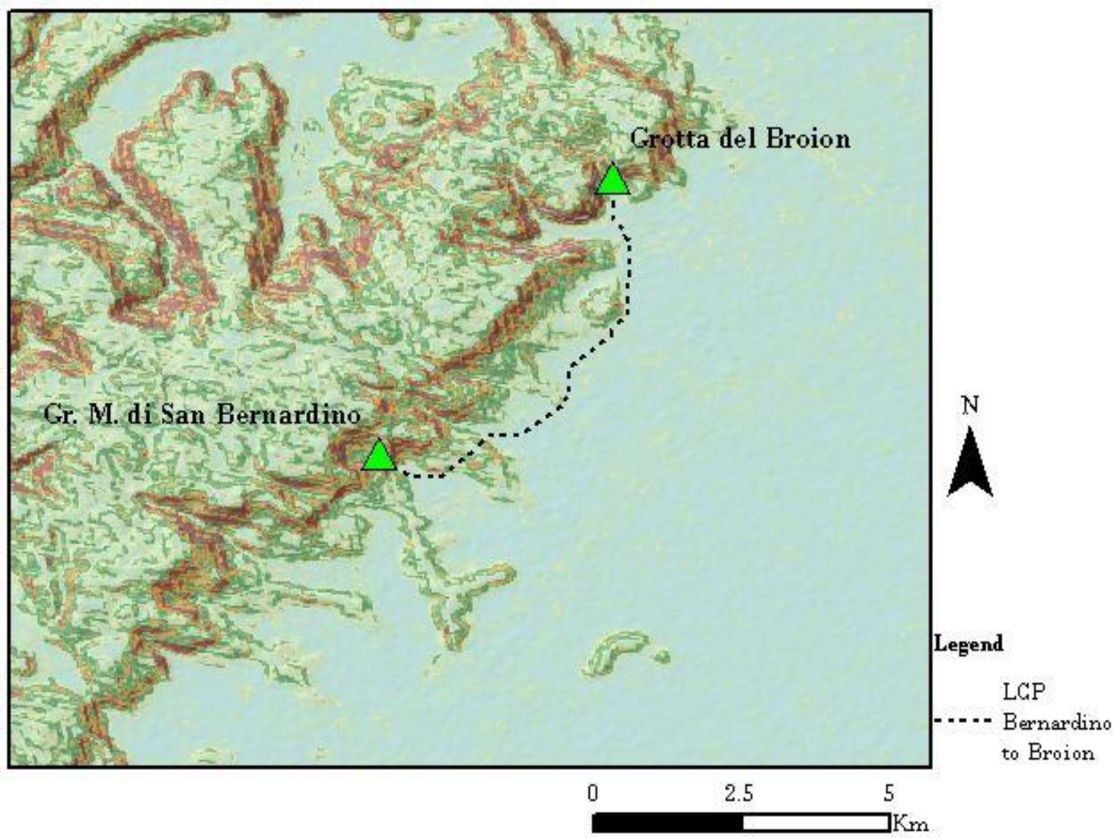


Figure 6.57: LCP between Grotta del Broion and Grotta Maggiore di San Bernardino (6.91 km).

The energetic costs of the LCPs were the highest for all of the sites in this research, due, however, to their increased distances rather than terrain (Appendix E.3). As the majority of the least-cost paths travelled over the Berici Plain, and thus incurred lower costs than the LCPs at Grotta di Fumane that covered more difficult terrain, the difference between distance and kcal expenditure was reduced (Figure 6.58).

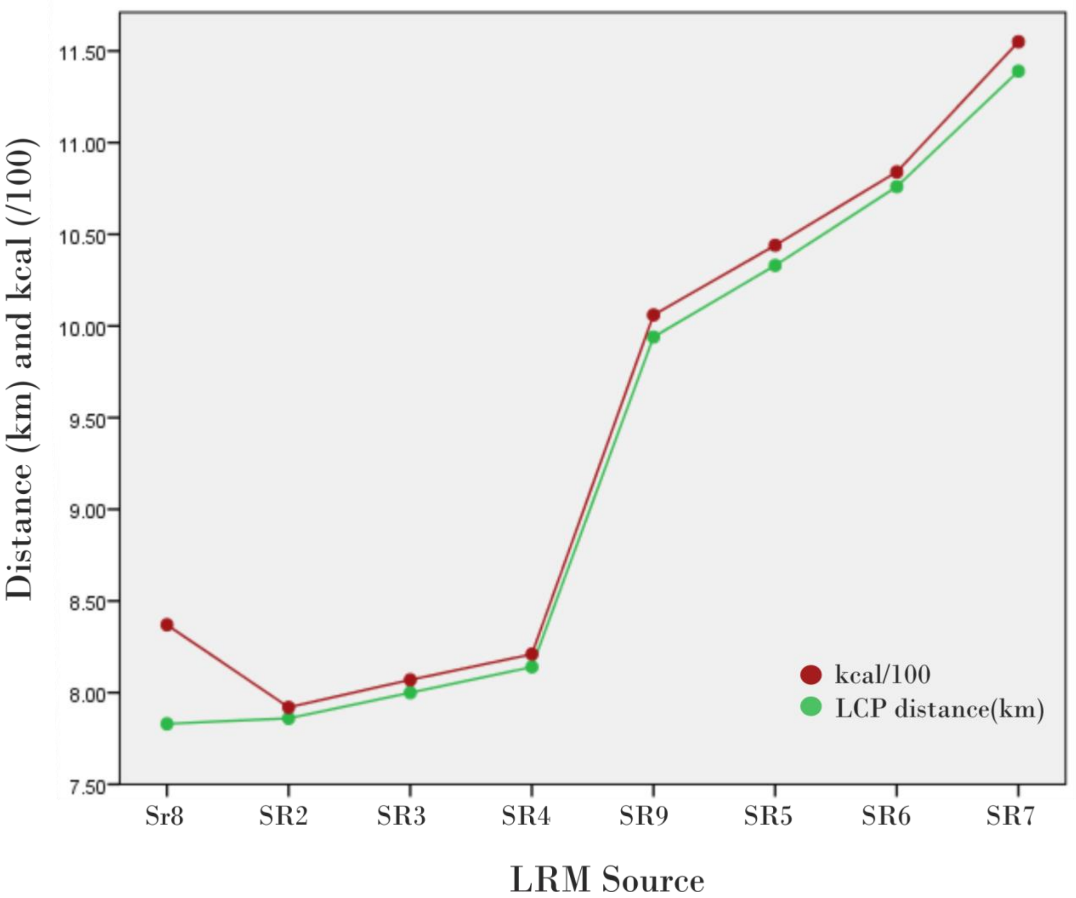


Figure 6.58: Relationship between least-cost path energetic costs (kcal/hundred for graphic comparisons) and distances, demonstrating the lower relative costs of mobility due to easier terrain

Refiguring the attractiveness equations for each LRM source to include the energetic costs generated by each least-cost path, source attractiveness was decreased, particularly in the cases of SR7 and SR2, which, despite this, remained the most attractive sources (Table 6.48). However, in the case of Grotta del Broion, where all LRM sources were exotic and thus costly, factoring terrain difficulty into LRM attractiveness did not yield any significant data regarding potential Neanderthal procurement strategies.

Flint Source	Quality	Extent of Source	Difficulty of Terrain	Cost of Extraction	Size	Scar city	AQ kcal	New Rank
SR2	4	4	792	1	4	3	2.69	2
SR3	2	3	807	1	3	4	0.56	6
SR4	4	4	821	1	3	4	1.46	4
SR5	4	2	1044	1	2	4	0.38	8
SR6	4	4	1084	1	3	4	1.11	5
SR7	8	4	1155	1	4	4	2.77	1
SR8	4	4	837	1	4	4	1.91	3
SR9	4	4	1006	1	1	4	0.40	7

Table 6.48: SR flint sources and LCP costs (kcal) with re-figured AQs.

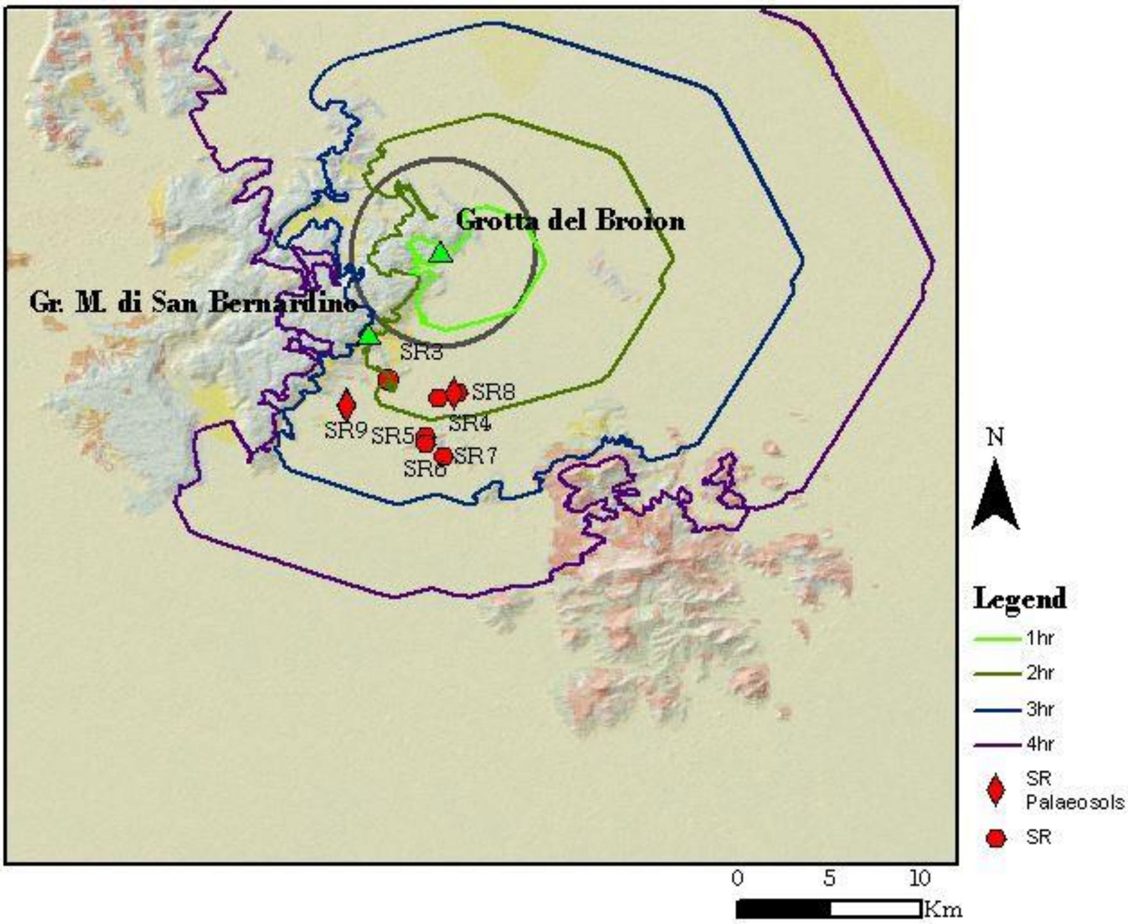


Figure 6.59: Temporal hiking buffers around Grotta del Broion in hourly increments.

The results of the temporal buffering demonstrated that flint sources were generally located beyond a two hour walking distance, not considering ground cover impediments such as vegetation or scree, resting breaks, or other activities taking place in the landscape (Figure 6.59; Appendix E.3). The temporal buffers also added a new dimension to source attractiveness; for instance, SR7, the highest quality LRM source, was not only the furthest distance (11.39km), but also the furthest away in terms of time (over 2.5hrs). These findings provide a new perspective into Neanderthal mobility as, based on time, these LRM sources could easily be obtained within a half day's journey. However, the costs of procurement, which were the highest of each of the three study sites, seem to have impacted the site's function within wider Neanderthal land use strategies, as is demonstrated by the low density of the lithic assemblage, the lack of evidence for active lithic procurement, and the lack of subsistence activities observed in the site.

The results of the temporal buffering further showed that a smaller area (121.05km2) could be covered in an hourly range compared to Grotta Maggiore di San Bernardino (114km2) (Figure 6.55). As the environmental productivity of each site, based on the palaeoenvironmental reconstructions, was identical, these findings may indicate that the location of Grotta Maggiore di San Bernardino was preferential for a residential site based on the larger amount of lithic resources procurable within 3 to 8km.

Applying terrain modelling and lithic prospection results to the lithic assemblage of ES2

As was determined by cortical analyses, a large amount of the SR flint was procured from Monte Albettone (SR5-7) and from San Pancrazio (SR3); these data enabled precise LRM source path costs and distances to be determined (Table 6.49; Appendix E.3) and linked to the lithic technological record. The results of the least-cost path analyses demonstrated that the San Pancrazio source (SR3) was located at 8km, the Monticello sources (SR2, SR8, SR4) at 8-9km, and the Monte Albettone sources (SR5-7) ranged from approximately 10.5-11.5km. The greater proximity and costs of transporting these SR flints to Broion relative to San Bernardino was reflected by its representation at nearly half of ES2 versus 85% in Unit II.

LRM Type	% in Assemblage	Distance km	% Cortical	% Retouched	% Retouched with >1 Retouched Edge
SR	47.83	7.83+	29.55	40.91	22.22
Bi	25.00	20+	8.70	43.48	33.33
SV	19.57	20+	44.44	33.33	33.33
Eoc	4.35	50+	25.00	50.00	0.00
Ool	3.26	50+	0.00	0.00	0.00

Table 6.49: Lithotype techno-economic data against LRM distance data

Considering that all of the lithotypes in ES2 were beyond the local range, and thus of significant distance and costs, it was hypothesised that their assemblages would show indicators of increased transport distances, with higher retouch frequencies and truncated *chaînes opératoires* (Table 6.43). These indicators were evidenced in the Bi and SV assemblages, which were both procured from distances exceeding 20km. While the tools in these lithotypes were comparable, with mostly Levallois flakes and scrapers, the significantly lower cortical presence in Bi (8.7%) versus SV (45%) may indicate this lithotype was particularly intensively exploited and managed, and therefore may have been a preferred material type, likely due to its superior rheological characteristics. The distances (>50km) and costs of transporting the Eoc and Ool flints (summing ~5% of ES2) were reflected in their truncated reduction sequences and low representation in the assemblage (summing ~5%). The few recovered implements in Eoc flint, a portable core, a cortical flake, a heavily retouched flake, and a Levallois flake, signal a mobile toolkit. The three Levallois flakes that comprise the Ool component of ES2 also seem to indicate the function of these select implements as personal gear. In all of the lithotypes, Levallois flakes were well represented, which is interpreted as a preference for Levallois flakes as standardised blanks within mobile toolkits, to optimise and meet tool needs.

However, despite that the character of each lithotype assemblage in ES2 at Grotta del Broion indicates a provisioning of individuals technological strategy, with clear indicators of the transport of personal gear by mobile Neanderthals, there is no significant evidence of lithic procurement actually in relation to the site, as would be suggested by full *chaînes opératoires* and a better representation of cores, cortical pieces, and manufacturing debris. Rather, the acquisition of the LRM observed in ES2 were likely originally associated with either other sites or activities, before their role within the mobile toolkits that were transported to and discarded at Grotta del Broion.

6.4.5 Grotta del Broion: results summary

The palaeoenvironmental reconstructions of Grotta del Broion demonstrated that during the MOIS-3 use of the site, conditions were temperate and humid, and the site was situated in proximity to diverse biotopes, where mixed forests dominated, but open forests, wetlands, rocky slopes, and limited grasslands also occurred. Summertime conditions were warm and arid, while winters were wetter, with snow and sub-freezing temperatures.

Techno-economic analyses of ES2 showed a low density lithic assemblage, where truncated reduction sequences and a high degree of retouch were observed for all lithotypes, which is interpreted as evidence for personal gear (*sensu* Binford 1979), in agreement with Porraz (1997). Levallois flakes were well represented in each flint type, perhaps indicating that this technological product was preferentially selected for transport within mobile toolkits. In total, the Levallois assemblage indicated strategies for lithic management and conservation strategies that were correlated to the distances required for lithic transport, which could exceed 50km.

Lithic prospection confirmed the absence of local LRM sources and determined that the nearest flint sources were those SR outcrops and palaeosols in a semi-local range, identified during pedestrian survey around Grotta Maggiore di San Bernardino.

Terrain modelling demonstrated that the shortest distance to a flint source of good quality was nearly 8km, and that the costs of procurement at Grotta del Broion were higher than observed for either Grotta di Fumane or Grotta Maggiore di San Bernardino. While temporal buffering indicated that viable SR flint sources could be obtained in around 2 hours' time; techno-economic analyses indicated that lithic procurement did not take place at Grotta del Broion; rather, a provisioning of individuals strategy appears to have met lithic needs for mobile Neanderthals who were travelling to the site to carry out short-term, task specific activities. The absence of LRM resources may have determined its *locational* role within the wider settlement system, as both residential type sites Grotta di Fumane and Grotta Maggiore di San Bernardino were located in areas with greater lithic potential within shorter physical and time distances and with lower costs. Further, determining the shortest distance and shortest time route between Grotta del Broion and Grotta Maggiore di San Bernardino reiterated the importance of considering terrain in determining distances, as the route was significantly longer than that indicated by a two-dimensional straight-line route.

