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Settlement and Site Location in the Middle and Upper Paleolithic of the Vézère Valley, France

A Dissertation Presented

by

Matthew Learoyd Sisk

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Abstract of the Dissertation

Settlement and Site Location in the Middle and Upper Paleolithic of the Vézère Valley, France

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Human settlement is guided by a suite of economic and social decisions. Hunter-gatherer populations are not restricted by extensive ownership and often focus settlement on important resources. Analysis of settlement patterns left by these groups reveals key information about subsistence and sociality. Patterning among modern groups is extremely varied and represents a dynamic and adaptable land-use strategy. The antiquity of this adaptability is unknown, but comparisons with the patterns left by other hominin species often show it as a derived trait of *Homo sapiens*. However, most of these settlement models are built at a species-level resolution and encompass great chronological and environmental variation. Also, the dense record of recent *Homo sapiens* populations makes the chance of recognizing settlement variability higher than for preceding hominin species.

This project addressed these issues by testing aspects of species-level models for late Middle Paleolithic (Neanderthal) and early Upper Paleolithic (*Homo sapiens*) sites in the Middle Vézère Valley (Dordogne, France). This region has the advantages of diverse environmental characters and a well-understood archaeological chronology representing several subdivisions of these broad periods. Using tools from Geographic Information Systems, taphonomic biases in the sample were investigated and site locations correlated with relevant landscape characters.

The patterns revealed both support and contradict aspects of species-level settlement models. Upper Paleolithic sites are found significantly closer to the river and at low elevation sheltered locations. They are more likely to be near natural fords in the river and have a good

view of these areas. Middle Paleolithic sites, in contrast, are found in variable locations but more often on the higher elevation plateau and within a short distance from multiple biomes.

The final distillation of these correlations reveals a pattern of Middle Paleolithic focus on heterogeneous environments where diverse resources would be available. Upper Paleolithic settlement is instead focused a specific environment, possibly indicating intense exploitation of a single resource. In this region, this appears to be places where migrating herd animals would be at a disadvantage, like river crossings and narrow valleys. In this small region there is a clear settlement difference between Middle and Upper Paleolithic populations, but more focused studies must be undertaken before these results can be broadly extended.

Dedication Page

To Jenni, with all my love.

And, to Ian, who's passion for science and love of France are an inspiration.

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Chapter 1: Introduction

What makes us, as humans, unique is one of the fundamental questions of anthropology. From an evolutionary standpoint, one of the most useful ways to address differences is by examining the uniquely derived behavioral and biological characteristics that separate one species from another. With our species, *Homo sapiens*, there is a major complicating factor. A great many of our behavioral and biological traits (language, bipedality, technology) are unique to our species and not found in our closest primate relatives.

One recourse is to examine the evolutionary history of the hominin clade; our ancestors and closely related species that share many these derived traits. This can encompass both the biological record, through the study of fossils, modern biology and genetics and the behavioral record through the study of archaeological material. Biologically, there is significant evidence that *Homo sapiens* evolved in Africa around 200 thousand years ago (ka).

Behaviorally, the picture is more complicated. Until relatively recently, the change from pre-modern to modern behavior was thought to be an abrupt phenomenon followed by a rapid spread of *Homo sapiens* throughout the Old World. However, the more transitional African record suggests that this pattern is the result of a history of research focused on small, marginal, areas of Western Europe. In this area, there is a sharp transition between a presumed non-modern record, the Middle Paleolithic, and a so-called modern record, the Upper Paleolithic. While there is debate, it appears that this abrupt shift was caused by the extinction of Europe's indigenous Neanderthal populations and the arrival of *Homo sapiens.*

This rapid shift in the biological and cultural record may be the result of location, but it also yields an excellent ability to test hypotheses on the character of early *Homo sapiens*' adaptation by comparing them with a closely-related hominin species living in a similar environmental and chronological context.

This project uses the rich record of Western Europe to test several hypotheses about Paleolithic settlement and land-use. Historically, models of Middle and Upper Paleolithic settlement have been synthetic; using data from a wide range of environmental and chronological contexts to build an overall model of Neanderthal and *Homo sapiens* settlement strategies. Much recent work in other primate species has highlighted variability in behavior and mobility across different environmental conditions. There is no reason to assume that Paleolithic hominins would not exhibit significant variation as well. It is thus important to control for this variability by holding constant as many variables as possible.

The current work aims to do this by performing a detailed study of Middle and Upper Paleolithic site location patterns in the Middle Vézère Valley of southwestern France. This region is ideal for such a study because of its constrained area and rich Paleolithic record. A series of topographic and environmental variables are examined using Geographic Information Systems (GIS) software and analytical techniques. These are then quantitatively compared with hypotheses from broader studies and relevant ethnographic data.

This document is split into seven chapters, with the relevant figures and tables following each chapter. This initial chapter outlines the larger questions and the importance of systematic, quantitative inquiry into Paleolithic settlement.

Chapter 2 presents necessary background information. First, models of human, and in particular, hunter-gatherer settlement are discussed. Next is a detailed presentation of the Middle and Upper Paleolithic of western Europe and a discussion of the applicability of modern settlement models to this time period. A synthetic model of overall Neanderthal and early *Homo sapiens* settlement patterns is then followed by a discussion of the necessity for more focused research on this topic.

Chapter 3 is then focused on the particulars of the dataset and guiding questions of this project. It begins with the study area: the Middle Vézère Valley of Dordogne, France. Its physical character, archaeological history and suitability for detailed landscape analysis are all discussed. The overall structure of this project then proceeds from broad-scale hypotheses to a list specific testable observations distilled from previous work on Paleolithic settlement in the region. Finally, the twin assumption of minimal taphonomic bias and topographic continuity are presented with reference to minimizing factors and quantitative ways to address their effects.

Chapter 4 discusses the methods used here to analyze Paleolithic settlement. An initial discussion of the utility of restricting data to site location and a rough typological attribution is followed by sources and criteria used to locate and classify sites. Next, the GIS-based methods are presented in the context of hypotheses to which they can contribute. Finally, the statistical tests used to analyze patterns and investigate potential bias are discussed.

Chapter 5 contains the results of each of these diverse analyses. First, the results of investigations into sample bias are outlined. Statistical comparisons are made between the Middle and early Upper Paleolithic and among the smaller subdivisions within each. These results are discussed in the context of the larger models of Paleolithic settlement. Because of the high likelihood of correlation between topographic variables, they are then ranked by importance using a multi-variate, Maximum Entropy technique.

Chapter 6 reports on a detailed case study investigating the assumption that the modern topography serves as an acceptable proxy for the Paleolithic topography. This was done using data from the Castel-Merle Vallon. Excavation, geological inquiry and electrical resistivity were used to investigate the bedrock morphology and its relation to Paleolithic occupations. The area has been subject to significant erosional modification following the Paleolithic. The implications on the larger study are then discussed and other potentially affected areas are isolated.

Chapter 7 then concludes by placing these findings in the context of the Middle to Upper Paleolithic transition in western Europe. Implications for our understanding of this time period and this method's applicability in other areas are discussed.

Two appendices follow: Appendix A is an annotated table with all of the data collected for each of the 89 sites used in this study. Appendix B contains methodological details. The GIS workflow for each analysis, with computer code, is discussed in cases where it is too extensive or detailed for inclusion in Chapter 4.

Chapter 2: Background

a. Introduction

This chapter presents background information on the topics of settlement choice, the time periods of interest to this study and a discussion of how the two can be integrated. It is designed to give the theoretical and factual context of this study's approach to modeling the settlement of pre-modern humans. The context and background of these topics are broad, so only relevant information will be presented. In addition, this chapter will provide an argument for the necessity of moving beyond the large scale of most previous studies. In essence, using isolated settlement patterns to interpret the settlement strategies of radically different chronological and biological groups fails to take into account the variability in these characters. Thus, the argument is made that we can begin to isolate the key differences in large scale groups by first understanding the variability in constrained regions.

b. Modeling settlement choice

Where to settle is a complex choice for any human group. Settlement decisions are based on available resources, history, proximity to other groups and a host of other social and economic factors. This diversity of components makes settlement a complicated concept to model. How an archaeologist approaches these questions is largely based on his or her theoretical orientation. The development of these theoretical orientations largely mirror those of broader archaeological thought. In essence, two broad approaches based on either the economic or social basis of settlement can be distinguished. This distinction is largely artificial and most modern settlement models include elements of both economic and social factors.

Primarily economic models present settlement decisions as a weighing of costs and benefits. For instance, a given site may have the benefit of close proximity to potable water, but at the cost of being quite distant from a necessary raw material. Thus, in choosing a location for settlement, a human group should choose the location that is optimally placed to minimize costs. The New Archeologists initially adopted these techniques, (e.g. Binford, 1962; Chang, 1968; Vita-Finzi and Higgs, 1970; Hodder and Orton, 1976) and produced a multitude of studies linking resources and environmental characters to settlement choices.

With the development of post-processual theory in the 1980s, economic models were criticized for both their imposed view of maximum utility and their inability to include offsite activity. Settlement models based less on economic principles and more on the social and cultural influences of settlement began to gain prominence (e.g. Hodder, 1990; Bender, 1993; Barrett, 1994; Tilley, 1994). Models based on these components are designed to address cultural biases in economic approaches, namely that non-western cultures often have a dramatically different idea of human-environment interaction and may not view the environment simply as a resource to be exploited (Pálsson, 1996). In contrast to strictly economic models, these post-processual models tend to emphasize the cultural or symbolic meaning of a given location. Settlements may be placed near, or in view of, a particular landscape feature with significant meaning for the group. The nature of this meaning is often site- or culture-specific, but can be determined through ethnographic correlates or landscape analysis.

In using a dichotomous system of social and economic factors, one ignores the certain interplay between the two. It is often impossible to isolate a given behavior as a strictly cultural or ecological response (Ingold, 1988). This is especially true in studies of settlement, where it can be difficult to disentangle the economic and social factors. There is no reason to assume that a ritually important site would not also be located in an area of high productivity or that productive areas would be devoid of ritual importance. In fact, the ritual or cultural importance of settlements is often related to their perceived or actual antiquity (Bender, 1999). In these cases, one could assume that economically disadvantageous sites would be more prone to abandonment (or the extinction of local populations), even when social causes are the primary explanation of settlement.

Thus, it is more accurately an interplay of both social and economic factors that controls settlement. Most modern scholars follow this idea and address both in their settlement models. For example, in a study of settlement and farming in historic Sweden, Widgren (1999) explained farm settlement and abandonment using both cultural (land rights and farming practices) and environmental (climate and optimal crop locations) factors. While combining social and economic factors is less difficult for the well-understood historic periods then for further distant periods, this sort of study serves to demonstrate that integration of both can be successfully completed.

c. Hunter-gatherer settlement

For the vast majority of human history, groups followed a hunter-gatherer[1] subsistence strategy. Thus, modern hunter-gatherer groups are frequently studied to provide models of social and economic life in prehistory. Hunter-gatherer groups were originally thought to serve as the baseline (i.e. the most simple) human adaptation and thus to provide a direct view of how our hominin ancestors lived. In recent years, an increased understanding of the complexity, variability and nature of the modern hunter-gatherer adaptation has changed this view. Hunter-

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[1] Here, I use the traditional term hunter-gatherer in place of the alternate, and potentially more descriptive, *gatherer-hunter* or *forager*. This is not to downplay the importance of gathered resources in the economy but simply for ease of understanding. The term hunter-gatherer is the common usage and the specifics of this adaptation are not the focus of this work.

gatherers are today recognized as a complex and diverse adaptation that may provide some insights into the types of factors controlling settlement and sociality in the past (Leacock and Lee, 1982; Shott, 1992).

Defining hunter-gatherers

Modern hunter-gatherer groups are typically defined as those who rely primarily on foraged and hunted food. As the name "hunter-gatherer" suggests, resources are both collected (as in plants or shellfish) and hunted (as in large or small game animals). This may be augmented by trade with sedentary societies, limited agriculture, or food storage, but none of these are universal. Groups tend to be mobile, often moving at least several times per year. Because they do not rely on animal husbandry or agriculture, the diet of hunter-gatherer groups tends be highly diverse, often exploiting many resources from varied micro-environments. This buffers the group against a reduction in any one resource (Kelly, 1995).

Many definitions for the hunter-gatherer adaptation also outline an aspect of the social structure, usually resting in the presence of egalitarian, band-level groups (Lee and DeVore, 1968). However, other anthropologists are quick to point out the presence of exclusively foraging groups with stratified societies and dense populations, like those historically found in the US Pacific Northwest (Ames, 1994). A distinction between simple and complex hunter-gatherers is often used to separate these egalitarian and stratified societies (Hayden, 1992; Arnold, 1996). Table 2-1 outlines the key differences between simple and complex hunter-gatherer adaptations.

The recent study of hunter-gather lifeways has highlighted variability in this adaptation (e.g. Kelly, 1995). Not all groups of hunter-gatherers are organized into bands or follow the same kinship system. Some groups rely heavily on trade with local populations, while some are isolated. Some store food extensively, others rarely maintain a surplus. Environments occupied can range from the arctic to tropical rainforests to arid deserts.

Mobility and settlement

Variation in economic and social behavior of human groups often represents itself in variation in mobility and settlement strategies. Modern hunter-gatherer populations are no exception. Because these groups were historically thought to represent the lifeway of our hominin ancestors, their economic systems have been paid considerable attention. In general, hunter-gatherer groups tend to be highly mobile and less constrained to individual locations than agriculturists or even pastoralists. There is considerable variation, but most modern hunter-gatherer groups move between 1 and 60 times a year (though some remain stationary). These moves typically range between 2 and 30 kilometers, though moves of up to 60 kilometers are reported (see Kelly, 1995:111-115).

While in some cases idiosyncratic, the choice to move for a hunter-gatherer population is thought to be controlled by both social and economic factors. Disparate groups often aggregate to renew social bonds and expand the gene pool (Lee, 1976). Also, hunter-gatherer groups sometimes relocate to seek exotic or prestige goods with little functional, but great social or ritual value (Wiessner, 1982; Whallon, 2006). Economically, the most important factor is usually thought to be the exhaustion of local resources, although movement to exploit seasonally available resources is possible. Storage can buffer groups against this need to move. In modern hunter-gatherers, increased storage of resources is inversely correlated with mobility (Binford, 1980) and the number of residential moves (Kelly, 1983). Highly mobile populations can store resources in seasonally revisited caches in, but this limits the type of resources that can be stored and is often a risky proposition (Stopp, 2002).

Models of hunter-gatherer settlement

Models of hunter-gatherer settlement typically seek to explain why groups travel and settle differently. Mobility strategies are, for hunter-gatherer populations, deeply intertwined with different settlement patterns. Because of this, most models of hunter-gatherer settlement rely on components of mobility.

Early observations on the mobility and settlement of hunter-gatherer groups tended to consider these factors defining characteristics of the social system and not as a response to specific stimuli. More specifically, the constraints of a highly mobile lifestyle on culture and material goods were often highlighted (e.g. Mauss and Beuchat, 1904; Sahlins, 1972). Variation in mobility between different hunter-gatherer cultures was often noted and codified into systems for classifying the mobility of specific groups (e.g. Beardsley et al., 1956; Murdock, 1967). These systems were largely classification tools and rarely served to explain the presence of variation.

The creation of the generalized foraging model during the “Man the Hunter” conference began to isolate the important economic and social factors controlling settlement variability (Lee and DeVore, 1968; Isaac, 1990). Many components of these early explanations of hunter-gatherer settlement were distilled into more concrete economic settlement models. The minimal storage of hunter-gatherer groups were thought to largely mandate economic decisions. More specifically, these economic models rest on the assumptions that human choice is rational and that the chosen location represents the optimal location to minimize costs related to resource acquisition (Wood, 1978; Winterhalder and Smith, 1981). Foremost among this type of model is Optimal Foraging Theory, a ecological model which states that there should be a strong selection for locations that minimize the cost of resource acquisition (Smith, 1983). In essence, populations that do not optimally locate their settlements will be at a selective disadvantage compared with those that do.

Based largely on this core principle, a series of predictions for hunter-gatherer settlement in areas of different resource availability has be developed. Primary among these is the model of environmentally driven settlement dynamics proposed by Harpending & Davis (1977). This model suggests that in the case of high regional variability in resource density it is optimal for human populations to settle in large groups near rich locations. In contrast, if resource density is sparse, but uniformly distributed, then it is best for populations to settle in small groups across the landscape.

Furthermore, the size of resource patches plays a role in the mobility of hunter-gatherer populations. The length of stay, or when to move, is usually determined by the depletion of local resources. Using ethnographic data, Binford (1980) outlined adaptations that can address this need to move. In comparing choices made by the arctic dwelling Nunamiut and by the desert dwelling !Kung San, he recognized the endpoints of a continuum. Logistic mobility, or a collector system, occurs when resource patches are separated by areas too distant for daily travel. Here, large populations tend to settle in a large group near one resource and send out foraging parties for other resources. Group movements are over long distances and often in a new territory, potentially with different resources. Residential mobility, or a forager system, occurs when resource patches are less dispersed. Settlements are smaller and tend to be located between several resources.

Because it is often misinterpreted, it is important to stress two key points about the Binford's forager/collector model. First, this distinction was not designed to serve as a binary classification system, but instead as two points along a continuum (Binford, 1980; Kelly, 1995). Second, the forager/collector model discusses a large-scale division in subsistence strategy and should not be used as as a way to predict the characteristics of an individual group's mobility or subsistence strategy (Kelly, 1992; papers in Fitzhugh and Habu, 2002). Despite these caveats and the forager/collector model's development through ethnographic research in a restricted range of environments, most other hunter-gatherer groups fit within this model (Kelly, 1983).

In reality, settlement choices are rarely as perfectly rational as these models present (Gremillion, 2002). As with most human behavior, the vagaries of individual agency cannot be excluded (Mithen, 1989; Ingold, 1996). This has led to a series of criticisms and refinements of these models. Most saliently has been the acknowledgement that decision making in humans often incorporates more than strictly economic concerns (e.g. Belovsky, 1988; Mithen, 1989). Also, a group's social structure can can impact foraging decisions. For example, food-sharing among hunter-gatherer groups often buffers individuals from the need to always forage for the highest return resources (Hill et al., 1987). Finally, the importance of non-utilitarian factors in modeling hunter-gatherer settlement has been explored. Modern hunter-gatherers often maintain extensive social networks and the desire to meet with another group to trade information, arrange marriages or exchange goods remains an important component in mobility decisions (e.g. Whallon, 2006).

One key way that these issues can be addressed in an optimal foraging framework is through the principles of Human Behavioral Ecology. This field began in the 1970's as criticisms of economically deterministic models gained precedence (Winterhalder, 1977, 1986; Smith and Winterhalder, 1981). In essence, it uses evolutionary theory and concepts to address human behavioral diversity. Because this body of theory is not strictly economical, the importance of social and ritual adaptations are not excluded. These adaptations are, however, usually couched in terms of their evolutionary advantage. This has led some scholars to find Human Behavioral Ecology largely indistinguishable from other economic approaches that downplay human uniqueness (e.g. Ingold, 1996) or too theoretically diverse to function scientifically (e.g. Joseph, 2000; but see Winterhalder, 2002). Despite these criticisms, Human Behavioral Ecology remains a valuable theoretical and analytical with great applications to the archaeological record and studies of human evolution (Hawkes et al., 1997; Shea, 1998).

d. Relevant time periods

This project focuses on the Middle and Upper Paleolithic of Western Europe. These two time periods are commonly thought to hold important insight into what makes us "human." In European contexts the Middle Paleolithic is associated with indigenous Neanderthal populations and the Upper Paleolithic is most frequently associated with *Homo sapiens*. Thus, the contrast between these two time periods have historically been thought to provide an important difference between our species and one of our closest hominin relatives. The specifics of the taphonomy, environmental contexts, nature and chronology of these time periods make a direct "us" vs "the other" comparison problematic, but key differences between these two groups can provide insight into the fundamental characteristics of human adaptation. The following section presents these time periods in the context of the biological species and archaeological material relevant to this project.

Evolutionary Actors: Late Pleistocene Homo in Europe

During the Late, or Upper, Pleistocene (~126 – 12 ka) our species, Homo sapiens, cemented its position as the dominant hominin on the planet. By the end of the Pleistocene, all other hominin species, save one isolated example (Brown et al., 2004; Morwood et al., 2004), were extinct. However, throughout most of the Late Pleistocene, another major hominin species, the Neanderthals, was found throughout Eurasia. Evolutionary relationships between these two species have been debated for nearly 200 years, but a general consensus about the morphological and geographic range of each can be distilled.

Homo sapiens[2] have a distinct skeletal morphology not found in other hominin species. The most obvious of these features are found on the skull. These include a flat, non prognathous face, a high, rounded cranial vault and the presence of a bony mental eminence, or chin. In the postcrania, *Homo sapiens*, is mostly distinguished by a gracile build with long limb elements. Most of these features point to an initial adaptation for tropical environments.

Fossil evidence collaborates this, with the oldest definitively *Homo sapiens* fossils coming from the East African sites of Omo Kibbish (McDougall et al., 2005) and Herto (White et al., 2003) between 200 – 150 ka. From this origin until around 50 ka, *Homo sapiens* appears to be endemic to Africa, with only the Skhul and Qafzeh fossils found outside of Africa, but in the contiguous Levant region at around 80 ka. After approximately 50 ka, *Homo sapiens* rapidly spread throughout the Old World, eventually reaching the New World by the end of the Pleistocene. However, the specifics of this range expansion are less clear, even in the typically well-understood European record. It is believed that *Homo sapiens* were present in western Europe by around 40 ka, but there is little fossil evidence to support it. In fact, Peştera cu Oase, the only European site to yield *Homo sapiens* fossils predating 35 ka, comes from the territory's eastern margins and is not associated with archaeological material (Trinkaus et al., 2003). There is, thus, some debate about the earliest dates for *Homo sapiens*' colonization of western Europe (e.g. Karavanić, 1995; Karavanić and Smith, 1998; Straus, 2003), but the affinities of isolated teeth indicate a *Homo sapiens* presence in the 30 - 40 ka range (Bailey et al., 2009). Somewhat later, around 30 ka, there is more direct fossil evidence for *Homo sapiens* presence in Western Europe. These include fossils from the French site of Cro-Magnon and the British site of Kent's Cavern at around 30 ka (Klein, 2009).

The Neanderthals, or *Homo neanderthalensis*[3], are often presented as *Homo sapiens*' closest anatomical relative. Despite this, the two species have several important morphological differences. Cranially, Neanderthals are characterized by their projecting mid-face and large nasal aperture, low and long cranium with an occipital bun and lack of a mental eminence, or chin. The post-cranial of Neanderthals indicates that their body form was stocky and robust, with thick bones, a wide pelvis and shoulders and short distal limb segments. These are classically thought to indicate an adaptation for cold stressed environments, although they may also represent an adaptation to a highly active lifestyle (Trinkaus and Howells, 1979; Churchill, 2006). Neanderthal fossils are found mainly in colder areas, throughout Europe, but also in the warmer Levant region. Their range includes most of Europe and may extend throughout significant parts of Asia as well (Krause et al., 2007). Most current evidence points to the

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2: While many authors will use the term "modern humans" I am intentionally avoiding this designation and instead using the species name *(Homo sapiens)*. This is because there is morphological and cultural variability in these extinct human populations that exceeds that found within modern populations.

3: The elevation of Neanderthals to a separate species (*Homo neanderthalensis*) is not globally accepted. Here, biological differences are less important than behavioral difference between the two groups, so the more common species-level distinction is used.

Neanderthal species evolving from the indigenous *Homo heidelbergensis* in the cold Middle Pleistocene environments of Europe. While some Neanderthal traits can be seen in later *Homo heidelbergensis*, the earliest unambiguous Neanderthal fossils occur in the range of 150-200 ka. Most of the classic Neanderthal fossils, including La-Chapelle-aux-Saints, La Ferrassie and Le Moustier date from less than 100 ka. The youngest conclusive Neanderthal fossils date from older than 30 ka at sites in Croatia (Higham et al., 2006) and Spain (Hublin et al., 1995), although there is some evidence for Neanderthal survival until 24 ka at Gibraltar (Finlayson et al., 2006)

Evolutionary relationships between Neanderthals and *Homo sapiens* have been the subject of considerable debate. Most of this debate is centered on the role that *Homo sapiens* played in the extinction of the Neanderthals. Three main categories of models can be distilled: those that present no link between *Homo sapiens* and the extinction of the Neanderthals (d' Errico et al., 1998; Finlayson, 2009); those that present competition with *Homo sapiens*, whether direct or indirect, as the most important contributing factor in Neanderthal extinction (Shea, 2003, 2007); and those that present a process of Neanderthal biological or cultural assimilation with *Homo sapiens* as the crucial factor in their disappearance (Wolpoff et al., 2004). At present, there is no consensus view on either the genetic fate of Neanderthals or *Homo sapiens'* role in their disappearance

The MP/UP Archaeology of Western Europe

Irrespective of the model best explaining the biological relationships between Neanderthals and *Homo sapiens*, most authors do not deny that there is a fundamental behavioral difference between the Middle and Upper Paleolithic. What remains more contentious are the fate and intellectual capabilities of the Neanderthals.

Specifics of the taphonomy, environmental contexts, nature and chronology of these time periods make a direct "us" vs. "the other" comparison problematic, but by key differences between these two periods can provide insight into the fundamental characteristics of human adaptation.

Thus, a discussion of these two time periods in their Western European context is warranted. In the following section relevant information on the Middle and Upper Paleolithic is presented. The best known, (i.e. the recent facies of the UP) are presented first with a transition to the less well understood. For each techno-complex[4] information most germane to a discussion of Paleolithic settlement and subsistence is distilled from the available literature. A more complete discussion of the character of these time periods can be found in Klein (2009). For the majority of these techno-complexes, stone tools serve as the main chronological marker.

4: Techno-complex is used here in place of the older "culture" because these industries do not resemble modern anthropological cultures in terms of longevity and variability. In addition, techno-complex is used in a scale-independent manner. This term can refer to the Upper Paleolithic as a whole, or each of the subdivisions of the UP (Aurignacian, Gravettian, etc).

Although this project does not explicitly make use of lithic analysis, rough chronological classification comes from these data, so a brief presentation of key tool types is required.

The Middle Paleolithic

The Middle Paleolithic spanned from approximately 250 ka to 40 ka. In Western Europe, MP assemblages are associated only with the remains of Neanderthals. In comparison with the older Lower Paleolithic, the MP shows a denser occupation, increased tool standardization and complexity and permanent colonization of an increased range, including many parts of Western Europe.

The chronological range of the Middle Paleolithic spans Oxygen Isotope Stages (OIS) 3 – 8. This long span of the Late Pleistocene is characterized mainly by variable shifts from warm, interglacial periods, (like OIS 5e) and cold glacial periods (like OIS 4). During these different periods, the environment and landscape of Europe tended to shift from a mosaic of tundra and steppe in the cold periods and woodlands in the warmer periods (van Andel and Tzedakis, 1996). Although Neanderthals, the primary occupants of Europe during the MP, have been presented as adapted to cold weather, there appears to be a restricted extent of settlement during the colder phases of the Pleistocene (Hoffecker, 2005).

The Mousterian

In Western Europe, the chronological term "Middle Paleolithic" is broadly synonymous with the Mousterian techno-complex (named after the site of Le Moustier in Dordogne, France). Mousterian industries are found throughout the MP, dating from 250 to 40 ka. Geographically, archaeological material classified as Mousterian has been found throughout all of Europe, the Levant and into Asia and northern Africa. However, many important Mousterian sites are from southwestern France. These include the sites of Le Moustier (Peyrony, 1930), La Chapelle-aux-Saints (Boule, 1909) and La Ferrassie (Capitan and Peyrony, 1912, 1921).

Technologically, the Mousterian is mainly characterized by the presence of prepared core lithic reduction techniques. These techniques yield a predictable, large thin flake that can then be shaped or retouched into a desired form. The retouched tools in Mousterian lithic assemblages are most often sidescrapers (often referred to by the French as *racloir*). While the original typology for MP tools presents that the variability in these sidescraper forms was related to different uses (Bordes, 1961a), others have convincingly shown that they could be from resharpening over the life of the tool (e.g. Dibble, 1984).

The Mousterian comprises several named lithic industries. While this project does not focus on the specifics of stone tool production, these industries merit a brief discussion because significant work has focused on relating them to subsistence strategies and climatic characters. These industries include:

1. *Mousterian of Acheulean Tradition* (MTA; includes handaxes / backed knives)
2. *Quina Mousterian* (low proportions of Levallois, presence of steep retouch)
3. *Ferressie Mousterian* (similar to Quina, with higher proportions of Levallois)
4. *Denticulate Mousterian* (sidescrapers rare, denticulates common)
5. *Typical Mousterian* (variable proportions of scrapers).

Early explanations for MP lithic variability rested upon cultural differences (e.g. Bordes, 1961b; Bordes and Anderson, 1968) but other researchers preferred to explain the variation as the result of different tasks carried out by one cultural group (e.g. Binford and Binford, 1966; Binford, 1973). Other syntheses suggest that there is a consistent chronological sequence from Ferressie to Quina to MTA in many of the well excavated French caves (Mellars, 1969, 1986, 1996). The Denticulate and Typical Mousterian in contrast are found throughout time, indicating that these techno-complexes may have a functional component. Additionally, recent work has linked Typical Mousterian, Quina, and Ferressie assemblages, which tend to consist of more heavily retouched tools, to an intensive, partially nomadic, settlement pattern taking place during colder periods in more marginal environments (Rolland, 1977, 1981, 1988).

Regardless, most Mousterian assemblages preserve evidence for advanced behavior not seen as frequently in preceding hominin species. Most saliently, it appears that Mousterian populations did selectively hunt particular species and often chose prime-aged individuals (e.g. Stiner, 1992; Gaudzinski, 2000), although scavenging may have played a role in their subsistence as well (e.g. Stiner, 1994; but see Marean, 1998). It does, however, seem apparent that small game were less often or less intensely exploited (Stiner, 1993; Stiner et al., 2000). There is ample evidence for the use of fire (e.g. Bordes, 1972; Rigaud and Geneste, 1988; Goldberg et al., 2011), though the fires do not appear to be as structured as later examples (Mellars, 1996: 296). Hafting technology appears to have been developed, both from evidence for glue production (Boëda et al., 1996; Grünberg, 2002; Mazza et al., 2006) and from stone tool use-wear resembling impact damage (Shea, 1988).

Mousterian assemblages are, in Western Europe, universally associated with Neanderthals. There are several apparent intentional burials in from Middle Paleolithic contexts. These burials are found throughout Europe, but are, to date, only from within the caves and rockshelters that also serve as apparent living surfaces. Southwestern France has produced some of the best known Neanderthal burials with associated Mousterian material at the sites La Chapelle-aux-Saints (Boule, 1909; Bouyssonie et al., 1909), Le Moustier (Peyrony, 1930), La Ferrassie (Capitan and Peyrony, 1912, 1921; Peyrony, 1934; Heim, 1968). There is significant debate about the anthropogenic nature of these burials (Gargett, 1989, 1999), but the majority of paleoanthropologists accept that in some cases Neanderthals did bury their dead (Pettitt, 2002). The symbolic or functional implications of this are considered less clear. In particular, most reports of intentional grave goods (e.g. Bouyssonie et al., 1909; Movius, 1953) or symbolic activity during the burial (e.g. Solecki, 1971; Leroi-Gourhan, 1975) can also be explained by natural or taphonomic processes (Gargett, 1989, 1999; Dibble and Chase, 1990).

Through all of this we are left with a view of the Middle Paleolithic, and its Mousterian industries, as a stable, long term, low density occupation of variable environments. Questions of the technological and symbolic acumen of the Neanderthals remain unanswered, but it appears that this was a complex adaptation that allowed the exploitation of relatively harsh environments.

The Upper Paleolithic

The Upper Paleolithic (UP) dates from approximately 45 ka to the end of the Pleistocene at around 12 ka (Mellars, 2006). This period falls into OIS 4-2. These phases, particularly OIS 4 are typified by their rapid (1-2 ka) shifts between warm interglacial and cold glacial periods. This rapidly shifting environment is often interpreted as making Europe during this period a relatively difficult place to inhabit, but one that helped stress populations into developing innovative adaptive and social strategies (Gamble et al., 2004).

For most of its span, the UP is associated mainly with modern humans (*Homo sapiens*). Given a relative dearth of diagnostic remains(e.g. Conard et al., 2004) some debate about the hominins associated with the earliest Upper Paleolithic industries exists (e.g. Karavanić, 1995; Karavanić and Smith, 1998; Straus, 2003), though recent reanalysis of isolated dental remains (Bailey and Weaver, 2006) indicates that the traditional view of *Homo sapiens* as the primary UP species is the most likely.

In contrast with the MP, the Upper Paleolithic (UP) has far more variety in material culture over a substantially shorter time period. Sites tend to be more densely occupied cave and rock-shelter sites. These are found in a wide range of locations, including colder environments. The subsistence strategies of UP populations are usually reconstructed as more complex and intensive than their MP precursors. Evidence for systematic hunting of a single species exists for several UP sites throughout Europe (Movius, 1977). This is coupled with more intense exploration of both opportunistic prey species, like tortoises and fast, difficult to access species, like hares and birds (Stiner, 1993; Stiner et al., 1999, 2000).

Technological adaptations are equally varied, with strong evidence for pyrotechnology, ceramics, and an increased variety of tool forms (including bone and antler tools). Importantly, this period also contains some of the earliest evidence of artistic representation and perceived symbolic thought. Thus, the early UP industries have frequently been cited as among the first examples of fully modern behavior in western Europe (but see d' Errico et al., 1998; Mellars, 1999; Klein, 2003).

The UP of Western Europe is typically split into five main divisions; the Châtelperronian, Aurignacian, Gravettian, Solutrean, and Magdalenian. This project focuses primarily on the earlier UP industries. Thus, the Solutrean and Magdalenian will not be discussed further. Because the level of variability between the remaining three is relatively high, each will be discussed in some detail.

The Châtelperronian

The Châtelperronian (often called the Lower Perigordian or Castelperronian) gets its name from the Grotte des Fées in the commune of Châtelperron in central France. Dating of the Châtelperronian usually falls within the range of 38 – 32 ka, or roughly contemporaneous with the earlier Aurignacian (see Mellars, 1994 for a full list of dates). Châtelperronian sites are only found in western Europe (mostly central and southern France). However, many authors have stressed its similarities to other European industries on the transition between the Middle and Upper Paleolithic. These include the Uluzzien in Italy (Riel-Salvatore, 2009) and the Szeletian in central Europe (Allsworth-Jones, 1990).

The Châtelperronian is the only Upper Paleolithic industry believed to have been made primarily by Neanderthals. This attribution is based on the discovery of diagnostic Neanderthal skeletal remains associated with Châtelperronian artifacts (Leroi-Gourhan, 1958; Lévêque and Vandermeersch, 1980) and similarities between Mousterian (MTA) and Châtelperronian stone tools (Pelegrin, 1995; Soressi, 2005; Pelegrin and Soressi, 2007).

Technologically, this industry is characterized by the presence of Châtelperron points, backed blades, and blade industry. Châtelperronian sites have also yielded examples of presumed symbolic objects and personal adornments. These objects are either thought to represent acculturation during an overlap in Neanderthal and modern human occupation (i.e. a last effort by Neanderthal populations on the brink of being out-competed) or an independent genesis of symbolic and artistic representations by Neanderthals before the arrival of modern humans (d' Errico, Henshilwood, et al., 2003; Soressi, 2005).

Currently, there are no "exemplary" Châtelperronian sites because nearly all aspects of the character and chronology are contested. Few Châtelperronian sites were excavated using modern techniques. The majority are older excavations revisited and reanalyzed by contemporary researchers, with resulting uncertainties in stratigraphy and artifact provenience (e.g. Gravina et al., 2005; Zilhão et al., 2006; Mellars et al., 2007). Despite this, several Châtelperronian occupations do appear to be discrete artifact assemblages and not the result of geological admixture (e.g. Morin et al., 2005). However, the attribution of Neanderthal remains and / or personal adornments to Châtelperronian layers remains more contentious. The stratigraphic uncertainty of older sites and the relative paucity of personal adornments (primarily from Arcy-sur-Cure and Quinçay) and Neanderthal remains (primarily from Arcy-sur-Cure and Saint-Césaire) have led to significant debate on Châtelperronian as an example of Neanderthal symbolic behavior (e.g. Bordes, 1981; Vandermeersch, 1984; de Sonneville-Bordes, 1989; Hublin et al., 1996, 2006; White, 1998, 2001; David et al., 2001; d' Errico, Julien, et al., 2003).

The Aurignacian

The Aurignacian, dating from 38 – 28 ka, is named for the cave of Aurignac (Haute-Garonne, France) where the first attributed material was discovered. Archaeological material defined as Aurignacian is found throughout Europe and into the Middle East and Levant. The stone tool technology of the Aurignacian is characterized by large blades and carinated pieces (Straus, 2003; but see Zilhão, 2006). A second key technological component is manufacture of varied bone and antler tools, particularly the split base points (*pointe à base fendue*) that often serve as a *type-fossil* of the Aurignacian (Peyrony, 1936; Tartar, 2007). The Aurignacian is also well known for its rich record of personal adornments and artistic representations. When compared with the earlier Middle Paleolithic, these objects are thought to represent a huge transformation in the development of not only modern behavior, but also complex social systems (White, 1992; Vanhaeren and d' Errico, 2006). These "symbolic" representations include beads and pendants (White, 2001), small statuettes (Conard, 2003, 2009) and engraved and painted caves and rockshelters (Valladas et al., 2005; White et al., 2010).

The Aurignacian exhibits significant internal variability. This is somewhat unsurprising given that the majority of the period falls with in the Middle Pleniglacial, a period characterized by relatively rapid swings between cold and somewhat mild phases (Hoffecker, 2005). In Western Europe, the Aurignacian is usually divided into three chronological periods: the Proto-Aurignacian, the Early Aurignacian and the Late Aurignacian (Bon, 2006; Bordes, 2006), although other facies of the Aurignacian have been identified (de Sonneville-Bordes, 1960). In addition to their chronological ranges, there is also technological variability in these three periods. This seems to somewhat reflect adaptations to the changing climate of the Middle Pleniglacial, although the correlation is not perfect and a full explanation for Aurignacian variability remains elusive (Zilhão, 2006).

There are many important, and varied, Aurignacian sites throughout the regions of Europe. Much of the variability within the West European Aurignacian is also represented at sites throughout southwestern France. Some of the best-known Aurignacian sites in this regions are the type site of Aurignac, Abri Pataud (Movius, 1977), Abri Blanchard (Didon, 1911a; White, 2009) and Cro-Magnon (Henry-Gambier, 2002).

The Aurignacian is the earliest UP industry believed to have been manufactured exclusively by modern humans in Western Europe. However, fossils are notoriously rare in Aurignacian deposits. Furthermore, in recent years most burials were discovered to be intrusive from later time periods (Churchill and Smith, 2000; Conard et al., 2004). This leaves the makers of the Aurignacian debatable (Karavanić, 1995; Karavanić and Smith, 1998; Straus, 2003), but analysis of isolated teeth from Aurignacian deposits throughout Europe shows strong affinities with modern humans (Bailey et al., 2009).

The Gravettian

The youngest of these techno-complexes, the Gravettian (sometimes called the Upper Périgordian) dates to roughly 28-22 ka and is named for the site of Abri de la Gravette à Bayac in Dordogne, France. The Gravettian coincides with the descent into and initial recovery from a very cold phase of the Pleistocene, the Last Glacial Maximum. In many ways, it represents populations adapting to difficult quasi-glacial environments. Major technological characteristics of the Gravettian include diverse stone tool types including burins (e.g. Noailles and flat types), points (Gravette and Font Robert types) and truncated pieces. Bone and antler technology is similarly diverse (Otte, 1984). There is also direct evidence for the use of nets and other technologies in trapping smaller prey animals (e.g. Adovasio et al., 1996; Soffer et al., 2000).

Gravettian material is found throughout Europe, ranging from Western Europe to the Russian Plains. Similar industries are also found well into Siberia. The chronological extent of the Gravettian is affected by the LGM. Prior to 24 ka, sites are found throughout the plains Europe and Southern Siberia, but after 24 ka many of these areas were abandoned (Conard and Moreau, 2004; Hoffecker, 2005). The Gravettian techno-complex also shows both chronological and spatial variation in artistic representations (Clottes, 1996) and lithic technology. Specifically, in France, there are several well-understood facies of the Gravettian. These are usually distinguished based on statistical differences in tool frequencies and are well correlated with environmental changes (Bosselin, 2002). Southwestern France also preserves many excellent Gravettian sites. These include the type site of La Gravette (Delporte, 1972), Laugerie-Haut (Bordes, 1958b) and Abri Pataud (Movius, 1977).

Gravettian fossils are almost exclusively thought to be *Homo sapiens*. Burials are more common than in preceding epochs and often have elaborate grave goods. These can include children (e.g. Lagar Velho: Duarte et al., 1999; Zilhão and Trinkaus, 2002) multiple burials (e.g. Dolní Věstonice: Klíma, 1987; Formicola et al., 2001) and complex grave goods (e.g. Arene Candide: Pettitt et al., 2003).

e. Applicability of modern hunter-gatherer models to the Paleolithic

Most introductory anthropology classes stress that for over 99% of human history we were hunter-gatherers. There is, however, uncertainty about the specifics of this hunter-gatherer adaptation over time. Not all aspects of the modern hunter-gatherer lifestyle are directly applicable to ancient human groups. Nor can we even know that, beyond the general nature, there is any significant similarity between the two. In fact there may be fundamental differences.

In particular, ethnographically derived models serve to explain the annual or seasonal movements of a population. In contrast, an archaeological study needs to explain patterns across a much wider chronological range. This is particularly true for the Paleolithic, where a geological time scale is the most accurate representation of the record at hand. Even further, modern hunter-gatherers generally have low population densities, are relegated to marginal environments and often have many interactions with sedentary groups (Kelly, 1995) while Paleolithic hunter-gatherers did not face these restrictions. Recent studies show that these factors indicate that the behavioral variability present in modern hunter-gatherer groups probably only represent a small portion of the possible variation in this adaptation (Spielmann and Eder, 1994; Kuhn and Stiner, 2001).

Despite these issues, most researchers accept that modern hunter-gatherers represent the best possible analog for Paleolithic humans. However, using settlement data derived from ethnographic data without proper reflection is a pitfall into which all analyses of Paleolithic landscape can fall (Wobst, 1978). More specifically, there are several potential criticisms that must be addressed.

The primary complication is the nature of most ethnographic data on hunter-gatherer populations. Many studies are of groups living in environments very different from the late Pleistocene of Europe. Most often this problem arises from simply using patterns derived from rich tropical environments to explain variation in temperate climates . However, in the case of the Mammoth Steppe of glacial Europe there is no directly analogous modern environment (van Andel and Tzedakis, 1996; Guthrie, 2001). In either case, care must be taken not to import the specific patterns from ethnographic groups, but to instead focus on those patterns present in multiple groups from different environments (Kuhn and Stiner, 2001).

Additionally, in the case of the European MP, the population in question is from a different, although closely related, biological species than any ethnographic data. It has frequently been noted that aspects of the settlement patterns evidenced by Neanderthals do directly not match any specific hunter-gatherer population (Kuhn and Stiner, 2001). A theoretical basis in human behavioral ecology helps address these issues (Clark, 2009). This framework, with its basis in evolutionary theory, already has the toolset to discuss intra-species comparisons and address the “success” of an adaptation in unbiased terms (Winterhalder and Smith, 2000; Winterhalder, 2002).

Similarly, there is very little chronological control in Paleolithic data compared to ethnographic data. Even very good dates for late MP and early UP sites rarely have an uncertainty of less than a thousand years (Jöris, 2003; Jöris and Street, 2008). Thus, it is almost impossible to talk about contemporaneity or the order of occupations across a landscape. This can make the cause of any patterning in settlement somewhat ambiguous. What may appear to be one pattern may, in fact, be a palimpsest of the traces left by many different settlement strategies. Conversely, there is always the possibility of key components of a settlement pattern being removed by taphonomic effects on site preservation or discovery . However, these restrictions can be partially overcome. Lumping sites from the same techno-complex, while undoubtedly hiding some interesting variation, increases the sample size available to characterize particular groups. This in turn, leaves the sample less likely to be affected by individual, potentially aberrant, sites. More effectively, choosing an area with minimal taphonomic biases and a well-researched chronology, one can minimize most of these difficulties.

None of these issues can be fully removed from a study of Paleolithic settlement. There will always be real restrictions on the application of settlement patterns derived from ethnographic populations to ancient time periods. However, through judicious choices of theoretical framework and study area, many of these limitations can be minimized. The study area used in this project has several characteristics that make it ideal for such an analysis. The unique suitability of the dataset and study area will be discussed in Chapter 3.

f. Previous studies on Paleolithic settlement

Over the past several decades there have been many different studies of Paleolithic landscape use, settlement and mobility. These studies make use of a wise variety of data sources ranging from mammalian fauna to lithics to topography and GIS-based analyses (e.g. Kuhn, 1990; Kolen, 1999; Barton et al., 2002; Stiner and Kuhn, 2006). Instead of presenting the results of these individual studies, the following section will summarize a recent synthesis of large-scale settlement differences between the Middle and Upper Paleolithic (Finlayson, 2004). Any synthesis of an extensive literature will have particular studies that fit and those that do not. This particular model of MP and UP settlement and mobility is no exception. Thus, the summary of this model will be followed by a brief review of other analyses and their adherence to the presented model.

Neanderthal and **Homo sapiens** *mobility and settlement: A recent synthesis*

In a recent volume, Finlayson (2004) proposed that the core differences between Neanderthals and *Homo sapiens* were the result of different economic strategies for exploiting different niches. Middle Paleolithic Neanderthals were focused on heterogeneous environments, or optimal locations to extract resources from as many micro-environments (ecotones) as possible. Such locations would yield a diversity of plant and animal species. Specifically, this theory postulates that Middle Paleolithic Neanderthals most often occupied the margins between closed forest and open plain environments (Finlayson, 2004). An additional constraint on Neanderthal settlements was proximity to sources of fresh water. This would have the dual advantage of easy access to drinking water and opportunistic hunting of other animals as they drank (Finlayson, 2004). In contrast, Finlayson (2004) proposes modern humans were more often located in open, homogeneous environments. The successful utilization of these environments would require high mobility and specialized hunting techniques and technology.

Because modern humans were adapted to hunting the plains of Africa, Finlayson and others believe that these components were already in place before, and likely played a role in, the modern human colonization of Europe (Finlayson, 2004; Shea and Sisk, 2010).

More specifically, Finlayson uses these patterns to interpret broad settlement strategies for the Middle and Upper Paleolithic (2004). First, the MP and UP settlement fit broadly into the two extremes of Harpending & Davis' (1977) model of environmentally driven settlement dynamics. *Homo sapiens*, in Africa and Europe, were focused on hunting migratory herd animals, a patchy but dense resource. They would would selectively settle in large groups near rich locations. Neanderthals, with sparse but uniform resources (individual prey), would instead optimally settle in small groups across the landscape. Furthermore, the type of mobility, as proposed by Binford (1980), is used to explain how often and far groups move. Finlayson suggests that this model can be applied to the seasonality of occupations. He views the majority of Neanderthal populations as having high residential mobility, moving between settlements as the resources at one are depleted. In contrast, modern humans would have moved between sites seasonally in order to exploit resources not available year round (Finlayson, 2004).

In summation, this model of Neanderthal and modern human subsistence strategies indicates several key differences in Middle and Upper Paleolithic settlement (summarized in Table 2-2). Middle Paleolithic settlement is focused on heterogeneous environments where resources from a variety of ecotones can be accessed. Population size should be relatively low and movements should be frequent as local resources are exhausted. Upper Paleolithic settlement is instead focused on individual, sometimes seasonal resources in open environments. This subsistence strategy requires a higher number of individuals for hunting and foraging distant resources. Movements would be less common and likely related to seasonal resources in other environments.

Evidence for/against Finlayson's Synthetic Model

Finlayson's model addresses the core differences between Neanderthals and modern humans. By its very nature it is a simplification of the complex nature of adaptation and the archaeological record. However, the patterns outlined in this model are generally supported by archaeological data. Most saliently, Middle and Upper Paleolithic sites are often located in the types of environments outlined by Finlayson. For example, the Middle Paleolithic occupations of Northern France tend to be both near rivers and preferentially in environments reconstructed as wooded prairies and gallery forests These environments offer a wide variety of floral and faunal resources (Tuffreau, 1992). In Mediterranean Southern France MP sites are often located at the margins of different environments and with faunal evidence for a wide dietary breadth (Boyle, 1998). More divergent regions of Europe continue this pattern of MP sites near multiple environments. These include Iberia and Portugal (Finlayson and Giles Pacheco, 2000; Zilhão,

2001) the Russian Plain (Soffer, 1989a, 1994), Eastern Europe and the Levant (S. Binford, 1968; Shea, 1998).

Upper Paleolithic settlement, however, is often not tied directly to open plain environments, but instead to locations with a single rich resource. Along the Russian Plain and in Iberia, this resource does appear to be the large mammal herds on large open plains noted by Finlayson (Soffer, 1989b; Finlayson, 1999; Finlayson and Giles Pacheco, 2000), but elsewhere in Europe this is not the case. Reindeer specialization has often been proposed as a key component of the Western European Upper Paleolithic based on high densities of reindeer remains in many sites (Demars, 1996, 1998). These sites are not located in proximity to open plains, but often in caves and rockshelters in areas of high topographic relief. Additionally, a number of Upper Paleolithic sites in Southwestern France are located in narrow valleys and near natural shallows where seasonal migrating reindeer herds would potentially cross (White, 1985). The Aurignacian of Portuguese Estremadura (Thacker, 1996, 2001) indicates that in some cases larger settlement were tied to individual resources. In the Levant the several different Upper Paleolithic cultures (Ahmarian and Levantine Aurignacian) show a pattern of apparent resource tethering (Williams, 2000). This would seem to indicate that the core component of an overarching Upper Paleolithic niche is not open environments, but a focus on one resource while maintaining the ability to diversify.

Finlayson's (2004) interpretation of mobility in Middle and Upper Paleolithic peoples is also partially supported by the available data, but there is much more variability. Middle Paleolithic sites throughout Western Europe are usually interpreted as having a less dense occupation than their Upper Paleolithic counterparts (Mellars, 1982; Gamble, 1999). Also, throughout Europe and the Middle East, Middle Paleolithic sites tend to be found across the landscape and in a variety of environments (e.g. White, 1983; Mellars, 1996; Kandel, 2005). This supports the idea of smaller groups moving more frequently. The density and distance traveled of exotic lithic raw materials is also significantly greater in Upper Paleolithic assemblages throughout Europe (Féblot-Augustins, 1993). This indicates that the spatial scale of Upper Paleolithic societies was much greater, possibly resulting from higher mobility.

However, other studies indicate that the simplicity of this model does not sufficiently address the reality of the record. For instance, throughout most of Western Europe there are relatively few small open-air sites dating the early Upper Paleolithic (White, 1985; but see Thacker, 2001). A primarily logistic mobility model for the UP would suggest large core sites with smaller outlying sites as specialized groups travel to other resources. These sites would be less likely to discovered or excavated, but such low densities indicate that there may be a different pattern present. The seasonal occupations of sites is also partially supported by the data. When seasonality can be measured, MP occupations often show faunal remains from a variety seasons (Lieberman and Shea, 1994; Mellars, 1996; but see David and Farizy, 1994). Upper Paleolithic sites more often come from one specific season (e.g. Lieberman and Shea, 1994; White, 2008), but this is not invariably the case (Niven, 2003). Furthermore, these seasonal data can be used to interpret quite different patterns of mobility (e.g. Lieberman and Shea, 1994).

To conclude, determining a consensus view of Middle and Upper Paleolithic settlement is a difficult proposition. Much of the available evidence generally supports Finlayson's model, but there are several well-researched exceptions to these patterns. Local variation in environment and the character and spread of resources appear to drive the major exceptions. Given the economic underpinnings of most of these models, this should not be a surprise. Regardless, a global model, like that of Finlayson (2004) is a simplified version of the totality of variation. In this case, focusing on the median settlement pattern may in fact be an oversimplification a complex ecological adaptation.

g. Necessity of multiple scales of research

It is clear from the preceding discussion that there is wide variability in models of Middle and Upper Paleolithic settlement. These studies come from widely diverse geographical and climactic areas so this level of variation could be expected. Most of the preceding settlement models for the Paleolithic attempt to explain global or species-level variation; usually for the totality of the Middle and Upper Paleolithic or Neanderthals vs *Homo sapiens*. However, this may be overstepping the limited data set available for the reconstruction of Paleolithic settlement. In particular, in seeking to explain differences at this broad scale, these models ignore variability present in the Middle and Upper Paleolithic and in the techno-complexes of each.

Human, particularly hunter-gatherer, adaptations differ dramatically with regards to ecological and social factors (Kelly, 1995). Although, the accuracy of models based on ethnographic populations for Paleolithic hominins remains contentious, some variation should be present in the subsistence and settlement behavior of pre-modern species. Environmentally driven variation in subsistence strategy is present in many, if not most, non-hominin primate species. Multiple monkey and ape species show this variation across relativity slight environmental differences (e.g. Boinski, 1989; Kamilar, 2006; Kamilar et al., 2009). There is then no reason to expect a lack of this variation in species closely related to modern humans.

Furthermore, within chimpanzees and other great apes there are differing tool traditions, vocalization styles, and other behavioral variability that is usually attributed to culture (e.g. Whiten et al., 1999; van Schaik et al., 2003). If this level of behavioral variation is present in the the great apes, than it seems certain that there was as much, if not significantly more, variation in Paleolithic hominins. There is a wider behavioral variation among environments than among cultures, so factors related to subsistence in different habitats should play a larger role in shaping the behavior of Paleolithic peoples. However, this does not exclude cultural variation. During the extensive, climatically variable, time periods of the Paleolithic, it is possible that ephemeral cultural adaptations or those solely to local environment may be averaged out, leaving the important differences.

Thus, it is apparent that global or even regional models of Paleolithic settlement ignore real behavioral variation at the local scale. It is then obligatory that archaeologists who wish to understand the totality of settlement variation begin at the local level. Small-scale studies of Paleolithic settlement are difficult and with a few notable exceptions (e.g. White, 1985; Thacker, 1996; Miller and Barton, 2008) these studies are lacking in paleoanthropology. It is rare to have a sufficient density of known sites within a constrained region or sufficient chronological control. However, without a full knowledge of what factors influence settlement at this smaller, local, scale, we cannot hope to illustrate potential differences at the species or techno-complex level. Many of these differences are key to evolutionary arguments on the origin of our species and the replacement of the Neanderthals. This project is then designed to address some of the questions in a constrained, well-understood region in order to contribute to a future, larger model of Middle and Upper Paleolithic settlement.

h. Conclusions

This chapter has provided the necessary factual background for this project. Relevant information on settlement studies, hunter-gatherer populations and the Middle and Upper Paleolithic were provided. This was followed by a discussion of the possibilities and limitations of using models derived from modern populations to analyze Paleolithic settlement and of the necessity of performing these analyses on the small-scale before moving to large synthetic characterizations. The following chapter will present the dataset that is used to do this. Particular focus will be paid to the construction of testable hypotheses on Paleolithic settlement and the characteristics of the study area that make it ideal for such a study.

Figures and Tables: Chapter 2

Table 2-1: Key differences between simple and complex hunter-gatherers: After Kelley 1995: 294

	Simple	Complex
Environment	Unpredictable	Highly predictable
Diet	Terrestrial game	Marine or plant foods
Settlement size	Small	Large
Residential mobility	Medium to high	Low to none
Demography	Low density	High
Food storage	Little dependence	Medium to high dependence
Social organization	No corporate groups	Corporate descent groups
Political organization	Egalitarian	Hierarchical
Occupational specialization	Only for elders	Common
Territoriality	Boundary defense	Perimeter defense
Warfare	Rare	Common
Slavery	Absent	Frequent
Ethic of competition	Not tolerated	Encouraged
Resource ownership	Diffused	Controlled
Exchange	Generalized reciprocity	Wealth objects, competitive feasts

Table 2-2: Differences between Middle and Upper Paleolithic settlement and subsistence based on the model by Finlayson 2004

	Middle Paleolithic	Upper Paleolithic
Environment diversity	Heterogeneous	Homogeneous
Preferred environment	Plain / forest margins	Open plains
Resource focus	Broad	Narrow
Tethering resource	Water	Reindeer herds
Population density	Low	High
Mobility type	Residential	Logistical
Reason for movement	Variable	Seasonal resources

Chapter 3: Structure of Current Inquiry

a. Introduction

The preceding chapter discussed the broad-scale background and theories of human settlement strategies and the Paleolithic period of Western Europe. It concluded by arguing for first understanding local variation in Paleolithic settlement quantitatively before constructing models of the differences between techno-complexes or species. This chapter presents the specifics of this approach: the dataset, the broad-scale theoretical approach, and data that can be used to address hypotheses about Paleolithic settlement. First, the study area of the Vézère Valley of southwestern France is presented. This section highlights the qualifications of this region in terms of physical landscape, density of Paleolithic material and history of research. This is followed by a presentation of previous landscape analyses in the region. Next, the broad-scale research questions of this project are presented and refined into more specific questions on the differences between techno-complexes. Aspects of previous global and local-scale landscape-level studies that can contribute to these research questions are then discussed. This results in a list of specific testable aspects of local-scale Paleolithic settlement and the data sources that can be used to address them. The measurement and analysis of these data will then be discussed in the following chapter.

b. Study area

Physical description

The study area of this project is within the Périgord region of southwest France (conforming roughly to the department of Dordogne). Four major rivers flow from the Massif Central through the Périgord: the Dordogne, the Dronne, the Isle and the Vézère (Figure 3-1). The paths of these rivers are controlled mainly by a series of NE-SW running anticlines. More specifically, the study area for this project falls mostly within the Vézère River valley. The Vézère runs in a northeast-southwest direction for approximately 200 km mainly through the Black Périgord region. This region is characterized by abrupt gorges, dense plateau forests and high topographic relief (Laville et al., 1980).

Geologically, the major features of the Périgord region formed in the Tertiary. The bedrock is mostly Jurassic limestone, which, although massively bedded, does contain strata that are more susceptible to dissolution. Tectonically, the region is stable, with no known major tectonic events since the beginning of the Pleistocene (Laville et al., 1980). However, the landscape has undergone some more recent changes through the erosional impact of water on the limestone bedrock. Erosion from the river and the natural borders of the anticline controlling its path have created high limestone cliffs along the river banks. In addition, ancient above-ground drainage paths and the collapse of underground hollows have created to a series of dry valleys (known locally as *vallons* or *combes)*. These dry valleys often feed into to the main river valley, though tertiary and isolated valleys are also found in the study area. These dry valleys often have steep cliffs with a relatively uniformly sloped bottom. The upland plateaus that these features cut into tend to be less uniform, with rolling hills and small depressions.

The region has a high density of caves and rockshelters due to the high density of limestone cliffs and the differential dissolution of certain horizontal strata in the limestone bedrock. These caves and shelters are found throughout the region in both the main and dry valleys. Caves vary greatly, from small, short and barely accessible, to extensive cave systems spanning several miles and containing large chambers. More systematic are the presence of rockshelters, or *abris*, which can span the entirety of cliff face with a depth of several meters. On the modern landscape, most of these abris are found at ground level, though shallowly buried or collapsed examples are also relatively common. In some vallons, multiple levels of shelters are found, sometimes with one layer deeply buried or several meters up the cliff face. This indicates that there may be multiple layers of the limestone bedrock susceptible to Abri formation.

Environment

Given the topographic relief and landscape variability, environmental characteristics also vary across the Périgord. Often, the character of local vegetation is strongly controlled by the chemical and nutrient composition of the underlying soils. In this region, soils are formed mainly by bedrock weathering. This bedrock is not of uniform composition across the study area, giving the soils a corresponding spatial variability. In particular, the anticline forming the north and south banks of the river leads to differences in soil and vegetation composition. Even within a single depositional environment the chemical composition of the region's soils can vary based on inclusions in the bedrock. Topography also plays a strong role; different instances of weathering and erosion can lead to different soils, and environments, at the base and summit of the same slope.

One of the most important and predictable components of environmental variation is the degree of solar radiation, essentially how the time and intensity of sunlight throughout the year. Here, solar radiation is largely a product of orientation and location within the river and dry valleys. South-facing slopes are exposed to more sunlight and thus retain heat which causes more evaporation and a higher local humidity. North-facing slopes, however, are sheltered and tend to be colder throughout the year. Although, there is some variation, these differences in solar radiation, combined with variable elevations, can be used to divide the region into three main vegetation zones each with a unique modern flora: flat plateau and valley floor areas, south-facing slopes, and north-facing slopes (Comps quoted in White, 1985).

History of research

The Vézère Valley, and the whole Périgord region, are among the earliest and most intensely investigated Paleolithic occupation areas in the world. This is because of both the density of well-preserved sheltered sites and their location in a country with a long tradition of archaeological exploration. Because of this extensive history, many key transformations in our understanding of the European Paleolithic have their origins, or are reflected, in the record of the Vézère Valley. Excavations and collections began in the region as early as the start of the 19th century. But it was not until the discovery of human fossils in association with extinct animals and stone tools at the Abri de Cro-Magnon in 1868 that the Périgord was brought to international attention. With the interest following this contentious discovery, the sites of the Périgord became the basis for many of the initial classifications of Paleolithic variability, including the initial division of the Paleolithic into different chronological epochs (Lartet and Christy, 1875). The primary goal of excavations during these early stages of Paleolithic archaeology was establishing a broad cultural history. Thus, their techniques and results frequently look slipshod to modern eyes. With little provenience information, these data are rarely used to address the more refined questions of modern research (White, 1985).