6.5 Results Summary

The results of this research demonstrated that Neanderthal lifeways at Grotta di Fumane, Grotta Maggiore di San Bernardino, and Grotta del Broion were impacted by each's unique environmental diversity. The rugged terrain of the Fumane landscape, presenting a mosaic of productive forested and open environments that offered not only access to diverse fauna and vegetation, but lithic materials, as well, facilitated repeated, intense residential occupations. Grotta Maggiore di San Bernardino and Grotta del Broion, located within 7.5km of each other in somewhat gentler terrain, were also situated in proximity to productive forested environments and a wide range of faunal and vegetative species. However, while Grotta Maggiore di San Bernardino signalled residential occupations, these appear to have been more constrained that at Grotta di Fumane, perhaps by the distribution of lithic materials to the site, which were of a more limited quality and abundance. Grotta del Broion, locally devoid of flint, contained an archaeological assemblage of stark contrast, with a sparse lithic record and lack of subsistence activities that appear to indicate Neanderthal site use for short term, task-specific activities, likely within the wider scope of landscape use in a pattern of residential mobility.

The distribution of LRM and the character of the terrain are correlated with each site's lithic assemblage composition, where the cost and time distances from LRM source to site were reflected in lithotype representations, cortical presence, retouch, and differing phases of *chaînes opératoires*. Lower costs and distances associated with LRM sources, both primary and secondary, correlated to their greater representation in site assemblages, higher percentages of cortex, and full reduction sequences, with lower percentages of retouched implements. These lithic assemblages, paired with evidence for diverse on-site activities and hearths, signal residential occupation of the sites. This scenario was shown to be reversed where costs were substantially higher, and flint was procurable beyond a two to two and a half hour hiking distance, as at Grotta del Broion, which is also lacking in evidence for subsistence resources and structures that would indicate a residential use of the cave. These results indicate that in relation to LRM quality and source extent, higher quality flints with larger source extents were best represented in assemblages, when, however, these could be procured at reduced distances and energy and time costs.

Chapter 7: *Interpretations and Conclusions*

7.1 Technology in Context

Lithic raw materials represent a vital resource in Neanderthal subsistence needs. However, flint sources were neither ubiquitous nor of equal quality, nor was mobility in the landscape of equal cost due to varied terrain. Adaptations by Neanderthals to such off-site environmental variability can be observed by linking the character of the lithological landscape with the site material record. It is through these methods that technological provisioning, seen through patterns of flint management and maintenance strategies, can be perceived as evidence of Neanderthal economic responses to their ecological settings, aimed at maximising lithic potential and minimising procurement costs.

To elucidate the impact of environmental variability on Neanderthal raw material economy, this research examined the lithic technological assemblages of three late Middle Palaeolithic sites in northeast Italy within their wider ecological contexts of mobility, subsistence strategies, and settlement patterning. A better understanding of how, and to what extent, environmental variability impacted the observed technological provisioning strategies was sought by this research through an interdisciplinary research framework that integrated palaeoenvironmental, lithological, and topographic reconstructions of MOIS-3 landscapes. The palaeoenvironments and climates of the study region were reconstructed from data drawn from site-level indicators, regional sediment cores, and palaeoclimate simulations. Lithic prospection survey documented the distribution and associated attractiveness characteristics of LRM sources, which provided a foundation for understanding acquisition choices and procurement strategies. The final stage of this research involved the integration of techno-economic analyses with the off-site landscape: terrain modelling yielded novel perspectives on technological provisioning and site-formation as impacted by the variability and costs imposed by each site’s unique ecological context.

7.2 The Influence of the Lithological Landscape on the Lithic Artefact Record

The findings of this research clearly demonstrated that the Neanderthal economic behaviours observed in each of the final Mousterian lithic assemblages in the study region were influenced by the differential character and distribution of flint resources in their off-site landscapes. The diverse technological provisioning strategies recorded in Grotta di Fumane, Grotta Maggiore di San Bernardino, and Grotta del Broion served to negotiate procurement costs to maintain toolmaking potential and manage lithic needs while minimising procurement costs. The relationship between LRM source distance, quality, and the techno-economy recorded in the lithic assemblages of these three sites are largely in agreement with previous observations of Neanderthal raw material economy in Europe (e.g. Geneste 1985, 1989; Turq 1989; Féblot-

Augustins 1997a, 1999a; Roth and Dibble 1998). Where flint sources were locally available, these were more represented in the lithic assemblages, and exhibited a lesser degree of retouch than sources of semi-local and particularly exotic provenance, which were typically more reduced, indicating their management and maintenance of over time and space and the costs involved in their replacement, as observed by Geneste (1985, 1989), Kuhn (1993, 1995), Dibble (1995), and Turq (2013). The representations of exotic flints in lithic assemblages as selected tool blanks and retouched implements are interpreted to represent the provisioning of individuals (*sensu* Kuhn 1995) with mobile toolkits, where lithic tools and tool potential were carried by mobile Neanderthals in anticipation of need and resource scarcity, indicating the cognitive capacity for planning depth. Within the 5km local economic radius, flints of greater quality (cryptocrystalline) and abundance were also more greatly represented than those with poorer rheological characteristics (microcrystalline).

Regarding Brantingham's (2003) neutral model that indicates that the above lithic variability could reflect random flint encounters rather than adaptive procurement strategies to optimise this resource, the research yields data that could belie this possibility. That there is evidence of direct procurement strategies, namely of the proximal streambed sources of Bi and SV in Unit A5-A6 of Grotta di Fumane and the hypothesised direct procurement of higher quality Albettone SR at Grotta Maggiore di San Bernardino, implies planning depth and an optimisation strategy to meet lithic needs. Further, unlike in the neutral model, flint distribution is in no way uniform: lithic prospection demonstrated that the lithic landscape of Grotta di Fumane is locally very rich, whereas flint is entirely absent around Grotta di Fumane. Indeed, while the assemblages of these sites do, superficially, appear to contain assemblages that parallel the findings of the neutral model, namely, that more proximal sources will be better represented, and more distant sources will be quantitatively less and will show more indicators of reduction, cortical analyses contradict that these assemblages represent random encounters with LRM.

Rather than stasis in procurement strategies between the archaeological levels, assuming that flint presence was relatively unchanging, there is an observed change between level A8+A9 of Fumane and the proceeding Unit A5-A6: while LRM types are similarly represented, cortical analyses indicate that the sources of these change. The Eocene and Oolitic flint in A8+A9 were predominantly procured from primary outcrops and, in contrast, these sources were not at all exploited in A5-A6, and palaeosol sources were increasingly utilised. As there are no clear indicators of shifting subsistence foraging ranges away from either of these sources between the levels (there is an increase in subsistence activity on the Lessini Plateau in A8+A9; however both the palaeosol and outcrops sources were identified here, and therefore, both sources had the potential to be randomly encountered). Further, Peoc outcrops, quite near the Eoc outcrops, were exploited in A5-A6, this may suggest that both LRM sources were selected due to the morphologies of their blocks and nodules, and a preference for Peoc over Eoc may have been practiced: if either of these hypotheses stands, then these indicate active strategies geared toward technological aims.

At Grotta di Fumane, where flint is the most abundant and of the highest quality, Neanderthal raw material economy was characterised by more profligate attitudes toward lithic production in response to the availability of flint in the off-site landscape. Abundant flint of diverse types was recovered from each of the three MOIS-3 assemblages considered in this research (A8+A9, A6, A5-A5+A6), indicating a predominantly provisioning of places strategy. The frequency of cores, cortical products, and full *chaînes opératoires* were most evident on those high quality cryptocrystalline flints procurable within 3km of the site, or within two hours. Based on the elevated procurement of streambed sources in Biancone across the MOIS-3 levels, a degree of direct procurement is hypothesised. The proximity of the streambed sources of this flint type would have represented the least cost source that would facilitate a steady supply of what could be considered the preferred flint type in the western Lessini pre-Alps, based on its high quality, widespread availability, and dominant exploitation in the lithic assemblages not only of Grotta di Fumane, but of other Middle Palaeolithic sites in the Monti Lessini, including Riparo Mezzena and Riparo Tagliente.

The microcrystalline varieties and the Palaeocene flints, identified at greater distances with increased costs from Grotta di Fumane, were less represented in the lithic assemblages and demonstrated lower cortical frequencies and off-site initial production sequences. These findings are in line with research that demonstrates a link between off-site reduction at a procurement source and transport costs, namely, that observed later stage reduction sequences at a site are linked to increased distance from the acquisition source (Beck *et al.* 2002; Shott 2015). Despite that these were introduced in a more reduced state, these LRM are also interpreted to be in line with a provisioning of places strategy, as their *chaînes opératoires* were largely complete, and their technological character did not appear to represent mobile toolkits. Rather, the provisioning of these flints likely represents either procurement activities embedded in more distant forays into the landscape for subsistence activities; conversely, these LRM sources may have been (more limitedly) directly procured. However, while it is likely that Neanderthals were intimately familiar with their off-site environments and aware of these flint sources, which thus facilitated either direct or embedded lithic procurement scheduling, based on the data demonstrating that the microcrystalline lithotypes are of a reduced rheological character (Longo *et al.* 2006) and also were manufactured following the same *chaînes opératoires* as the higher quality, more proximal cryptocrystalline flints, this latter scenario is not as highly supported as the hypothesis supporting embedded procurement. Further, based on the observation of off-site initial reductions, and the relatively lower quality of the microcrystalline flints, an opportunistic element may be attributed to their procurement, where, upon encounter, acquisition took place. These observations imply that technological provisioning in the study area likely incorporated mixed procurement strategies that were organised around lithic objectives and landscape knowledge.

Regarding the exclusive use of the Discoidal technology in level A8+A9 of Grotta di Fumane, sandwiched between the Levallois-dominated A levels of the final Mousterian site record, this techno-cultural shift is likely a response to subsistence scheduling and procurement and associated mobility in response to fluctuating ecological conditions. The adoption of the Discoid technology may have been in response to climatic influences on subsistence resources rather than differential access to LRM, which were widely available in primary and secondary sources. This has been demonstrated by Delagnes and Rendu (2011), who link variations in technology with subsistence resources: the Discoid industries were related with mobility surrounding focussed hunting strategies aimed at seasonally available prey species. In A8+A9 an increased presence of Neanderthals at higher altitudes for subsistence activities (20% in A8+A9 vs 13.5% in Unit A5-A6) is evidenced by the greater procurement of LRM sources and faunal resources from the Lessini Plateau than in the following MOIS-3 levels; this may have been in response to colder climate conditions that pressured more intense occupations (as demonstrated by the relatively dense archaeological record of lithic artefacts, exploited faunal resources, and hearths) and expanded foraging range. The exploitation of LRM resources at higher altitudes is demonstrated by the varied lithic procurement strategies in the Discoidal A8+A9, where primary outcrops, located on the Lessini Plateau, were the main source of Scaglia Rossa, Eocene, and Oolitic flints. As there is not a change in lithotype preferences between the Discoid and Levallois levels, technological aims cannot explain these shifts in resource scheduling. However, a move away from acquiring these flint types from more distant primary sources and increased secondary source procurement is noted in the final Levallois levels A5-A6, where Eocene and Oolitic procurement moved completely away from primary outcrops to predominantly palaeosols sources, and Palaeocene flints, albeit in limited quantities, were procured and introduced to site.

At Grotta Maggiore di San Bernardino, where flint distribution, abundance, and quality was significantly reduced compared to Grotta di Fumane, mixed economic strategies of flint management and maintenance were observed in the lithic assemblage of Unit II, which, based on the range of activities and presence of structures recorded, indicates that it represented a residential location. A provisioning of places strategy is interpreted from the full *chaînes opératoires* and higher cortical indices observed on the dominant lithotype, the local and semi-local Scaglia Rossa flint. However, a provisioning of individuals strategy is also observed for the exotic flint types, which were originally procured from either the Colli Euganei some 20km to the south, or the Monti Lessini 20-50km to the north. These exogenous flints showed truncated reduction sequences and higher frequencies of retouched tools, signalling their role as personal gear, meeting the lithic needs of mobile Neanderthals. It is interesting to note that cortical flakes and Levallois flakes appear to have been preferred for tool blanks rather than by-products, an observation which was also made by Picin *et al.*(2011) in their study of denticulate and notch tools across the stratigraphic sequence of San Bernardino, and which was also seen in the SR assemblages of Unit A5-A6 at Grotta di Fumane.

ES2 of Grotta del Broion, in contrast to both San Bernardino and Fumane, recorded not only a lack of subsistence activities and features indicating residential occupation, despite the apparent diversity and productivity of biomes around the site, but a sparse lithic assemblage. The composition of the lithic assemblage appears to be in direct response to the paucity of LRM within a local radius of the site. This research posits that flint provisioning was not associated with site use: rather, the lithic record represents mobile toolkits that were transported to Broion in anticipation of lithic scarcity and to carry out task-specific activities, which, based on the lithic assemblage, may have been limited to re-tooling and lithic management.

7.3 The Impact of Terrain on Technological Provisioning and Site Formation

The creation of source-to-site hypothetical Neanderthal mobility routes directly tested archaeological methods of delineating space and economic zonation in the Middle Palaeolithic. The results of this research demonstrate that Euclidean-derived, straight-line delineations of space are unrealistic and inaccurate. This research also demonstrated that 3D straight-line mobility was also improbable in most Neanderthal landscapes, as these routes do not avoid unnavigable slopes, nor do they consider the additional impetuses of Neanderthal mobility (e.g. subsistence activities, active selection of lower cost routes). Least-cost path modelling of direct lithic procurement provided an alternative method to study Neanderthal mobility that considered the impact of variable terrain on mobility as quantitative energetic costs.

The generated least-cost paths were winding routes that resembled natural human movement, and added a dimension of realism to environmental reconstruction. The least-cost paths took advantage of natural low-cost corridors, such as streambeds, upland plateaus, and steady slopes to minimise energetic and time costs. While, as discussed above, correlations between distance and lithotype frequencies in the three study sites were in agreement with previous observations of local economic zonations in Europe, these assumed that increased proximity correlated to decreased energy and time costs. The findings of this research belie these assumptions, and demonstrate that energy and time costs were more greatly impacted by topographic features than distance alone. Thus, Neanderthal raw material economy must be assessed within the context of the three-dimensional off-site landscape.

7.3.1 Distance

Comparing the least-cost path modelling outputs demonstrated that the hypothetical direct LRM procurement distances were different between each of the three study sites (Figure 7.1). These seem to indicate a distance threshold of LRM procurement activities between the sites of 7.5km, as beyond this threshold, Grotta del Broion does not appear to record the introduction of LRM for on-site production.

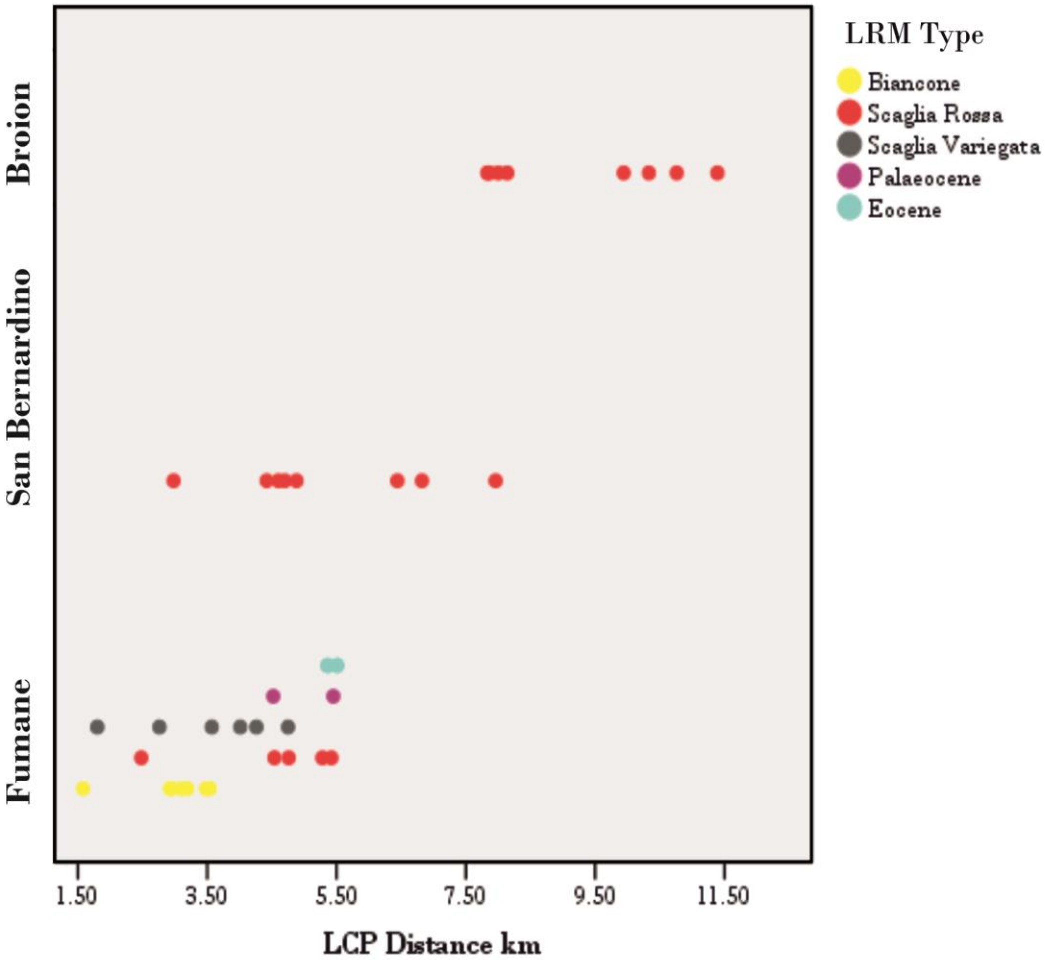


Figure 7.1: Inter-site comparisons of LRM source distance distributions, as determined by linking lithic prospection results with least-cost path analyses.

To statistically test this threshold and the distribution of the hypothetical direct route LCP distances, a null hypothesis was proposed: for each site, LCP distances would be uniform. To this end, a one-way ANOVA was run in SPSS, including descriptive statistics; these demonstrated differences in each site's total distance means, with Fumane yielding the shortest procurement distances (3.87km), and Broion the greatest (9.28km); however, it should be addressed that Fumane only modelled local LRM sources, in contrast to the other sites. Of local sources only, San Bernardino was comparable to Fumane at 3.05km; however, this is a limited sample (n=2) versus Fumane (n=23), and thus despite comparable distance means, the productivity of their lithic environments was much different. To address the variable sample sizes, a bootstrap of 5000 was added for all analyses. Levene's Test of Equality of Error Variances resulted a p-value of .369 (alpha =.05), indicating that sample distribution was of equal variance. The ANOVA results also generated a statistically significant p-value result of .000, suggesting that the null hypothesis could be rejected. To address where these significant differences were found, an equal variances post-hoc test (Scheffe) was run. The pairwise comparisons (Table 7.1) demonstrated that the original null hypothesis was rejected only for Fumane-Broion and San Bernardino-Broion, which presented statistically significant differences: Broion has a significantly greater mean than both Fumane (+5.41km) and San Bernardino (+3.93km): this supports the visualised distribution of time costs in Figure 7.1.

Site	**Distance (km) Cost Means**	**Pair-wise comparisons Alpha=.05**	**Null Hypothesis rejected**
Fumane (F)	153.86	F-SB p-value .001 F-B p-value .103 SB-B p-value .104	F-SB (p-value = 0.001), significant differences in distance distributions between sites.
San Bernardino (SB)	103.76		
Broion (B)	129.38		

Table 7.1: Pair-wise comparisons of mean distance and the statistical significance values rejecting the null hypothesis that distances are not different between the three sites

Statistical procedures were also utilised to quantify relationships between LCP distance and LRM type; in this test, the null hypothesis was that each LRM type was located at the same distance from sites. This was accomplished using the two-way ANOVA, with both site and LRM type as fixed factors. These demonstrated diverse means for each LRM type at Grotta di Fumane. While the sample sizes of the LRM types and standard deviations of the LCP distances were varied at Fumane, they were the same for the San Bernardino and Broion SR sources. The Levene's Test of Equality of Error variances suggested (p-value of .025) that there were significant differences in distance distributions between the LRM types. Pairwise comparisons demonstrated that a range of LCP distances were observed between the sites overall and within lithotypes at Fumane, where Bi sources were at the nearest distance (2.97km) and SR the most distant (6.38km) (Table 7.2), rejecting the original null hypothesis that time costs were the same for all flint types. However, where SR is concerned, the analyses are skewed: since SR is the only lithotype represented in San Bernardino and Broion, it is therefore overrepresented in Fumane.

Site	LRM	Distance (km) Cost Means	Statistically significance of pair-wise comparisons across all sites Alpha=.05	Null Hypothesis rejected
Fumane (F)	Bi (7)	2.97	Bi-SR p-value .000 Bi-Eoc p-value .018 SR-SV p-value .000	There is a statistical difference between the distances associated with the direct hypothetical procurement of Bi to SR and Eoc, and SV to SR
	SR (5)	6.38		
	SV (6)	3.53		
	Peoc (2)	4.99		
	Eoc (2)	5.44		
San Bernardino (SB)	SR (8)	5.35		
Broion (B)	SR (8)	9.28		

Table 7.2: Pair-wise comparisons of LRM types and their mean procurement distances. Statistical significance between the direct distances to the LRM types to test the null hypothesis that each hypothetical mobility route was the same distance from each site

Therefore, the two-way ANOVA was re-run for Fumane, and post-hoc tests (p=.406, Scheffe equal variances assumed) were conducted. These yield a new SR distance of 4.52km, and in pair-wise comparisons, while significant differences remain between Bi-SR and Bi-Eoc, SV-SR is no longer significant and SV-Eoc becomes so (Table 7.3); these results are more in line with what is observed in Figure 7.1. Very high p-values were observed for Bi-SV (.876), SR-SV (.568), SR-Peoc (.981), SR-Eoc (.827), and Peoc-Eoc (.993); these results therefore support the alternative hypothesis and suggest that the time costs between these were similar, but as the null hypothesis was not rejected, these cannot be assumed in all cases.

Site	LRM	Distance (km) Cost Means	Statistically significance of pair-wise comparisons of LRM at Fumane Alpha=.05	Null Hypothesis rejected
Fumane	Bi (7)	2.97	Bi-SR p-value .011 Bi-Peoc p-value .014 SV-Eoc p-value .021	There is a statistical difference between the distribution of distance associated with the procurement of Bi to SR and Peoc, and SV to Eoc
	SR (5)	4.50		
	SV (6)	3.53		
	Peoc (2)	4.99		
	Eoc (2)	5.44		
	Avg mean	4.28		

Table 7.3: Re-assessment of the statistical significances between LRM type and LCP distances at Grotta di Fumane with Bernardino and Broion SR samples removed

The conclustions of the LCP distance analyses have implications for Neanderthal technological provisioning strategies and mobility, and suggest that overall distances were statistically comparable at Fumane and San Bernardino, within 5km. Overlap between the sites suggests a distance threshold of 7.5km. At Grotta di Fumane, this distance threshold likely was rarely met, as it was situated within a relatively rich lithic landscape with the highest quality flint resources. This ecological context correlates to repeated, intense use of the cave for residential type occupations, with ample evidence of subsistence activities, hearths, and lithic processing, and may have favoured a balance between direct and embedded procurement strategies, which can be hypothesised based on the significant proportions of Bi and SV streambed cobbles in all of the layers, which could have been accessed within a kilometre of the site. This strategy would not require significant distances to be covered, thereby providing a cost-effective method of maintaining a constant supply of high quality LRM.

In terms of distances by lithotype, these observations can only be made at Grotta di Fumane; unfortunately, as at the other sites only SR is present, and there is no comparative sample. However, as discussed, procurement of higher quality Albettone SR from greater distances on the Berici plain may have been direct, as these distances may have been excessive for prey transport if one assumed embedded procurement in that area. For Fumane, the greater distances of Peoc, Eoc, and SR sources may be correlated to technological provisioning strategies, as it was demonstrated in Chapter 6 that the Eoc and Peoc assemblages of Fumane recorded incomplete *chaînes opératoires.* Further, the assemblages on SR flint, which was mostly identified at greater distances, recorded relatively high frequencies of *entames* over later Phase implements, which suggests that these were manufactured elsewhere in the landscape, perhaps at their source, and transported to site. This may indicate a reduction in carried load, as useful implements were manufactured, personal gear, based on technological objectives, or site provisioning with a valued (based on SR frequency) resource to maintain its steady supply. In all scenarios, embedded procurement strategies could be assumed to an extent, as based on the high representation of Phase 0 and 1 implements over cores, in some instances raw material blocks, tested blocks, or minimally-shaped cores were not transported to site.

7.3.2 Energy

The modelled energetic costs of LRM procurement also appear to positively correlate to differential site-use, as well as technological provisioning strategies (Figure 7.2). The least-cost paths in the Fumane landscape had the lowest energetic costs, which were impacted largely by the greater proximity of the sources to the site, as the topographic setting was ultimately more tumultuous. Considering the greater representation of the Bi lithotype, in particular, as well as SV and SR in the Fumane assemblages, and elevated frequency of Bi and SV procurement from streambed sources, a cost threshold could be posited for potentially direct lithic procurement activities within a 400kcal range. The Palaeocene and Eocene flint sources identified within the 800kcal range were observed in relatively low proportions in the lithic site record, and their assemblages contained lower percentages of cortex and showed lower frequencies of Phase 0 and 1 implements as well as increased retouch frequencies. Numerous sources of Scaglia Rossa were also identified beyond the 400kcal range at Grotta di Fumane, which may explain the higher representation of Phase 0 cortical flakes in this lithotype in respect to cores, hypothesised to indicate mixed exploitation strategies for this flint type, where both on-site and off-site production sequences shaped the assemblage. The LRM sources from beyond the 400kcal threshold, then, may represent procurement embedded in other subsistence activities, perhaps the hunting of Alpine grassland species at higher altitudes on the Lessini Plateau where these flint types are largely distributed. In all, however, the modelled lower energetic costs of the lithic landscape of likely Fumane facilitated residential use of the site, where vital resources foraging did not necessitate high caloric outputs. Therefore, the different procurement strategies at Fumane may represent the mitigation of the known costs of direct procurement, where the procurement of more costly LRM sources alongside other activities reduced energetic loads.

The observed procurement and associated raw material economy at Grotta Maggiore di San Bernardino can also be linked to a provisioning cost threshold of around 800kcal, which likely applies to the direct rather than embedded procurement of LRM, a strategy that would have been dependent on a slew of ecological variables, including a limited, quality local LRM source and reduced energy costs due to flatter terrain. Because of the lack of evidence for differing reduction and management strategies in the SR flint in response to the variable distances and costs of its procurement, a lower cost threshold facilitating more expensive economic strategies was not observed. However, such costs were likely known and mitigated by Neanderthal populations: as the SR assemblage was heavily reduced, and cores were discarded when fully exhausted (3x3x2cm) (Porraz and Peresani 2006), the intensity of lithic exploitation at San Bernardino is interpreted to be a reflection of the costs of procurement at greater distances and thus, energetic costs. This research postulates that the procurement of the higher quality SR flints in the 6-8km range was direct, and extends the local *lithic* economic radius at this residential site, where quality played an important role in flint acquisition choices within a landscape where energetic and time costs of semi-local flints were reduced due to easier terrain. The hypothesis of direct procurement strategies for the higher quality SR from 6-8km is also tied into subsistence strategies, as these extended distances in the local lithic economic range may have been excessive for transporting prey. The exotic San Bernardino lithotypes procured from the Monti Lessini and Colli Euganei clearly incurred significantly larger costs, which explains their limited representations in the Unit II assemblage and their mobile toolkit character. This is observed for Grotta del Broion as well, where all identified Scaglia Rossa flints were located beyond the distance and energetic cost threshold.

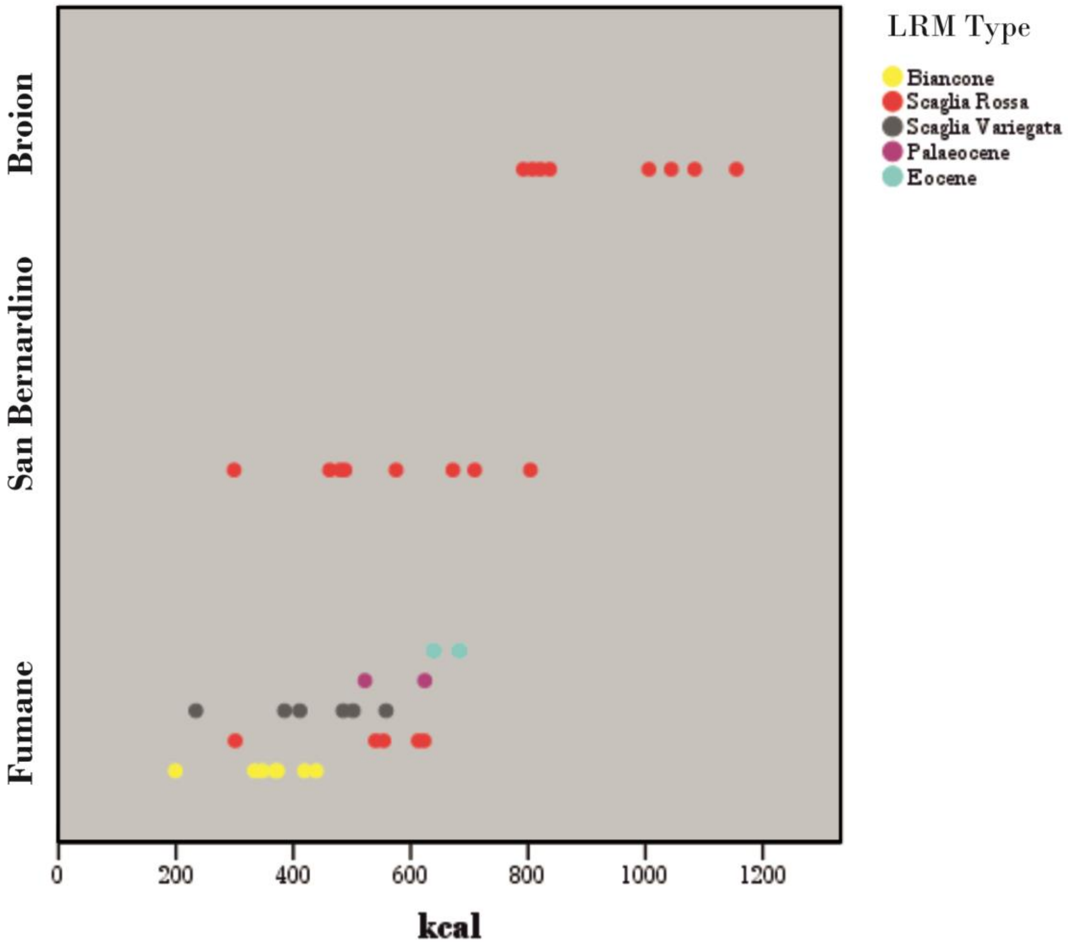


Figure 7.2: Inter-site comparisons of the energetic LRM direct procurement cost distributions, as determined by linking lithic prospection results with least-cost path analyses.

To quantify these proposed energetic thresholds, statistical analyses were carried out. To test the distribution of kcal energy costs between sites, a null hypothesis was proposed that the energetic costs of the hypothetical direct LCP routes from source to sites would be uniform. A one-way ANOVA was conducted on the normal distributed data and demonstrated differences between the sites in terms of overall costs. As Levene's Test of Equality of Error Variances gave a p-value of .826 (alpha =.05), the sample distributions are assumed to be equal. The ANOVA results also generated a statistically significant p-value result of .000, suggesting that the null hypothesis of equal cost distributions between the sites could be rejected, as is suggested by the comparing the means of the energetic costs by site. However, to determine where those differences lay, pairwise comparisons were carried out, and further supported that the original null hypothesis be rejected (Table 7.4). The paired samples indicate that the energetic costs of the LCPs were statistically significant, based on Fumane-Broion (.000) and San Bernardino-Broion (.000) (Table 7.5). Statistically significance is not observed in the Fumane-San Bernardino pair (.256), which, along with the differential distribution of energetic means, appears to support the distribution of data in Figure 7.2.

Site	**Energy (kcal) Cost Means**	**Pair-wise comparisons Alpha=.05**	**Null Hypothesis rejected**
Fumane (F)	461.55	F-SB p-value .256 F-B p-value .000 SB-B p-value .000	F-SB (p-value = 0.256), significant differences in kcal distributions between sites.
San Bernardino (SB)	561.55		
Broion (B)	943.25		

Table 7.4: Pair-wise comparisons of mean distance and the statistical significance values rejecting the null hypothesis that distances are not different between the three sites

Site	**LRM**	**Energy (kcal) Cost Means**	**Statistically significance of pair-wise comparisons across all sites Alpha=.05**	**Null Hypothesis rejected**
Fumane (F)	Bi (7)	354.29	Bi-SR p-value .000 Bi-Peoc p-value .041 Bi-Eoc p-value .005 SR-SV p-value .000 SV-Eoc p-value .034	There is a statistical difference between the energetic costs associated with the direct hypothetical LCP procurement of Bi to SR, Peoc and Eoc, and SV to SR and Eoc
	SR (5)	526.20		
	SV (6)	429.17		
	Peoc (2)	573.00		
	Eoc (2)	661.00		
San Bernardino (SB)	SR (8)	561.13		
Broion (B)	SR (8)	943.25		

Table 7.5: Pair-wise comparisons of LRM types and their energetic means. Statistical significance between the energetic costs directly to the LRM types to test the null hypothesis that each hypothetical mobility route was the same distance from each site

Site	LRM	Energy (kcal) Cost Means	Statistically significance of pair-wise comparisons of LRM at Fumane Alpha=.05	Null Hypothesis rejected
Fumane	Bi (7)	354.29	Bi-SR p-value .010 Bi-Peoc p-value .016 Bi-Eoc p-value .002 SV-Eoc p-value .013	There is a statistical difference between the energy costs associated with the procurement of Bi to SR, Peoc, and Eoc, and SV to Eoc
	SR (5)	508.73		
	SV (6)	429.17		
	Peoc (2)	573.00		
	Eoc (2)	661.00		
	Avg mean	505.24		

Table 7.6: Re-assessment of the statistical significances between LRM type and energetic costs of procurement at Grotta di Fumane with Bernardino and Broion SR samples removed

To quantify the energetic costs that were generated for the hypothetical direct procurement LCPs, the null hypothesis- energetic costs were the same for all flint types- was tested using the two-way ANOVA. The results demonstrated normal and equal variance samples with diverse means, which were also observed for each LRM type at Grotta di Fumane. While the sample sizes of the LRM types and standard deviations of the LRM time costs were varied at Fumane (San Bernardino and Broion were the same at eight SR sources), the Levene's Test of Equality of Error variances suggests (p-value of .126) suggests significant differences in energetic costs distributions between both LRM types and sites. Pairwise comparisons demonstrated that the energy cost means of Biancone were the lowest and Eoc were the highest of all LRM samples; this agrees with the distribution of energetic costs in Figure 7.2 (Table 7.5). The significance in these samples suggests that the original null hypothesis that energetic costs were the same for all flint types be rejected. However, again where SR is concerned, the analyses are skewed: since SR is the only lithotype represented in San Bernardino and Broion, it is over-represented in pair-wise samples. Therefore, the two-way ANOVA and post-hoc were re-run for Fumane. The pair-wise samples at Fumane show that the lower energetic costs Bi and SV were different from SR, Peoc, and Eoc (Table 7.6), which is more in line with what is observed in Figure 7.2. Additionally, the SR mean at Fumane is now reduced (minimally) to 508.73, and while the Bi-SR pair is still significant, SV-SR no longer is.