The next stage of inquiry in the region began with the publication of Breuil's (1913) comprehensive local chronology. As with much early archaeology, this chronology followed geological techniques. It was unilinear and used specific artifacts as type fossils to directly indicate the time and culture represented. The primary goals of later excavations in this stage remained cultural-historical, with most researchers working to refine Breuil's chronology and fit all Paleolithic variability into a unilinear scheme. During this period many researchers were extremely prolific in excavating and publishing sites (e.g. Peyrony, 1930, 1934). Of particular note is Denis Peyrony, who oversaw the excavations of a staggering number of sites in the region. Peyrony was also among the first to recognize the potential for contemporaneous occupations with different archaeological signatures (1933a). Because the details of chronology were the most contentious subjects during this period, some of these excavations conducted well, with sub-meter proveniences and sieving used at certain sites. However, the selective nature of many collections (only museum quality tools made of certain raw materials were kept) and the trend of splitting excavation material among several museums, limit the interpretive value of most excavations (White, 2008; Dibble et al., 2009).

This index fossil approach, with the presence of a particular artifact as the only chronological control, did not account for variability within a techno-complex and made it difficult to compare different sites. In the middle of the 20th century, methodological approaches were developed to address broader questions. The most important of these were the influential typologies generated for the Middle Paleolithic by Bordes (Bordes, 1961a) and for the Upper Paleolithic by de Sonneville-Bordes and Perrot (1953, 1954, 1955, 1956). This work produced a systematic method for describing and analyzing variation within and between assemblages. Within this framework, even older biased collections can yield some rough chronological and cultural data.

In recent years, archaeological investigations in the Périgord continue to stand at the methodological forefront of Paleolithic archaeology. These new investigations are usually multi-disciplinary and collaborative, often involving both North American and European scholars and excavators. Examples include the projects at Roc de Marsal (Goldberg et al., 2011; Sandgathe et al., 2011), Pech de l'Azé (McPherron et al., 2001), Abri Pataud (Movius, 1977), Solvieux (Sackett, 1999), and Abri Castanet (White, 2008; Sisk, 2010; White et al., 2010).

Suitability for landscape approaches

To apply a landscape approach to the Paleolithic one needs a large number of sites and correspondingly dense environmental data. At present there are relatively few areas in the world that fit these requirements. The Vézère Valley, with its long history of research, is one such place. There are over 150 known or purported Paleolithic sites within the study area of this project alone[5]. However, many of these sites were excavated in the early days of archaeological inquiry, and thus without the strict controls used in modern archaeological investigations. Nevertheless, rough information on the locations and techno-complexes present at these early sites are known, making them potentially useful for landscape studies.

It is not, however, just the presence of archaeological sites that makes the Vézère an excellent location for settlement or landscape analysis of the Paleolithic. The area's high topographic relief, with distinct valleys, plateaus and river margins, leads to considerable landscape and environmental differentiation across a relatively small area. This in turn allows investigators to tie more varied environmental characters into models of settlement choice.

Despite these advantages, there are potential biases in the record of settlement in the Vézère Valley. Most importantly, the ratio of cave and rockshelter sites to open-air sites is likely artificially inflated. Sheltered sites often have a complex sequence of multiple techno-complexes and were thus the focus of most early cultural-historical excavations. These sites also preserve perishable material (e.g. bone, antler, ivory) better than open-air sites. For these reasons, sheltered sites continue to be the focus of most large-scale inquiry. Despite this, there is a high density of smaller open-air sites in the region. Although few have been excavated, and even fewer published, location and technological data for many of these sites can be obtained through governmental records of salvage excavations and consultation with local amateur archaeologists.

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[5] This estimate comes from the archaeological map of the service régional de l'archéologie for the Department of Dordogne. It includes sites of all Paleolithic time periods and many that are reported as potentially Paleolithic. It should not be taken as an absolute measure of site density.

Finally, with recent declines in farming in the Périgord, many formerly plowed agricultural fields along the plateaus are returning to their dense native forest. Plowed fields, unlike forest cover, make archaeological materials easy to locate. When agricultural land returns to forest it becomes more difficult to find new plow-zone occurrences and to locate older sites (Barton et al., 2002). Most of these plow-zone locales contain open-air sites. Thus, they provide very important data to complement the well-researched rockshelter and cave assemblages of the region.

c. Previous settlement analysis in the Périgord

Given all of these advantageous characteristics, it is not surprising that the Périgord region has been the focus of several earlier landscape and settlement studies. Although not all of these studies focus on the exact study area (the Vézère River Valley) used in this project, they do come from similar environments in the same region. Thus, their conclusions are particularly relevant to the creation of models in this project and can be used to determine locally important landscape characters. These previous studies have focused on the river valleys of the Dronne (Geneste, 1985; Duchadeau-Kervazo, 1986, 1989), the Dordogne (Turq, 1989, 1992), and the Vézère (White, 1980, 1983, 1985). A summary of these data follows, with specific observations from these studies listed in Table 3-1.

These earlier landscape analyses highlight several important issues concerning the location/orientation of Paleolithic sites that are particularly relevant for this research project. These studies (Mellars, 1996) often draw attention to the preponderance of cave and rockshelter occupations over open-air sites during all time periods. These shelters are thought to provide protection from the elements, proximity to water sources and to be a natural conduit for prey species. While these advantages may have made rockshelters a strongly preferred settlement locations, it is equally possible that these dense, well preserved, sites are more likely to be discovered, excavated and published. In addition, these studies report that most sites of all periods are oriented in a roughly southern or southwestern direction. This would seem to indicate a choice based on maximizing exposure to warmth from solar radiation (White, 1985; Duchadeau-Kervazo, 1986).

The proximity of Middle Paleolithic sites to sources of lithic raw material is another feature of Paleolithic settlement that is often highlighted in earlier studies (e.g. Geneste, 1985; Turq, 1989; Mellars, 1996) . The majority of sites are found less than 2-4 km away from a flint outcrop. The apparent importance of the availability of stone tool resources is usually presented as the driving force controlling MP settlement.

Interestingly, although it is a significant feature on the landscape, the river itself does not appear to be an important component of Middle Paleolithic settlement. Cave and rockshelter sites are more commonly found at moderate elevation in tributary valleys and are less often located in the main or secondary valleys (Mellars, 1996). Middle Paleolithic sites tend to be well protected from the elements, located above the flood plain and to provide access to open plateau areas. Additionally, many authors have observed higher densities of open air sites in the plateau areas between the main valleys (e.g. Turq, 1989; Mellars, 1996). Even these open air sites are observed to have a slight southern orientation and to be frequently located in a depression which would provide some protection from wind and weather (White, 1983). All of these patterns are usually distilled into a view of Middle Paleolithic settlement being controlled by a need for protection from a harsh environment and with easy access to lithic raw materials.

Upper Paleolithic, and in particular early UP, settlement exhibits a somewhat different pattern. There does not appear to be a strong correlation between site locations and sources of lithic raw materials. Open-air sites are rarer, though this may be related to difficulty in recognizing UP sites from small assemblages (Duchadeau-Kervazo, 1986). Sites are most frequently found in main or secondary river valleys and are most often positioned at relatively low elevations (i.e. below the flood plain) and are typically less than a kilometer from the river. This is thought to represent the increased importance of the rivers themselves in Upper Paleolithic settlement as compared to that of the Middle Paleolithic. One of the most striking patterns is a strong correlation between sites and the location of natural shallows, or fords, in the river. Open-air sites, either in the river valleys or on the plateau, are rare for the early UP. In general, these observations indicate a pattern that is strongly focused on the river, with natural fords potentially playing a role in the groups' subsistence adaptations (White, 1985).

d. Structure of current inquiry

This project was designed to study several of aspects of settlement during the Middle and early Upper Paleolithic periods in the Vézère Valley. Testable hypotheses about settlement patterning during these two periods come both from previous work in the region and from global models of these time periods. The primary data used here are site location and a rough chronological classification of the culture(s) present. Though these are relatively simple measures, limiting the data in this way has two main advantages. First, it allows one to test observations and models put forth by other authors in a systematic and repeatable way. By limiting the interpretation of excavation data it removes much of the difficulty of comparing results from different teams. Second, it maximizes the available data by allowing the inclusion of old, poorly excavated and unexcavated sites. In particular, this project aims to test, from these site location data, both aspects of the large-scale models discussed in the previous chapter (Table 2-2) and the observations on the Paleolithic settlement of the region discussed above. Above all else, the structure of this inquiry is designed to be both deductive and repeatable. Thus, the following section systematically steps through the guiding research questions of this project in descending scale. Then a discussion of the data that were used to address these questions is distilled from the global models and local observations of Paleolithic settlement. Finally, a list of specific testable factors, and what questions and models they are relevant to, is presented.

Guiding research questions:

At its most simple, the guiding research question for this dissertation is:

> **Is there patterned variability in site location for the Paleolithic of the Vézère Valley?**

While this broad question is clearly testable, it tells us very little about the importance of any variation that may be uncovered. Indeed, no animal or plant species is totally randomly distributed across the landscape; there are always areas with more favorable resources, which will have an impact on the distribution of a population. Thus, even if taphonomy and site visibility were not issues, one can assume that the answer to this question would always be "yes." It then becomes important to refine this question for the specific issues addressed by this project, namely:

> *Accounting for taphonomy and preservation, are there significant differences in site location between the Middle and Upper Paleolithic in the Vézère Valley?*

In order to fully address the character of any variability, a series of more refined questions will be addressed. These include:

1. Do any differences between the Middle and Upper Paleolithic reflect characteristics of the global or species-level models (as discussed in Chapter 3)?
2. Are there significant differences in settlement among the techno-complexes of the Upper Paleolithic (Châtelperronian, Aurignacian, Gravettian) in the Vézère Valley?
3. When Middle Paleolithic data are of sufficient resolution to determine techno-complexes, are there significant differences among them?
4. Does the Châtelperronian more resemble the early UP (Aurignacian / Gravettian) or the MP?

All of these guiding questions remain testable, although there is no single data source that can answer any one of them. In order to fully address these questions, a list of contributing data sources must be developed for each. With these data in hand, actual hypotheses and predictions for each data sources can be formulated and evaluated. Following this, each techno-complex must be characterized from the collected landscape data. Then any differences between techno-complexes in relevant landscape characters can be tested against hypotheses concerning key settlement variables.

Predictions and factors from global models

Chapter 2 distilled a series of observations on Middle and Upper Paleolithic settlement from the global or species-level settlement models. The factors of particular relevance to this project are included in Table 3-2. To summarize, the majority of these global models postulate that Middle Paleolithic hominins settled in small groups with high residential mobility. Their settlement system appears focused on heterogeneous environments, where a variety of resources can be obtained within the site catchment. This may have aided encounter or ambush hunting of large game. Although their settlements were often near water, they do not appear to have practiced systematic fishing.

Upper Paleolithic settlement, in contrast, appears further along the spectrum to logistical mobility, with a strong focus on specific resources in homogeneous environments (frequently the open plains of wester Europe). This focus, and the technological adaptations that allow it, meant UP groups practiced a different hunting strategy than encounter or pursuit hunting of individual large game. There is also ample evidence for foraging of smaller, but more technologically complex game like fish and birds.

Testable observations used in this project.

By combining these aspects of the global models with the observations from previous studies in the region, one can formulate a series of testable hypotheses on the nature and differences in Paleolithic settlement strategies. These hypotheses, and the types of data that can help address them, are outlined in Table 3-2. All data and calculations were collected for each time period, even when there was no direct hypothesis of its importance (i.e. a tie between fords and MP sites is not expected). Table 3-3 presents each of these characters of settlement independent of time period or techno-complex and outlines the specific measurements that were used to address them. In addition to the data relevant to these hypotheses, a general landscape characterization for the MP, UP and each of their techno-complexes was created. This isolated other important factors influencing settlement and allows a quantitative analysis of the differences among them.

Given the nature of archaeological data, equifinality is a common problem in investigations of the ancient past, and this project is no exception. In some cases, the same type of data can be applied to different settlement hypotheses, or one important factor could erroneously cause a correlation with another. For example, in the UP, close proximity to the river could also cause good views of natural fords, even if this was not an important component of the settlement strategy. Whenever possible, these cases will be marked and when the resulting analyses are discussed, any issues will be addressed. A detailed discussion of each of the nature, calculation and analysis of these data sources follows in Chapter 4.

e. Discussion of assumptions

As demonstrated above, the Vézère region is very well suited for landscape-level analyses of Paleolithic sites. However, all quantitative projects focusing on ancient archaeological data must have a sample of sites that is both sufficiently dense and representative of the true variability. This project uses modern landscape characteristics to interpret the landscape of the Paleolithic. Thus, representative variability in these landscape characters is also required. Before progressing to a discussion of the specific methodology, two key underlying assumptions must be made clear. These assumptions are:

1. Taphonomic biases are minimal
2. Modern topography is an acceptable proxy for Paleolithic topography

The first basically states that there has been no systematic taphonomic bias towards the preservation of one period or the destruction of another. As this project uses the minimal data possible from each site (location and a rough chronological classification) most taphonomic biases will be minimized. For example, neither the size and quality of preservation nor the quality of excavation will exclude sites from consideration. Only completely eradicated, deeply buried or undiscovered sites will be missing from the dataset used in this project. This should, for this study area, yield a sufficiently dense and representative sample.

Slightly more troublesome is possibility of directed bias; conditions that leave sites from one techno-complex more susceptible to eradication or prevent discovery than others. In essence, the data for this project only demonstrate presence. Thus, an absence of evidence can never be taken as evidence of absence. No archaeological project can fully overcome this assumption, but there are analytical techniques designed to minimize its effects. A characterization of the physical environment (e.g. soil, vegetation) of each techno-complex can indicate a systematic bias. Also, statistical methods (Maximum Entropy) designed to work with presence-only spatial data will be employed. These techniques are fully discussed in the following chapter.

The second assumption, of rough topographical conformity, while related to the first, is partially overcome by the tectonic stability of the region since the Last Glacial Maximum (Laville et al., 1980). However, erosion undeniably plays a role in site preservation. Again, using minimal data should mitigate its effects. However, as is reported in a high resolution case study in Chapter 6, this assumption may be more troublesome as the effects of infill and plateau erosion on the topography of the region are not yet fully understood.

f. Conclusions

This chapter has focused on the specifics of this project's approach to analyzing Paleolithic settlement on a local scale. The Vézère Valley is of particular suitability for such an approach because of its varied landscape, density of Paleolithic sites and well understood culture history. Previous settlement analyses in this and similar regions give this project an excellent starting point. In analyzing potential settlement differences between the Middle and Upper Paleolithic and among their techno-complexes, aspects of the global-scale models discussed in Chapter 2 are combined with the results of these previous regional studies. A series of questions and hypotheses is then distilled and the data of particular relevance presented. The specific analytical methods for each of these data will be discussed in terms of the hypotheses they can help address in the following chapter.

Figures and Tables: Chapter 3

Table 3-1: Characters of Middle and Upper Paleolithic spatial patterning isolated by previous studies in the Dordogne.

Observation	Source
Middle Paleolithic	
Site location is controlled largely by proximity to lithic raw material sources	Geneste 1989 Turq 1989: 194-6 Mellars 1996: 247, 258
Cave and rockshelter sites are most often located in minor tributary valleys (vallons or dry valleys) and not in the main river valleys	Mellars 1996: 248-9
Cave and rockshelter sites are more frequently located at moderate elevations; above the flood plain, but close to the valley floor	Mellars 1996: 250
Cave and rockshelter sites are almost always located on the south or southwest facing side of valleys to maximize exposure to sunlight	Duchadeau-Kervazo 1986
Open air sites are found across the landscape, but most densely on plateaus between valleys	Turq 1989: 194-6 Mellars 1996: 254-5
High-elevation open air sites are usually located in a depression protecting them from the elements	White 1983: 115
Upper Paleolithic	
The majority of sites are located in caves and rockshelters near the main and tributary river valleys and often in dry valleys	White 1985: 90-3
Nearly all sites are located within 1000 m of a river	White 1985: 90
Caves and shelters tend to be located at low elevations relative to the valley floor. The Châtelperronian may be an exception	White 1985:103-8
Cave and rockshelter sites are almost always located on the south or southwest facing side of valleys to maximize exposure to sunlight	White 1985: 110-18
Sites are often situated near a natural, geologic, ford in the river	White 1985: 118-31

Table 3-2: Testable hypotheses and observations of Middle and Upper Paleolithic settlement and data sources that can contribute to them.

Middle Paleolithic	
Observation / Hypothesis	**Contributing data sources**
Heterogeneous environments	Site location near eco-clines Access to valley and plateau
Residential mobility	Smaller occupations More dispersed occupations
Protection in cold climate	Sites oriented towards the south Open-air sites in a depression
Important resources	Lithic raw materials Water
Encounter hunting of isolated fauna	Sites oriented with view of open plateau areas or good views of water sources
Upper Paleolithic	
Homogeneous environments	No correlation between sites and eco-clines
Logistic mobility	Large occupations Some satellite camps
Protection in cold climate	Sites oriented towards the south
River focus	Sites near river Sites at low elevation relative to valley floor Sites oriented with good view of the river
Systematic hunting of single species	Sites with view of areas where herds at disadvantage
Valleys and natural fords in river	Sites near natural fords in the river

Table 3-3: Settlement characters applicable to hypotheses about Paleolithic settlement with data that can contribute and specific measurements. The final measurements are included in Appendix A.

Settlement Character	Contributing data	Specific Measurements
Environmental diversity	1. Site location relative to eco-clines 2. Access to valley and plateau	Elevation Topographic classification Modern vegetation classification Satellite imagery
Important resources	1. Proximity to lithic raw materials (MP) 2. Proximity to Water (MP) 3. Proximity to River (UP) 4. View of river (UP)	Straight-line distance to resource Cost-weighted distance to resource Elevation Viewsheds
Mobility Strategy	1. Size of occupations 2. Dispersed / concentrated occupations	Size not feasible with these data Density of sites in region
Protection	1. Sites oriented towards the south 2. Open air sites in a depression	Site Aspect Site Slope
Subsistence Strategies	1. View from each site 2. Proximity to fords / concentrated points 3. Good views of water sources	Total viewshed Viewshed of particular area Straight-line distance to resource Cost-weighted distance to resource

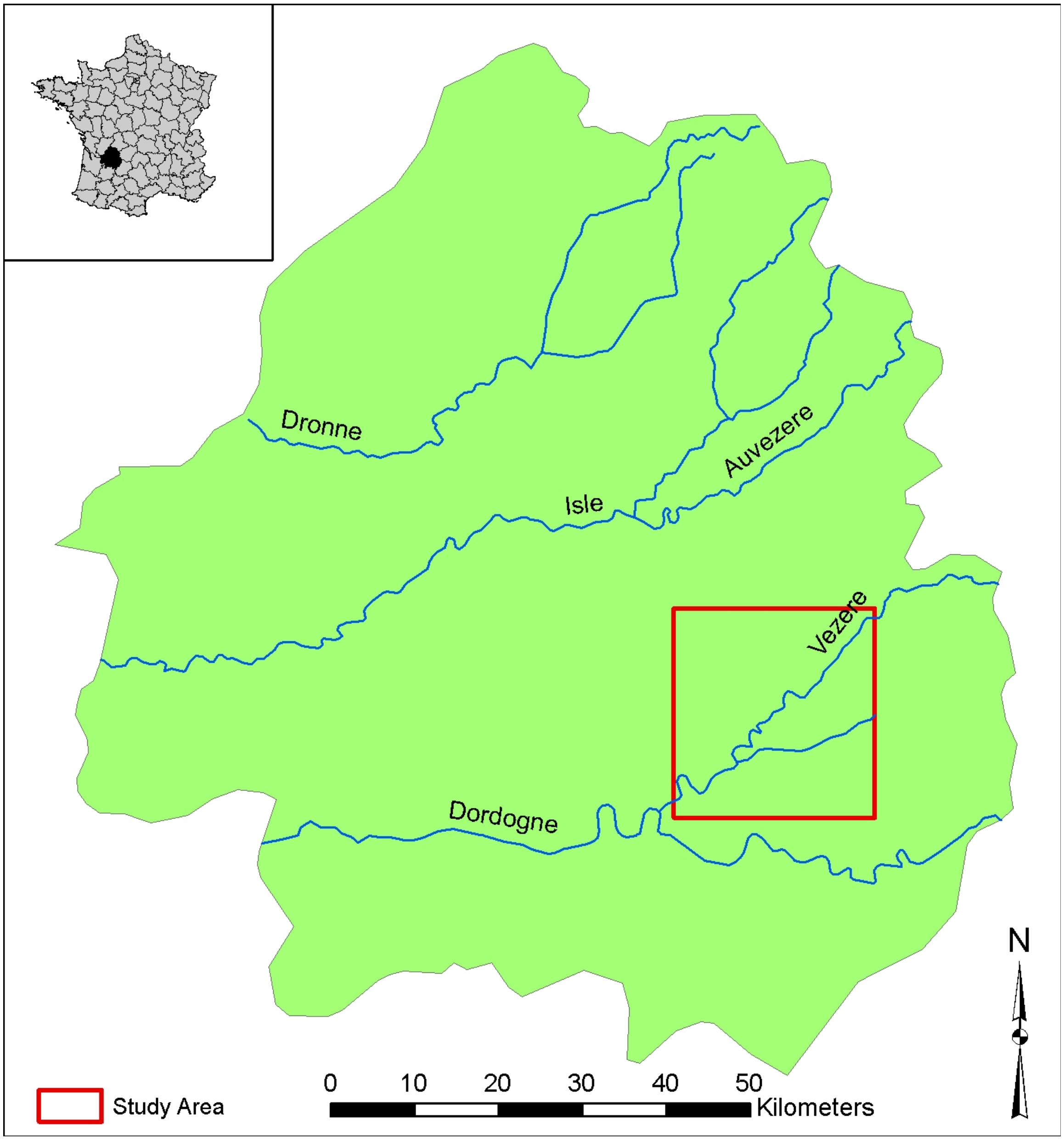

Figure 3-1: The major rivers of the Department of Dordogne

Chapter 4: Methodology

a. Introduction

Landscape projects, especially modern GIS-based ones, use data from a wide variety of sources. This project is no exception, using a combination of personally collected data, published accounts and maps, and satellite imagery. In particular, the locations of archaeological sites representing known techno-complexes are correlated with landscape characters hypothesized to be important to models of settlement during different Paleolithic epochs. In this approach, the primary data are simple site location and a rough chronological classification of the culture(s) present. This chapter outlines the analytical methods used in this project. Because the data and methods both build upon each other and are relevant to particular questions or hypotheses, this chapter can be divided into four main sections.

First is a discussion of the raw data used to locate and classify sites. This includes the varied sources of site locations (literature, survey and consultation) and the protocol used in entering sites into the database. A discussion of potential errors in site locations, and ways they can be addressed, is also included.

Second are the methods used to calculate landscape characters from the GIS database. The methods used in calculating and analyzing each character are presented in the context of relevant hypothesis and predictions outlined in the preceding chapter (Table 3-3). In many cases, the methodology is complex and frequently requires a detailed explanation of the algorithms and code used. Thus, in the interest of clarity, cursory explanations of the approach are provided in the text and detailed overviews, with relevant computer code, are provided in Appendix B and referenced in the text.

Third, the methods needed to assess any systematic bias in the sample are presented. These are of particular relevance for the assumption of no systematic taphonomic bias. While these methods cannot disentangle whether trends are the result of bias or different settlement strategies, they do provide a quantifiable record of where sites from each techno-complex are more likely to be found.

Fourth, and finally, the statistical methods used in the large-scale analyses are outlined. These include the methods for analyzing correlations between techno-complexes and landscape characters.

b. Data sources

In contrast to many other landscape-level analyses of Paleolithic data (e.g. Williams, 2000; Miller and Barton, 2008), this project uses very little excavation data. For each site, little beyond location and a rough typological classification is included in analysis. This typological classification, or techno-complex, then yields, at minimum, a relative date for the assemblage. Such an approach is only possible because the chronological control of typological markers is well understood for Western Europe, and the Vézère Valley in particular. Even if the typology, and thus the chronology of techno-complexes, is revised, this approach still yields important data on the broad chronological periods of the Middle and early Upper Paleolithic. Using minimal data, of course, reduces the resolution of any inferences, but it also yields significant advantages over more detailed analyses. Mainly, it allows the inclusion of the maximal number of sites, including known, but unexcavated, sites. For a region with some bias towards the excavation of deeply stratified rockshelter and cave sites, this provides an important record of open-air sites. Additionally, the quality of excavation is largely unimportant with this approach so data from older (late 19th and early 20th) projects can be included.

Site location data sources

The primary sources of site locations used in this project were published surveys or gazetteers of Paleolithic sites in the region (e.g. Reverdit, 1878; Peyrony, 1949; de Sonneville-Bordes, 1960; Laville et al., 1980; White, 1985). These sources usually contain a rough location of the site, the observed techno-complexes and references to more detailed analyses. In the case of sites excavated after these reviews, locations were garnered from site reports and publications.

Site locations from the archaeological maps of the *Service Régional de l'Archéologie* (SRA) for the Aquitaine region (housed in Bordeaux) were also incorporated into the database. The sites indexed on these maps largely mirrored the published records of sites. However, important data on salvage and contract excavations were also included (Appendix *B-i*).

Additional site locations were obtained through field survey. Most importantly, a series of unpublished maps showing areas of systematic surface collection and testing graciously provided by R. White yielded valuable information on Mousterian open-air assemblages. Additionally, in two areas (near the sites of le Puy Mangou and La Porte) the author conducted small-scale pedestrian field survey in agricultural fields. While these areas only cover a small portion of the total study area, the statistical method discussed below allows a partial correction for this bias.

A final source of site locations was consultation with local amateur archaeologists, who are familiar with sites that have neither been published nor systematically studied. This included only those individuals who both record artifact provenances and collect in disturbed plowzone localities (contacted through R. White and other sources). Work with these individuals generally encompassed surveys of the sites, brief analysis and photography of any collections and consultation about characterization of material not collected.

Site visits

These site locations came from several sources with variable levels of precision, coordinate systems and age. In combining these data, problems of different sites listed under the same name, and the same site listed under junior synonyms, were relatively common. Accurate three-dimensional measures of site location and the general character of associated material are vital for this project. Therefore, as many sites as possible were visited. The aim of these visits was to verify coordinates listed in the SRA maps (the most accurate of the data sources) and to confirm elements of local environment generated from other sources (see below). Site visits often took place in the company of individuals who were well informed about the site's history and this process frequently proved invaluable in locating troublesome sites.

Site visits took place during the summers of 2008 and 2009. Approximately 50 of the sites listed in Appendix A were visited (sites visited are marked in the "Visit" column). During visits GPS points were taken and a series of field observations recorded. These observations were recorded digitally on a Dell Axim 51v pocket PC (see Table 4-1 for a list of characters). The primary GPS unit was a GlobalSAT BT50, but in cases of tree cover the slower Holux GPSlim236 unit with a 2 meter antenna was used. Both GPS recorders transmitted data via Bluetooth to ESRI ArcPad mobile GIS software running on the PocketPC. Among other options, ArcPad allows the user to set maximum uncertainty measure and a minimum number of satellites for which it will record a point. Because the accuracy of GPS is related to the number of and relative location of satellites, these settings control the error of each measure. In this case, no point was taken with fewer than six satellites or a value exceeding 3.0 in Positional Dilution of Precision (PDOP: the combined differences among estimates from different satellites). The software then recorded and averaged 500 GPS points (UTM Zone 31 North: WGS 1984 Datum) close to the center of each site. Averaging a high number of points helps overcome some additional sources of error. This single average point was then used as the main location for each site.

The final site database consists of 88 individual sites. Many of these sites preserve multiple techno-complexes. In these cases, the same site point represented all known techno-complexes. This reduces the statistical likelihood of differentiating sites based on landscape characters, but it also gives a better picture of the total variability in site locations among the techno-complexes. Table 4-2 shows the number attributable to each techno-complex and Figures 4-1 to 4-5 show the spatial distribution of each techno-complex.

Caveats about site location

Many of the well-known sites found in the literature represent multiple periods, often spanning both the Middle and Upper Paleolithic. In these cases, the same point was used for all occupations unless there was a compelling reason to separate them. It should be noted that this approach does not take into account the fact that later occupations were necessarily on top of those preceding them. Thus, they may have had a different quantity of usable area and a slightly different elevation. However, it is assumed that these differences would be below the scale of measurement in a large project such as this. Similarly, there are several sites in the region that, although separately named and excavated, are potentially two parts of the same occupation. An example of this is the boundary between the Aurignacian sites of Abri Castanet and Abri Blanchard. Most authors consider this division to be based on property boundaries and excavators rather than a real separation in either time or space (de Sonneville-Bordes, 1960; Delluc and Delluc, 1978; White, 2008). In ambiguous cases where roughly contemporaneous sites are within 200 meters of each other, the individual site locations were preserved and used, but a single point for the complex was also included.

The sites used in this project vary widely in their modern, and presumed Paleolithic, extent. Whenever possible during site visits, outlying GPS points along the extent of the site were taken. But these estimates were not possible for all sites. Thus, for the vast majority of visited sites, and all that were extrapolated from other sources, only a single point serves as the locational record. It is likely that this individual point is not an accurate representation of the landscape variability across the site's true extent. In fact, previous work has demonstrated that points do not always serve as a good model for area (polygon) data (Mink et al., 2006). To systematize this potential error, measures of the local average and variability in each landscape character must also be calculated. For the majority of this project's analyses, a 200-meter radius around each site point was averaged. The variability measure, usually the standard deviation, was also calculated over this area (Appendix *B-ii).*

c. Data generated from GIS database

This project makes use of a large GIS database of site locations, landscape and environmental data coming from a wide variety of sources. The methods used to analyze each of these types of data are similarly diverse. As outlined in the preceding chapter, different types of data generated from this GIS database are of particular relevance to certain questions or hypotheses about Paleolithic settlement. In this section the methods used for each major data type (Table 3-3) used in this project will be discussed in the context of those questions to which it can contribute. The methods used to collect and analyze each type of data are then briefly presented. Because many of these methods are complicated, and require the presentation of computer code for transparency, the full details are presented in Appendix B and referenced in the following sections.

Topography

For this type of project, an accurate measure of the modern topography is absolutely crucial. Not only are topographic factors considered regionally important settlement predictors (e.g. White, 1985) but many of the subsequent analyses are based on a model of the topography. This measure then contributes, directly or indirectly, to most of of the hypotheses outlined in Table 3-2. In a GIS setting, one of the most useful ways to represent topography is as a Digital Elevation Model (DEM). A DEM is a raster data type, where the only pixel value is the average elevation of the area represented by that area. A DEM is essentially a matrix of numbers, allowing the systematic application of many mathematical analyses. For DEMs this is usually done by analyzing the neighborhood of each cell (the cells around it). Using this process, it is relatively simple for the computer to extrapolate layers representing slope, aspect, viewshed and hydrology from a DEM.