In all, the statistical outcomes largely fit the distribution of generated LCP energy cost outputs in Figure 7.2. Regarding the proposed cost thresholds, these are more difficult to quantify statistically, as the full lithic landscape has not been realised (the lithic prospection was given an arbitrary boundary). The 400kcal may be supported based on the he averaged means of the most exploited LRM types at Fumane, Bi, SV, and SR (totally ~92% of averaged levels), equals 430.73, which falls around this margin. However, for the less exploited sources, this is less quantifiable: Eoc and Peoc means average 617, but there was also a semi-local component to the lithic assemblages of Fumane (Ool), whose costs are assumed to be higher, based on increased distance and terrain, to be considered. Therefore, alongside the other indicators discussed above surrounding LRM distribution and modelled LCP costs, it is theoretically possible to assume an 800kcal threshold. It must be kept in mind that these costs represent model-generated outputs and therefore do not represent quantitatively-definitive caloric thresholds; however, heuristically these serve as hypotheses to be tested in future modelling endeavours.

7.3.3 Time

Because of the diverse topography of the study region, LRM procurement incurred widely varied time costs based on the modelled data. Looking at the distribution of these costs in Figure 7.3, it is difficult to propose a time threshold limiting procurement, as there is overlap in time costs amongst the sites. Therefore, based on the differences in technological provisioning between the sites (and the lack of evidence for the on-site provisioning and production at Broion), we could exclude the Broion data and base a time cost threshold to residential sites. This would be supported for the provisioning of places at Fumane and San Bernardino, with raw material blocks and on-site early stage reduction implements and complete production sequences alongside subsistence resources and hearths. Comparing the time outputs of these two sites, we see that for those lithotypes falling within a threshold of 2.5hours, complete *chaînes opératoires* are observed. Regarding the lithotypes observed beyond this threshold, assemblage frequencies are relatively lower and truncated *chaînes opératoires* and retouch are increased, indicating that time costs could be linked to provisioning strategies.

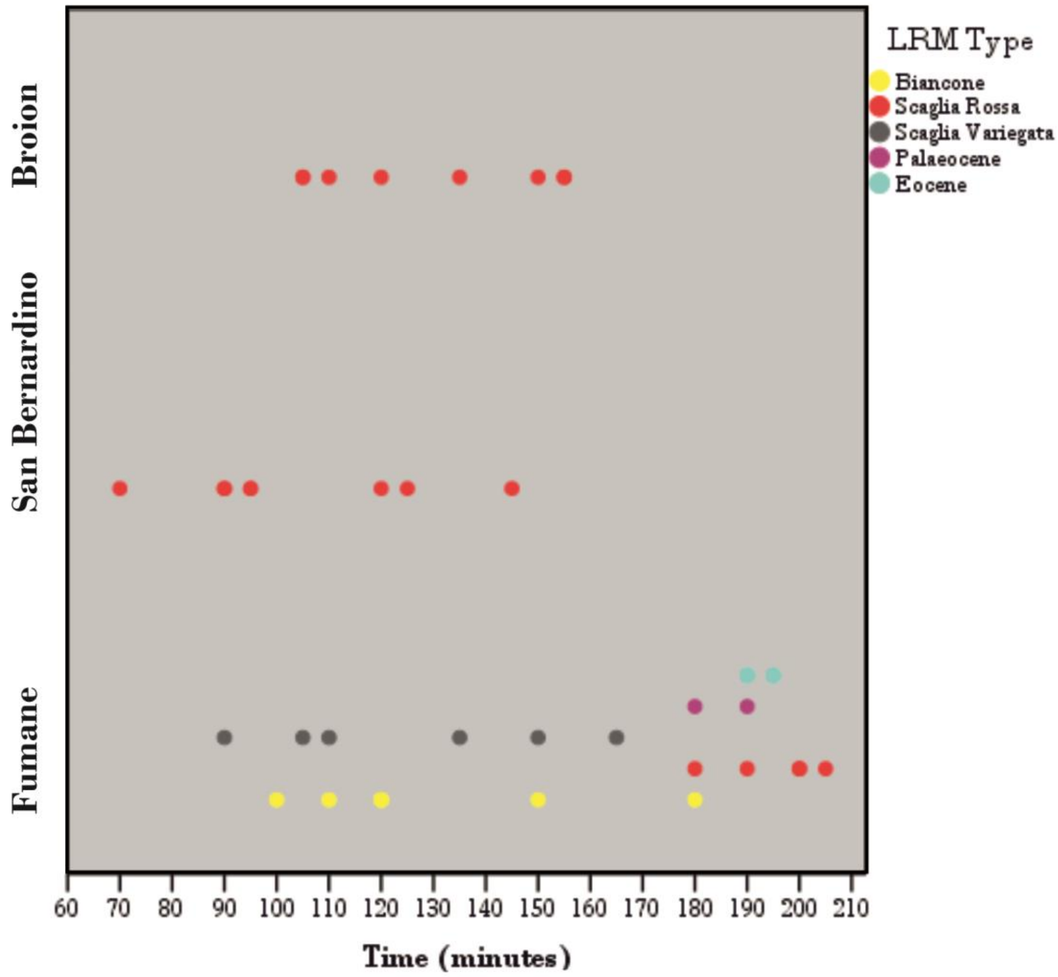


Figure 7.3: Inter-site comparisons of the distribution of LRM procurement time costs as determined by linking lithic prospection results with least-cost path analyses

In order to quantitatively test the distribution of time costs between sites, a null hypothesis was proposed that costs between the sites would be uniform. To this end, a one-way ANOVA was run in SPSS, including descriptive statistics; these demonstrated differences in site time cost means and that variances are not equal, based on the significance Levene's Test of Equality of Error Variances result of a p-value of .007 (alpha =.05). The ANOVA results also generated a statistically significant p-value result of .003, suggesting that the null hypothesis of equal cost distributions between the sites could be rejected; however, this result cannot be used based on the violation of the equal variances. To address this issue, Welch and Brown-Forsythe robusticity tests were added to the ANOVA, as well as the non-equal variance post-hoc test Games-Howell, suitable to the uneven sample sizes of the sites, an issue that was also addressed with a bootstrap of 5000. The robusticity tests each showed significant results (.002 and .000), so the pair-wise comparisons shown by the post-hoc test were considered (Table 7.7). The pairwise comparisons demonstrated that that the original null hypothesis was rejected only for the San Bernardino-Fumane pair (p-value .001), and that the time cost distribution for Fumane was greater than Broion, and both were greater than San Bernardino: this supports the visualised distribution of time costs in Figure 7.3.

Site	Time Cost Means	Pair-wise comparisons Alpha=.05	Null Hypothesis rejected
Fumane (F)	153.86	F-SB p-value .001 F-B p-value .103 SB-B p-value .104	F-SB (p-value = 0.001), significant differences in time cost distributions between sites.
San Bernardino (SB)	103.76		
Broion (B)	129.38		

Table 7.7: Pair-wise comparisons of mean time costs and the statistical significance values rejecting the null hypothesis that time costs are not different between the three sites

Statistical procedures were also utilised to quantify time costs in relation to each procured LRM type, to test the null hypothesis that time costs were the same for all flint types. This was accomplished using the two-way ANOVA, with both site and LRM type as fixed factors. These demonstrated diverse means each LRM type at Grotta di Fumane. While the sample sizes of the LRM types and standard deviations of the LRM time costs were varied at Fumane (San Bernardino and Broion were the same at eight SR sources), the Levene's Test of Equality of Error variances suggests (p-value of .057) that there are no significant differences in time costs distributions between the LRM types. Pairwise comparisons demonstrated that Biancone incurred significantly lower time costs than all flint types except for SV, which was approximately comparable (Table 7.8), rejecting the original null hypothesis that time costs were the same for all flint types. However, where SR is concerned, the data is skewed: since SR is the only lithotype represented in San Bernardino and Broion, it is overrepresented in pair-wise samples. Therefore, the two-way ANOVA and post-hoc were re-run for Fumane, yielding very interesting results: rather than a difference in time cost between the Bi, SR, and SV and the Peoc and Eoc, with the corrected SR sample, a significant difference is seen between it and the time costs of Bi and SV, *not* Peoc and Eoc (Table 7.9), which is more in line with what is observed in Figure 7.3 and in the pair-wise comparisons of energy costs for Fumane as discussed in the previous section. Rather, these present very high p-values, and therefore support the alternative hypothesis and suggest that the time costs between these were similar.

Site	**LRM**	**Time (hr) Cost Means**	**Statistically significance of pair-wise comparisons across all sites Alpha=.05**	**Null Hypothesis rejected**
Fumane (F)	Bi (7)	128.57	Bi-Peoc p-value .005 Bi-Eoc p-value .002 SR-Peoc p-value .020 SR-Eoc p-value .007 SV-Peoc p-value .004 SV-Eoc p-value .001	There is a statistical difference between the time costs associated with the procurement of Bi, SR, and SV as compared to Peoc and Eoc
	SR (5)	195.00		
	SV (6)	125.83		
	Peoc (2)	185.00		
	Eoc (2)	192.50		
San Bernardino (SB)	SR (8)	103.75		
Broion (B)	SR (8)	129.38		

Table 7.8: Pair-wise comparisons of LRM types and their mean time costs, and the statistical significance between the time costs of the LRM types to test the null hypothesis that each LRM type presented the same time costs

Site	**LRM**	**Time Cost Means**	**Statistically significance of pair-wise comparisons of LRM at Fumane Alpha=.05**	**Null Hypothesis rejected**
Fumane	Bi (7)	128.57	Bi-Peoc p-value .000 Bi-Eoc p-value .003 Bi-SR p-value .007 SR-SV p-value .004 SV-Peoc p-value .006 SV-Peoc p-value .003	There is a statistical difference between the time costs associated with the procurement of Bi and SV as compared to SR, Peoc, and Eoc
	SR (5)	195.00		
	SV (6)	125.83		
	Peoc (2)	185.00		
	Eoc (2)	192.50		
	Avg mean	165.38		

Table 7.9: Re-assessment of the statistical significances between LRM type and time costs at Grotta di Fumane with Bernardino and Broion SR samples removed

The LRM-cost relationship has significant implications for Neanderthal technological provisioning strategies and mobility at Grotta di Fumane; unfortunately, the presence of only SR at the other sites limits the scope of their individual analyses. For Fumane, the greater mobility time costs of SR, Peoc, and Eoc sources may be correlated to technological provisioning, as it was demonstrated in Chapter 6 that the Eoc and Peoc assemblages of Fumane recorded incomplete *chaînes opératoires,* and the SR assemblages recorded relatively high frequencies of *entames* over later Phase implements, which suggests that these were manufactured elsewhere in the landscape, perhaps at their source, and transported to site. This may indicate a reduction in carried load, as useful implements were manufactured, personal gear, based on technological objectives, or site provisioning with a valued (based on SR frequency) resource to maintain its steady supply. These behaviours may be associated with embedded procurement, where lithic acquisition took place in conjunction with other foraging activities in the area and thus its cost was reduced as compared to the direct procurement costs tested by this research. However, based on the lower frequencies of the Eoc and Peoc flints, and considering the higher frequency of SR (given demonstrated costs), these LRM may have been selected against in favour of SR for its higher knapping qualities.

The observations made regarding the model-generated time costs in relation to each site overall and LRM sources reiterate how critical it is to consider the impact of terrain on mobility, as well as the relative ease or difficulty of navigating, for example, open versus closed forests. Time costs should also be considered along lithic attractiveness in assessments of technological provisioning and settlement choices. For instance, At Fumane, those flint types most represented in the lithic assemblages, Biancone and Scaglia Variegata (but not Scaglia Rossa), were procurable within two hours walking distance. Scaglia Rossa, interestingly, as well as the Palaeocene and Eocene flints, were located at the farthest time distances from the site, at time costs exceeding those of Scaglia Rossa sources located 11.5km away from Grotta del Broion. However, the SR flint is well represented in the Fumane assemblages. The distribution of hiqh quality flint and its abundance can be perceived as part of the wider overall lithic and environmental productivity of the Fumane landscape, which likely impacted residential site use. This variability in distribution and time costs can also be seen reflected in different management strategies in the Grotta di Fumane lithic assemblages. As was discussed above for energetic costs, Bi and SV flints with lower time costs were potentially directly procured from streambed sources, while the more time consuming LRM such as Eoc and SR indicate off-site production and procurement that was likely embedded in other subsistence activities, which would have mitigated these costs..

While the distances and costs of flint procurement at Grotta del Broion do correlate to relatively low artefact densities, interestingly, time costs do not, largely due to the relatively flat terrain of the Berici Plain as compared to the Monti Lessini. For instance, flint source SR7, 11.5km away, and the most attractive in terms of quality and source extent, was located at just over 2.5 walking hours. While exceeding both Vita-Finzi and Higgs' (1970) and Binford's (1982) proposed 2 hour local foraging radii, the observed 2.5 hour procurement time is comparable to that of the Biancone and Scaglia Variegata at Grotta di Fumane, and is still *less*, and shown to be significantly statistically different, than the time costs of Eocene and Palaeocene flints for Fumane. As the energetic and time costs of this source (and all SR in relation to Broion) exceeded proposed distance and kcal thresholds, and exceeded the LRM procurement costs as compared to both Fumane and San Bernardino, it is likely that these were more impactful of Neanderthal technological provisioning strategies and site use than time costs. Further, the time costs for Grotta Maggiore di San Bernardino demonstrated that even the most distant (and quality) flint source, SR7 (7.96km), was acquirable within 2.5 hours, which is again, a shorter time cost than that required for the Palaeocene, Eocene, and Scaglia Rossa flint types identified in the lithic assemblages of Grotta di Fumane.

7.3.4 Accumulated costs

The accumulative effect of these distance, energy, and time costs must be considered alongside LRM attractiveness variables when assessing the bigger picture of regional raw material economy. The complexity of the lithic archaeological record can be highlighted within this multi-variate model, which can be reproduced to test observations of Neanderthal mobility, technological provisioning, and procurement strategies both over time and space.

Linking the individual costs generated from terrain modelling to LRM attractiveness (AQ) between the three sites yielded interesting results, and demonstrated that flint sources of higher quality and abundance paired with lower terrain costs (kcal costs per kilometre) were better represented in the archaeological assemblages (Fig. 7.4). These findings suggest that Neanderthals actively organised their provisioning strategies around maximising lithic potential and minimising procurement costs. This is best observed at Grotta di Fumane, where abundant and diverse LRM sources were located within 5km (factoring in terrain). Where LRM sources presented comparable terrain difficulty, those with higher AQs (Bi, SV, SR) were more positively linked to Neanderthal exploitation, with the exception of the Peoc outcrop (AQ 5.13), which is not well represented in the assemblage. The highest quality flint, Biancone, is best represented in all of the Fumane MOIS-3 assemblages, and was procured in nearly equal measure from streambed sources (not shown in Figure 7.4) and primary outcrops, indicating that its lower costs and high quality made it a preferable resource that was likely in many instances to be directly procured to maintain its constant availability.

At Grotta Maggiore di San Bernardino, the higher quality SR flints in the Unit II assemblage were located at the greatest distances with increased costs, but because of their abundance these had high AQs. These findings demonstrate not only the preference for and selection of higher quality flint types and sources at these sites, and may suggest direct procurement strategies, but also landscape movement: in lieu of geochemical and petrological analyses, the determined distribution of higher quality flint types in the landscape can represent the nearest potential sources of exploited LRM.

For Grotta del Broion, while the terrain difficulty in terms of kcal per kilometre was the lowest, total kcal costs were the highest, and therefore, in relation to the site, AQs were low. As previously discussed, these distances and their associated costs may have exceeded reasonable procurement strategies involving on-site lithic production, which is demonstrated by the absence of raw material blocks and evidence for lithic manufacture other than the reworking of pre-formed implements within the small assemblage. Rather, a provisioning of individuals strategy is applied to Broion, where the lithic assemblage of ES2 is interpreted as the personal gear of mobile hunter gatherers bearing LRM from both the Monti Lessini and Colli Euganei.