The creation of an accurate DEM can be a difficult process. Although single source DEMs (from topographic maps or satellite imagery) are possible, it is often more accurate to compare and combine data from multiple sources. For this project, the primary elevation data came from the pre-generated ASTER gDEM. This image records most of the world at approximately 30 meter resolution DEM generated from stereo pairs of the backward and nadir infrared sensors[6]. These ASTER data are usually accurate in a relative sense, but typically require some post-processing to remove erroneous readings and to be tied to actual elevations (San and Süzen, 2005). Here, the main additional data source was point elevations from digitized topographic maps (1:25,000) from the French *Institut Géographique National* (IGN), although other data were used (IGN, 2007a, 2007b, 2007c, 2007d). All of these disparate data were integrated into an accurate DEM for the region using ESRI ArcGIS (Appendix *B-iii*). The final DEM (Figure 4-6) has a resolution of 25 m and covers an area 10 km beyond the maximum extent of sites (Appendix *B-iv*). After the DEM was created, the accuracy was estimated by a root mean squares measurement comparing unused real elevation values to those estimated by the DEM. The results of this accuracy assessment are found in Figure 4-7. From the final DEM a series of raster maps representing landscape characters based on topography was created. These analytical layers include rasters representing the slope and aspect.

Site orientation

Several previous studies found a preferred orientation for sites of a particular period (e.g. White, 1983, 1985; Duchadeau-Kervazo, 1986; Boyle, 1998). Obviously this measure is of less importance for open-air sites than for rockshelters and caves, though other work has found a preferred orientation in open-air sites (e.g. White, 1983, 1985; Boyle, 1998). In both covered and open-air sites, a preferred orientation is usually presented as being a choice to maximize warming from solar radiation or protection from winds.

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[6] : ASTER GDEM is a product of METI and NASA

In this project, a raster image of the aspect was created from the DEM using the ArcGIS Spatial Analyst extension. Orientation measurements for each site point and an average value for the surrounding area (200 m) were then calculated. Variability of the area surrounding each site was measured using the angular variance. Aspect is a circular measure, so calculating these descriptive statistics required some advanced geometry (Appendix *B-v*).

Classification into valley or plateau

Several key theories about Paleolithic settlement postulate that MP settlement was concentrated on the side valleys and plateaus while UP settlement was focused on the main river valley. Before any quantification of this character can take place, the study area must be classified into discrete classes. For this project, a binary classification of valley / plateau was created by dividing the area into two classes based on an elevation threshold. There is a slight difference in average elevation between the two banks of the river. Thus, this binary calculation was done using a different threshold for each. Although most sites were clearly within one class, a ratio of which classes were present within 200 m of the site point was also calculated for each site.

Proximity to water sources

Proximity to fresh water sources is usually considered an important control on settlement. In this project, the sources of fresh water contributes directly as a hypothesized factor influencing settlement. However, this character may be influenced by other aspects of settlement patterns. If Upper Paleolithic settlement is focused on the river, as has been hypothesized, we would predict UP sites to be closer, on average, to these features. Also, if part of the Middle Paleolithic subsistence strategy was ambush hunting large mammals, then water sources could be locations where prey species were at a disadvantage and thus important to a different aspect of settlement. Thus, there is a large issue of equifinality in using raw proximity to water as a direct contribution to a single hypothesis.

In the study area, the primary fresh water sources are the rivers. The Vézère is the most important of these, although the Dordogne and the Beune also fall within the study area. Several other spring sources are also known in the region (Marchand, 1971; White, 1980, 1985; BRGM, 1999a; IGN, 2007a). A map of these other locations can be seen in Figure 4-8. Neither their antiquity nor whether these represent all of the potential sources is known for these data. Because of these uncertainties, analysis of proximity to water was calculated twice, once including the spring sources and once with the rivers as the only water source. This also has the advantage of potentially isolating proximity to the rivers from simple proximity to water.

In calculating the distance to a given feature, there are two methods one can use. The first is simple straight-line, or Euclidean, distance. The second attempts to weight the distance by how difficult the terrain is to cross. For example, the straight-line distance from a site to a river might be very short, but if several cliffs stand in the way, reaching it would be very difficult. These cost-weighted models can be very complex, taking into account landcover, vegetation and soil types. Most of these characters are unknown for the Paleolithic, so in this project only the slope was used. Unless otherwise noted, both were used in calculating the distances to discrete features.

Proximity to lithic raw materials

Proximity to lithic raw material sources is often considered to be a very important character of Paleolithic settlement. In particular, MP settlement is often presented as tied to raw material sources. Thus, proximity to outcrops of usable stone was originally envisioned as a key component of this project. However, the relatively small study area severely limited the utility of this character. Within this region, are essentially two diffused sources of raw material: river cobbles from the Vézère, and inclusions of Senoian flint in the sediments on the southeast bank of the river (Morala, 1984; Demars, 1985; Morala and Turq, 1991). Further complicating matters, there are also some isolated inclusions of usable flint on the other bank (A. Morala *personal communication*). Very little of the material is distinguishable and some materials considered "exotic" are actually available in low densities from river cobbles.

After consulting with experts in local geology and raw material sourcing, raw material sources were not included in the spatial model. There are simply too many small patches of material for the proximity to them to be calculated with any accuracy. Furthermore, many authors have noted the presence of a source near a known site, but there is little data available on either other raw material sources or areas that are devoid of material (A. Morola / P. Gardere *personal communication*). Instead of using point locations to raw material sources, soil maps (BRGM, 1979, 1987, 1999a, 1999b) were digitized and measures of the variability in soil type (which carry information of density of flint inclusions) were calculated around each site.

Presence of open-air sites in a depression

If protection from the elements is an important control on site locations, then there should be a strong impetus to optimally place open-air sites. This pattern has been observed in the record, with open-air sites often found in a small depression that could hypothetically have minimized exposure (e.g. White, 1983; Duchadeau-Kervazo, 1986; Boyle, 1998). There does, however, remain the possibility of erosion and other taphonomic effects causing or modifying any patterning in this character. Quantitatively, this measure was investigated by analyzing variability in slope and aspect within 200 meters of each open-air site.

Proximity to ecoclines

Several of the proposed patterns for Middle and Upper Paleolithic settlement rest upon their proximity to different environments. This measure of how many environments are easily exploitable from each site can yield information about the subsistence strategy and the level of reliance on individual resources. Despite this, proximity to multiple ecosystems really only speaks to the resource availability at a site. Evidence of exploitation of these different resources cannot be proven in absence of direct evidence, but simple proximity can give a strong indicator as to important resources.

However, determining the exact character of ancient ecosystems is, at best, a difficult prospect. It is nearly impossible for a dataset like the one used here, where most sites have not been the focus of intense modern excavation and inquiry. Fortunately, most local environmental variation is because of predictable characters like the slope, aspect and soil. By locating the points where the modern landscape blends from one environment to another, one can determine a proxy for likely environmental transitions in antiquity. While this does not yield direct information on the character of these environments, using these locations of likely transition, or ecoclines, can yield important information on the number of different environments within site catchment.

There are number of different ways of determining these ecoclines for a modern environment, but nearly all rely on classifying landcover. This project makes use of three different classifications. The first is a 100-meter resolution Corine Land Cover 2006 (version 13, 02/2010) classification generated by the European Environmental Agency from satellite imagery (Landsat ETM+) and ground-truthing data (EEA, 2007). Table 4-3 shows the different landcover types found in this classification. A clear problem with the Corine classification is that defines landcover based on modern anthropogenic modifications (i.e. farmland, villages, etc.). In order to address this, a second classification was created by analyzing vegetation indices from satellite images across multiple sources and times. Combining the variation in each class across multiple times and imagery types allows for increased identification of areas with anthropogenic modifications and gives a statistically measurable view of this vegetation index (Appendix *B-vi*).

Even with these techniques, it remains very difficult to overcome modern influence in creating a landcover classification. The third classification is thus designed to classify the environments of the study area without reliance on the modern landcover. Following White (1980), the vegetation of the modern Périgord can be placed into three rough classes, each with a different vegetation type.

1. Flat uplands and valley bases: Deciduous forest
2. South-facing slopes: Mediterranean flora with young oaks and a variety of grass species
3. North-facing slopes: Sub-alpine flora with mostly hornbean, though ash and beech also present

As most of the characters defining these classes are inherently topographic, a classification was then created using the DEM and the raster images representing slope and aspect (Appendix *B-vii*).

Once these three classifications were created, the proximity of each site to different classes was measured. For this study, the number of different classes within a 200-meter radius of each site was calculated (Appendix *B-ii*). These results are then a relative measure of the environmental variation surrounding each site.

Proximity to natural river fords

The location of natural fords in the Vézère were previously found to have an important correlation with the location of Upper Paleolithic sites. These may be for travel of human groups, hunting of migratory prey species or for locating raw material cobbles in the riverbed.

In this project, the locations of fords were isolated from earlier work by White (1980, 1985). White collected these data by examining maps, exploration and talking with local farmers (1980). A non-systematic sampling of the locations of several of these fords with a GPS unit demonstrate that they are accurately referenced (shown in Figure 4-9). However, there remains a real chance that these are not all the fords and shallows the study area. Thus, a systematic search for additional natural shallows was performed using multi-spectral satellite imagery. Using this method, no additional fords were found in the study area. From this layer representing the locations of known fords, the distance of each site (both Euclidean and slope-weighted) to the nearest ford was then calculated.

Visibility analyses

What is visible from a site can potentially give insight into why a particular location was chosen for occupation. In the context of this project, an analysis of how much and what type of landscape is visible also contributes to hypotheses on hunting strategies, sociality and the type of environments that the groups focused on.

In modeling this character, researchers often make use of viewshed analysis (Lake et al., 1998). This GIS-based technique uses the Digital Elevation Model to estimate what is visible from a given location. The calculation of viewshed is not standardized, and can be complicated by a number of factors including the curvature of the earth, the size of the target and the haze of the atmosphere. Here, several different types of viewshed analysis were performed (Appendix *B-xiii*). In essence, two main forms of viewshed can be used: standard viewshed, where visibility is treated as a Boolean character and fuzzy viewshed, where percentages are used to model the reduction in visibility over distance. For this project, the viewshed was given a maximum radius of 10 km, but the reduction of visibility over distance was not modeled. Additionally, instead of a simple average around each point, measures representing the optimal and total viewshed within a 200 m radius were calculated. Because this radius is large enough to potentially include radically different landcover type the individual measurements were also filtered. These areas were then used to calculate both the total area and a ratio of what types of landcover are visible from each site.

Density of sites

The density of occupation is an often-discussed character in Paleolithic settlement (e.g. Mellars, 1973; White, 1982). It can contribute to hypotheses on mobility strategy, complexity of social organization and can help identify important locations for a given social group. Despite its utility, it is also difficult to accurately compare among different techno-complexes. In addition to taphonomic effects, there is a potential problem with different extents and intensities of sampling. Thus, density data should always be interpreted cautiously. For this project, density data were calculated for each techno-complex. These densities were scaled to help minimize the problems of taphonomy and unequal coverage. The raw density of sites for each techno-complex was calculated for a 2-kilometer buffer zone around the maximum extent of sites from that techno-complex.

Size of occupations

The size of an occupation, in extent, time and number of occupants, can also contribute useful data about the type of mobility, variability or importance of a given site. However, the methodology used here, by excluding most excavation data, renders this character unusable for the majority of sites. Several sites in the region do, however, have accurate estimations of chronological or physical extent. Thus, while there is no systematic sampling of this character, in the following chapters, occasional reference will be made to the size of individual sites.

d. Investigating bias

The patchy nature of archaeological site data nearly always results in a biased sample for landscape analyses. In essence this is because, no matter how good preservation is, not all sites that were present in antiquity are available for current analysis. Size, character and density all play roles in the likelihood of a given occupation being discovered or correctly attributed. In the case of a broad chronological period, it is more likely that recent sites will have less taphonomic influences and be more visible on the landscape, and thus more likely to be discovered and recorded.

This project attempts to use the maximum available data, but there remains a very real chance that the sample is biased towards one chronological period or type of occupation. It is difficult to assess this issue. To put it simply, it is far harder to understand what we do not know than to analyze what we do know. However, some measure of potential bias can be determined from correlations of sites from each techno-complex with landscape characters that may influence the visibility of the site. Of particular relevance are modern construction, soils and vegetation . These sources of these data are the landcover classification and soil maps discussed in the preceding sections.

It should, however, be noted that the simple presence of a correlation is not a certain indication of a sample bias. Certain landscape characters may also reflect choices in the settlement strategy of the groups. These issues will be discussed fully in the following chapter.

e. Statistical methods

As discussed throughout this chapter, this project uses a number of software packages and techniques. Because of this, there is a corresponding variety of statistical tests used to analyze the resulting data. Most data comparisons were made between the Middle and early Upper Paleolithic as a whole and among each of the techno-complexes. Standard parametric and non-parametric statistical analyses were used. After the various raster images were created, the custom scripts and standard GIS sampling techniques were used to place the variables for each site into a data table (Appendix A). SPSS statistical software was then used to calculate descriptive statistics for each time period and to perform pairwise comparisons on metrics among the techno-complexes.

These matrices then yielded information on which components are most strongly correlated with site location for each time period. There is, however, likely to to be auto-correlation and multicollinearity (i.e. some variables are more strongly correlated with each other than with chronological classifications) within these data. Additionally, any relationships discovered are the result of a biased sample (i.e. it is impossible to have either full coverage or negative data for archaeological material). To partially address these issues, the ecological modeling technique MaxEnt (Maximum Entropy) was used. In this context, MaxEnt uses a small sample of presence-only data to calculate the important characteristics of a given species' niche. This project used the software Maximum Entropy Species Distribution Modeling v.3.3.3e (Phillips et al., 2004, 2006; Elith et al., 2011) to calculate important environmental controls on the “niche” of Paleolithic techno-complexes.

f. Conclusions

This chapter has outlined the methodological approach of using a quantitative GIS-based techniques to address settlement in the Paleolithic. Important data sources, ranging from site locations to topography and other landscape data, were presented. The sources and analytical methods pertinent to each were then discussed in the context of larger hypotheses to which they can contribute. This methodology is complex, varied and reliant on computer scripting. The following chapter will present the results of each of these analyses and discuss how they can be used to characterize the differences among the Paleolithic techno-complexes of the Vézère Valley.

Figures and Tables: Chapter 4

Table 4-1: Site characters recording during visits

Character	Description
Site coordinates	Average of 500 GPS points (UTM zone 31N; Datum WGS 1984)
Elevation	Average of 500 GPS points: Inaccurate measure used to compare with real elevation taken from DEM
Site extent	Single GPS points around visible extent if applicable
Orientation	Recorded with compass to compare with DEM generates aspect. Mostly on cave and rockshelter sites
Modern vegetation	Notes on the character of the modern environment
Topography	Notes on variability in the slope and elevation that may be below the resolution of the DEM.
Local resources	GPS points and notes on any local springs, raw material sources or natural fords
Other	Any other relevant notes about the site character, history of excavation or local environment

Table 4-2: Total number of sites attributable to each techno-complex. Note that the early Upper Paleolithic class is composed of the Aurignacian and Gravettian samples with duplicated removed.

Techno-complex	Number of sites
Middle Paleolithic	**48**
MTA	9
Early Upper Paleolithic	**51**
Châtelperronian	13
Aurignacian	41
Gravettian	28

Table 4-3: List and total areas of Corine landcover classes found in the study area

Corine Class (level 3)	N	Area (km^2)
Broad-leaved forest	67	240.52
Complex cultivation patterns	148	111.84
Coniferous forest	9	4.46
Discontinuous urban fabric	8	3.7
Dump sites	1	0
Fruit trees and berry plantations	1	0.32
Land principally occupied by agriculture with significant areas of natural vegetation	16	7.34
Mixed forest	47	52.38
Non-irrigated arable land	24	18.65
Pastures	109	59.9
Transitional woodland-shrub	15	6.88