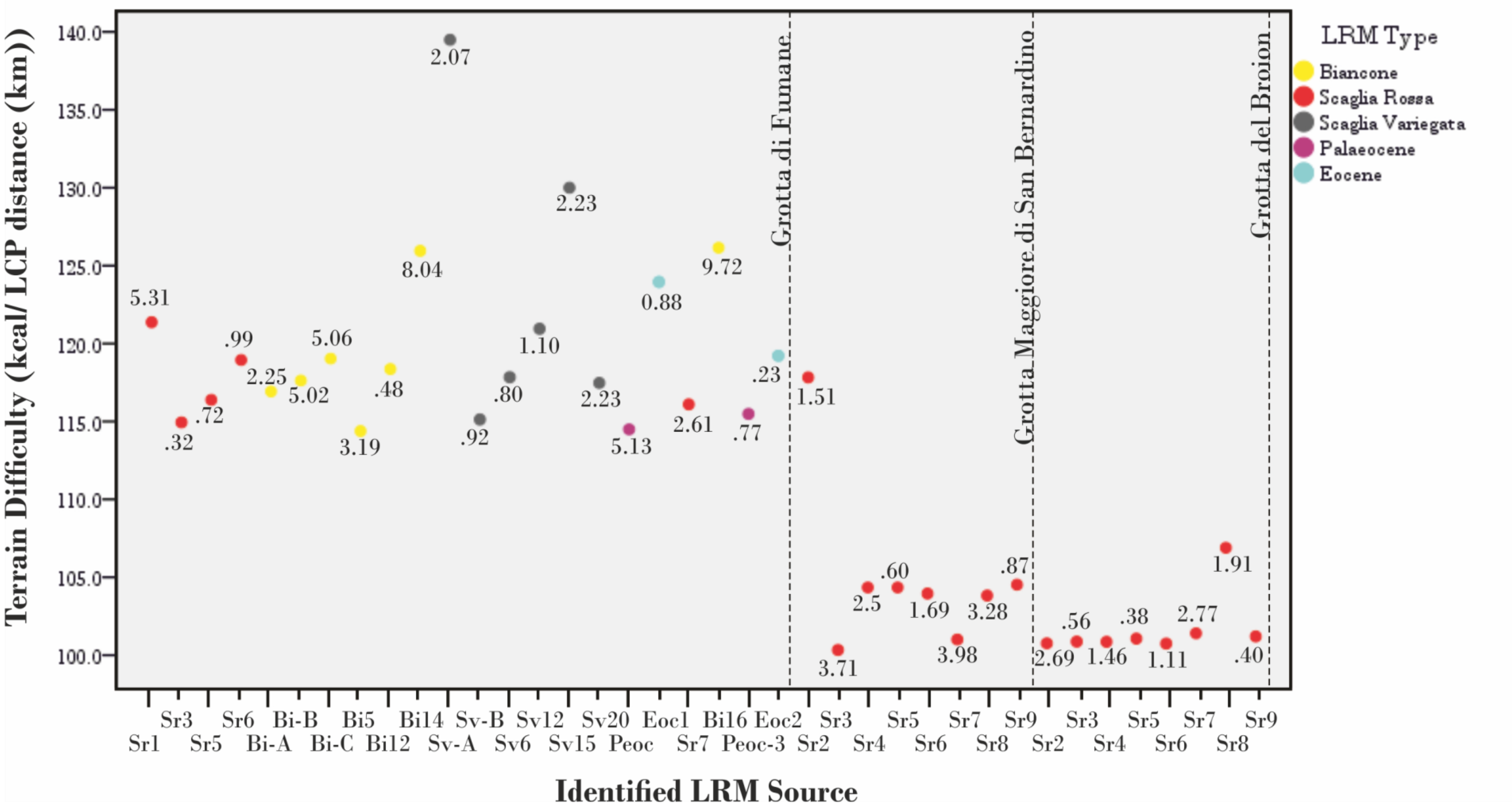


Figure 7.4: Inter-site comparisons of terrain difficulty considered as energetic costs to distance ratios, shown for each site and identified LRM source of greater than poor quality. Attractiveness quotients (AQs) factoring in terrain costs noted for each LRM source (Appendix E).

In all, the findings of terrain modelling analyses demonstrated that current thinking on Neanderthal economic zonation, namely, the delineation of local foraging ranges based on distance alone (and using Euclidean distances) should be reconsidered through site-by-site evaluations of topographic landscapes and LRM distributions that incorporate modelled mobility costs. This research proposes that energy and time costs can be perceived as economic thresholds that are amorphous and of variable distances around each site in response to its distinct ecological constraints and topographical settings. The findings of this research indicate an energetic threshold of 800kcal, which represents the extent of economical procurement costs for a residential type site. Further, a more limited threshold can be observed at around 400kcal, based on the costs of procuring those LRM most greatly represented (and expensively exploited) in lithic assemblages. In terms of time, considering the impact of topography on walking speeds, a local range of around two hours correlates with the dominant lithotypes observed in site assemblages with LRM distributions within energetic and distance thresholds.

These findings have significant impact on Neanderthal ecology. This research suggests that these energetic and temporal catchments, or procurement cost thresholds, pertained not only to LRM, but to subsistence activities, as well. It is postulated that these cost thresholds would have been cognitively recognised aspects of the Neanderthal landscape, and would have influenced settlement systems: sites located in environments with greater diversity in terms of faunal and floral biomes, and substantial LRM resources would yield greater returns at minimal costs, and thus would be more attractive and suitable to residential site use. Adding a greater level of complexity to the Neanderthal landscape, this research further recognises a *proximal zone*, which would represent the vast majority of direct lithic procurement that occurred in landscapes *with increased lithic potential*, as was observed for Grotta di Fumane. The proximal zone, based on the findings of this research, is found within a 2.5hr, 400kcal threshold, which cannot be universally delineated through distance measurements, as these costs are largely dependent on ecological contexts. Overexploitation of the proximal zone may have been mitigated by extended foraging, which is supported by the more limited presence of LRM beyond this range, and/or by seasonal mobility (discussion to follow in Section 7.5). At Grotta Maggiore di San Bernardino, a dominant procurement within the proximal zone cannot be refuted or denied, based on the uniformity of the flint types identified in the lithic landscape (SR only). Further studies linking site lithotypes with their off-site distribution through petrographic analyses, however, and considering the costs of mobility in three-dimensional landscapes, could serve to support of refute the existence of cost thresholds and the further delineation of proximal zones.

As the methodologies of the conducted terrain modelling analyses were largely in response to the novel research conducted by Wilson (2007b) and Browne and Wilson (2011), comparisons of this research's finding to these precedent and influential studies is imperative. In addressing the four hypotheses on route distance and energetic costs that were largely confirmed in the work of Wilson (2007a: 320) and further supported by Browne and Wilson (2011) (see Section 2.3.1), based on terrain difficulty, the findings of this research were in agreement with two:

Hypothesis #4 postulated that the raw material sources procured with the greatest terrain difficulty (determined by kcal to distance ratio) would be located relatively close to the site. For Grotta di Fumane, these sources are Bi14 and SV Group A, both of which were the best represented lithotypes in the studied assemblages (Figure 7.4). Additionally, the nearest viable outcrop of Scaglia Rossa flint, SR1, which was also the most attractive in terms of quality, abundance, and size, was procurable along a relatively costly route.

The results of this research are also in agreement with Hypothesis #3, which is essentially the inverse of Hypothesis #4, and postulates that the most distant sources would be procurable along relatively easy routes. At Grotta di Fumane, Scaglia Rossa sources, with the exception of SR1, were located at significant distances, but along routes that were less difficult than the more proximal Biancone and SV flints, as discussed in response to Hypothesis #4. At San Bernardino, the route to SR7, the highest quality flint, was found to be the most distant from the site, but had the lowest terrain difficulty.

Hypotheses #1 and #2 postulated that sources from easier routes would be found at greater distances, and vice versa, and that the LRM found along more difficult routes would be less represented in site assemblages. The findings of this research were ultimately unable to either confirm or refute these hypotheses, as, for all three sites, sources with comparable costs were also located at comparable distances. However, the discrepancy in the compared results is more to do with methodologies than results, as Wilson (2007a) and Browne and Wilson (2011, 2013) had at their disposal an arsenal of nearly 30 years of lithic prospection survey data and geochemical analyses of the flint of the Vaucluse, over a greater area, and further prefer a straight line route (avoiding slopes over 60%) to model mobility. Further lithic prospection and geochemical studies to link lithic assemblages with distinct LRM sources could yield results in line with Hypotheses # 1 and #2.

The main findings of Browne and Wilson’s (2011) research was that lower energetic cost LRM were more proportionally represented in Neanderthal lithic assemblages, and that when source terrain difficulty was higher, more proximal raw material types would be better represented. Further, sources with high quality raw materials with large source extents, greater abundance, and size, were also preferential to Neanderthals. These outcomes are in agreement with the findings of this research: Neanderthal technological provisioning was directly correlated to topographic and ecological constraints, where procurement strategies involved energetic and time minimisation as well as the selection of optimal resource patches. The comparability of these findings from southeast France and the study region of northeast Italy may indicate the beginnings of identifying consistent patterns of Neanderthal raw material economy on a larger geographic scale.

7.4 Neanderthal Ecology and Raw Material Economy

While the costs and constraints of off-site landscapes clearly impacted technological provisioning, these must be considered within the wider sphere of subsistence activities. LRM was a vital resource that was critical to subsistence, supporting hunting and butchering and vegetal processing activities. In this framework, LRM procurement and technological provisioning strategies alongside subsistence and mobility indicate Neanderthal behavioural ecology, recording interactions with the landscape.

As demonstrated by palaeoenvironmental reconstructions and simulations, Grotta di Fumane was positioned in proximity to mosaic environments. The distribution of biomes was influenced by the topography of the landscape, where open forests were situated on valley floors, forests ascended the hill slopes and occurred in ravine and streambeds, open alpine environments were situated on the Lessini Plateau, and rocky slope conditions were found between the Alpine grasslands and tree line. The proximity and diversity of these ecological contexts, including the demonstrated abundance of high quality flint resources in the reconstructed Fumane landscape, were able to sustain populations, as evidenced by the apparent residential use of the site.

To mitigate the costs and risks of faunal exploitation, Neanderthal populations at Grotta di Fumane appear to have practised diverse subsistence strategies, as evidenced through the exploitation of diverse resource patches. As was demonstrated in Chapter 6, the exploitation of these environments appears to correlate to the distribution of LRM in the landscape, indicating that flint acquisition may have been embedded in subsistence activities. This is demonstrated at Grotta di Fumane, where climate amelioration from level A8+A9 led to the further development of mixed forest environments, and shifting land-use strategies by Neanderthals were recorded by changes in faunal prey species representations and LRM procurement sources.

Shifting land-use strategies imply variations in subsistence strategies as well as mobility, and therefore the data produced by this thesis in support of varying procurement strategies can also be seen to represent Neanderthal ecology. As this research modelled, direct procurement may have been practiced for resources within a proximal cost threshold of 400kcal, or 2.5 hours, and embedded procurement strategies may have been practiced when procurement costs exceeded this threshold. Regarding the LRM procurement, embedded and direct procurement therefore each represent strategies singular to each sites ecological context, to secure resource needs, and maximise returns while minimising time and energy costs.

However, as was also demonstrated, the quality and abundance of LRM also positively correlated to Neanderthal acquisition choices, and thus the provisioning of the high quality cryptocrystalline Biancone flint from proximal primary outcrops as well as nearby streambed sources may indicate a secondary strategy for resource scheduling, in which direct procurement served to maintain an on-site supply of toolmaking potential. An additional impetus for the increased procurement and exploitation of the Biancone may be explained by its cryptocrystalline texture, which would wear out more quickly than the microcrystalline flints, and thus would require more frequent replacement, which would have been facilitated by its relatively low procurement costs.

A similar ecological scenario was demonstrated for Grotta Maggiore di San Bernardino: situated on the southern Monti Berici slopes, the cave was located in proximity to highly productive, mosaic environments in temperate, humid conditions, which were dominated by forests, with open forest conditions occurring on the Berici Plain and Berici Plateau, interspersed with grassy clearings and wetland environments. The ecological diversity and productivity in the San Bernardino landscape, including LRM of substantial abundance within a daily procurement range, sustained residential occupation of the site during MOIS-3, in which subsistence activities, animal processing, fire, and lithic production activities occurred.

As observed for Grotta di Fumane, the exploitation of faunal species from diverse environments at Grotta Maggiore di San Bernardino can be perceived as subsistence strategies to optimise hunting success, and mitigate diminishing foraging returns. In contrast to Grotta di Fumane, however, the topographic scenario and distribution of flint resources at greater distances from San Bernardino did not enable linkages between lithic procurement and hunting strategies, and so it is difficult to assume or refute lithic procurement strategies embedded in subsistence activities. However, the intensity of the exploitation in the Scaglia Rossa flint can be perceived as a lithic management strategy aimed at maximising flint potential in response to procurement costs. Therefore, based on the distribution of Scaglia Rossa flint beyond cost thresholds, and at distances that would likely be uneconomical for transporting hunted prey back to site, the procurement of semi-local SR can be hypothesised to have been direct rather than embedded.

While the reconstructed palaeoenvironmental conditions of Grotta del Broion are comparable, if not more productive, than those observed for Grotta Maggiore di San Bernardino, a contrasting image of site use is seen by the low density lithic assemblage and lack of evidence for subsistence activities or structured space that would indicate residential site occupation. Rather, the limited archaeological record of Broion signals its use as a location for task specific needs within a system of circulating residential mobility. As environmental productivity offering diverse and accessible resources was high, the locational role of Grotta del Broion appears to have been influenced by the lack of LRM within an acceptable cost threshold. While the high number of recovered cave bear remains could have been an occupational deterrent to Neanderthal inhabitation of the cave, the lack of flint was likely a greater factor in settlement choices, as the lithological environment would not have been suffice to sustain residential populations long-term

7.5 Regional Ecological Perspectives: Raw Material Economy, Mobility, and Settlement Dynamics

The costs and constraints of meeting resource needs within variable palaeoenvironments impacted Neanderthal settlement patterns and shaped regional settlement systems. While settlement choices may have been more greatly influenced by subsistence needs, namely proximity to diverse biomes offering an array of faunal and vegetative resources, a viable LRM supply within distance, energetic, and cost thresholds would have also been imperative in selecting a site for a home base (*sensu* Binford 1982) or central place (Isaac 1978).

Technological provisioning strategies, as demonstrated by the findings of this research, indicate Neanderthal planning depth, where mobility strategies, site use, and land-use strategies varied in response to the ecological character of the landscape. Each of the study sites, positioned in areas with very different LRM character, as well diverse climatic conditions, biomes, and terrain, contained lithic assemblages indicating different technological responses to flint availability, quality, and procurement costs.

As already discussed, based on the archaeological assemblages and environmental contexts of the three sites considered, this research proposes that Neanderthal populations in MOIS-3 northeast Italy appear to have practised a pattern of residential mobility, in which both Grotta di Fumane and Grotta Maggiore di San Bernardino represent residential sites, and Grotta del Broion represents a location. Discoid level A8+A9 of Grotta di Fumane, which could represent an increase in logistical mobility, based on the apparent intensity of occupation as compared to Unit A5-A6 and the evidence for foraging from greater distances. This was evidenced by faunal and LRM resources (particularly Eoc and more distant SR sources) from the the Alpine grasslands of the Lessini Plateau; as previously discussed, the procurement of Eoc, in particular, may have been embedded in subsistence resources, and these ideas, taken together, may represent task-specific forays. In this hypothetical scenario, the direct or embedded procurement of LRM represents a balancing of direct costs and returns against reduced costs when procurement is associated with other subsistence activities.

These observations on the regional settlement system is in agreement with previous research findings (Peresani 1995-1996, 2001; Peresani and Porraz 2004; Porraz and Peresani 2006). This thesis further proposes that residential mobility was circulating and potentially seasonal, serving to mitigate seasonal shortfalls in resource availability, not only of faunal and vegetative resources, but LRM, as well, which may have been visually obscured by snowfall, rendered inaccessible by ice (as postulated by Rolland and Dibble (1990)), or considered too costly as frozen precipitation increased surface friction costs in winter months.

Indeed, palaeoclimate simulations indicated harsher winter conditions in the Monti Lessini, with greater snow depth and days per year simulated for Grotta di Fumane, particularly at the time of the formation of A8+A9, than for the Monti Berici sites. Paired with seasonality indicators of spring through fall occupations from levels A6 and A5-A5+A6 of Grotta di Fumane as seen through hunted ungulate dental eruptions and wear, these findings support residential occupations of the Monti Lessini pre-Alps outside of the winter months, when ample and diverse subsistence and resource needs would have been highly productive (Peresani *et al.* 2011b). The presence of lithic cut marks on cave bear remains attributed to skinning action at Fumane further signals seasonally alternating cave occupations (Cassoli and Tagliacozzo 1994b; Peresani *et al.* 2011a). Monti Lessini occupations in the warmer months is supported by seasonality studies from Riparo Tagliente, where the presence of foetuses and neonates amongst the hunted ungulate assemblages of the MOIS-3 layers, as well as ungulate dental eruption analyses, demonstrate spring to summer occupations (Aimar *et al.* 1997; Thun Hohenstein and Peretto 2005). A similar scenario is observed in the MOIS-3 assemblages of Grotta del Rio Secco, where dense archaeological assemblages record Neanderthal residential occupations, as well as cave bear remains, which is interpreted to indicate seasonal rotating cave use (Talamo *et al.* 2014). Cutmarks on bear bone remains are interpreted as either attacks on sleeping cave bears or the opportunistic exploitation of the carcasses of those who died during hibernation, which would support the appearance of Neanderthals to the cave in the spring months (Romandini *et al.* 2013).