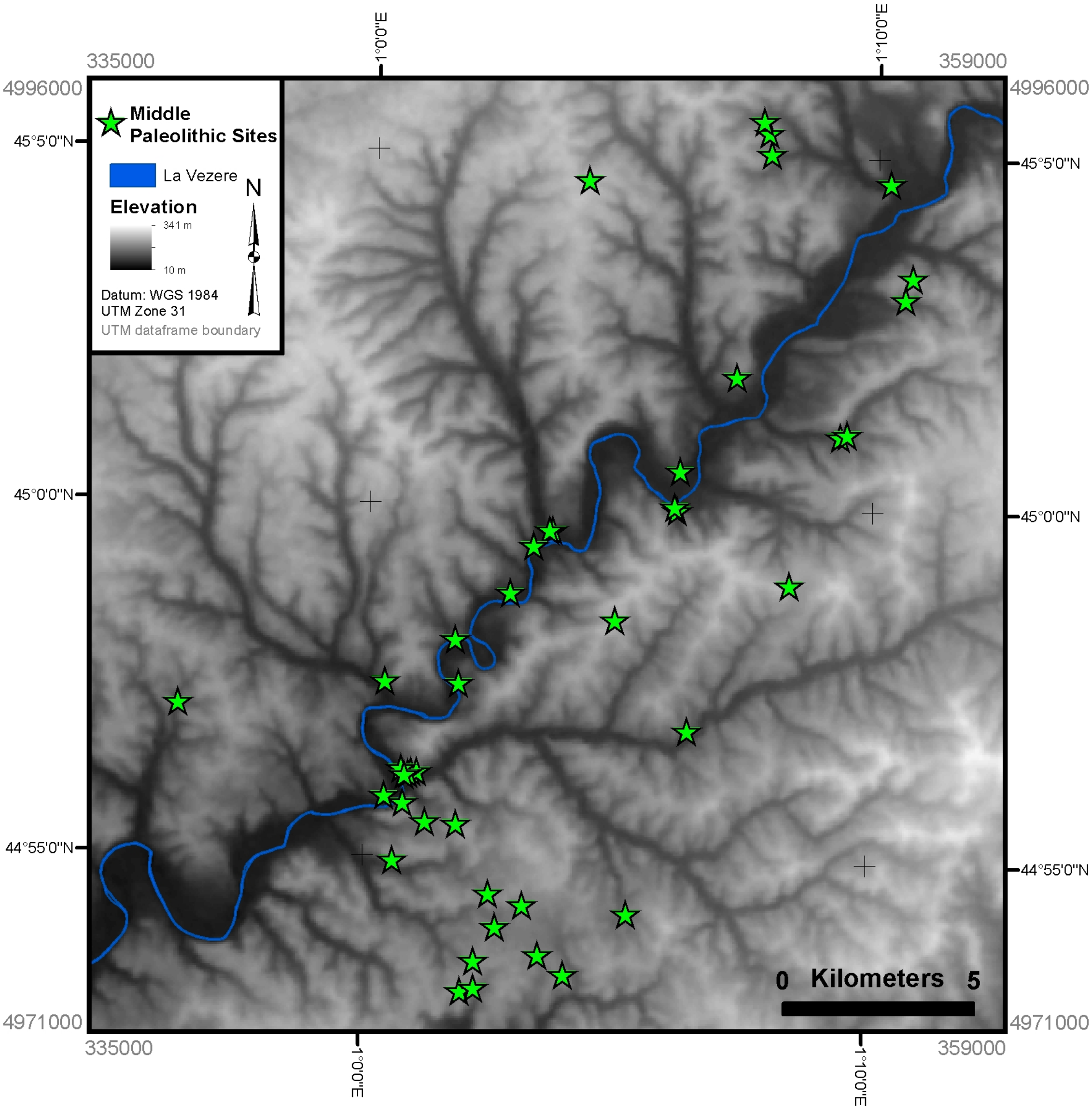


Figure 4-1: Distribution of Middle Paleolithic sites

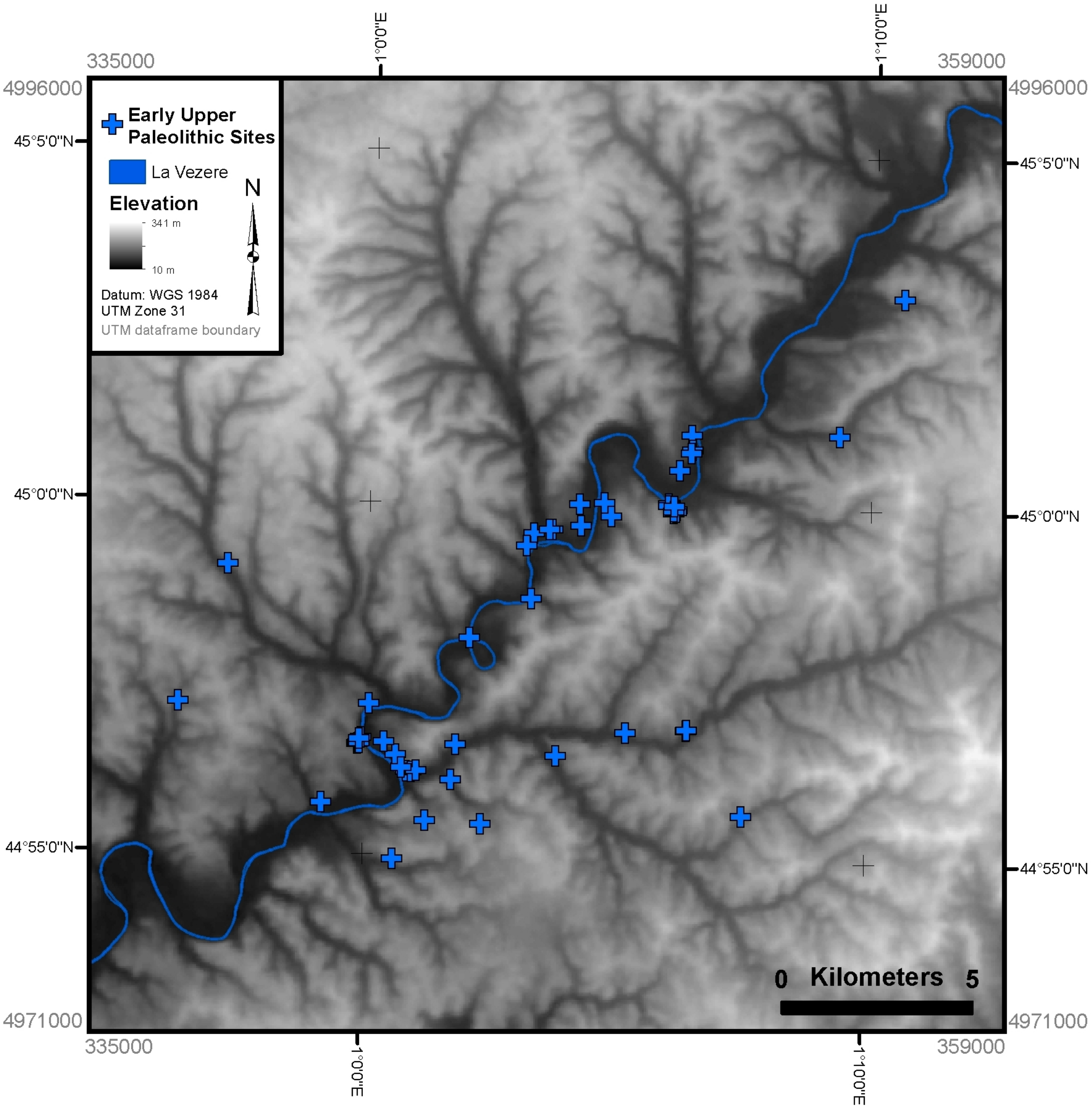


Figure 4-2: Distribution of all early Upper Paleolithic sites

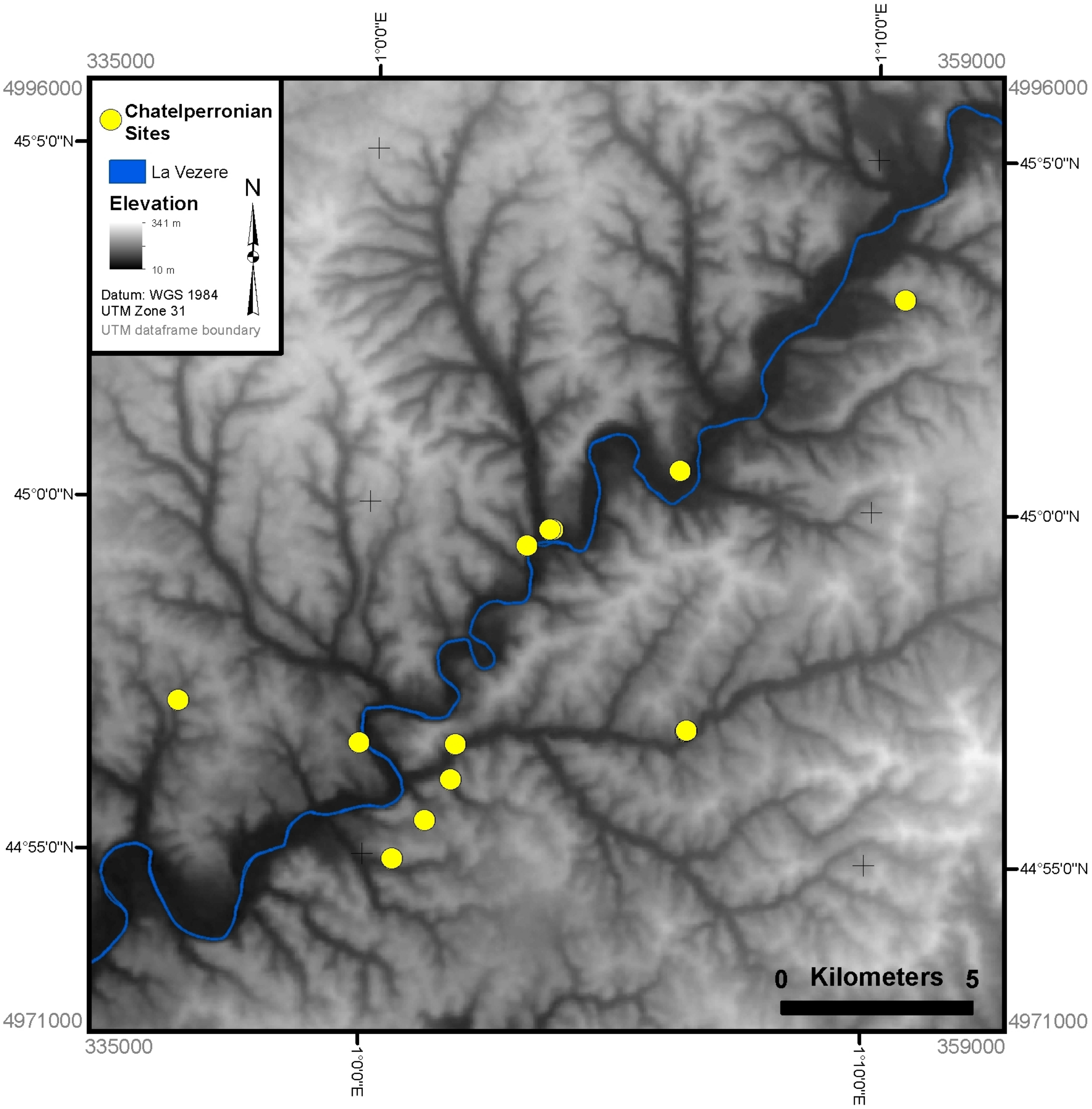


Figure 4-3: Distribution of Châtelperronian sites

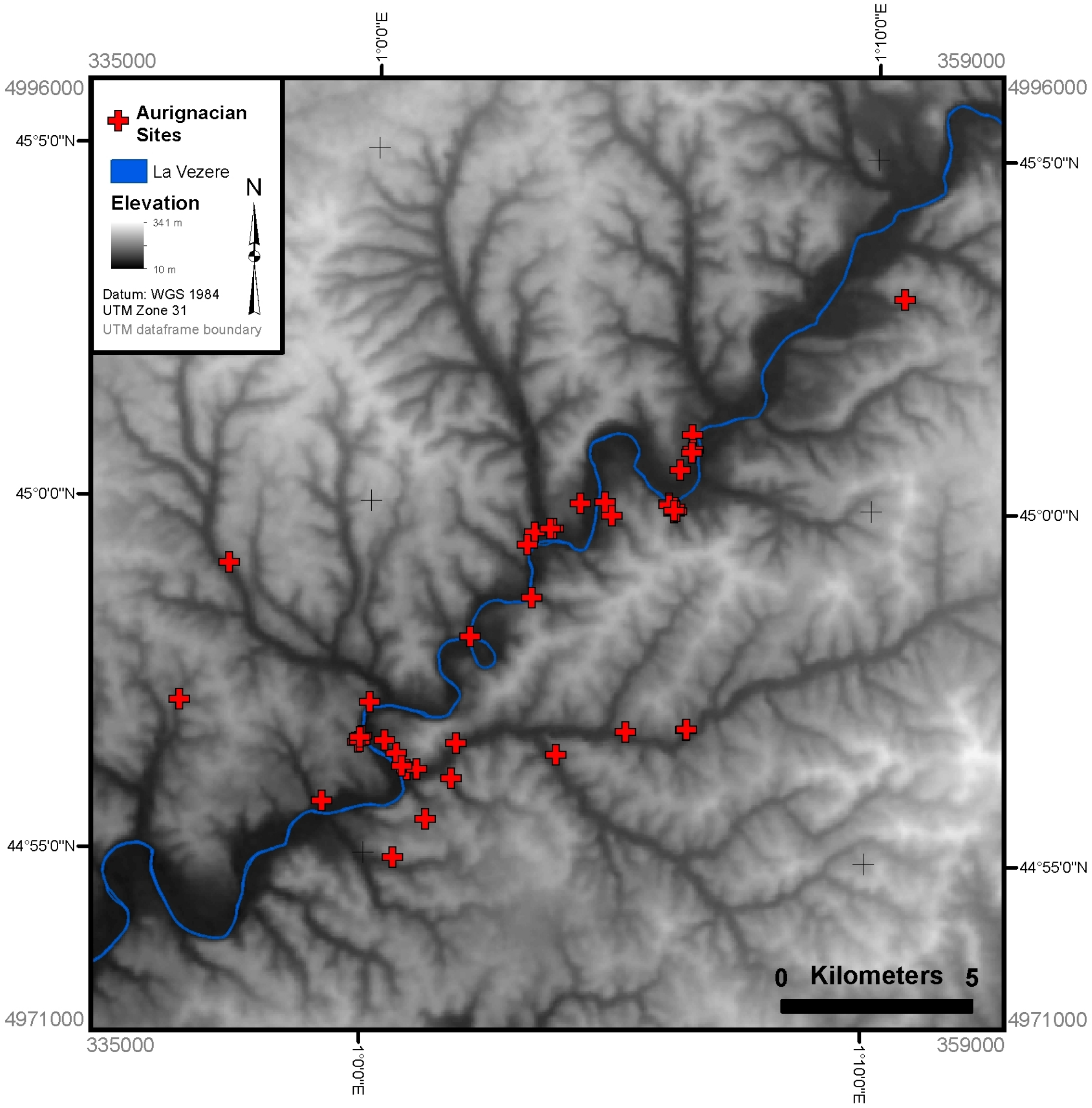


Figure 4-3: Distribution of Aurignacian sites

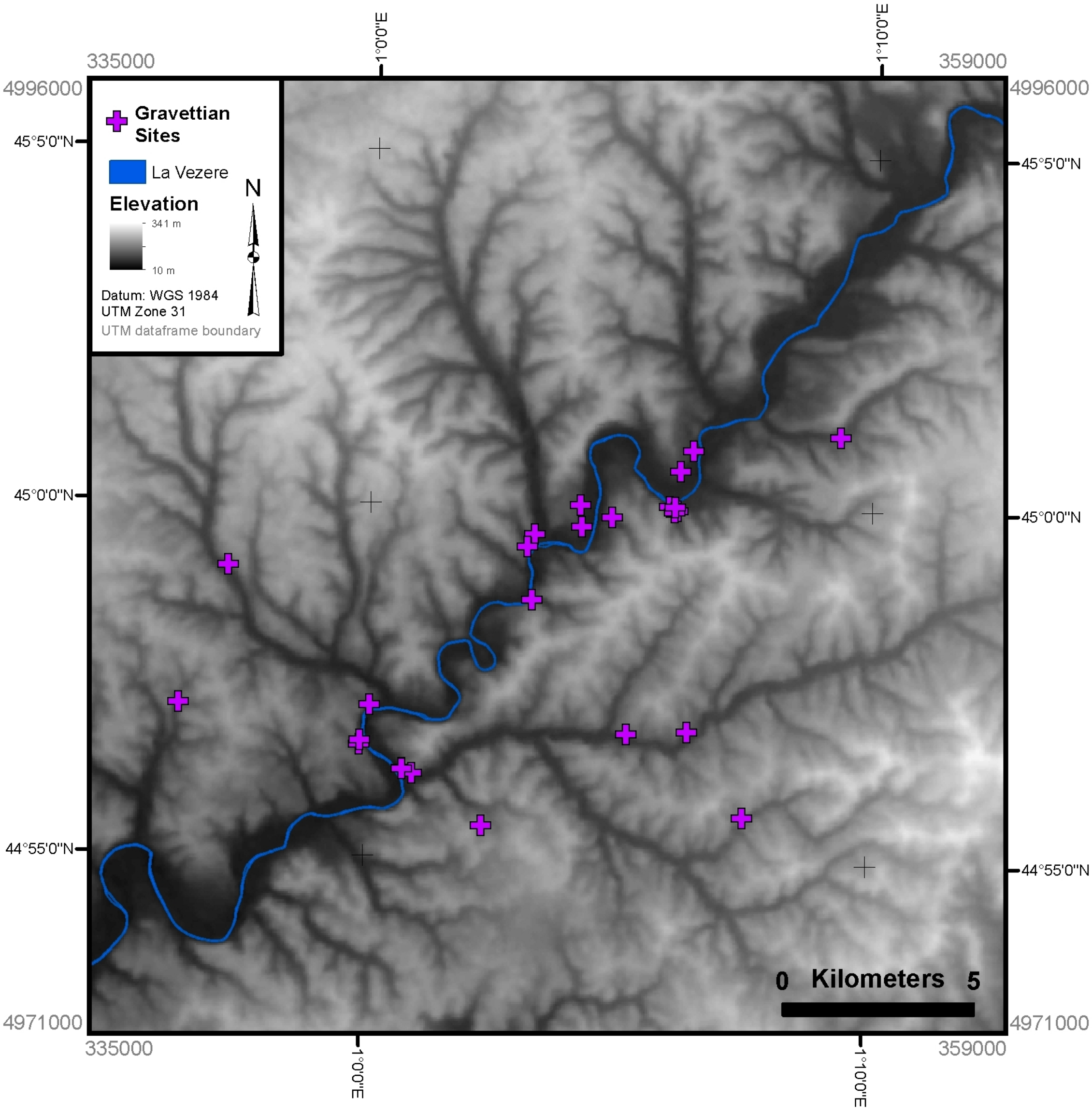


Figure 4-5: Distribution of Gravettian sites

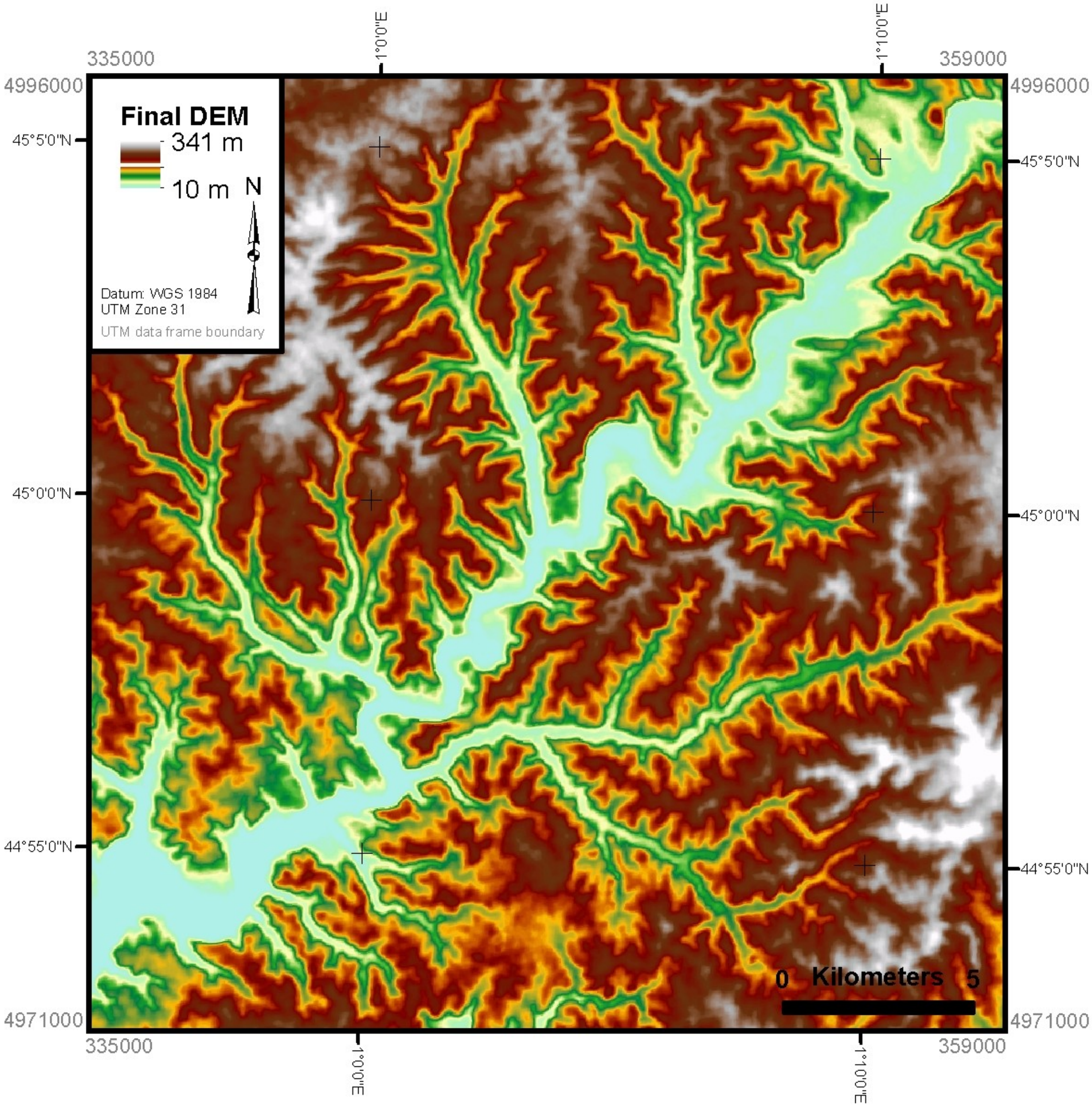


Figure 4-6: The final Digital Elevation Model for the study area

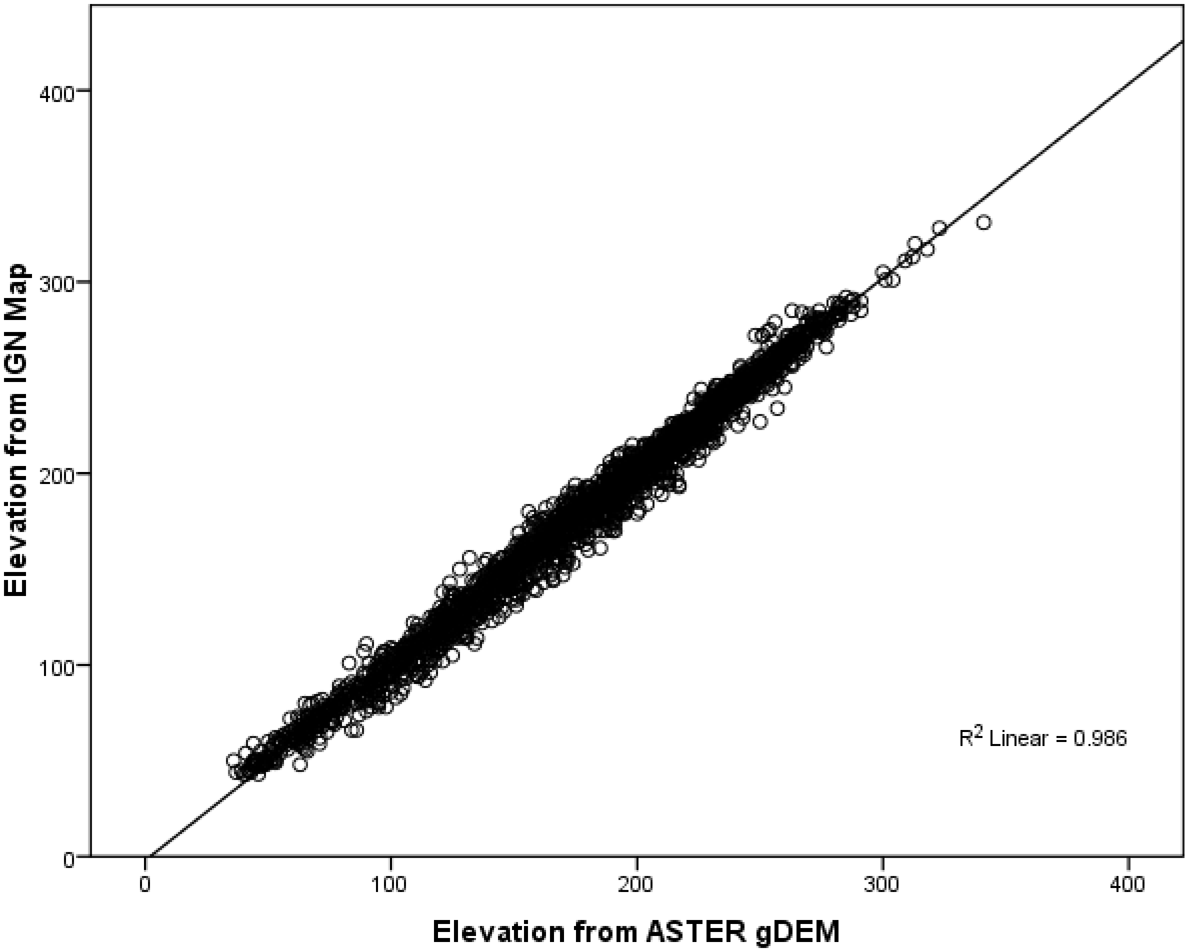


Figure 4-7: Results of accuracy assessment of DEM: Elevation from IGN topographic maps plotted against elevation values from ASTER gDEM. Most outliers are isolated peaks below the resolution of the DEM

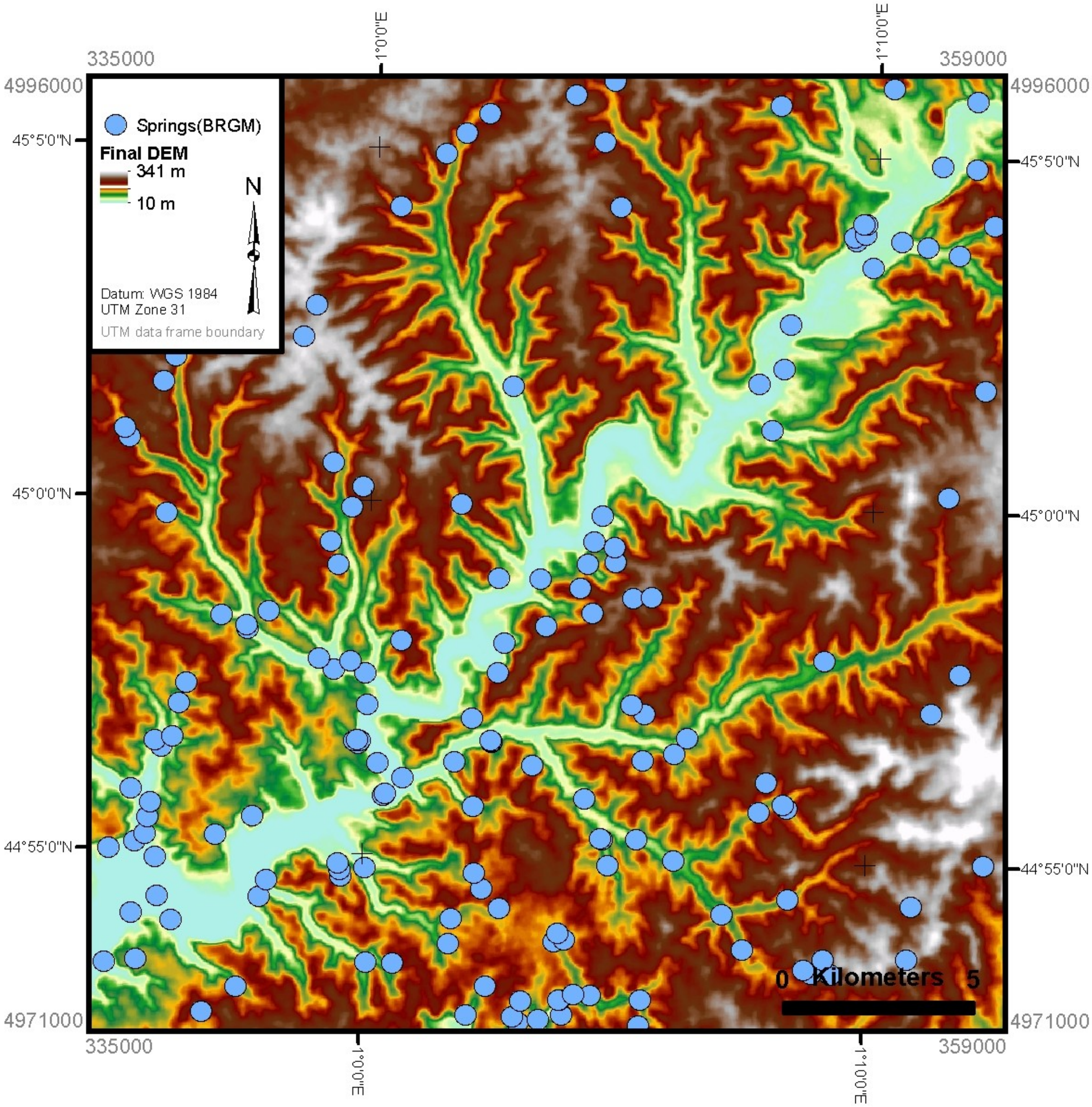


Figure 4-8: Locations of modern springs in the study area.

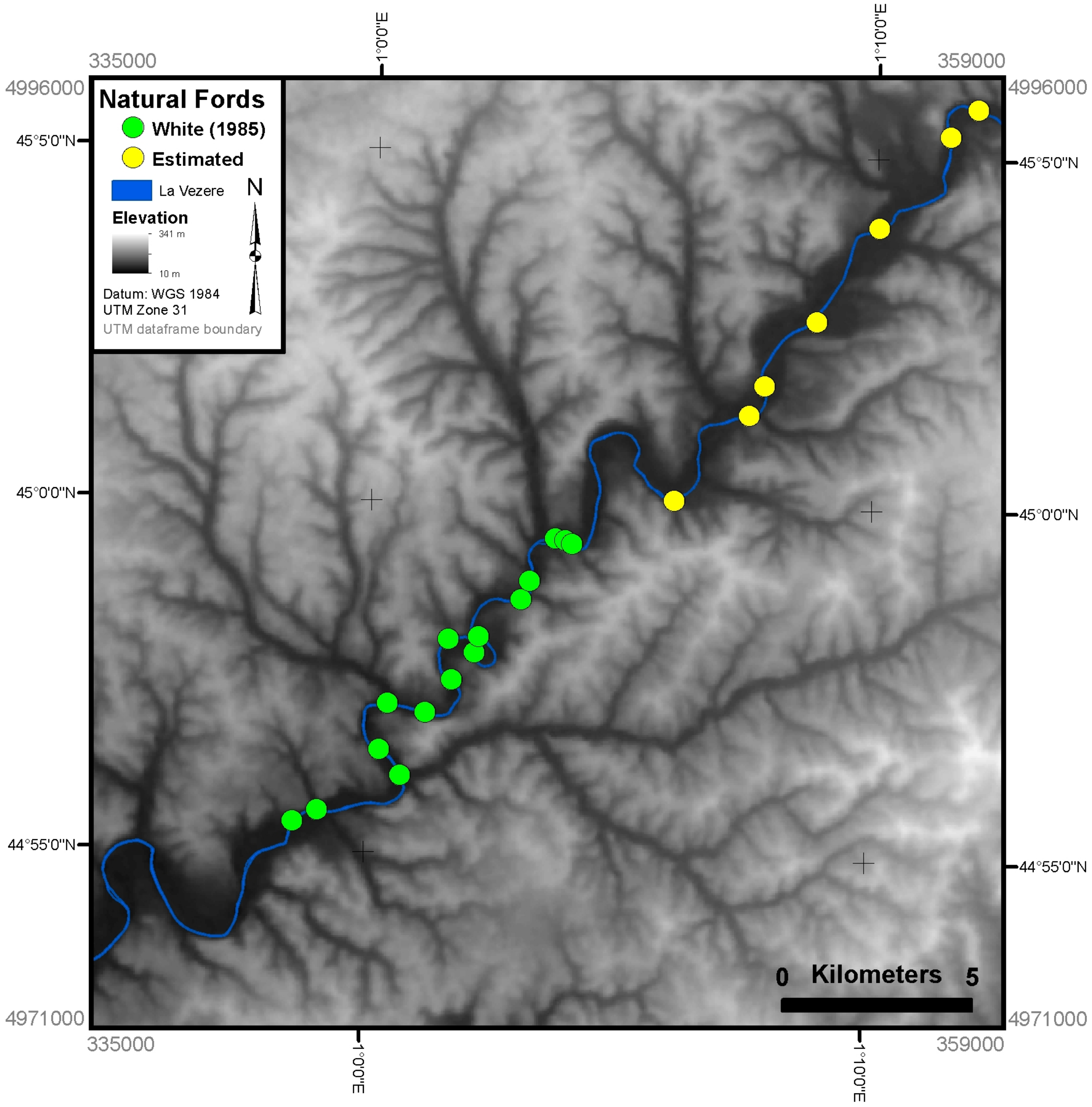


Figure 4-9: Locations of natural fords in the river (after White 1985). Because this source did not cover the entire study area, this also includes several ford locations estimated from high resolution imagery and geological data.

Chapter 5: Results

a. Introduction

This chapter discusses the results of analyses described in the preceding chapter. Because the datasets and analytical techniques are varied, these results are divided into several sections. First, the potential of sampling or taphonomic bias is examined through the lens of statistical patterns between known sites and random distributions. Next, overall patterns are presented and discussed in the context of broader hypotheses on Middle and Upper Paleolithic settlement. These are then distilled into an overall pattern for each of the techno-complexes in the Vézère Valley. Finally, the results of more direct statistical techniques aimed at isolating important settlement characters for each techno-complex are presented.

b. Investigating sampling bias

As with any study of archaeological land-use, the dataset used here is only a sample of the settlement traces left in antiquity. The utility of this sample is in many ways contingent on how accurately it represents the pattern that was present in the Paleolithic. One way to test for potential bias is to correlate site locations with specific landscape characters. This can reveal trends in the type of landcover where different techno-complexes are likely to be discovered. While this patterning could also be because of conscious settlement decisions, very strong patterning can reveal potential taphonomic biases in site preservation or discovery. In particular, it is important to test for the presence of conditions likely to eradicate or obscure the discovery of sites. For this study, three main variables can be considered likely to hide sites, but less important for Paleolithic settlement. These are modern vegetation density, soils formed by erosion after the Paleolithic and areas of modern construction.

The distribution of Paleolithic sites relative to these variables were compared to five test samples of proportionally identical, but randomly distributed, sites. Because Paleolithic sites would never be truly random across the landscape, the extent of these test points was constrained to a 2-km buffer zone around the sites from each techno-complex.

The density and health of modern vegetation cover was measured with a mean NDVI from a series of recent Landsat satellite images. Statistical tests (t-tests) reveal that there is no significant difference between this value for Middle and Upper Paleolithic sites when compared with each other or with any of the random samples (Table 5-1). There is, however, a significant difference between the sites and all but one of these random samples when they are compared with the mean for the entire study area. Essentially, this shows that the extent of known sites used to constrain the random points is not fully representative of the total variability of the study area. The influence of vegetation density outside this 2-km buffer zone cannot be excluded, but within this area there is no significant correlation between vegetation and site locations.

To test the potential of site eradication through geological processes, a soil map was classified into two sediment types alluvial / colluvial soils and those that are formed in place. This should give an indication of places where sites could be buried (colluvium) or removed through fluvial action or erosion (fluvial / alluvial). Using this binary character, comparisons between Middle and early Upper Paleolithic sample in the observed sample and the five random samples show a very similar pattern (Table 5-1). A possible outlier is Random Sample 5, but this individual data point should not be taken as evidence of a central trend in these data. The pattern holds between the total sample and for each of the techno-complexes, indicating that there is little indication of a systematic bias in geological contexts. Furthermore, there is no significant difference between the known sample and four of the five random samples when compared with the ratio of these two sediment classes across the entire study area (Table 5-2). While the regions soils are correlated with topographic and geomorphic characters, this lack of a difference in sediment type remains a good indicator that there is no significant bias in site preservation between the time periods. Other erosional effects such as infilling of dry valleys, are not fully addressed by this simple binary classification. A more thorough analysis of this potential issue, with a relevant case study, follows in Chapter 6.

Finally, the possibility of sites being hidden or destroyed by post-Paleolithic construction cannot be eliminated. To address this, the Corine landcover classification based on satellite imagery was split into artificial and natural classes. The artificial encompasses any large scale construction from villages to cities while the natural class includes farmland, pastures and native forests. For this variable, there are significant differences between the observed and four of the five random samples (Table 5-1). Counter intuitively, it is actually the observed sample that has a higher percentage of sites in areas classified as urban. This is almost certainly a product of sites such as le Moustier and Cro-magnon that sit at the center of small- to medium-sized population centers. The same pattern holds when each of the samples is compared with the total study area (Table 5-2). This test was designed to determine if construction in the area has influenced the spatial pattern of site locations. A higher density of sites in the artificial class is actually the inverse of what one would expect if this were true. Thus, while these results are far from conclusive it does not appear that there is no real negative effect of the region's small villages on site locations.

The dual contributions of settlement strategy and taphonomy are difficult to disentangle in all archaeological patterns. Using these three proxies, there does not appear to be a systematic spatial component of any taphonomic effects. These are not the only potential influences, but there are few others that would affect the area systematically and can be easily tested from the available data. In this dataset we cannot conclusively rule out other isolated influences on the discovery of sites from a particular time period. However, it does appear that, even if the sample of Paleolithic is not complete, it is representative of most of the variation within similar areas.

c. Presentation of data and basic spatial patterning

These caveats aside, there are significant differences between techno-complexes in several of the studied landscape characters. While individual differences could be the result error or correlation between variables (e.g. higher elevations are usually further from the river), a careful analysis of these differences can reveal important controls on the settlement locations of Paleolithic populations.

Before proceeding, it must be stressed that in these, and all other analyses, the broader classes (Middle and early Upper Paleolithic) are made up of the same sites found in the smaller divisions (MTA, Châtelperronian, Aurignacian, Gravettian). The broad classes have only one entry per site, even in cases where it preserves multiple techno-complexes (e.g. Abri Pataud has an entry in the Aurignacian and the Gravettian, but only one in the early Upper Paleolithic). At no site in the regions is the Châtelperronian found without either the Aurignacian or Gravettian, so questions of its inclusion in the UP cannot be addressed by this dataset.

For many of the measured quantitative variables the mean and variability measures indicate some clear differences among the various techno-complexes (Table 5-3). However, these differences could be the result of sampling error or high variability. Table 5-4 reports the results of pairwise comparisons (t-tests) to distinguish significant differences between the broad categories and techno-complexes for the measured landscape variables. In this table, each significant difference is shaded and the larger value is marked with the column ID of the smaller. Two patterns immediately become apparent from this table. First, the MTA cannot be statistically distinguished from any of the others. This is most likely a product of small sample size (n = 9). The broad Middle Paleolithic class contains more sites and assemblages that have been described as possibly MTA. But, a more rigorous standard was used to attribute sites as MTA because the differences between the techno-complexes within the Middle Paleolithic are more subtle than those of the Upper Paleolithic.

The second main pattern lies in comparing the Middle Paleolithic to the early Upper Paleolithic and its component techno-complexes. Based on these data, the MP is significantly different from the others in several variables. Discussion of most of these results will follow in the context of the larger questions and hypotheses to which they contribute. Notably, however, MP sites are located at higher elevations by both a direct measure and as an average of surrounding topography (Table 5-4, Figure 5-1) . The coefficient of variance (CV) on this elevation measure is, in contrast, significantly higher for the eUP (and the Aurignacian and Gravettian). This shows that while Middle Paleolithic sites are at higher elevations, early Upper

Paleolithic sites are found in more topographically varied locations. This finding is supported by significantly higher slope values for the eUP compared to the MP (Table 5-4, Figure 5-2) .

Ratios of the categorical variables — soil type (Table 5-5), modern landcover (Table 5-6), and topographically derived vegetation zones (Table 5-7) — also reveal some patterned differences between techno-complexes. Chi-squared and Fisher's exact test (when applicable) performed on these data (Table 5-8) illustrate that for all three, there is some evidence for differences between the Middle and early Upper Paleolithic.

d. Results for specific data types

Several of the relationships presented above have particular relevance to the individual models and observations on Paleolithic settlement that were isolated in Chapters 3 and 4.

Heterogeneous / homogeneous environments

Often Paleolithic settlement, and particularly Middle Paleolithic settlement, is thought to be controlled by access to multiple environments. This would allow a variety of resources to be exploited from each site without extensive travel. In this project, the modern landscape was used a proxy for different environments in the past. Because much of the local environmental variation is controlled by topographic features, the locations of modern ecoclines should be roughly analogous to Paleolithic ecoclines. Two landcover classifications were used to determine the variability of both sites and the areas immediately surrounding the sites. These classifications are the Corine modern landcover classification derived from multi-spectral satellite imagery, and a division of the area into vegetation zones based on the slope, aspect and topography.

The ratio of different modern landcover types for the Corine (Table 5-6) and modern vegetation zones classifications (Table 5-7; Figure 5-3) show some differences between the lumped Middle and early Upper Paleolithic as well as among the techno-complexes. Additionally, statistical tests (Chi-squared and Fisher's exact test, summarized in Table 5-8) demonstrate that the proportions of each are not randomly distributed. Primarily, it appears that the early Upper Paleolithic sites are located in specific landcover types. In contrast, the Middle Paleolithic sites are more evenly among among the various landcover types in both the classifications. This trend is less pronounced in the measures that average surrounding area. This is likely because in averaging larger areas, small-scale variability will be hidden by the larger classes.

Some indication of a pattern is apparent, particularly when one compares the total percentages of each landcover type found in the study area. In this case, few of the observed patterns match pure chance. When the percentage values of the entire study area are used as the expected values in a Chi-squared test, all of the techno-complexes are highly significantly different. Of particular note is the modern vegetation classification. The Middle Paleolithic sites closely match the values for the total study area. The Upper Paleolithic sites exhibit a different pattern, with no individual site points found on a north-facing slope. This could be driven by two factors. First, the majority of UP sites in the region are caves and rockshelters at the base of vallons, areas uniformly classified as "flat." This uniform classification could be ignoring real variation in vegetation profiles within vallons. Second, this could be a very real choice during the cold periods leading up the Last Glacial Maximum during the early Upper Paleolithic. The Middle Paleolithic, with its longer chronological span, may be exhibiting increased variability because of different controlling factors during the changing climate of the Pleistocene.

Residential / logistic mobility

Modern hunter-gatherer mobility can be placed along a continuum from residential to logistic strategies. Some indication of where a given archaeological population could fit can also be gained from examining characteristics such as the density, size and dispersal of occupations. However, the methodology adopted in this project precludes much of this type of analysis. Using old and unpublished records to maximize the sample size at the expense of detailed excavation records leaves the total size and character of most sites unknown. Also, the chronological resolution of Paleolithic data makes it nearly impossible to discuss contemporaneity of occupations.

Yet, some indication of the density of sites, if not occupation, can be obtained from from the distribution of sites. Although no statistics were calculated for these measures, maps of the number of sites falling within each one-kilometer catchment (Figure 5-4 and 5-5) show that the density is somewhat different for the Middle and early Upper Paleolithic. The MP exhibits the highest densities of sites in the southern areas, away from the main Vézère Valley. The early Upper Paleolithic, in contrast, has a greater overall density with the highest values in the main Vézère Valley. However, this result is almost certainly biased by the sites of the Castel-Merle Vallon, many of which may more accurately be viewed as separate sectors of the same occupation.

Despite this preliminary finding, it should be noted that because the ethnographic data used to generate the continuum of logistic to residential mobility are based on ethnographic data (Binford, 1980), we should not expect clearly analogous patterns in the Paleolithic. These data are closer to a geologic time scale (thousands vs. tens of years) and conceivably represent the average of many different mobility strategies. Regardless, if we treat the forager/collector as a large-scale distinction between two settlement broad types, then it there is potential to gain some insight into differences between the MP and eUP, despite their palimpsest nature.

Protection

Several previous studies have suggested that Paleolithic settlement may be controlled by protection from the elements in cold climates. Two of the characters identified as indicative of this are an orientation to the south to maximize solar exposure and the placement of open-air sites in a depression to maximize protection from the wind.

The aspect data (Table 5-2) show some patterning. Both the MP and eUP sites exhibit a mean orientation of roughly East (90º) when just an average of site points is taken. But, the mean orientation for the area surrounding each site is closer to South (180º), indicating that the individual points may not be an accurate measure of the total variation. This holds true for all of the smaller scaled techno-complexes as well, with only the Gravettian as a possible outlier. However, this result represents a non-significant trend, and when the measures of variability are examined (the StDev column for Aspect at Point and Aspect Angular Mean, and the Mean Angular Variance row), it is apparent that each of these samples is widely dispersed.

Rose Diagrams of the angular measures from each site (Figure 5-6) and the angular mean of the area around each site (Figure 5-7) show some patterns not apparent in the strictly metric data. First, the prevailing, although non-significant, trend is an orientation to the South. Second, outside of the Middle Paleolithic, there are very few sites with a direct orientation to the northwest. Because of local variation in exposure to the sun, this orientation would be the among the least heated by solar radiation. But these measures are orientations of individual pixels at a 25 meter resolution. It is possible that the individual measures are more prone to error. The mean values for the area surrounding each site gives an estimate of the prevailing orientation over a larger surface. For these plots, even the MP exhibits far fewer northwest orientations. The early UP shows a similar trend to the site point data, but with more variation. This is possibly because many eUP sites are rockshelters, and this measure of variability is likely to capture the cliff face in addition to the site orientation.

In contrast to the findings of several previous studies, this DEM-based aspect measure does not show a strong pattern in site orientation. But, some inferences can still be made. Sites of all time periods (with the possible exception of the Gravettian) show an overall southern trend in their orientation. This would maximize solar exposure, indicating that it is an important character controlling some settlement.

The topographic data used in this study have a resolution that is too coarse to quantifiably track the presence of small depressions. Some indication of this character could be apparent from high aspect variability surrounding each site. Middle Paleolithic sites do have higher variability in their orientations. This is not a direct demonstration of these sites being located in depressions for wind protection; it also does not contradict this hypothesis. If a site was in a depression, the aspect of the area surrounding it would face inwards and thus an average would approach zero. This is not immediately apparent in these data, but the southerly oriented pattern for individual points combined with a less clear pattern in the average for the area surrounding the site could suggest that MP sites are found in areas of increased topographic relief, and potentially in depressions.

Important resources

Proximity to important resources may also control the locations of settlements. Previously, many authors have stressed the proximity of Middle Paleolithic sites to sources of lithic raw material and Upper Paleolithic sites to the river. As was discussed in Chapter 4, the quantity and dispersed nature of the raw material sources in the area makes it difficult to precisely map all of their locations. Additionally, the river serves as a potential source of cobbles of flakeable stone. Thus, this variable was not included in this model. However, some dimension some raw material availability can be obtained by examining the types of soil found near each site. In this case, there are some differences in the type of soil found at each site point and in the area surrounding each (Table 5-5). Essentially, there are slight differences between the percentage of sites found in the fluvially derived soil types (FC, Fy and Fz) compared with the higher elevation Cretaceous soils (C4a, C4b, C5a, C5c, and several others). The early Upper Paleolithic sites are found in higher diversity of modern soil types, possibly indicating that with easy access to the river this character was less important. The majority of Middle Paleolithic sites are found either in colluvium (FC) of the vallons, or in the C4b class, which is found at moderate elevations upslope from the dry valleys. This pattern also holds for most of the other site types, possibly indicating that these were preferred locations regardless of other constraints. The FC class, for instance, encompasses almost all of the cave and rockshelter sites in the region. However, the most striking difference lies in the diversity of soil types represented in the Upper Paleolithic sample. The soil class distributions between the Middle and Upper Paleolithic can be significantly distinguished from a random sample (Table 5-8), although not among the smaller scaled techno-complex distinctions. Although, with several classes having low expected or observed values ($n < 5$) these tests must be regarded as flawed.

Correlations between proximity to water, either rivers or natural springs, and techno-complex were also explored. This was measured on raster images representing distance to the nearest major rivers (the Vézère and the Dordogne). These calculations were created with both the Euclidean distance (straight-line) and slope weighted distance, which estimates difficulty of travel. For these variables, Middle Paleolithic sites were located significantly further (Table 5-4) from the river than the early Upper Paleolithic in both the Euclidean (Figure 5-8; Table 5-3; MP mean = 2.5 km; UP mean = 1.02 km) and slope weighted measures (MP mean = 8.24; UP mean = 3.6). For slope weighted distance, this same pattern holds for the MP compared with the Gravettian and the Aurignacian. However, for the Euclidean distance, the MP could not be distinguished from the Gravettian. As other authors have noted a difference between Aurignacian and Gravettian settlement patterns, this may indicate a slight difference in the importance of close proximity to the river. Alternatively, it may be a question of sample size of the Aurignacian (n = 42) and the Gravettian (n = 26) or the fact that many sites have both of these techno-complexes. Despite this, there is a clear and statistically significant correlation between Upper Paleolithic and proximity to the river.

Distance to locations such as modern springs was also sampled in both Euclidean and slope-weighted distance. There were, however, no significant differences among the various techno-complexes. However, this may be because the modern springs do not serve as an accurate model for the locations of water sources during the Paleolithic. Also, the map of modern springs used to generate these data includes a few that are only accessible because of modern technology.

Visibility from sites

The amount and nature of land visible from each site may also play a role in settlement. One would expect that populations that rely on hunting would want to place settlements where they have good views of habitats occupied by their prey species. In this study, a viewshed character, was quantified in two ways: first as a raw value of the square kilometers visible within a 10-km radius and second as the percent of the visible area that is classified as "valley." Three different measures of the viewshed were taken for each, the raw (from the site point), the optimal (the best point in a 200 meter radius), and the cumulative (a binary sum of all viewsheds within 200 meters). All of these analyses were also run on a sample that filtered out areas that were greatly topographically different from the site point (i.e. plateau regions that fell within the 200-m radius of a valley site). There were no significant differences between these two analyses, so these filtered results will not be discussed further.

For the raw viewshed, the area visible measurement shows no significant differences either between the Middle and Upper Paleolithic or among the various techno-complexes (Table 5-4). Viewshed from a point is highly contingent on local topography, so these values are likely inaccurate representations of true visibility from the site. However, there are also no significant relationships for the optimal viewshed, though it is worth noting that the variance of this measurement is much smaller than for the raw measure (Table 5-3). There is a significant difference between the Middle and Upper Paleolithic for the area visible using the optimal viewshed measure. From this value alone it is unclear whether this is a true pattern or simply a product of the Middle Paleolithic sites being located at significantly higher elevations (Table 5-4). Additionally, this measure does yield much higher values than the others because it codes any pixel in the final image that is visible from any point in the original area as visible. Thus, unlike the raw and optimal viewsheds, it is not an accurate measure for an individual observer. It may, however, be a better approximation of the potential visibility for a group living at a specific location. The fact that the MP has a significantly higher value for this character could indicate that finding locations with a good view of the surrounding terrain was an important part of their settlement strategy. This would be important for groups that do not rely on predictable resources. In contrast, if UP settlement was more strongly focused on predictable resources, a good overview of the landscape from the site itself may not have been as important a control.

While the raw viewshed does illustrate some interesting patterns, the type of land visible from the site may also reflect important resources. Here this character is quantified as the percent of the total area classified as "valley." It should be noted that the valley/plateau classification is binary, so lower values indicate a higher visibility of the plateau. For all three measures of viewshed the Upper Paleolithic looks upon significantly higher percentages of the valley (Figure 5-9; Table 5-4). The inverse also holds true; the Middle Paleolithic sites overlook significantly higher percentages of the plateau. This result may again be driven by site location as there are more known MP sites on the plateau. However, if Upper Paleolithic settlement is indeed focused on extracting resources from the area around the valley, this is the pattern that one would expect. The values for the Middle Paleolithic show a higher percentage of plateau visibility, but still with a relatively large (~25%) component of valley visible. This finding holds with a theory that MP settlement is optimally located to exploit multiple environments. The focus does appear to be on the plateau regions, but areas that maximize views of both classes may have also been attractive.

e. Summary of results

To summarize, the observed pattern shows Middle Paleolithic sites at significantly higher elevations and at significantly lower average and absolute slopes than the early Upper Paleolithic. In this region, there is almost certainly correlation between these variables because of the high cliffs along the edges of most vallons. For both measures of distance to river and distance to fords, the overall eUP (and the Aurignacian) are significantly closer than the MP, while the Gravettian and Châtelperronian are not statistically distinguishable from either group. Modern spring sources do not appear to be a useful predictor of any Paleolithic group. For the measurements of viewshed, there are no differences in the total area visible from the site point or the optimal point within a 200-meter radius. The Middle Paleolithic does have a significantly larger cumulative viewshed than the total Upper Paleolithic, the Aurignacian and the Gravettian sample. But, using the valley percentage as a proxy of type of visible landcover, the eUP looks upon significantly greater proportions of the river and its valleys than the MP for all three viewshed measurements.

Only the modern vegetation classes are different from random among the smaller techno-complexes. For the soil classification (Table 5-5), the early Upper Paleolithic sites are located in a wide diversity of soils, while the Middle Paleolithic sites are more often found in a few types. This same pattern is shown in the modern, satellite derived, landcover classification (Table 5-6). In contrast, early Upper Paleolithic sites as individual points are more likely to be found in single modern vegetation zone (flat areas), but this pattern disappears when the average around the site is examined (Table 5-7).

f. Results of statistical tests using total data set

Isolating significant differences in individual landscape variables provides insight into important settlement factors, but it ignores almost certain correlation between these variables. For instance, in the Vézère Valley, and in most areas with a similar topography, the flat, high elevation, plateaus drive a significant negative correlation between elevations and slope. Thus, a finding that Middle Paleolithic site locations have both significantly higher elevations and significantly lower slopes may be tracking a trend in the landscape more than a trend in the settlement strategy. Statistical tests to examine the potential of correlation between variables must be employed to address this possibility. Here, a Maximum Entropy analysis was used to model which individual factors most strongly control the patterns found in the Middle and Upper Paleolithic samples. Most of the previously discussed topographic and classification variables were included (see Table 5-9). A notable exception from the included variables are the viewshed measurements. MaxEnt requires gridded raster inputs at an identical resolution. To use viewshed as a variable one would need to calculate a viewshed for each of the 2 million pixels of the DEM used in this study. Additionally, only the difference between the Middle and early Upper Paleolithic was analyzed. This is because of the small sample size of the MTA and Châtelperronian samples and the high incidence of Aurignacian and Gravettian material from the same site.

The MaxEnt analysis generates both a map of optimal "habitats" (Figures 5-10 and 5-11) and a histogram of the relative effect of each variable on the final model when is excluded or run in isolation (Figure 5-12). The percentage contribution of each can also be determined (Figure 5-13), but it is important to note that these measures are not scaled (i.e. a high importance for modern vegetation density does not imply higher density areas are preferred); it could just as easily be low values that are important.

For the early Upper Paleolithic elevation is the single strongest predictor variable, with distance to rivers, soil type and slope all playing significant roles. In this model, the exclusion of any of these variables does not greatly reduce its accuracy (Figure 5-12). For the MP, soil type has the largest single contribution, with distance to rivers, landcover class and elevation playing significant roles. Here, the removal of soil type does dramatically reduce the accuracy of the final model. In neither sample does the modern vegetation zone nor the vegetation density play an important role.

The MaxEnt study supports many of the patterns seen in the analyses of individual landscape characters. First, proximity to rivers in the early Upper Paleolithic is ranked as the most important. This character also contributes to the Middle Paleolithic model. In this case it is likely because the analysis does not interpret the direction of these data. The analysis will rank high values as valuable, even though this layer represents distance and higher values are indicative of unimportance. The importance of soil type for both techno-complexes also fits with the categorical data. The model accuracy decreases when this variable is removed from the MP analysis, supporting the observed pattern of MP sites in individual soil types. The importance of elevation to modeling UP site location may simply be a product of proximity to rivers. Support for this comes from the sustained accuracy of the UP model when either of these characters is excluded. Graphically, the two maps of ideal locations for MP (Figure 5-10) and eUP (Figure 5-11) sites present this point very well. Middle Paleolithic sites are predicted to be found across the landscape, both on the plateau and in the valleys. Upper Paleolithic sites, in contrast, are strongly controlled by the low elevation areas immediately next to the river.

g. Conclusions

The preceding work has demonstrated that there is significant spatial patterning in site location during the Paleolithic of the Vézère Valley. The distribution of Middle Paleolithic sites differs significantly from that of early Upper Paleolithic sites. Taphonomic components of this patterning can never be totally eliminated. But, a series of direct comparisons between proxies for post-depositional disturbance and site visibility do not reveal significant differences between the site distribution and random, though spatially constrained, samples. A multi-variate, maximum entropy analysis also shows that these characters are relatively unimportant for predicting site locations.

It then seems valid that the patterns seen in site location between the Middle and early Upper Paleolithic represent a suitable sample to discuss land-use and settlement patterns. In the Vézère Valley there is a strong pattern of early Upper Paleolithic sites located at low elevation caves and rockshelters near the river. Middle Paleolithic sites are more widely dispersed on the landscape, but show ties to particular soil and landcover types. The visible landscape from each type of site also reflects this pattern, with Middle Paleolithic sites viewing an overall larger area and particularly with good views of the plateau regions. Early Upper Paleolithic sites have slightly lower total visible areas, but a higher proportion of the river valley visible from any given site, even when potentially erroneous plateau values are excluded. This trend fits well with preexisting models of a shift in subsistence strategy between the exploitation of many biomes in the Middle Paleolithic to a focus on individual resources during the early Upper Paleolithic.

However, these analyses are only as accurate as the data they are built on. The patterns discussed in this chapter are statistically valid and fit well with previously collected data. But, there remains a real possibility that the spatial distribution of known sites is biased because the modern topography is not an acceptable analog for the Paleolithic landscape. To help address this issue, the following chapter discusses a detailed study of possible taphonomic effects in a constrained sector of the study area.

Figures and Tables: Chapter 5

Table 5-1: The known distribution of sites falling into three binary proxies for taphonomic influence (modern vegetation density, areas of fluvial action and modern use) compared to five randomly distributed, but proportionally equal, samples. Significant differences are shaded (NDVI = t-tests, Sediment and Landcover = χ^2).

		NDVI		**Sediment**		**Landcover**	
		Mean	**T-test *p***	**Fluvial**	**Others**	**Artificial**	**Natural**
Total Sample **n = 99**	Observed	143	0.16	30	69	5	94
	Random 1	146	0.28	32	67	1	94
	Random 2	147	0.11	31	68	1	98
	Random 3	146	0.4	28	71	3	96
	Random 4	147	0.11	32	67	0	99
	Random 5	145	0.52	21	78	0	99
Middle Paleolithic **n = 48**	Observed	138		12	36	2	46
	Random 1	147		16	32	0	48
	Random 2	146		14	34	1	47
	Random 3	145		14	34	1	47
	Random 4	145		17	31	0	48
	Random 5	147		9	39	0	48
Early Upper Paleolithic **n = 51**	Observed	149		18	33	3	48
	Random 1	146		16	35	1	46
	Random 2	149		17	34	0	51
	Random 3	146		14	37	2	49
	Random 4	150		15	36	0	51
	Random 5	143		12	39	0	51

Table 5-2: The known distribution of sites and five randomly distributed, but proportionally equal, samples falling into three binary proxies for taphonomic influence (modern vegetation density, areas of fluvial action and modern use) compared to the mean values for the entire study area. Significant differences are shaded (NDVI =t-tests, sediment and landcover = Fisher's exact test).

	NDVI	**Sediment**			**Landcover**		
	t-test	**Fluvial**	**Others**	**Fisher**	**Artificial**	**Natural**	**Fisher**
Study Area	142 .76	29.98	69.12		1.53	97.47	
Observed	$p < 0.01$	30	69	n.s.	5	94	$p < 0.01$
Random 1	$p < 0.001$	32	67	n.s.	1	94	n.s.
Random 2	$p < 0.01$	31	68	n.s.	1	98	n.s.
Random 3	$p < 0.05$	28	71	n.s.	3	96	$p < 0.05$
Random 4	$p = 0.07$	32	67	n.s.	0	99	n.s.
Random 5	$p < 0.001$	21	78	$p < 0.01$	0	99	n.s.

Table 5-3: Mean and variability values for each of the landscape measures organized by techno-complex

	Middle Paleolithic		Early Upper Paleolithic		MTA		Châtelperronian		Aurignacian		Gravettian	
	Mean	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
Elevation at Point	135.00	0.39	90.00	0.26	110	0.34	99.00	0.29	88.00	0.23	90	0.24
Elevation Mean	134.75	0.37	94.46	0.24	108.99	0.32	103.93	0.27	92.50	0.22	95.56	0.24
Elevation CV	0.13	0.84	0.22	0.40	0.17	0.51	0.18	0.32	0.23	0.35	0.23	0.43
Slope at Point	9.81	0.86	14.14	0.47	12.61	0.69	11.60	0.46	14.36	0.46	14.91	0.37
Slope Mean	8.08	0.50	11.21	0.26	9.86	0.31	10.64	0.32	11.41	0.24	11.16	0.25
Slope CV	0.54	0.26	0.54	0.19	0.53	0.17	0.53	0.13	0.55	0.18	0.55	0.19
Aspect at Point[1]	86.72	58.7	94.38	54.99	52.9	74.22	99.48	46.04	97.38	52.46	121.45	48.03
Aspect Angular Mean[1]	184.58	58.58	149.18	48.63	212.98	69.32	171.04	48.6	158.59	48.46	120.64	49.04
Aspect Angular Variance	2.50	0.89	1.02	1.68	1.65	1.22	1.69	1.13	0.93	1.65	1.31	1.60
Distance to river	8.24	0.78	3.60	1.14	5.02	1.09	5.45	0.86	3.37	1.08	4.04	1.19
Weighted distance to river	0.83	0.70	0.90	0.80	1.14	0.62	0.79	0.83	0.91	0.79	0.86	0.88
Euclidean dist to springs	3.59	0.65	3.52	0.63	4.13	0.55	3.20	0.73	3.59	0.63	3.32	0.66
Weighted dist to springs	2.50	0.89	1.02	1.68	1.65	1.22	1.69	1.13	0.93	1.65	1.31	1.60
Distance to all fords	2.79	0.84	1.36	1.29	1.83	1.20	2.00	0.94	1.30	1.20	1.66	1.28
Weighted distance to all fords	8.89	0.73	4.29	1.00	5.99	1.05	6.30	0.84	4.10	0.95	4.86	1.05
Distance to known fords	4.52	0.83	2.26	1.04	4.01	0.92	2.89	1.06	2.13	1.03	2.47	0.95
Weighted dist to known fords	11.79	0.64	6.09	0.78	9.74	0.71	7.64	0.79	5.78	0.77	6.55	0.78
Viewshed Area from Point	4.93	1.08	3.38	0.67	4.13	0.56	2.56	0.89	3.51	0.65	3.44	0.67
Visibility Index from Point	3.33	0.84	2.72	0.69	2.92	0.71	2.04	0.74	2.81	0.68	2.78	0.72
Viewshed Mean[2]	0.76	0.42	0.70	0.46	0.81	0.46	0.85	0.51	0.71	0.46	0.67	0.48
Viewshed CV	0.62	0.45	0.83	0.13	0.73	0.30	0.82	0.15	0.84	0.12	0.82	0.13
Optimal Viewshed Area[2]	10.48	0.66	7.81	0.47	10.03	0.50	6.98	0.38	8.00	0.45	7.57	0.49
Visibility Index from Optimal[2]	0.56	0.45	0.73	0.19	0.70	0.23	0.68	0.19	0.75	0.15	0.72	0.24
Cumulative Viewshed Area[2]	14.54	0.63	10.31	0.42	12.63	0.42	9.80	0.37	10.58	0.40	9.75	0.43
Visibility Index Cumulative[2]	0.58	0.38	0.73	0.18	0.70	0.21	0.70	0.17	0.74	0.12	0.71	0.21

1: For this measurement, columns labeled StDev report angular variance

2: The filtered version of this measure (see Appendix B) exhibited the same patter so it is excluded from this table but the raw values can be found in Appendix A.

Table 5-4: Pairwise comparisons between the techno-complexes. Each significant difference is shaded and the significantly greater techno-complex is marked with the column ID of the smaller.

	Middle Paleolithic	**Upper Paleolithic**	**MTA**	**Châtelperronian**	**Aurignacian**	**Gravettian**
Sample n =	**48**	**51**	**9**	**13**	**41**	**26**
Column ID	**A**	**B**	**C**	**D**	**E**	**F**
Elevation at Point	B D E F					
Elevation Mean: 200 m Radius	B D E F					
Elevation CV: 200 m Radius		A			A	A
Slope at Point		A			A	A
Slope Mean: 200 m Radius		A		A	A	A
Slope CV: 200 m Radius						
Euclidean Distance to River	B E F					
Slope Weighted Distance to River	B E F					
Euclidean Distance to Springs						
Slope Weighted Distance to Springs						
Euclidean Distance to Fords	B E					
Slope Weighted Distance to Fords	B E F					
Viewshed from Point (m2)						
Viewshed Mean (m2): 200 m Radius						
Viewshed CV: 200 m Radius						
Visible from Point: Percentage "Valley" Class		A		A	A	A
Optimal Viewshed: 200 m Radius	B D E F					
Visible from Optimal: Percentage "Valley" Class		A			A	A
Cumulative Viewshed: 200 m Radius	B D E F					
Visible from Cumulative: Percentage "Valley" Class		A			A	A

Table 5-5: Percentages of sites and cells surrounding sites falling into each of the soil types

	FC	Fy	Fz	A	C4a	C4b	C5a	C5c	Other	N (Others)
Individual Points										
MP	23.53	1.96	9.80	0.00	0.00	56.86	7.84	0.00	---	---
eUP	12.50	4.17	2.08	6.25	6.25	45.83	18.75	4.17	---	---
MTA	11.11	0.00	0.00	0.00	0.00	77.78	11.11	0.00	---	---
Châtelperronian	15.38	7.69	7.69	0.00	0.00	61.54	7.69	0.00	---	---
Aurignacian	21.43	2.38	9.52	0.00	0.00	59.52	7.14	0.00	---	---
Gravettian	30.77	8.85	11.53	0.00	0.00	42.01	11.54	0.00	---	---
Area Surrounding										
MP	14.43	1.73	21.56	0.13	0.00	45.74	15.51	0.00	0.90	3
eUP	7.53	2.19	13.22	5.92	3.71	35.76	24.00	2.33	4.94	6
MTA	11.74	0.00	15.82	0.00	0.00	57.06	15.38	0.00	0.00	0
Châtelperronian	16.96	3.99	20.82	0.52	0.00	46.12	11.58	0.00	0.00	0
Aurignacian	14.73	2.10	21.86	0.16	0.00	45.89	14.23	0.00	1.02	1
Gravettian	12.45	2.53	22.07	0.00	0.00	44.44	17.38	0.00	1.13	2
Entire Study Area										
	6.65	1.36	5.95	14.16	1.19	10.81	23.42	13.38	23.06	

Table 5-6: Percentages of sites and cells surrounding sites falling into each of the Corine landcover classes

	Discontinuous urban fabric	Non-irrigated arable land	Pastures	Complex cultivation	Agriculture and natural	Broad-leaved forest	Mixed forest	Transitional woodland
Individual Points								
eUP	4.17	2.08	8.33	39.58	4.17	33.33	6.25	2.08
MP	5.88	1.96	3.92	17.65	1.96	68.63	0.00	0.00
Aurignacian	4.76	2.38	4.76	16.67	2.38	69.05	0	0
Châtelperronian	0.00	0.00	7.69	23.08	7.69	61.54	0	0
Gravettian	11.54	0.00	3.85	23.08	0.00	16.00	0	0
MTA	0	0	11.11	33.33	0.00	55.56	0	0
Area Surrounding								
eUP	3.83	4.84	9.27	36.59	4.25	31.60	7.64	2.00
MP	5.93	9.15	6.70	15.40	3.08	58.80	0.93	0.00
Aurignacian	5.42	10.32	7.65	13.45	2.95	59.61	0.59	0.00
Châtelperronian	0.00	5.08	9.24	17.74	6.90	59.13	1.91	0.00
Gravettian	6.37	7.24	8.11	19.73	3.18	53.53	1.83	0.00
MTA	2.20	6.21	11.68	24.98	0.00	51.16	2.76	1.00
Entire Study Area								
	0.73	3.69	11.84	22.10	1.45	47.53	10.35	1.36

Table 5-7: Percentages of sites and cells surrounding sites falling into each of the modern vegetation zones

	Flat Areas	South Facing Slopes	North Facing Slopes
Individual Points			
MP	75.00	14.58	10.42
eUP	90.20	9.80	0.00
MTA	55.56	22.22	22.22
Châtelperronian	76.92	23.08	0.00
Aurignacian	92.86	7.14	0.00
Gravettian	88.46	11.54	0.00
Area Surrounding			
MP	78.48	12.76	8.76
eUP	79.33	13.68	6.99
MTA	72.44	17.70	9.86
Châtelperronian	74.10	21.87	4.03
Aurignacian	79.65	13.95	6.40
Gravettian	77.95	13.87	8.18
Entire Study Area			
	77.34	11.81	10.85

Table 5-8: Significance values for comparisons among the observed and expected distribution of soil type, Corine landcover classification and modern vegetation zone. X^2 and Fisher's exact test. Significant differences are shaded.

	Test	Corine: Points	Corine: Average	Modern Vegetation: Points	Modern Vegetation: Average	Soils: Points	Soils: Average
eUP vs MP	χ^2	0.009	0.43	0.04	0.04	0.013	0.03
	Fisher	0.007	---	0.03	---	0.018	---
Among Others	χ^2	0.91	0.54	0.003	0.06	0.94	0.85
	Fisher	0.87	---	0.02	---	0.91	---

Table 5-9: Number and percentage of sites near natural fords in this data site and compared with the values found by White 1985

	Sites within 1 km of a natural ford		Percent of total	
	Current Project	**White 1980**	**Current Project**	**White 1980**
MP	18 / 48	---	37.5	---
eUP	31 / 51	---	60.78	---
MTA	5 / 9	---	55.56	---
Châtelperronian	5 / 13	7 / 15	38.46	31.82
Aurignacian	25 / 41	33 / 62	59.52	53.23
Gravettian	16 / 26	23 / 42	61.54	54.76

Table 5-10: Variables used in MaxEnt analysis

Data Layer	Data type	Code
Euclidean distance to rivers	Continuous	distrivers
Elevation as a raster DEM	Continuous	elevation
Elevation re-sampled as a measure of variation within 200 m	Continuous	elevationstd
Euclidean distance to fords (known and estimated)	Continuous	fordsed_raw
The Corine landcover classes	Categorical	landcover
The number of landcover classes within 200 meters	Categorical	landcoverfreq
NDVI from Landsat imagery	Continuous	ndvi
Slope calculated from raster DEM	Continuous	slope
Slope re-sampled as a measure of variation within 200 m	Continuous	slopestd
Soil classes from digitized BRGM soil maps	Categorical	soils
The number of soil classes with 200 m	Categorical	soilsfreq
Topographically derived modern vegetation zones	Categorical	veg3class
The number of vegetation zones with 200 m	Categorical	veg3freq

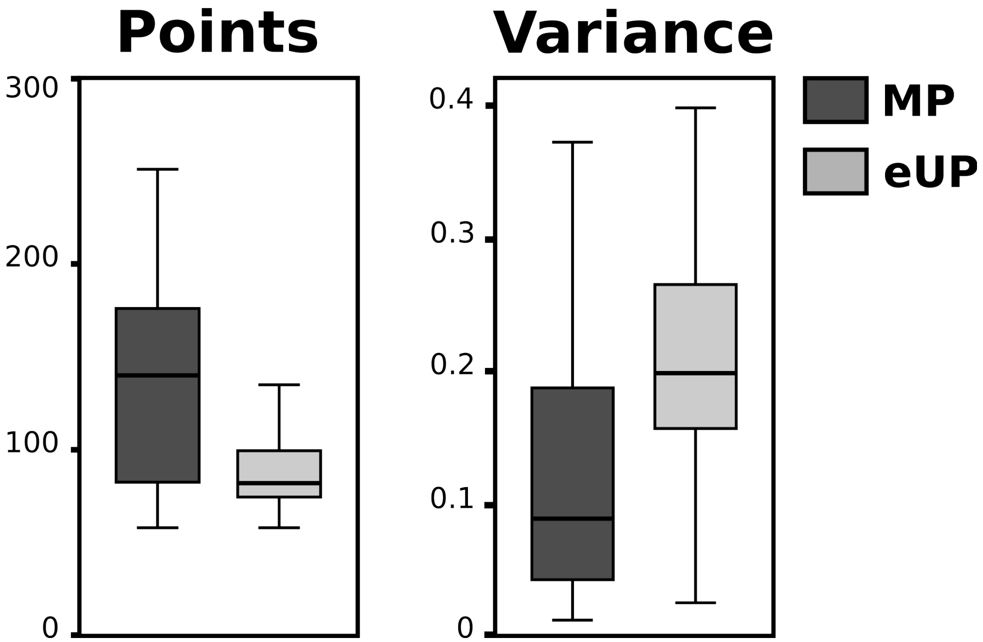


Figure 5-1: Box and whisker plot of the elevation values for all MP and eUP sites (left) and the coefficient of variance for a sample of the landscape around each site (right). In both cases, the difference is significant at $p < 0.05$. Summary data are found in Table 5-3.

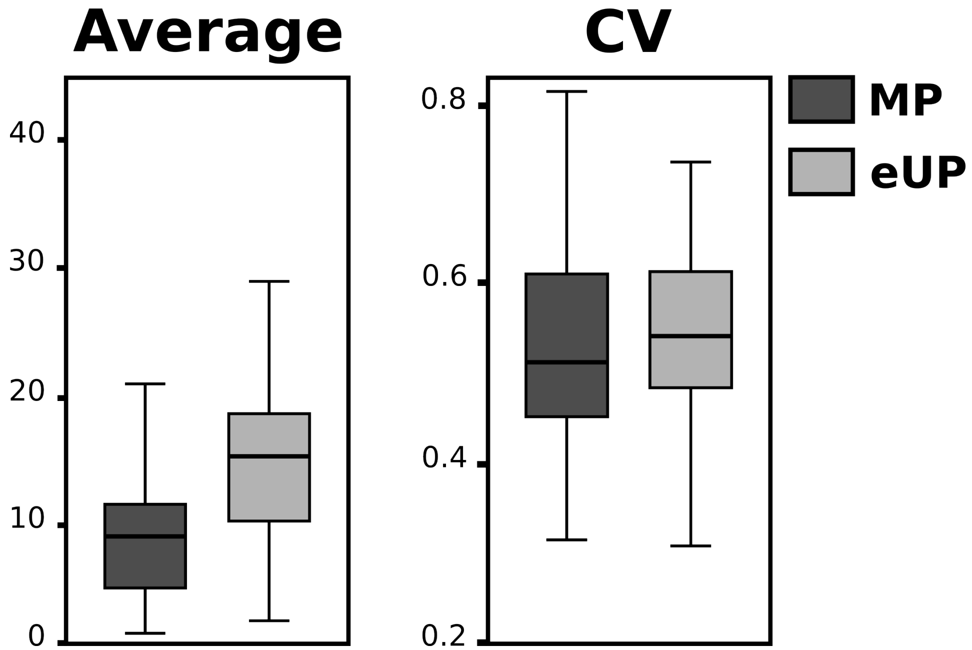


Figure 5-2: Box and whisker plot of the the average slope surrounding the sample of MP and eUP sites (left) and the coefficient of variance for the same area (right). Only the mean value is significant at $p < 0.05$. Summary data are found in Table 5-3.