This research postulates that seasonal mobility shifted toward the lower latitude forested and humid environments of the Monti Berici during winter months. This claim is supported by the significant presence of LRM (Biancone, Scaglia Variegata, Eocene, and Oolitic flints) of an exotic Monti Lessini provenance in Unit II of Grotta Maggiore di San Bernardino (Peresani 1995-1996), showing southward mobility. Further, while underlying archaeological levels at this site record sparse lithic assemblages and higher frequencies of cave bear remains (Units V-III), the levels indicating intense human site use, with evidence of diverse activities and residential type occupations (Unit VI and MOIS-3 Unit II) show cave bear and overall carnivore presence decreased by over 25%, and predominantly Neanderthal-accumulated herbivore remains (Cassoli and Tagliacozzo 1994a). This could suggest seasonally-alternating use of the cave between carnivores and humans; unfortunately, seasonality data from the Neanderthal occupations of the site are lacking to support this hypothesis.

In this proposed scheme of circulating residential mobility, Grotta del Broion represents a location, with evidence supporting short term and task-specific activities, which seemed to be focussed on lithic resharpening, perhaps in association with organic materials that were not preserved over time. The character of the lithic assemblage is in line with a provisioning of individuals with mobile toolkits. High levels of retouch and selected implements (with a clear preference for Levallois flakes) that maximised lithic utility indicates the management and curation of lithic resources over distance and time, in response to anticipated technological and/or provisioning needs. As previously discussed, the locational role of Grotta del Broion within a settlement system was likely less a product of subsistence resources, as environments appear to have been productive and diverse, and more influenced by the lack of sustainable LRM sources with costs below energetic and distance thresholds. Further, if the extensive use of the site by large carnivores, particularly cave bears, additionally influenced the short-term use of the site, then this would support a wintertime occupation of the Monti Berici landscape.

While, in terms of percentages, the Monti Lessini flints were more greatly represented in Grotta del Broion than San Bernardino, by frequency Unit II of Grotta Maggiore di San Bernardino contained a much higher number of these lithotypes. These findings may indicate that Grotta del Broion was associated and techno-economically linked with the residential occupation of Grotta Maggiore di San Bernardino in the Monti Berici. Further, the Monti Lessini flints introduced to Broion by mobile Neanderthals represent carefully selected implements for meeting anticipated lithic needs and carrying out tasks over significant distances. Further, the lithic assemblage of ES2 from Broion as evidence of a provisioning of individuals strategies supports previous claims by this research that flint procurement activities were likely not associated with the lithic accumulations.

7.6 Conclusions

Raw material economy studies represent a critical link between Neanderthal landscapes and lifeways. As LRM distribution and its associated characteristics can be more accurately reconstructed by archaeologists than faunal or floral distributions, these methods serve to best elucidate Neanderthal economic responses to environmental variability, impacting subsistence and mobility strategies, site use and location, and settlement patterning.

Gamble (1999: 85) states: “The image that foragers have of the world is linked to an itinerary, not a concentric surface area as proposed by site catchment analysis.”

This statement rings true in the light of this research’s findings, which clearly demonstrate that environmental variability impacted Neanderthal lifeways. While the ecological scenarios of the three sites are unique such that extended foraging distances to accommodate longer residential occupations were not necessary, as each site was situated in highly productive mosaic environments, site-specific constraints impacted mobility and resource scheduling. In particular, in relation to this research, the costs and constraints associated with lithic distribution and character and its procurement played a critical role in shaping the lithic assemblages that are the most common Palaeolithic artefacts that we as archaeologists have at our disposal to study Neanderthal ecology.

Adhering to an interdisciplinary methodological framework, this research drew from palaeoenvironmental, geological, geographic, and archaeological data to address the key issues surrounding the role of environmental variability on Neanderthal raw material economy. Through inter- and intra-site comparatives of this research's results, this thesis contributes toward a better understanding of mobility, subsistence strategies, and settlement dynamics in MOIS-3 northeast Italy as directly impacted by the costs and constraints of the off-site economic landscape on Neanderthal ecology.

Future research would like to compare the Uluzzian and AMH lithic assemblages of Grotta di Fumane (as these are lacking from San Bernardino and Broion) to the Mousterian raw material economy studies of this research. In particular it would be interesting to consider LRM type and acquisition choices in relation to procurement cost minimisation and mobility strategies that would indicate similarities or differences in technological provisioning between these different cultural strata, particularly considering the trend of climate deterioration in the region heading toward the Last Glacial Maximum.

Additionally, geochemical and petrological analyses would serve to expand the scope of this thesis' research: determining clear linkages between exploited LRM sources and the lithic record would enable testing of some of the hypotheses proposed in this research, including cost and distance thresholds. Such studies would also clarify procurement strategies at San Bernardino, where it is difficult to say with any certainty which LRM sources were exploited; determining precise acquisition sources could confirm a predominant exploitation of the proposed *proximal zone*, and could test if the higher quality Scaglia Rossa flint from the sub-local range was preferred over the poorer quality, more proximal SR sources, despite the increased associated costs. Further, while minimal ground-truthing was conducted during lithic prospection, the expansion of this methodology of testing energetic expenditures, distances, and time costs against GIS models would lend further credibility to the methodological framework of this research.

Appendices

Figure A.1: Geological map Carta Geologica della provincia di Verona, indicating lithological flint potential around Grotta di Fumane, with relevant late Jurassic through Eocene formations shown. Images represent portions of larger geological map (Piano Regionale Attività di Cava 1982). 299

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Figure A.5: Geological map Carta Geologica della provincia di Verona, indicating lithological flint potential around Grotta del Broion, with relevant Cretaceous formations shown. Images represent portions of larger geological map (Piano Regionale Attività di Cava 1982) 307

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Figure C.14: Grotta di Fumane, streambed source SB19 345

Figure C.15: Grotta di Fumane, source SV Group A 347

Figure C.16: Grotta di Fumane, source SV16 349

Figure C.17: Grotta di Fumane, source SV27 351

Figure C.18: Grotta di Fumane, source Palaeocene Group 353

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Figure C.20:Grotta di Fumane, source Eoc1 357

Figure C.21: Grotta di Fumane, source Eoc1 359

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Figure C.23: Monti Berici, source SR1 365

Figure C.24: Monti Berici, source SR3 367

Figure C.25: Monti Berici, source SR3 369

Figure C.26: Monti Berici, source SR5 371

Figure C.27: Monti Berici, source SR7 373

Figure C.28: Monti Berici, source SR7 375

Figure C.29: Monti Berici, source SR8 377

Figure C.30: Monti Berici, source SR9 379

Table E.1: 2D and 3D straight-line route and LCP distances and time from identified LRM sources to Grotta del Broion, with LCP costs and original and re-figured AQ 397

Appendix A *The Lithological Landscape: Geological and Lithological Maps*

A.1 Grotta di Fumane

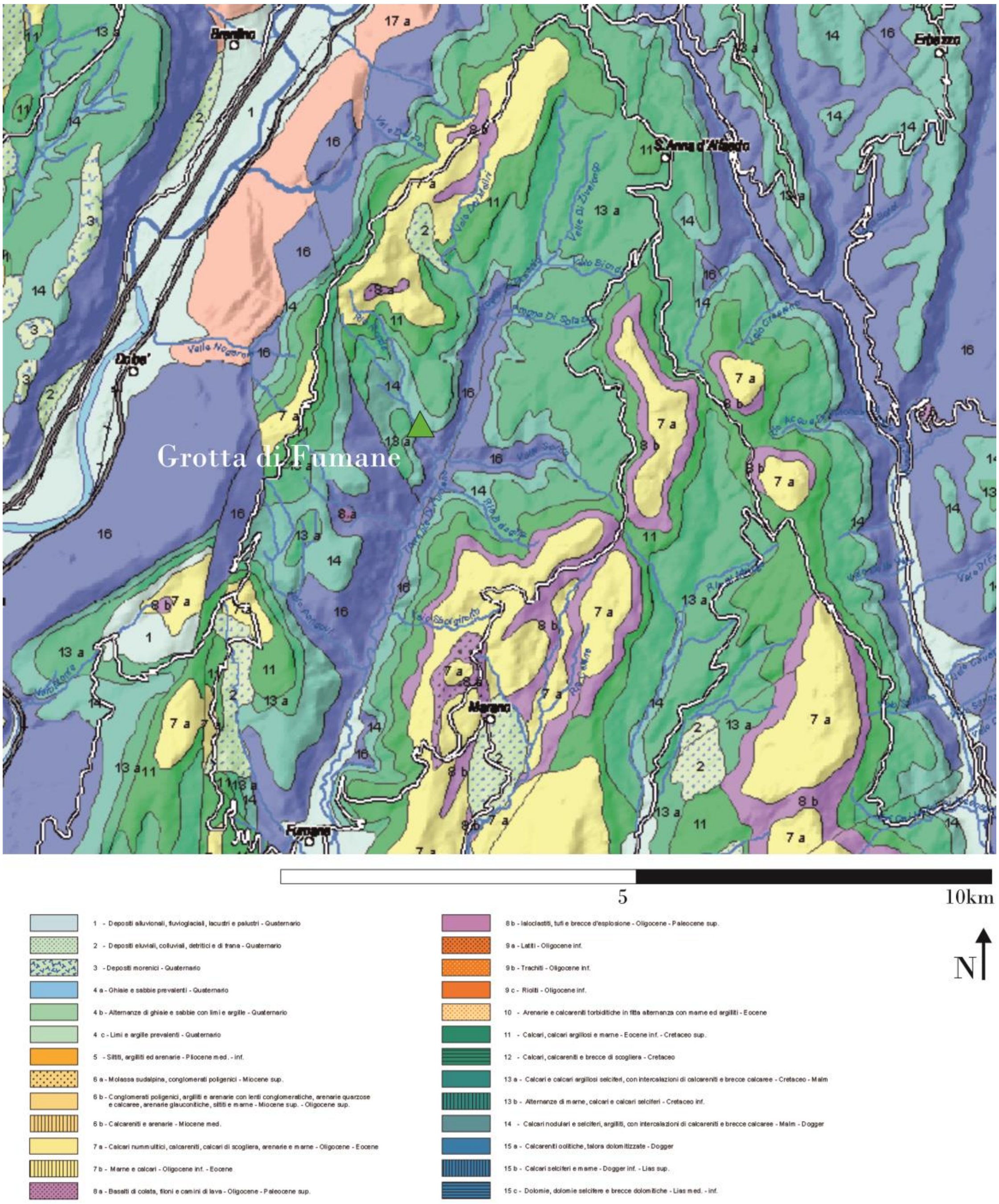

Figure A.1: Geological map Carta Geologica della provincia di Verona, indicating lithological flint potential around Grotta di Fumane, with relevant late Jurassic through Eocene formations shown. Images represent portions of larger geological map (Piano Regionale Attività di Cava 1982).

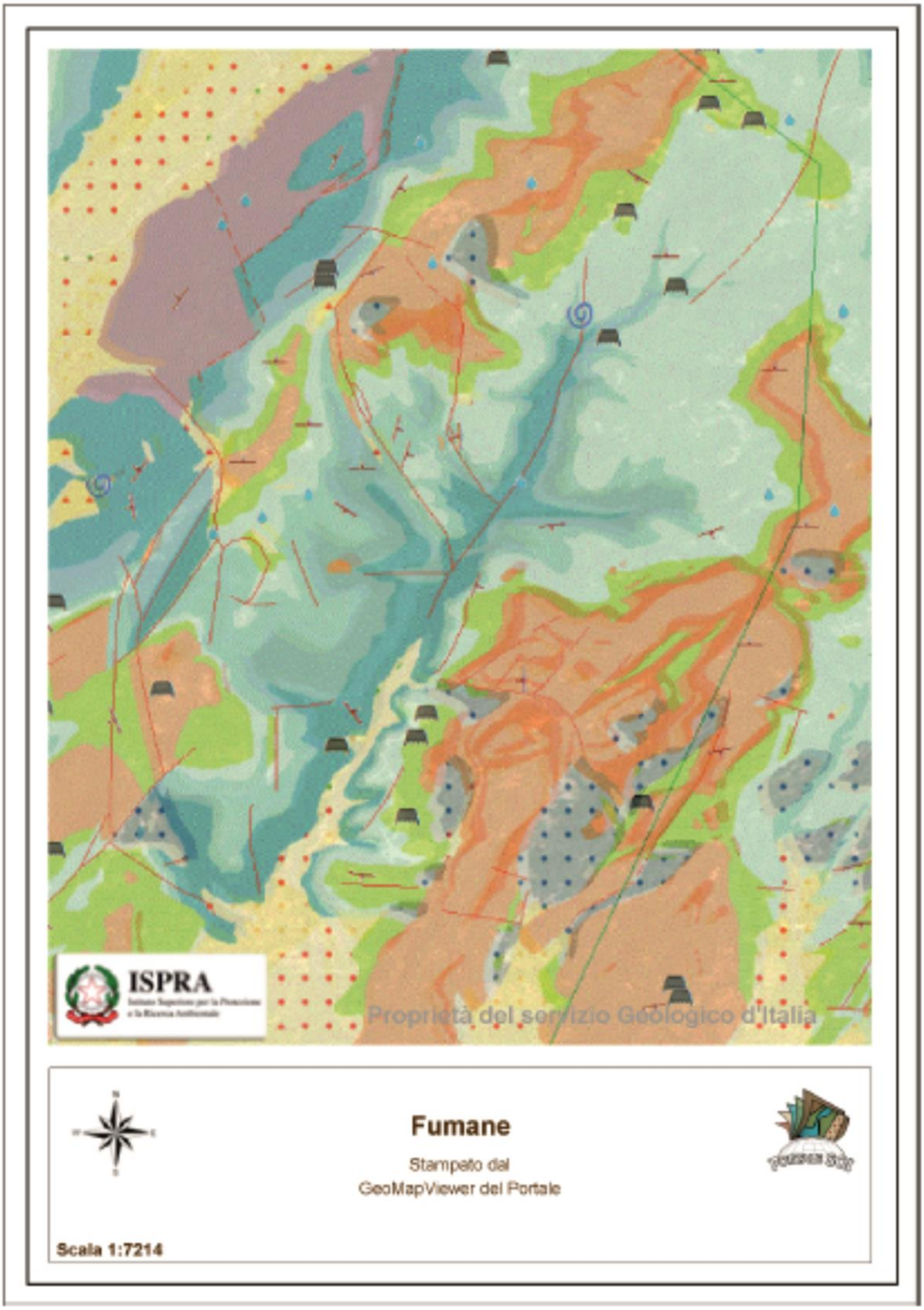

Figure A.2: Geological map of the Fumane landscape, via ISPRA. Legend available at the ISPRA Portale SGI via the Geomapviewer, http://sgi.isprambiente.it/geoportal/catalog/main/home.page

Figure A.3: Lithological map of the Fumane landscape, via ISPRA. Legend available at the ISPRA Portale SGI via the Geomapviewer, http://sgi.isprambiente.it/geoportal/catalog/main/home.page