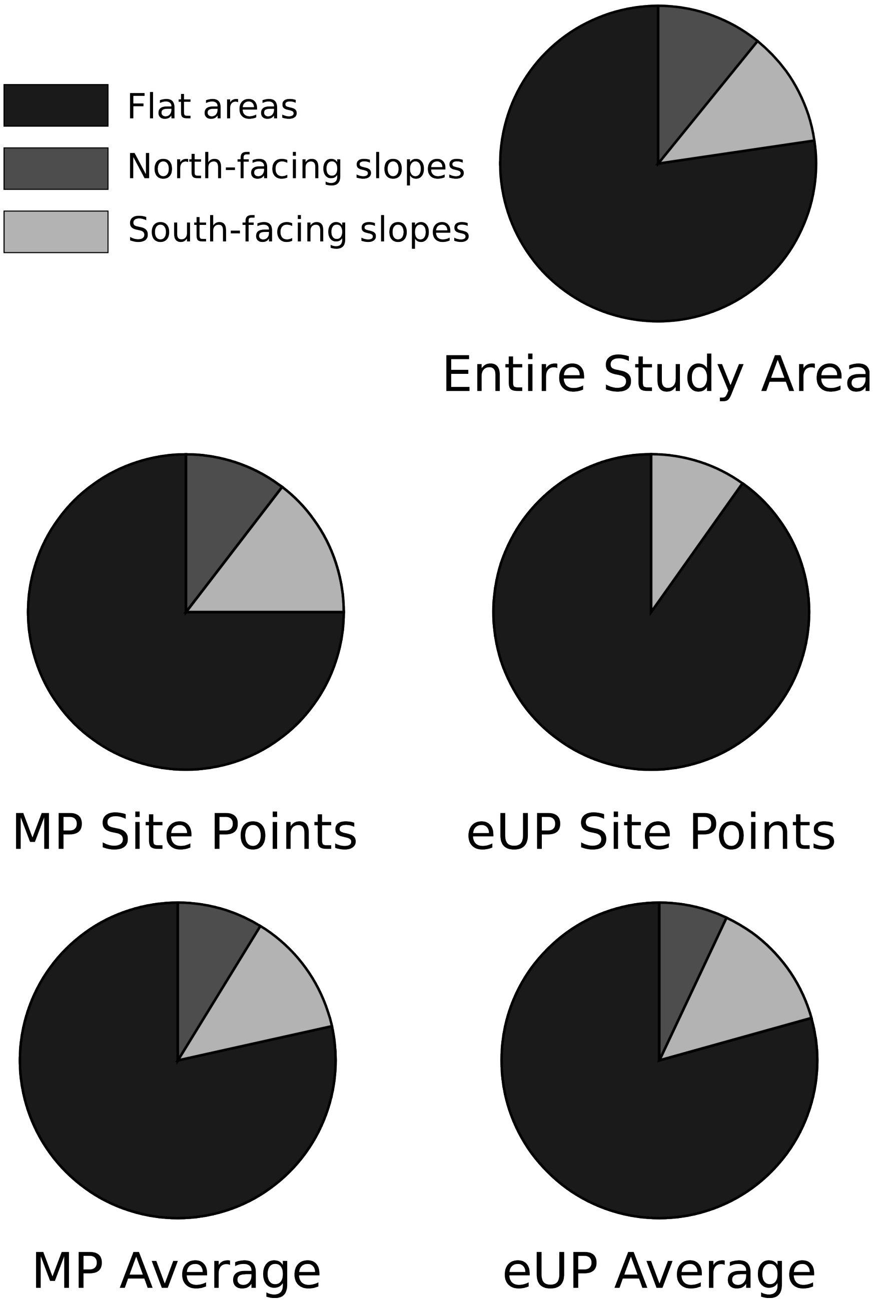


Figure 5-3: Pie charts showing the division of the modern vegetation classes for the entire study area, the sample of MP and eUP sites, and the average values surrounding each site. A tabular view of these data is presented in Table 5-7.

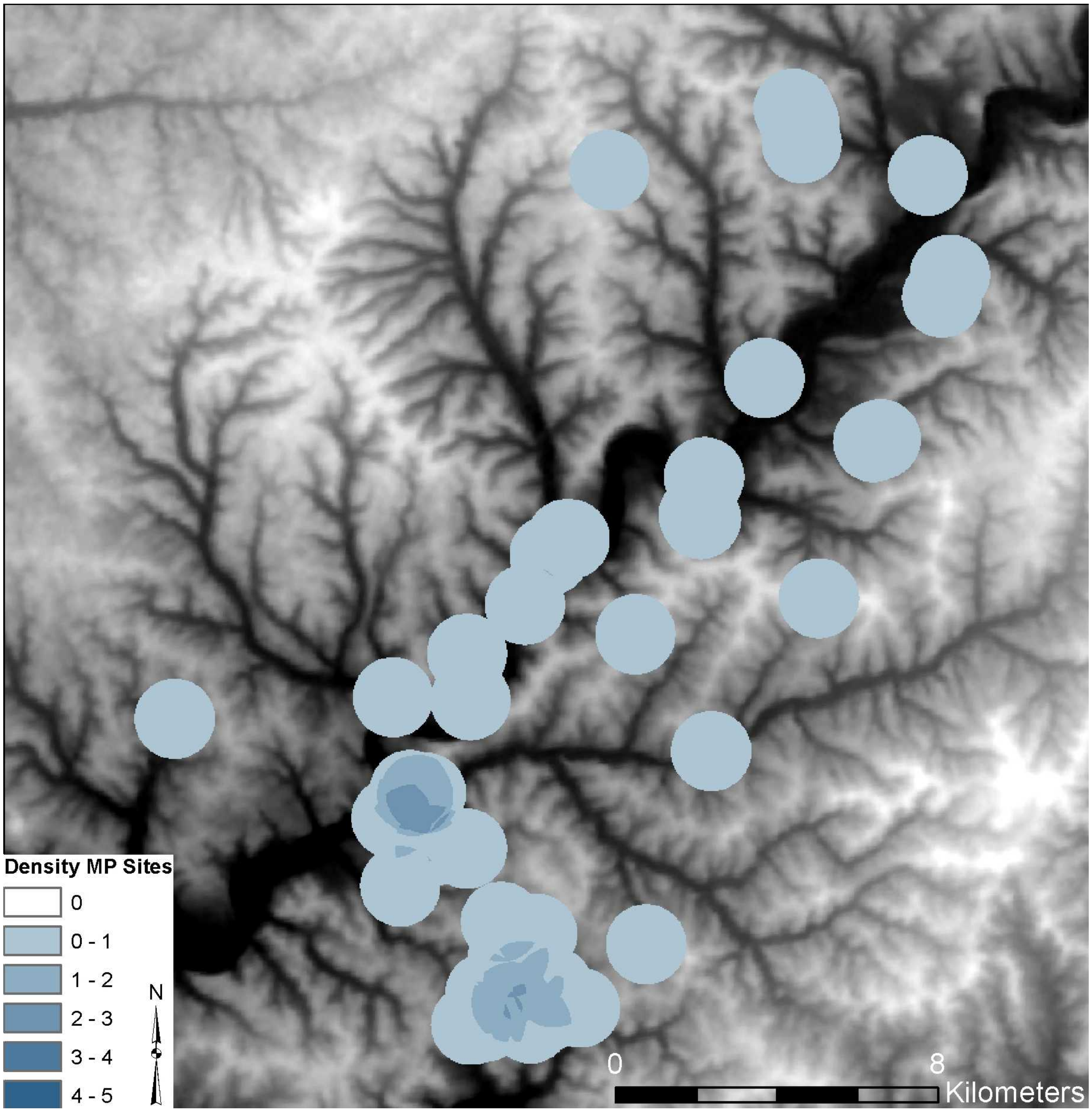


Figure 5-4: Density of Middle Paleolithic sites in the Vézère Valley

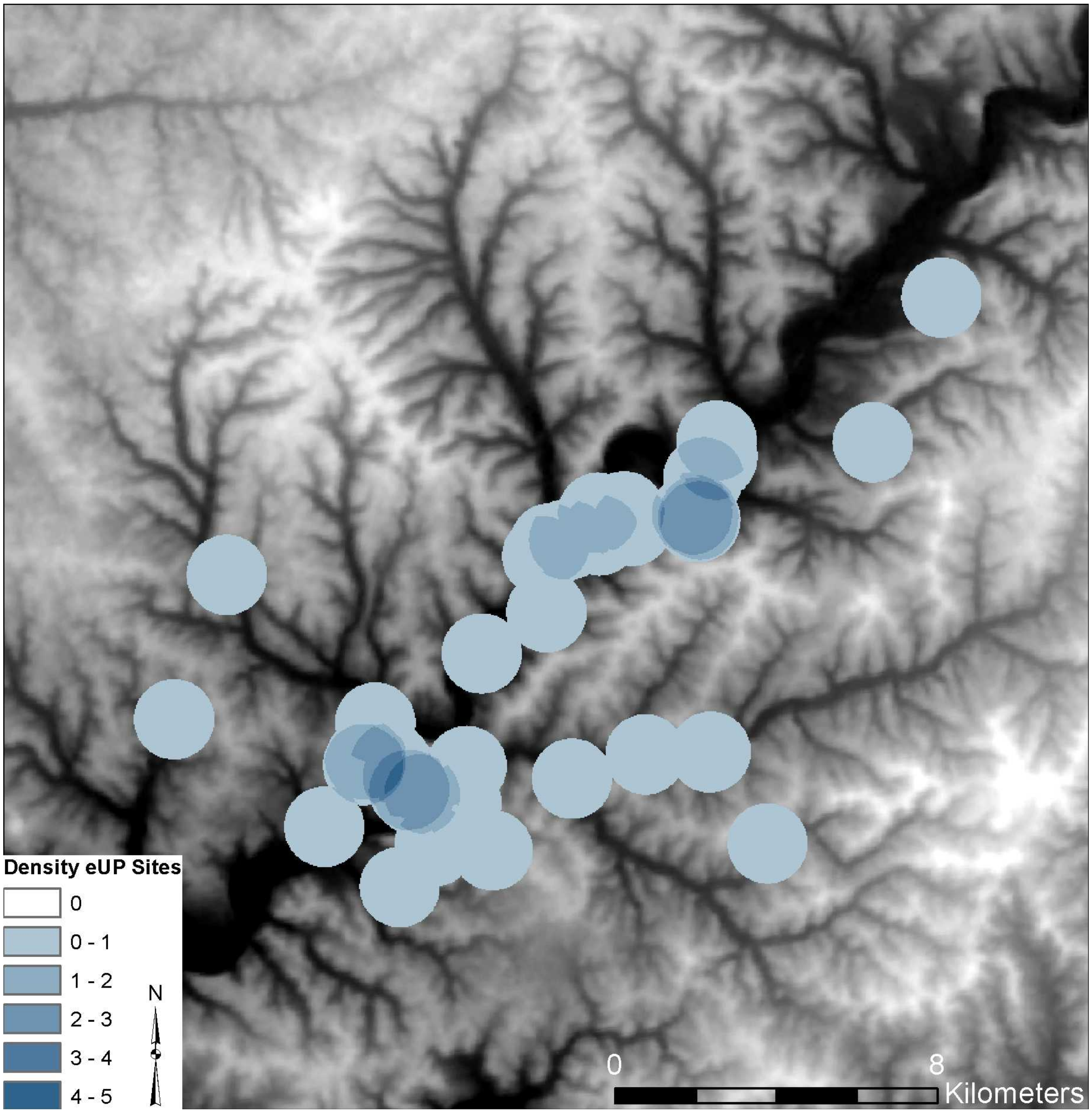


Figure 5-5: Density of Early Upper Paleolithic sites in the Vézère Valley

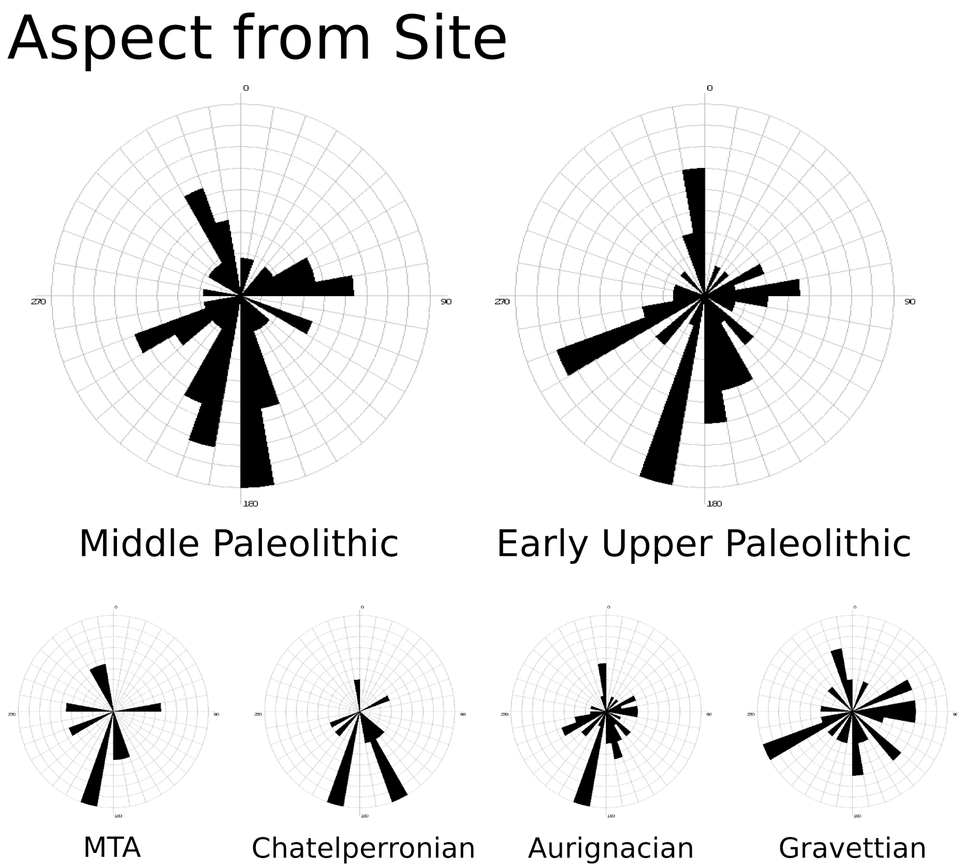


Figure 5-6: Rose Diagrams of the aspect from each site point organized by techno-complex

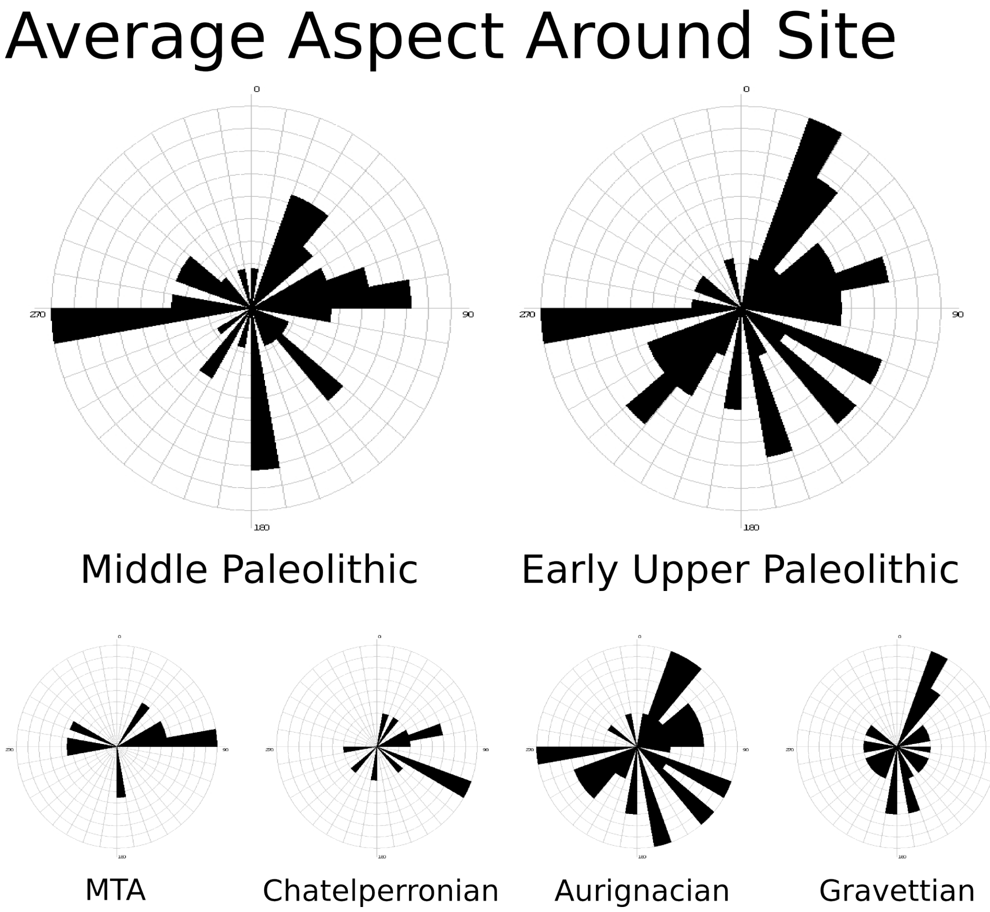


Figure 5-7: Rose Diagrams of the angular mean in a 200 meter radius around each site point organized by techno-complex

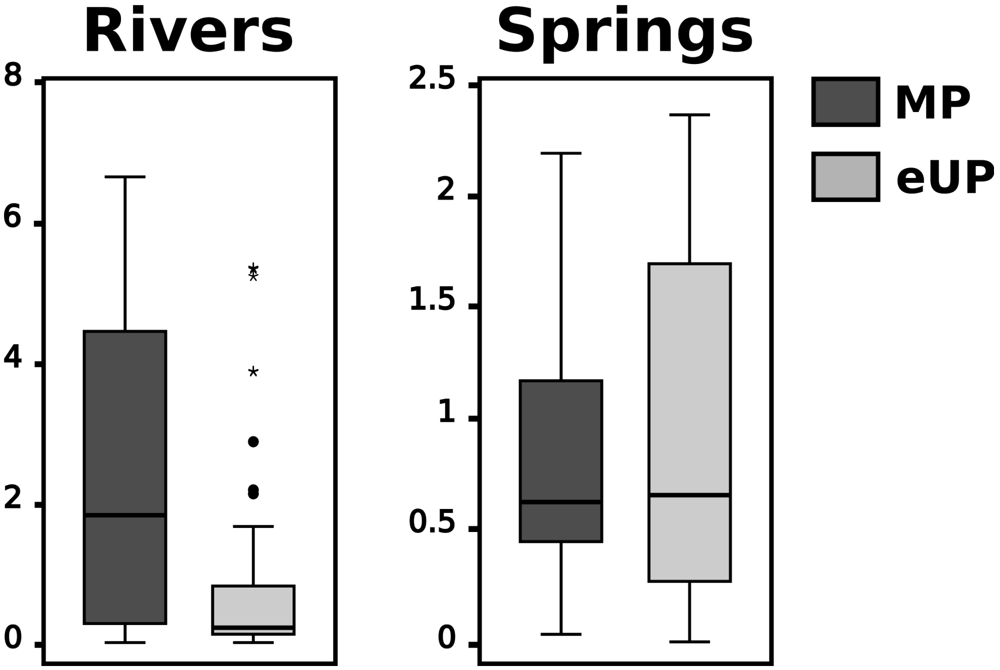


Figure 5-8: Euclidean distance from MP and eUP sites to river (left) and natural springs (right). The difference between MP and eUP is significantly different for distance to rivers, but not for distance to springs. Note that distance to natural fords in not presented, but the relationship is nearly identical to that of the distance to rivers. Summary data are found in Table 5-3.

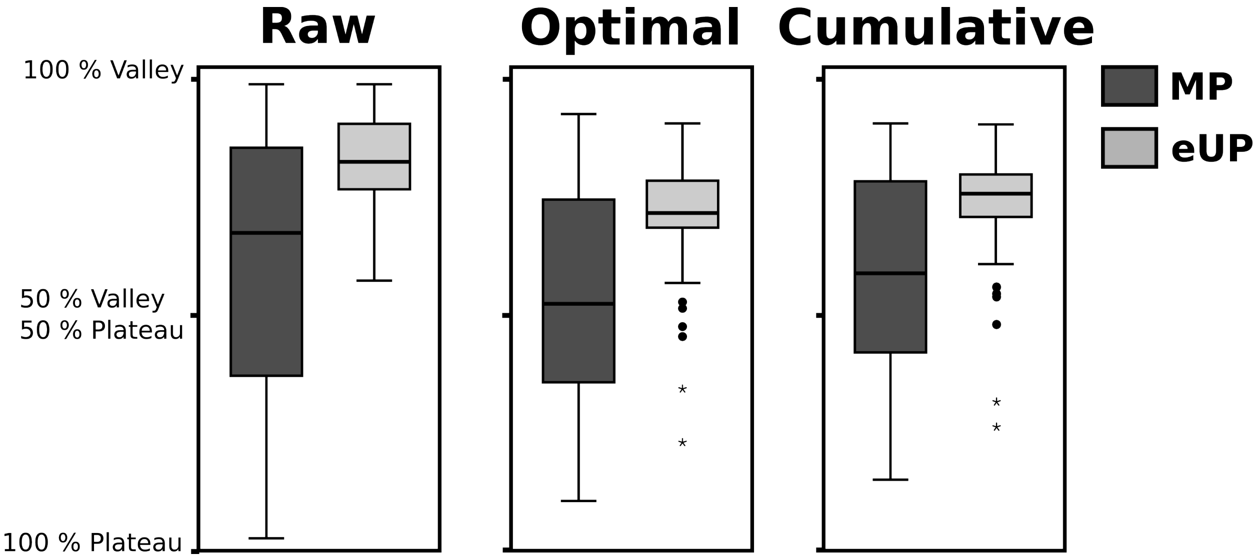


Figure 5-9: The distribution of landscape types visible from the sample of MP and eUP sites for each of the three viewshed measures. In all cases the eUP looks upon significantly higher percentages of the valley.

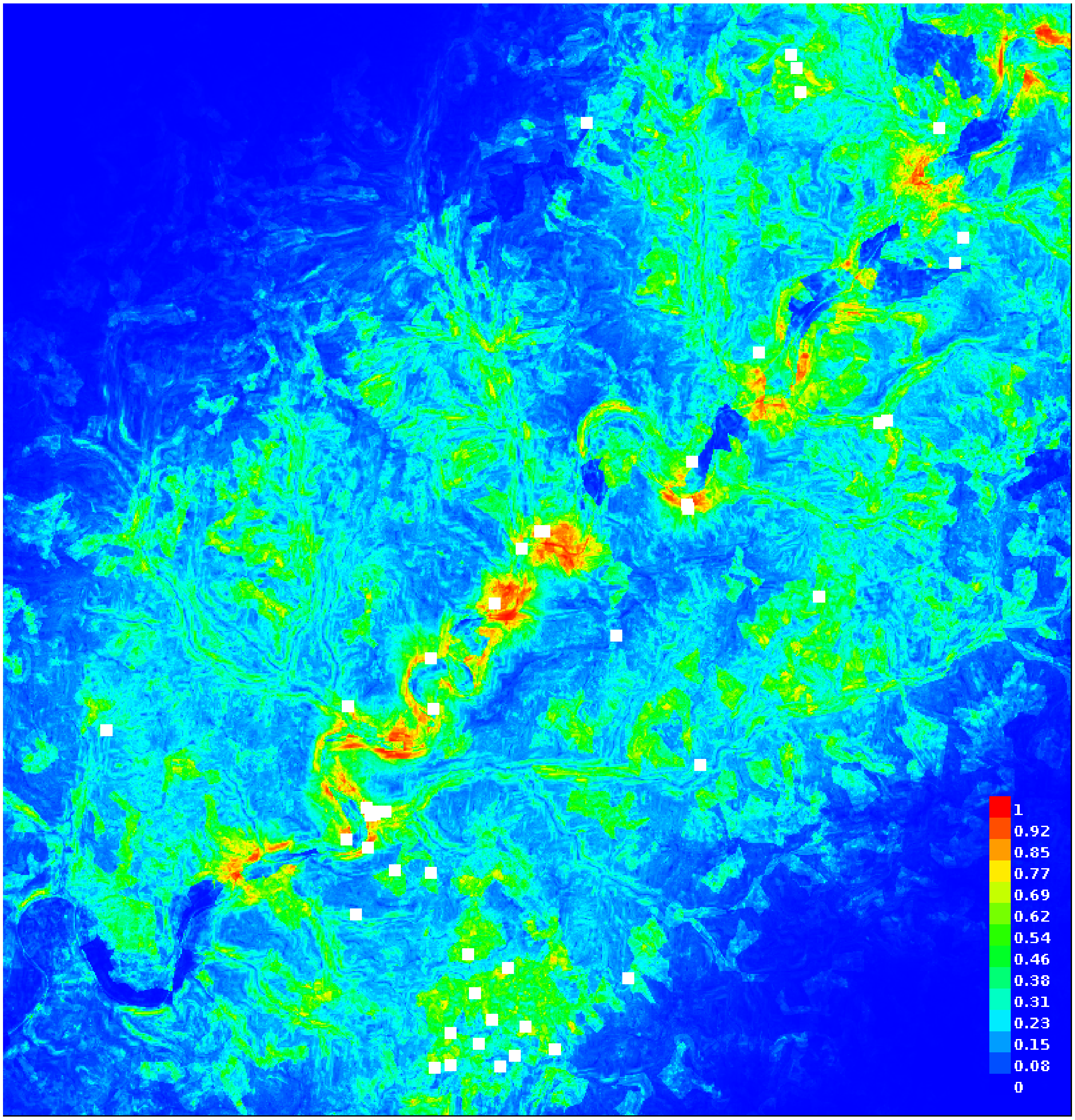


Figure 5-10: Results of MaxEnt analysis for the Middle Paleolithic. Warmer colors indicate a more suitable habitat. White points are sites used to create the model.

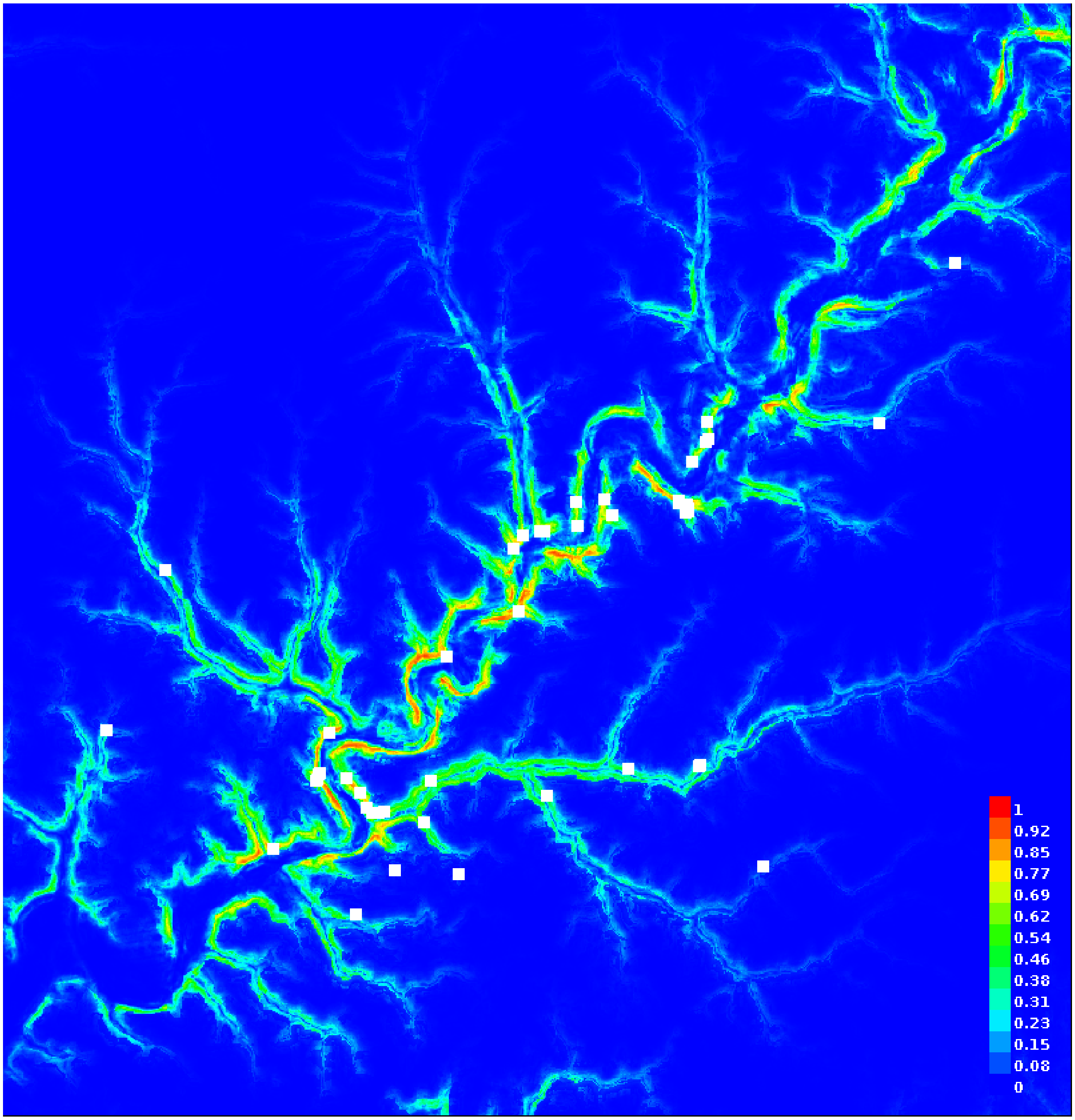


Figure 5-11: Results of MaxEnt analysis for the early Upper Paleolithic. Warmer colors indicate a more suitable habitat. White points are sites used to create the model.