A.2 Grotta Maggiore di San Bernardino

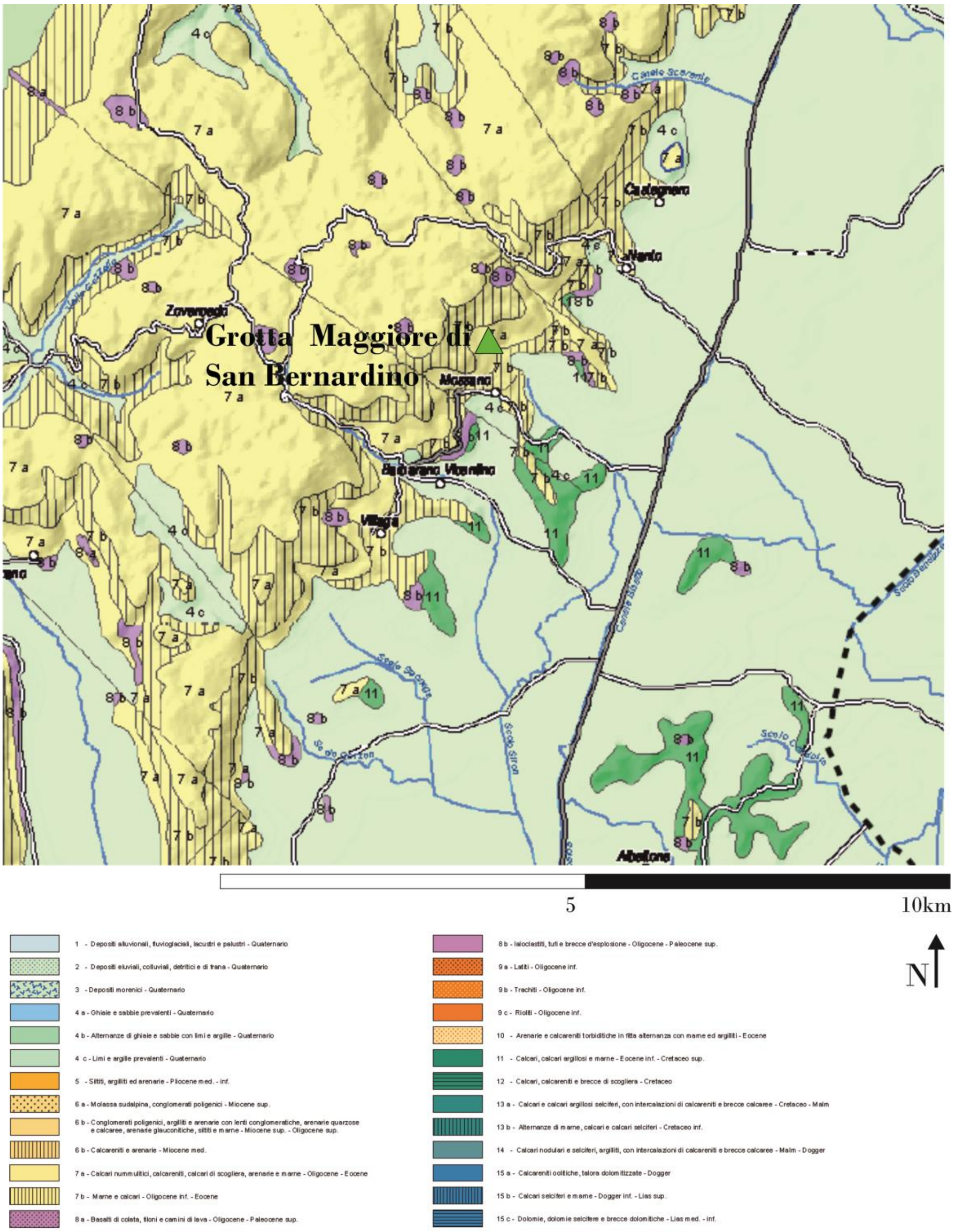

Figure A.4: Geological map Carta Geologica della provincia di Verona, indicating lithological flint potential around Grotta Maggiore di San Bernardino, with relevant Cretaceous formations shown. Images represent portions of larger geological map (Piano Regionale Attività di Cava 1982)

A.3 Grotta del Broion

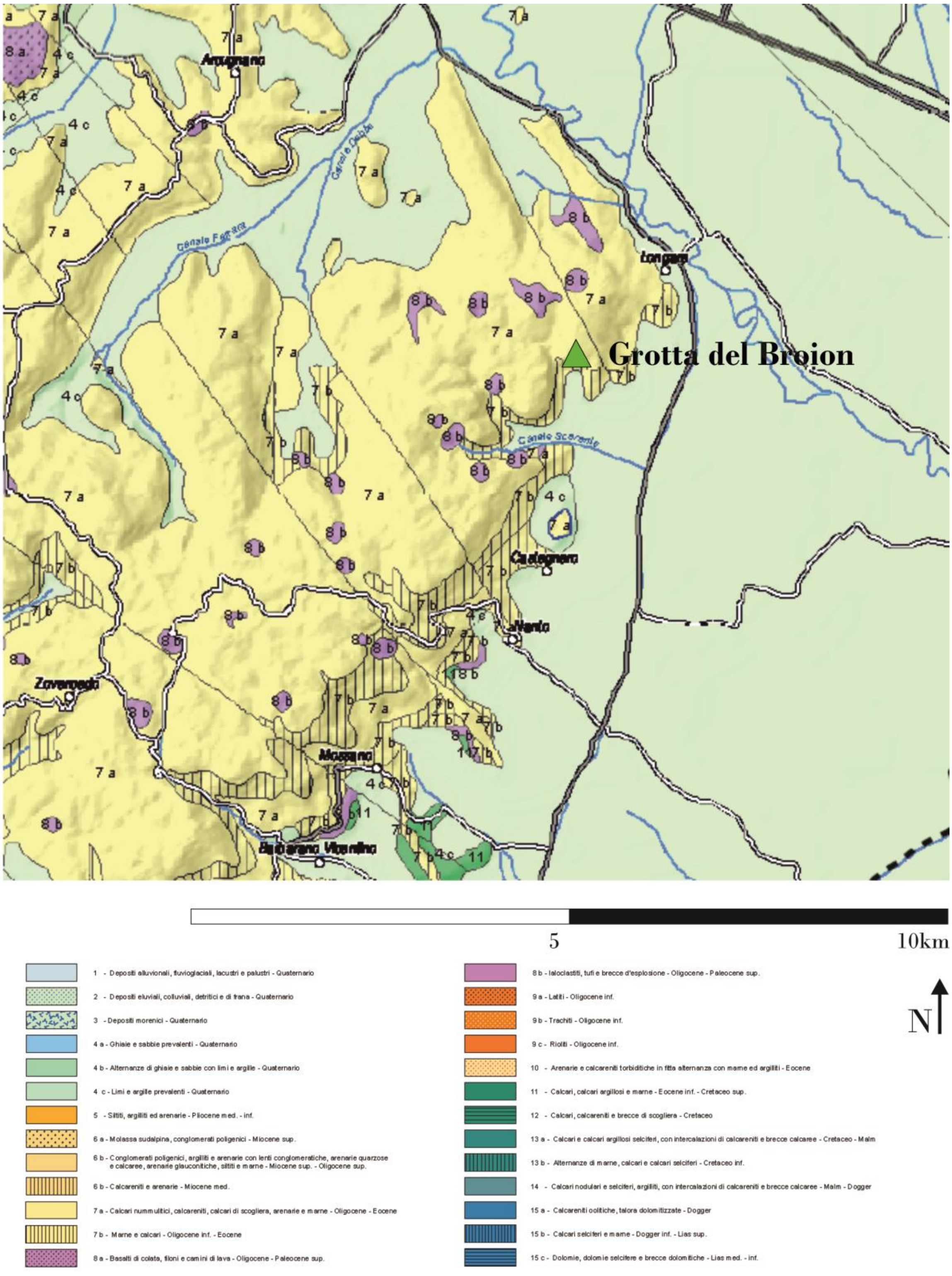

Figure A.5: Geological map Carta Geologica della provincia di Verona, indicating lithological flint potential around Grotta del Broion, with relevant Cretaceous formations shown. Images represent portions of larger geological map (Piano Regionale Attività di Cava 1982)

A.4 Monti Berici and Colli Euganei

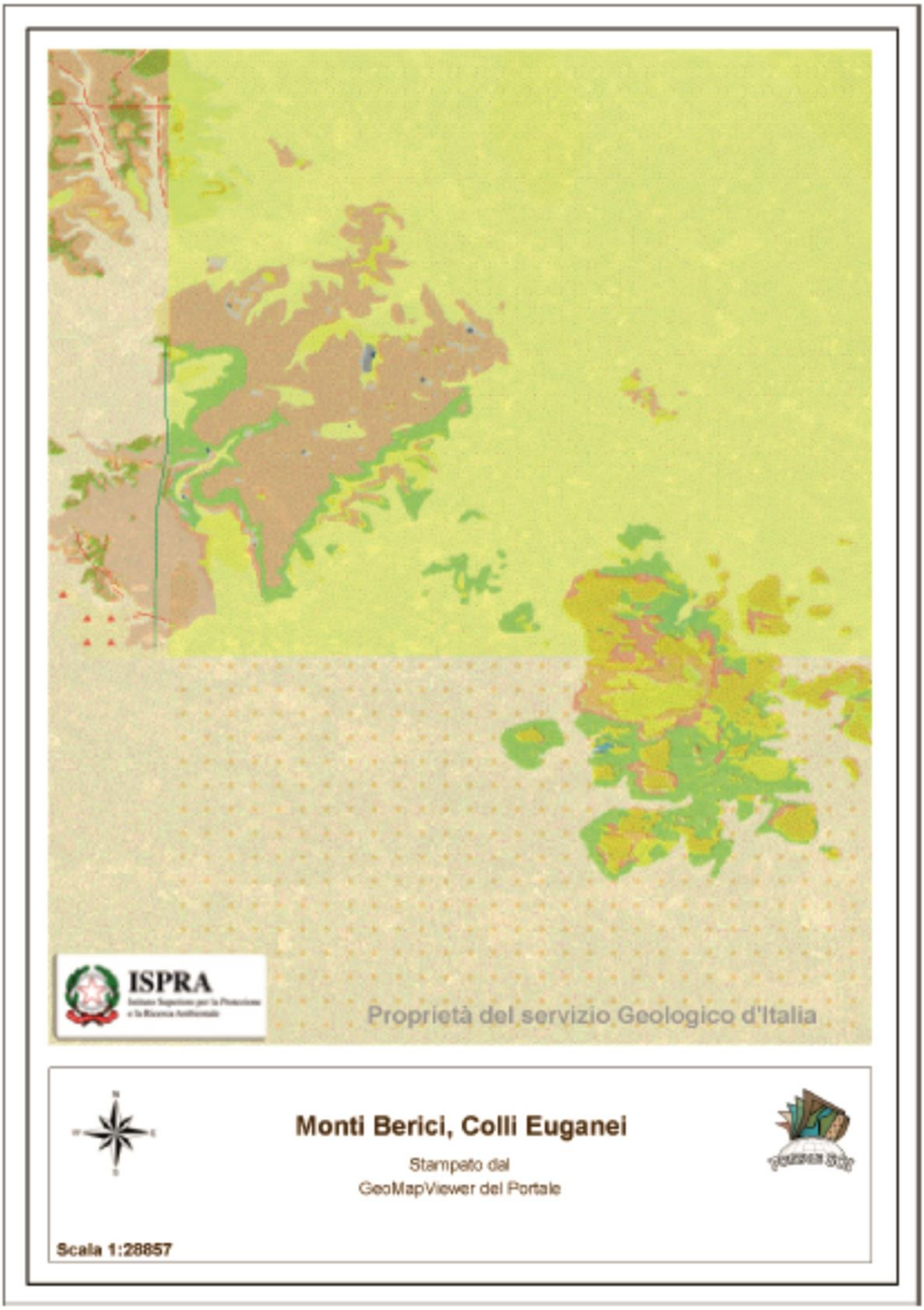

Figure A.6: Lithological and Geological map of the Monti Berici and Colli Euganei, via ISPRA. Legend available at the ISPRA Portale SGI via the Geomapviewer, http://sgi.isprambiente.it/geoportal/catalog/main/home.page

Appendix B *Field Guide to Flint Identification in the Study Region*

B.1 Lithic raw material characteristics

Flint Type	Colour(s)	Texture	Cortex	Fossil Inclusions
Palaeocene	Grey-brown	Cryptocrystalline	Limestone marls, pinkish to greyish-white	Undetermined: not identified in the Monti Lessini
Middle Eocene	Grey	Microcrystalline	White rough calcarenites with bioclasts including mummulites, discocycline, alghe rosse, echinoderms, and mollusks	Nummulites and discocyclines (macrofossils)
Lower-Middle Eocene	Grey or olive green	Microcrystalline	Off-white to brown micritic and pelagic limestone marls with globigerine and globorotalie planktonic microfossils	Globigerine and globorotalie planktonic microfossils
Scaglia Rossa (late Middle Cretaceous)	Red to pinkish red to dark reddish brown	Cryptocrystalline	Pinkish micritic limestone marls	Radiolarites, planktonic foraminifera Globigerinelloides, Hebergella, Dicariniella, Preglobotruncana, Whiteinella, bentonic foraminifera
Scaglia Variegata (late Middle Cretaceous)	Dark grey to black	Cryptocrystalline	White or yellow micritic and marly limestone with planktonic foraminifera and radiolarites.	Radiolarites, planktonic foraminifera Globigerinelloides, Hedbergella, Rotalipora, Dicarinella, Preglobotruncana, bentonic foraminifera
Scaglia Variegata (Middle Cretaceous to late Middle Cretaceous)	Dark grey to black	Cryptocrystalline	Greyish micritic and marly limestone with planktonic foraminifera and radiolarites.	Radiolarites, planktonic foraminifera Globigerinelloides, Hedbergella, Rotalipora, Preglobotruncana, Planomalina, bentonic foraminifera
Scaglia Variegata (early Middle Cretaceous)	Dark grey, olive grey, dark olive brown	Cryptocrystalline	Whitish micritic and marl limestone with planktonic foraminifera and radiolarites.	radiolarites, planktonic foraminifera Globigerinelloides, Hedbergella, Rotalipora, Shackoina, bentonic foraminifera
Biancone (Early Cretaceous to late early Cretaceous)	Light grey to brown or pinkish	Cryptocrystalline	White or micritic limestone with nanoplankton and radiolarites.	Radiolarites, Protoglobigerine, echinoderms, bentonic foraminifera
Biancone (Upper Jurrasic to early Cretaceous)	Pale white, reddish brown, yellowish brown	Cryptocrystalline	White or pinkish micritic limestone with nanoplankton and radiolarites.	Tintinnids, radiolarites, echinoderms (Saccocoma), bentonic foraminifera (Lenticulina, Spirillina), bivalves
Rosso Ammonitico (Middle to Late Jurassic)	Red to dark red	Microcrystalline	Dark red or pink micritic limestone, with numerous fossils inccluding radiolarites, pelagic chrinoids, ammonites, and belemnites.	Radiolarites, pelagic pivalves, sponge spicules, echinoderms, bentonic foraminifera
Oolitic (late Early to Middle Jurassic)	Whitish to brown	Microcrystalline	Yellowish or brown limestone with radiolarites and sponge spicules	Radiolarites and sponge spicules

Tablexx B.1: Study region flint data with geological formation, colour , texture, cortex, and fossil inclusions to aid in field identification. Data acquired from Bertola 2001.

Appendix C *Photo-Log and Physical Locations of Identified Flint During Pedestrian Survey*

C.1 Grotta di Fumane

	LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
BI Group A	BI1	Bei	45.61207	10.92389	628
	BI2	Bei	45.61224	10.92418	633
	BI11	Bei	45.61210	10.92394	633

Figure C.1: Grotta di Fumane, source Biancone Group A

	LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
BI Group B	BI4	Bi	45.61518	10.91796	610
	BI6	Bi	45.61466	10.91855	608
	BI9	Bi	45.61425	10.91845	605

Figure C.2: Grotta di Fumane, source Biancone Group B

Figure C.3: Grotta di Fumane, source Biancone Group B, view of plates in limestone

	LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
BI Group C	BI3	Bei	45.61135	10.92114	631
	BI7	Bei	45.61156	10.91956	616
	BI10	Bei	45.61216	10.91933	614

Figure C.4: Grotta di Fumane, source Biancone Group C

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
BI5	Bei	45.61252	10.91560	602

Figure C.5: Grotta di Fumane, source Bi5

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
BI8	Bei	45.59530	10.90715	491

Figure C.6: Grotta di Fumane, source B8

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
BI12	Bei	45.61447	10.92606	642

Figure C.7: Grotta di Fumane, source Bi12

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
BI14	BI	45.58664	10.91733	587

Figure C.8: Grotta di Fumane, source Bi14

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
BI16	Gbi	45.56594	10.89785	308

Figure C.9: Grotta di Fumane, source Bi16

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
SR1	SR	45.60490	10.88376	865

Figure C.10: Grotta di Fumane, source SR1

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
SR1	SR	45.60490	10.88376	865

Figure C.11: Grotta di Fumane, source SR1

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
SR2	SR	45.59676	10.90969	538

Figure C.12: Grotta di Fumane, source SR2

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
SR4	SR	45.59463	10.90904	510

Figure C.13: Grotta di Fumane, source SR4

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
SB19	SR	45.632597	10.91346	830

Figure C.14: Grotta di Fumane, streambed source SB19

	LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
SV Group A	SV5	SV	45.58298	10.93257	634
	SV23	SV	45.58254	10.93094	643

Figure C.15: Grotta di Fumane, source SV Group A

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
SV16	SV	45.62873	10.90666	778

Figure C.16: Grotta di Fumane, source SV16

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
SV27	Nsv	45.58268	10.92212	618

Figure C.17: Grotta di Fumane, source SV27

	LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
Peoc Group	Peoc1	Peoc	45.63232	10.92184	939
	Peoc1	Peoc	45.63254	10.92260	946

Figure C.18: Grotta di Fumane, source Palaeocene Group

Figure C.19: Grotta di Fumane, source Palaeocene Group

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
Eoc1	Eoc	45.63243	10.92625	936

Figure C.20:Grotta di Fumane, source Eoc1

Figure C.21: Grotta di Fumane, source Eoc1

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
Eoc2	Eoc	45.63136	10.92523	926

Figure C.22: Grotta di Fumane, secondary source Eoc2

C.2 Grotta Maggiore di San Bernardino and Grotta del Broion

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
SR1	SR	45.42343	11.56813	32

Figure C.23: Monti Berici, source SR1

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
SR3	SR	45.40393	11.56371	45

Figure C.24: Monti Berici, source SR3

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
SR3	SR	45.40393	11.56371	45

Figure C.25: Monti Berici, source SR3

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
SR5	SR	45.37651	11.58229	35

Figure C.26: Monti Berici, source SR5

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
SR7	SR	45.36706	11.59087	59

Figure C.27: Monti Berici, source SR7

Figure C.28: Monti Berici, source SR7

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
SR8	SR	45.39813	11.59614	30

Figure C.29: Monti Berici, source SR8

LRM Source	LRM Type	Latitude	Longitude	Elevation m asl
SR9	SR	45.39158	11.54355	39

Figure C.30: Monti Berici, source SR9

Appendix D *Lithic Prospection Results: LRM Field Recordings*

D.1 Grotta di Fumane

Grotta di Fumane: Identified primary LRM sources within 5km radius.

Group	LRM Source	Type	Munsell Hue	Latitude	Longitude	Elevation (m)	Form	Quality	Source Extent (m)	Size (cm)	Scarcity
BI Group A	BI1	Bei	10YR 7/8	45.61207	10.92389	628	Blocks	Good	<10	20	<5%
BI Group A	BI2	Bei	10YR 7/8	45.61224	10.92418	633	Nodules and Plates	Fair	<10	20	20%
BI Group A	BI11	Bei	10YR 7/6	45.61210	10.92394	633	Nodules	Fair	<10	25	20%
BI Group B	BI4	Bi	GL2 5/5PB	45.61518	10.91796	610	Blocks	Good	30	40	15%
BI Group B	BI6	Bi	10YR 7/6	45.61466	10.91855	608	Blocks	Very Good	20	20	<5%
BI Group B	BI9	Bi	GL2 4/5PB	45.61425	10.91845	605	Nodules	Fair	<10	25	10%
BI Group C	BI3	Bei	7.5YR 4/6	45.61135	10.92114	631	Nodules and Plates	Good	<10	25	10%
BI Group C	BI7	Bei	10YR 7/6	45.61156	10.91956	616	Nodules	Very Good	20	20	<5%
BI Group C	BI10	Bei	10YR 7/6	45.61216	10.91933	614	Nodules	Good	<10	20	<5%
	BI5	Bei	10YR 6/2	45.61252	10.91560	602	Nodules and Plates	Good	30	40	10%
	BI8	Bei	10YR 5/3	45.59530	10.90715	491	Nodules	Poor	<10	25	10%
	BI12	Bei	10YR 7/6	45.61447	10.92606	642	Nodules	Fair	<10	30	10%
	BI14	Bi	7.5YR 5/1 to 5YR 5/1	45.58664	10.91733	587	Nodules and Blocks	Good	100+	20	10%
SV Group A	SV5	SV	5YR 2.5/1 to 5YR 4/4	45.58298	10.93257	634	Nodules	Fair	20	10	<10%
SV Group A	SV23	SV	5YR 2.5/1 to 5YR 4/4	45.58254	10.93094	643	Nodules	Good	20	10	10%
SV Group B	SV9	nSV	5YR 4/1 to 5YR 4/6	45.58966	10.94260	710	Nodules	Fair	30	10	<5%
SV Group B	SV10	nSV	5YR 4/1 to 5YR 4/6	45.59056	10.94318	712	Nodules	Fair	30	15	7%
	SV6	SV	5YR 5/2	45.56166	10.92103	448	Nodules	Fair	20	25	<10%
	SV7	SV	5YR 2.5/1	45.56276	10.93136	438	Nodules	Poor	20	15	<5%
	SV8	nSV	5YR 2.5/1	45.56132	10.91742	399	Nodules and blocks	Poor	20	10	<5%
	SV11	nSV	5YR 4/1 to 5YR 4/6	45.59105	10.94357	724	Nodules	Poor	40	15	10%
	SV12	SV	10YR 4/1	45.61285	10.93393	667	Nodules	Good	25	10	12%
	SV14	SV	5Y 6/1 to 2.5YR 5/3	45.54930	10.88942	281	Nodules	Poor	<10	10	10%
	SV15	SV	10YR 2/1	45.60528	10.90067	610	Nodules	Good	25	15	10%
	SV16	SV	10YR 2/1	45.62873	10.90666	778	Nodules	Poor	2	25	10%
	SV17	SV	10YR 5/6	45.62897	10.90494	753	Nodules	Poor	2	20	<5%
	SV20	nSV	2.5Y 3/1	45.55512	10.89808	303	Nodules	Fair	<10	10	10%
	SV21	nSV	2.5Y 3/1	45.56401	10.90131	390	Nodules and Plates	Poor	100+	20	<5%
	SV27	nSV	5Y 2.5/1	45.58268	10.92212	618	Nodules	Poor	20	10	<5%
	SV30	SV	5Y 3/2	45.60118	10.93016	760	Nodules	Poor	15	15	20%

Table D.1: Identified primary outcrops of Biancone and Scaglia Variegata LRM sources within 5km of Grotta di Fumane, with associated field-recorded characteristics

	Grotta di Fumane: Identified primary LRM sources within 5km radius.										
	LRM Source	Type	Munsell Hue	Latitude	Longitude	Elevation (m)	Form	Quality	Source Extent (m)	Size (cm)	Scarcity
	SR1	SR	5YR 4/6	45.60490	10.88376	865	Nodules	Good	100+	25	5-25%
	SR2	SR	5YR 5/8	45.59676	10.90969	538	Blocks	Poor	<10	35	<5%
	SR3	SR	5YR 5/3	45.63310	10.90615	870	Nodules	Fair	20	10	<5%
	SR4	SR	5YR 5/8	45.59463	10.90904	510	Blocks	Poor	<10	40	<5%
	SR5	SR	5YR 5/3	45.62808	10.90753	801	Nodules	Good	30	15	<5%
	SR6	SR	5YR 4/6	45.62648	10.90108	863	Nodules	Very Good	<10	15	10%
Peoc Group	Peoc1	Peoc	7.5YR 4/1 to 4/2	45.63232	10.92184	939	Nodules	Very Good	100+	35	25%
Peoc Group	Peoc2	Peoc	7.5YR 4/1 to 4/2	45.63254	10.92260	946	Nodules	Very Good	100+	35	25%
	Eoc1	Eoc	GL1 8/1	45.63243	10.92625	936	Blocks	Fair	<10	30	>50%

Table D.3: Identified primary outcrops of Scaglia Rossa, Palaeocene, and Eocene flints within 5km of Grotta di Fumane, with field recorded characteristics

Grotta di Fumane: Identified secondary LRM sources from soils within 5km radius										
LRM Source	Type	Munsell Hue	Latitude	Longitude	Elevation (m)	Form	Quality	Source Extent (m)	Size (cm)	Scarcity
SR7	SR	5YR 5/8	45.55791	10.87768	516	Nodules and Blocks	Good	>100	20	10%
BI16	gBi	7.5YR 4/6	45.56594	10.89785	308	Nodules	Very good	>100	40	20%
Peoc3	Peoc	7.5YR 4/1	45.62609	10.90525	898	Nodule	Very good	<10	20	<5%
Eoc2	Eoc	2.5Y 5/1	45.63136	10.92523	926	Nodules	Poor	50	30	<5%

Table D.2: Identified secondary, palaeosol sources of LRMs within 5km of Grotta di Fumane, with field-recorded variables

LRM Sources	Type	Form	Quality	Source Extent (m)	Size (cm)	Scarcity
SB1	Bi, SV, nSV, Peoc	Rolled blocks and nodules	Good, very good	>100	10-15	25%
SB2	Bi, bei, SV, Eoc	Rolled blocks and nodules	Poor, good, very good	>100	10-15	25%
SB3	Sv, Bei	Rolled blocks and nodules	Good	>100	10-15	10%
SB4	Bi, Bei	Rolled blocks and nodules	Good	>100	10	<5%
SB5	Negative					
SB6	Sv, Bi, Bei, Ool	Rolled blocks and nodules	Good	>100	10	15%
SB7	Negative					
SB8	Bi, Bei, SV, nSV	Rolled blocks and nodules	Poor, good	>100	20	25%
SB9	Bi, SV	Rolled blocks and nodules	Good	>100	6-10	<5%
SB10	Bi, SV, nSV	Rolled blocks and nodules	Poor, good	>100	10-15	10%
SB11	Bi, SV, nSV	Rolled blocks and nodules	Poor, good	>100	10-15	10%
SB12	Negative					
SB13	Negative					
SB14	SV, nSV	Rolled blocks and nodules	Poor	>100	10-15	<5%
SB15	Negative					
SB16	SR, SV, Eoc	Nodules	Good	>100	10-15	<5%
SB17	Eoc	Rolled nodules	Poor	>100	10-15	<5%
SB18	Peoc, Eoc	Rolled nodules	Poor, good	>100	10-15	<5%
SB19	Peoc	Rolled nodules	Very good	>100	10	<5%
SB20	SV, SR, Peoc	Rolled blocks and nodules	Good, very good	>100	10-15	10%
SB21	Negative					
SB22	Negative					

Table D.4: Identified LRM within sampled 1x1m^2 streambed test areas, with associated field recordings

D.2 Grotta Maggiore di San Bernardino

Grotta Maggiore di San Bernardino: Identified primary LRM sources within 5km radius.

LRM Source	Type	Munsell Hue	Latitude	Longitude	Elevation (m)	Form	Quality	Source Extent (m)	Size (cm)	Scarcity
SR1	SR	10R 5/6	45.42343	11.56813	32	Plates	Poor	>100	30	10%
SR3	SR	10R 5/4	45.40393	11.56371	45	Nodules and blocks	Fair	60	25	<5%

Gr. Maggiore di San Bernardino: identified primary LRM sources within 5-7km radius.

LRM Source	Type	Munsell Hue	Latitude	Longitude	Elevation (m)	Form	Quality	Source Extent (m)	Size (cm)	Scarcity
SR2	SR	10R 5/6	45.39774	11.59786	24	Nodules	Good	>100	40	15%
SR4	SR	10R 5/4	45.39522	11.58857	40	Nodules and blocks	Good	>100	25	<5%
SR5	SR	2.5YR 5/4	45.37651	11.58229	35	Nodules	Good	30	15	<5%
SR6	SR	2.5YR 4/4	45.37340	11.58163	53	Nodules and blocks	Good	>100	30	<5%
SR7	SR	2.5YR 5/4	45.36706	11.59087	59	Nodules and blocks	Very good	>100	35	<5%

Gr. Maggiore di San Bernardino: identified secondary LRM sources within 5km radius.

LRM Source	Type	Munsell Hue	Latitude	Longitude	Elevation (m)	Form	Quality	Source Extent (m)	Size (cm)	Scarcity
SR8	SR	10R 5/4	45.39813	11.59614	30	Debris	Good	>100	40	<5%
SR9	SR	10R 5/4	45.39158	11.54355	39	Debris	Good	>100	5	<5%

Table D.5: Identified primary and secondary LRM sources within 5km and 7km of Grotta Maggiore di San Bernardino, with associated recorded field variables

D.3 Grotta del Broion

Grotta del Broion: Identified primary LRM sources within 10km radius.										
LRM Source	**Type**	**Munsell Hue**	**Latitude**	**Longitude**	**Elevation (m)**	**Form**	**Quality**	**Source Extent (m)**	**Size (cm)**	**Scarcity**
SR1	SR	10R 5/6	45.42343	11.56813	32	Plates	Poor	>100	30	10%
SR2	SR	10R 5/6	45.39774	11.59786	24	Nodules	Good	>100	40	15%
SR3	SR	10R 5/4	45.40393	11.56371	45	Nodules and blocks	Fair	60	25	<5%
SR4	SR	10R 5/4	45.39522	11.58857	40	Nodules and blocks	Good	>100	25	<5%
SR5	SR	2.5YR 5/4	45.37651	11.58229	35	Nodules	Good	30	15	<5%
SR6	SR	2.5YR 4/4	45.37340	11.58163	53	Nodules and blocks	Good	>100	30	<5%
SR7	SR	2.5YR 5/4	45.36706	11.59087	59	Nodules and blocks	Very good	>100	35	<5%

Grotta del Broion: Identified secondary LRM sources within 10km radius.										
LRM Source	**Type**	**Munsell Hue**	**Latitude**	**Longitude**	**Elevation (m)**	**Form**	**Quality**	**Source Extent (m)**	**Size (cm)**	**Scarcity**
SR8	SR	10R 5/4	45.39813	11.59614	30	Debris	Good	>100	40	<5%
SR9	SR	10R 5/4	45.39158	11.54355	39	Debris	Good	>100	5	<5%

Table D.6: Identified primary and secondary LRM sources within 10km of Grotta del Broion

Appendix E *Terrain Modelling: Least-cost Path Distances and Costs*

E.1 Grotta di Fumane

Grotta di Fumane: Identified viable primary LRM sources within 5km radius.							
LRM Source	**2D Distance km**	**3D Distance km**	**LCP Distance km**	**LCP Path cost kcal**	**LCP Route Time (mins)**	**AQ**	**AQ LCP**
SR1	2.21	2.81	2.48	301	200	16.00	5.31
SR3	4.13	4.61	5.42	623	205	2.00	0.32
SR5	3.64	4.08	4.76	554	190	4.00	0.72
SR6	3.5	3.91	4.54	540	180	5.34	0.99
BI Group A: Bi1, Bi2, Bi11	2.75	3.1	3.19	373	120	2.33	2.25
Bi Group B: BI3, Bi7, Bi10	2.49	2.78	2.95	347	120	6.33	5.02
Bi Group C: BI4, Bi6, Bi9	2.64	2.97	3.10	369	120	8.22	5.06
BI5	2.32	2.61	2.92	334	110	10.67	3.19
BI12	3.09	3.45	3.54	419	150	2.00	0.48
BI14	1.11	1.47	1.58	199	100	16.00	8.04
SV Group A: SV5, SV23	2.16	3.13	2.76	385	110	3.34	2.07
SV Group B: SV9, SV10	2.81	4.22	3.57	411	135	2.34	0.92
SV6	3.4	3.79	4.26	502	150	4.00	0.80
SV12	3.57	4	4.01	485	165	5.33	1.10
SV15	1.42	1.59	1.80	234	90	4.00	2.23
SV20	3.73	4.14	4.75	558	105	1.34	0.24
PEOC Group: Peoc1, Peoc2	4.42	4.93	5.45	624	190	32.00	5.13
Eoc1	4.58	5.1	5.51	683	195	6.00	0.88

Table E.1: 2D and 3D straight-line route and LCP distances and time from identified primary LRM sources to Grotta di Fumane, with LCP costs and original and re-figured attractiveness quotients

LRM Source	**2D Distance**	**3D Distance**	**LCP Distance km**	**LCP Path cost kcal**	**LCP Route Time (mins)**	**AQ**	**AQ LCP**
SR7	4.36	4.83	5.28	613	200	12	2.61
BI16	2.68	2.98	3.48	439	180	42.67	9.72
Peoc3	3.43	3.84	4.52	522	180	4	0.77
Eoc2	4.44	4.97	5.36	639	190	1.5	0.23

Table E.2: 2D and 3D straight-line route and LCP distances and time from identified secondary palaeosol LRM sources to Grotta di Fumane, with LCP costs and original and re-figured attractiveness quotients

E.2 Grotta Maggiore di San Bernardino

Grotta Maggiore di San Bernardino: Identified primary viable LRM sources within 5km radius.							
LRM Source	2D Distance km	3D Distance km	LCP Distance km	LCP Path cost kcal	LCP Route Time (mins)	AQ	AQ LCP
SR3	2.43	2.69	2.98	299	70	4.5	1.51

Gr. Maggiore di San Bernardino: identified primary viable LRM sources within 5-7km radius.							
LRM Source	2D Distance km	3D Distance km	LCP Distance km	LCP Path cost kcal	LCP Route Time (mins)	AQ	AQ LCP
SR2	4.40	5.77	4.88	575	90	21.34	3.71
SR4	4.61	5.11	4.6	480	95	12	2.50
SR5	5.71	6.35	6.44	672	120	4	0.60
SR6	5.95	6.60	6.82	709	125	12	1.69
SR7	6.96	7.73	7.96	804	145	32	3.98

Gr. Maggiore di San Bernardino: identified secondary viable LRM sources within 5km radius.							
LRM Source	2D Distance km	3D Distance km	LCP Distance km	LCP Path cost kcal	LCP Route Time (mins)	AQ	AQ LCP
SR8	4.60	5.58	4.70	488	90	16	3.28
SR9	3.66	4.07	4.42	462	95	4	0.87

Table E.3: 2D and 3D straight-line route and LCP distances and times from each identified LRM source to Grotta Maggiore di San Bernardino, with LCP costs, and original and re-figured attractiveness quotients

E.3 Grotta del Broion

Grotta del Broion: Identified viable primary LRM sources within 10km radius.							
LRM Source	2D Distance km	3D Distance km	LCP Distance km	LCP Path cost kcal	LCP Route Time (mins)	AQ	AQ LCP
SR2	6.89	7.59	7.86	792	105	21.34	2.69
SR3	6.76	7.48	8.00	807	120	4.5	0.56
SR4	7.1	7.84	8.14	821	110	12	1.46
SR5	9	9.95	10.33	1044	150	4	0.38
SR6	9.32	10.34	10.76	1084	155	12	1.11
SR7	9.91	10.98	11.39	1155	155	32	2.77

Grotta del Broion: Identified secondary LRM sources within 10km radius.							
LRM Source	2D Distance km	3D Distance km	LCP Distance km	LCP Path cost kcal	LCP Route Time (mins)	AQ	AQ LCP
SR8	6.83	7.56	7.83	837	105	16	1.91
SR9	8.79	9.73	9.94	1006	135	4	0.40

Table E.1: 2D and 3D straight-line route and LCP distances and time from identified LRM sources to Grotta del Broion, with LCP costs and original and re-figured AQ

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