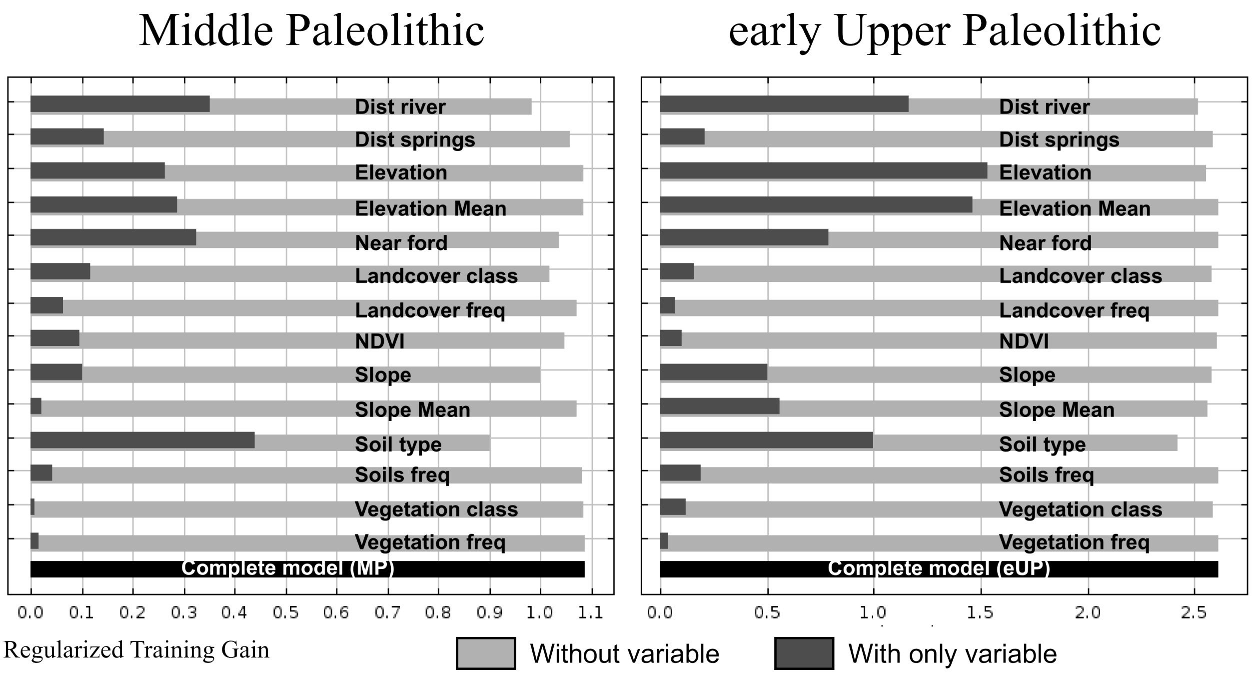


Figure 5-12: Relative importance of environmental variables to the MaxEnt model: Jackknife test of variable importance showing how well the model functions with each variable excluded and in isolation measured by the regularized training gain.

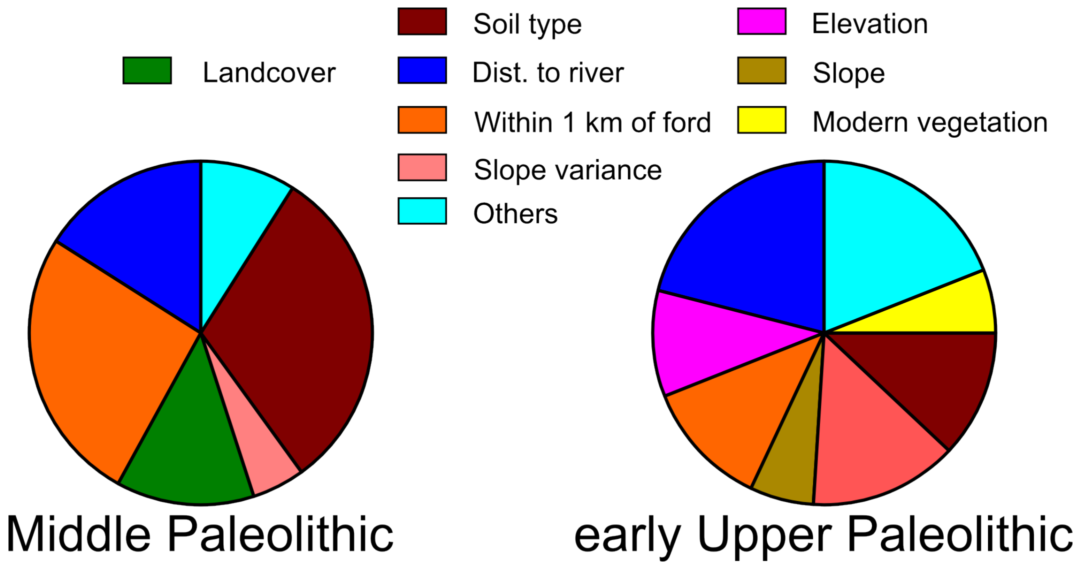


Figure 5-13: Pie charts showing the total contribution of each variable to the MaxEnt models. Variables in the center contribute more than 10 % to both models.

Chapter 6: Case Study: The Castel-Merle Vallon

a. Introduction and aims of project:

This chapter reports on an in-depth case study in and around the Castel-Merle vallon (Figure 6-1), the location of several well-known Upper Paleolithic, and two Middle Paleolithic, occupations. As discussed in Chapter 3, there are the two main assumptions for this dissertation: that taphonomic bias is minimal and that modern topography accurately represents the Paleolithic topography. This case study was undertaken to test these assumptions, particularly the assumption of modern topography serving as an acceptable proxy for Paleolithic topography. To address this, magnetic resistivity and bedrock depth measurements were conducted in the Castel-Merle vallon and these data were incorporated into a preexisting high-resolution database of the study area's surface topography.

Study goals

The goals of this case study were twofold: first, to record the bedrock topography in relation to the surface topography, and second, to use this recreation to test the modern surface's utility as a proxy for the Paleolithic surface. This was intended not only to yield important data for this work, but also to inform the ongoing excavations at Abri Castanet about the nature of the site during its occupation. The subsurface bedrock data were then combined with excavation information to yield fuller understanding of the occupied landscape for the sites in this case study.

Excavation data from relevant Castel-Merle sites will be discussed below. But in addition, the Abri Castanet project has conducted extensive high-resolution studies of the vallon's topography, particularly along the eastern side (e.g. Gardère et al., 2008). Because all of the localization for the resistivity study used the same instruments, these data can be compared directly to the subsurface resistivity and penetrometer data yielded by the this study.

Project development

As this case study was carried out in conjunction with the Abri Castanet excavations, a brief discussion of the project development is important. Abri Castanet and several others of the Castel-Merle preserve occupations resting directly on limestone bedrock. As there is no major drop-off in front of the site, it was previously assumed that during occupation these rockshelters were at ground level and that the subsurface bedrock would largely track the modern topography.

However, test trenching in 2008 demonstrated that the bedrock plunges dramatically down from the occupation surfaces while the modern surface slopes gently down to the small channel in the center of the vallon (Gardère et al., 2008). If the vallon bedrock was largely exposed during the Paleolithic, as suggested by the occupation surfaces, this would indicate that the rockshelters were further above ground level than previously thought. Because this would be a significant change in the reconstruction of the site, remote sensing techniques for determining the depth and character of the bedrock were sought. The technique of electrical resistivity in combination with a penetrometer was eventually chosen and will be described below.

b. Overview of the Castel-Merle Vallon

The Castel-Merle Vallon (also known as the Vallon des Roches) contains eight well-known Paleolithic sites within a small side valley of the Vézère. The vallon opens to the north on the east bank of the Vézère. It is, however, located along a meander in the river, so the Vézère flows directly in front of the opening. The opening of the vallon is located at approximately 90 meters above sea level and is characterized by dramatic cliff faces on both the eastern and western sides. The floor of the vallon then slopes gradually up to the south, eventually bifurcating and reaching the plateau in two locations. Intuitively, as the vallon floor slopes upwards, the height of the cliff faces also decreases. Thus, it is only the northern 300 meters that have visible rockshelters or significant cliff faces. In the northern center is a small spring feeding into the Vézère, and this same channel serves as a drainage during high rains.

The sites in and around the Castel-Merle Vallon represent most of the Paleolithic periods relevant to this dissertation. They include Mousterian, several subdivisions of Aurignacian, Solutrean and Magdalenian (Delage, 1935). Table 6-2 contains a description of each of these sites and Figure 6-2 shows their location. Additionally, there is a strong likelihood of other unexcavated or destroyed sites in the vallon. Several locations have medieval troglodytic structures, occasionally with removed strata apparent. Also, opportunistic digging on the floor of the vallon (R. White / I. Castanet *personal communication*) and at its mouth (Gardère et al., 2009) occasionally yields archaeological material. Each of the main sites of the Castel-Merle vallon with relevant material will now be discussed in some detail.

Abri Blanchard:

Abri Blanchard (also known as Abri Blanchard des Roches or Abri Didon) is a collapsed rockshelter site along the east wall of the Castel-Merle vallon. It was excavated between 1911 and 1912 under the direction of L. Didon (Didon, 1911a, 1911b, 1912; Montandon, 1913). The published size is approximately 20 meters long with a mean width of 6.5 and a depth of 3 m. Two main layers were described: an Upper and Lower Aurignacian, separated by 20-50 centimeters of rockfall. The Lower Aurignacian rests directly on bedrock and both layers have well formed hearths. Abri Blanchard preserved extensive lithic collections, well preserved faunal remains, high densities of bone tools and many art objects including engraved and painted limestone blocks, beads, pierced teeth and worked bone objects (Didon, 1911a, 1911b, 1912). The best known of these is a small bone plaque with incisions and circular holes that has been interpreted by Marshack (1970) as a lunar calender. Recent investigations have also discovered that *in situ* material remains at the north of the excavated area (Mensan et al., 2008).

Abri Blanchard II:

Abri Blanchard II (also known as Second Abri Blanchard, Sous Castelmerle or gisement des Grandes Roches) is a poorly known Mousterian site to the northwest of Abri des Merveilles just outside the Castel-Merle vallon. The site was excavated by both Reverdit (1878) and Peyrony (1909), though accurate measurements are unavailable. However, de Sonneville-Bordes (1960) classified a small collection from the upper layers of Peyrony's excavations as Gravettian

Abri Castanet:

Abri Castanet is another collapsed rockshelter site along the eastern wall south of Abri Blanchard. The site was excavated by M. Castanet for Denis Peyrony 1910 - 1913 and again for a month in late 1924. The sites of Castanet and Blanchard are separated by only approximately 25 meters. When the site was published in 1935 (Peyrony, 1935), the stratigraphy and material culture matched closely that of Blanchard. This led to the conclusion on the part of most researchers that “the two sites, Blanchard and Castanet, were occupied simultaneously, the comparison of profiles makes this evident” (les deux abris Blanchard et Castanet ont été occupés simulatanément, ce que la comparasison des coupes montre évidemment: de Sonneville-Bordes 1960: 101) and that "the limit that separates these two sites is more administrative than prehistoric (la limite qui les sépare est plus cadastrale que préhistorique: Delluc and Delluc, 1978:261).

Modern excavation at Castanet resumed in the late 1990s (Pelegrin and White, 1998) and, after a hiatus, has been ongoing since 2005. These modern studies at Castanet have discovered no Upper Aurignacian occupation either in the Peyrony's southern profile or in a larger an excavation area 10 meters to the south (White, 2007, 2008, 2009). In contrast, the Castanet Aurignacian sits directly on, and is some cases is excavated into, the platy limestone bedrock. The main Aurignacian level is approximately 20 cm thick and shows clear spatial variation. This is turn overlain by the massive collapse of the rockshelter and later colluvium. There are rolled and eroded archaeological objects in these upper layers but they are very rare and non-diagnostic.

In addition, in 2007 the Castanet team discovered an engraved limestone block from the shelter roof resting directly on the Aurignacian layers. Thus, we are left with a picture of Abri Castanet where the rockshelter collapse quickly followed the Aurignacian occupation and any material in the upper layers is more likely the result of an eroded site from the plateau above and not an *in situ* Upper Aurignacian (White, 2008; Sisk, 2010). Whether this pattern can be extended to Abri Blanchard remains to be seen.

Abri Labatut:

Abri Labatut is a collapsed rockshelter on the west side of the vallon to the north of Abri Rochers d'Acier. Though it was excavated by Didon between 1912 and 1913, the results were never published. It was not until after his death that the collections were available (Delage, 1927). Didon described a Solutrean and Gravettian site 50 meters long with a depth of 30 meters (Movius, 1995). This is far more profound than any of the other sites in the vallon, so this estimate must be questioned. Later work on the lithic collections discovered a small Aurignacian assemblage within the larger collections, leading to the conclusion that a small area of Aurignacian occupation was missed during excavation (de Sonneville-Bordes and Perrot, 1953). More recent work (Mormone, 1983) supports the general stratigraphy but found no Aurignacian.

Abri des Merveilles:

Abri des Merveilles is a semi-circular rockshelter facing the Vézère, outside of the Castel-Merle vallon. The site preserved two levels of Mousterian occupation (Quina underlying MTA) separated by a sterile layer. On top of this was a thin Gravettian layer. The site was primarily excavated as a field school for the American School of Prehistoric Research between 1924 and 1930 (MacCurdy, 1926, 1927, 1931; Delage, 1936). Recent work in the area has also revealed that there is an opening to an extensive cave system along the cliff face behind the Abri des Merveilles excavations (Figure 6-3).

Abri Reverdit:

Abri Reverdit is the only solely Magdalenian site in the vallon. It is the southernmost site on the west cliff face, just to the south of Abri Rochers d'Acier. It was excavated by Reverdit (1878) and later work was carried out by Delage and M. Castanet (Delage, 1935). The site yielded significant lithics, fauna, and an important series of parietal art.

Abri Rochers d'Acier:

This small section of the west cliff face is a collapsed rockshelter located between Abris Reverdit and Labatut. The site was discovered and first excavated by Reverdit (1882) and later excavations were undertaken by Delage (1935) in the remaining sections. Clear Gravettian and Solutrean objects can be found in these later excavations, though Reverdit mixed the the two layers, so the early collections are less clearly distinguishable (Delage, 1935, 1947). It has also presented that the size of some of the tools from the early Abri Rochers d'Acier excavations might indicate an Aurignacian affinity (Movius, 1995) though this is not been shown conclusively.

Abri de la Souquette:

This site is located at the western opening of the Castel-Merle Vallon, roughly across from Abri Blanchard and cut into by medieval construction. It was first excavated at the start of the 20th century. The site was then a frequent location for collectors and was finally mostly destroyed by the Hauser excavations in 1911. Fortunately, the stratigraphy can be somewhat reconstructed from the original excavator's journal (Delage, 1935) and a brief description of the stratigraphy before destruction (Peyrony, 1909). Additionally, between 1980 and 1981 a small excavation was undertaken in a restricted sector to the north, which appeared to preserve the original stratigraphy (Rigaud, 1982). The site appears to have Magdalenian, Solutrean and Aurignacian occupations. The basal Aurignacian levels were directly on the limestone bedrock (Rigaud, 1982).

Spatial patterning

Spatially, the sites of the Castel-Merle vallon illustrate some interesting patterns. First, there are no Middle Paleolithic sites within the strict confines of the vallon. Abri Blanchard II (Peyrony, 1909) and Abri des Merveilles (MacCurdy, 1931), the only two sites with Mousterian assemblages, are both found to the southeast of the eastern opening of the vallon, along the Vézère, but not within the narrow vallon (Figure 6-2). Second, the east side of the vallon, to date, preserves only Aurignacian assemblages. This seems to indicate that the rockshelter collapsed before later occupations. Third, for the well-excavated sites (Abri Castanet and Abri Blanchard, possibly La Souquette) there is a trend of Aurignacian assemblages resting directly on limestone bedrock bedrock (Didon, 1912; White, 2008). Most other caves and rockshelters in the region preserve either sterile sediment or earlier occupations beneath the Upper Paleolithic. While this may represent a large-scale geological event either creating or emptying the shelters, there is little direct evidence to support this. This case study is then designed to marshal data to help address some of this spatial patterning by recording the bedrock topography along the eastern half of the vallon, near Abri Blanchard and Abri Castanet.

c. Methodology

Electrical resistivity

The electrical resistivity study was carried out by *Sol-Hydro-Environnement* (*SHE*), a private contracting firm based in Marsac-sur-L'Isle. This firm was chosen primarily because they had previously undertaken a subsurface study on the west bank of the Vézère for a proposed well construction. Financing for this project was provided by an National Science Foundation grant to the Abri Castanet Project (Award Number 9806531; Principle Investigator: Randall White) and a Geological Society of America Research Grant (Principle Investigator: Matthew Sisk).

The survey conducted by *SHE* consisted of 1). the creation of electrical resistivity profiles 2). the use of a dynamic penetrometer to refine the depths yielded by the resistivity study and 3). the combination of these data into a model of the subsurface.

Electrical resistance survey functions on the simple principle that electrical current passed into uniform sediment will spread evenly throughout. But, if the current hits a change in substrate density it will change its course. This works because the electrical current is carried through ions in the soil, usually via salt crystals that have broken down in the ground water. Because these ions are pushed by the current, modern resistivity equipment uses an alternating current to prevent the crystals being pushed to the depth of the sensor or pulled to the surface. The resistivity is then measured by passing current through two steel electrodes and measuring the resulting potential through a second pair of electrodes (Schmidt, 2009). In this case, a two-dimensional technique was used. For this, the current and potential electrodes are kept at a fixed distance and progressively moved along a line. As the measurements are repeated throughout, this yields a high depth for the center of the transect (with the maximum of overlap) with a decreasing depth towards the start and finish (Samouëlian et al., 2005).

For the Castel-Merle study, the soil resistivity was measured along four lines of 64 uniformly spaced electrodes. By comparing this with the recorded resistivity between electrodes through uniform soil, this then yields a measure of the depth of limestone bedrock. Additionally, anomalous areas of high resistivity should reflect the presence of other buried features such as underground chambers, colluvial fill, or major geological events. The four lines were chosen to be representative of major changes in the surface topography, and were sampled at different intervals depending on their length. Table 6-1 summarizes the data from each other these profiles and their location are illustrated in Figure 6-4. After primary analysis of these data in the field, Transects 1 and 2 were performed twice with varying resistivity measurements. This allows the sensors to capture smaller-scale variation within high resistivity areas. Transect 4 yielded an apparent error and was analyzed twice, once with the raw data and once with these data treated to remove the error (Olivier et al., 2009).

Penetrometer

A dynamic cone penetrometer works by striking a probe with a known weight. The penetration of the probe then rests upon the kinetic energy applied, the morphology of the probe's tip and the resistance of the soil. Because the probe's tip and the kinetic energy are held constant, the physical resistance of the soil can be measured (Herrick and Jones, 2002). Though these instruments can be used to create profiles based on differences in soil density, in this case they were mainly used to record absolute depths for the sub-strata found in the electrical resistivity study. Depending on accessibility, two different types of penetrometers were used in this study. Transects 2, 3 and 4 were accessible from the road so a heavy dynamic penetrometer with a 64 kg weight was used. However, Transect 1, nearest the cliff face, was inaccessible to this machine, so a PANDA-type (Galinie et al., 2003), hammer driven, light penetrometer was used. Penetrometer data was sampled at 11 locations (eight with the heavy penetrometer and five with the hammer-driver penetrometer) along the electrical resistivity transects (Olivier et al., 2009). The locations of these points can be seen in Figure 6-4.

Model creation

Following the collection of both types of data, *SHE* created profiles of the electric resistivity correlated with the penetrometer depths. From these they then estimated the depth of the bedrock surface for each each point along the transects and in some cases locations of other subsurface features. While *SHE* also created an interpolated surface for both the ground surface and the upper limit of the bedrock, they did not specify their interpolation algorithm, and in some cases reported interpolated surfaces too far outside the known area (Olivier et al., 2009). Thus, for this project, independent interpolations were completed for both the surface and the bedrock (Figure 6-15).

d. Results and discussion

Results of electrical resistivity study

The resistivity study demonstrates that the bedrock in the Castle-Merle Vallon does not always track the surface topography and is often deeper than was previously thought. Table 6-3 reports the details of each transect, from the *SHE* report (Olivier et al., 2009). The four resistivity transects (Figures 6-5, 6-6, 6-7, and 6-8) show some interesting differences in the substrata, particularly when plotted along the same east-west axis (Figure 6-9). Transect 1, the nearest to the cliff face, shows consistent areas of high resistivity within a few meters of the ground surface. These areas likely represent the limestone bedrock at the base of the Abri Blanchard excavations (Didon, 1912; Mensan et al., 2008). Given the uniformity of most of the initial profile, Transect 1 was resampled with a wider electrical resistivity range, to yield detail on the variability within these sectors. Both of these samples show blocks of high-resistivity limestone surrounded by less resistant matrix to the north. This sector is near a small test trench that revealed potential *in situ* deposits at the norther edge of Abri Blanchard and matches the observed stratigraphy (Mensan et al., 2008). Interestingly, in several areas of the Transect 1 (highlighted in black on Figure 6-5) there are low resistivity inclusions below a layer of high resistivity. These areas could be the result of karstic cavities below the surface or could represent a previously accessible lower rockshelter or cave opening.

Transect 2, located along the eastern edge of the access road to Castel-Merle shows large areas of high resistivity. Again, it was sampled two times, once with the standard range and once with an expanded range. Like Transect 1, Transect 2 shows in its south and central sections areas of high resistivity surrounding areas of low resistivity. In this case, however, they are less extensive and tend to be more isolated. While some of these areas may represent underlying deposits, the nature of the upper resistant areas more closely resembles large limestone blocks, indicating that these regions may be rockfall from the shelter collapse or blocks moved from other areas in the recent past. Additionally, to the north of both profiles for Transect 2 is a deep area of low resistivity overlying and grading into a compact layer of high resistivity. This could either be the result of *in situ* sedimentation or of infilling and erosion from the higher elevation southern parts of the site.

Transect 3 was located between the western edge of the access road and the deeper channel in the center of the vallon. This profile, which was only performed with the standard resistivity range, shows a pattern of the resistivity gradually increasing with depth. There is a clear limit between the high resistivity bedrock and overlying sediments, some of which may be recent fill. In this profile, the bedrock topography roughly follows the surface topography. The depth of the bedrock increases to the north, varying between an estimated 4 and 7 meters.

Transect 4 was located along the central axis of the vallon at its lowest point and through the drainage/spring channel. The transect was only sampled once, but after analysis there were several apparent errors in the sample, resulting in a significant depression to the north (marked in black on Figure 6-8). These samples were removed from the second analysis. The profile for Transect 4 roughly matches that of Transect 3, though with more topographic variability in both the surface and bedrock. Interestingly, there seem to be variations in the bedrock that are not tracked by the overlying sediment, potentially the result of infilling.

Correlation with penetrometer samples

Table 6-4 reports the raw data from the penetrometer sampling and Table 6-5 shows their correlation with the electrical resistivity data. With the exception of the samples along Transect 2, there is good correlation between the two data sets. In cases where the two data types do not match, there are three potential causes. First, the penetrometer could be stopped before reaching the bedrock by a limestone block embedded in a low electrical resistivity matrix. This could be the case for samples P5 and P8 (Table 6-5), which Figure 6-6 demonstrates are placed near very localized areas of high resistivity. It is possible that even a moderate sized limestone block (~20 cm) embedded in the matrix may have stopped the penetrometer prematurely. Second, if high-resistivity limestone blocks are embedded in a high-resistivity matrix (e.g. degraded limestone) t the penetrometer may record a far deeper measurement than the electrical resistivity study. This may be the case for sample P7. And, third, in some cases the penetrometer was offset from the true line of the electrical resistivity transect. For example, sample P2 was placed closer to the base of the vallon than the electrical resistivity samples. As the available data show that the bedrock plunges towards the center, an anomalous result for this sample is unsurprising.

Discussion

The four resistivity transects show an interesting pattern for the east side of the Castel-Merle vallon. Profiles 3 and 4 clearly deliminate a massive limestone bedrock with up to 10 meters of overlying sediment. While the antiquity of this sediment cover is largely unknown, the initial test trenching in front of Abri Castanet that led to this project (Gardère et al., 2008) did not discover any obviously *in situ* deposits of Paleolithic age. In fact, the upper two meters consisted of material presumably eroded from the plateau. Under this is a thick layer of travertine, very tentatively dated to the Pleistocene-Holocene boundary (Gardère et al., 2008). This, combined with the placement of Aurignacian occupations directly on the bedrock (White, 2008, 2009) would seem to indicate only a light sediment cover during the Paleolithic. More work on the subsurface stratigraphy of the vallon, through coring, additional remote sensing and excavation is required (and planned) before this can be known conclusively. However, if the vallon was only covered by a shallow layer of sediment during the Paleolithic, the depth of the bedrock very close to the occupied shelters indicates an drastically different topography than that seen today. Instead of being located at ground level, the occupied shelters would have been located at a significant height above the center of the vallon.

Also, with the exception of the Transect 1, the shortest and least topographically diverse, all of the profiles show an increase in sediment cover to the north. This would seem to indicate that the dominant movement of sedimentation through erosion is towards the north. The surface topography and bedrock in Profiles 3 and 4 show a gradual downward slope (an average of 6-7 degrees). The importance of erosion and infill in the creation of the modern topography of the vallon is also attested to by preliminary hydrological modeling. Figure 6-10 shows the direction and accumulation of water flow for the vallon. The Castel-Merle vallon is a relatively large drainage for surrounding sections of the plateau. Approximately 0.976 square kilometers of modern plateau drain through the vallon. This is further attested to by anecdotal accounts of significant drainage streams flowing through the center of the vallon during periods of heavy rainfall, including one encountered during the fieldwork for this project during the summer of 2010 (Figure 6-12).

Transects 1 and 2, nearest to the occupied areas, yield some interesting contrasts to the those at the vallon floor and are equally important for reconstructing the paleo-topography of the vallon. Profile 2, at the eastern edge of the vallon and at the base of the slope up to Abri Blanchard, was the least well correlated between the resistivity and penetrometer data. The blocky, discontinuous upper layer of high resistivity limestone was underlain by discrete areas of low-resistivity sediment and far more uniform areas of high resistivity bedrock. This could be indicative of several things. First, these blocks may, and in some cases certainly are, the buried spoil heaps of the pre-modern excavations at these sites. Second, they could be rolled and eroded material from higher along the slope to the east cliff face. Third, this layer could partially be the margin of the collapsed shelter, either in primary or secondary position, overlying *in situ* deposits from in front of the shelter. The reality is likely a combination of the three. The landscape of the vallon has been altered from medieval times through to the 1963 construction of the access road. Transect 2, at the base of the slope and next to the road, in places is one of the most altered areas of the vallon. Clearly, more investigation into the history of excavations and alterations is necessary before a complete picture of this area can be reached.

Transect 1 follows a key section of the vallon, along the base of the cliff face from the northern extent of Abri Castanet through Abri Blanchard. The results of this transect are interesting. Importantly, the pattern seen in Transect 2 of dense limestone layers surrounding less resistive sediments is much clearer in the profiles of Transect 1. The upper limestone regions are very large and while it is possible that they represent massive roof collapses onto previous sedimentation, this is unlikely because the exposed limestone in this region resembles the bedrock. It is more likely that these low resistivity regions are a different material within the *in situ* bedrock. Two possible situations could explain this pattern.

First, there is a karstic cave system in the limestone cliff of the east side of the vallon. This cave opens at the back of the Abri des Merveilles and proceeds roughly south for over 350 meters. The cave system has been explored and mapped (Gardère et al., 2008), though its exact orientation and scale is unclear. A preliminary plotting of this cave system within the site grid (Figure 6-3) shows the possibility of a filled opening in roughly same area as the resistivity study. Today, the cave system is difficult to access and for most of its extent too low in which to stand upright. However, as the Aurignacian predates the massive shelter collapse which likely formed most of the slope from the vallon base to the east wall, it is possible that the lower strata and potential cave opening were accessible. While the cave system itself may not have served as a habitation site, it is still possible that it was visible and utilized for other purposes during the early Upper Paleolithic and preceding periods.

The second potential explanation is that during the Paleolithic there was an accessible lower level of rockshelters beneath the current visible level. Differential dissolution in certain strata of the limestone and the freeze-thaw cycle are responsible for the formation of rockshelters in the region (Laville et al., 1980) and there are indications that these levels are relatively consistent throughout the region. Other sites, for example le Moustier (Peyrony, 1930) and Laussel (Capitan and Peyrony, 1903), exhibit multiple levels of shelters roughly within the same vertical extent as the the depth of Profile 1. If this upper level of shelters then collapsed, it could easily explain both the burial of the lower level and the presence of large blocks and infill in Profile 2. Later erosion could then have moved sediments into the base of the vallon and to the north. Figure 6-13 shows a profile based on this interpretation of the resistivity data (Olivier et al., 2009).

Relevance to spatial patterning in the Castel-Merle Vallon

As previously discussed, there are three main trends in the spatial patterning of sites in the Castel-Merle Vallon: a lack of Middle Paleolithic in the excavated rockshelters within the vallon, only Aurignacian occupations on the east side and Aurignacian assemblages directly on bedrock. The theory that the Castel-Merle rockshelters were, at the time of occupation, high up the cliff face with a rockshelter or cave entrance underneath offers some intriguing insight. This theory cannot be conclusively demonstrated without further research. However, if correct, it does help to explain some of the odd spatial patterning in the Castel-Merle vallon.

1. No Middle Paleolithic occupation within the vallon,

Though this pattern could be the result of a simple lack of Mousterian occupation, a MP presence in the vallon is indicated by at least one find of characteristic Mousterian objects while digging in the base of the vallon (R. White *personal communication*). Regardless, rockshelters far above the base of the vallon would be a difficult location to colonize. A lower population density may have made it unnecessary to occupy these areas. Alternatively, if there was no easy point of access, one could easily envision the largely expedient technology of the Mousterian restricting access to such difficult locations. However, there is evidence of Neanderthals sporadically occupying high, difficult-to-access caves and shelters (e.g. Grotte Vaufrey and Grotte XVI: (Rigaud, 1982, 1988). But, these sites yield a good overview of the surrounding landscape while the view from an upper-level in the Castel-Merle vallon is restricted by the opposite cliff face. Thus, there may not have been sufficient reason to occupy a high rock shelter. A potential lower, currently buried, shelter or cave entrance could then have been the focus of Mousterian occupation. This would also explain why the Mousterian assemblages are found outside the vallon in an area less prone to erosional infill.

Furthermore, if the Abris Blanchard and Castanet were located significantly above ground level and difficult to access it would explain the high density of *pierres à anneaux*, or small rings cut into larger blocks of limestone (see Figure 6-14 for examples). These objects, in addition to assumed symbolic value, have long been thought to be used in suspending objects from the ceiling (Delage, 1947; Lhote, 1947; Delluc and Delluc, 1978). At Abri Castanet there are, however, indications that they also were made on isolated limestone blocks (Bourrillon et al., 2009). Function studies of these *anneaux* (the weight that could be supported and use-wear) remain to be undertaken. However, the high density of *pierres à anneaux*, and in particular broken examples, within the vallon could potentially be related to an elevated occupation with its needs of access both for people and objects.

2. East side with only Aurignacian occupations

All available data (White, 2008; White et al., 2010) indicate that the roof of Abri Castanet (and potentially Blanchard) collapsed directly onto the Aurignacian living surface. This would, of course preclude any further occupation, but it also would likely block access to any lower occupations. While it is unknown currently what, if any, time periods are represented deep within the strata, it can be assumed that a catastrophic collapse of the shelter would have resulted in a terminus after the Aurignacian as well.

3. Aurignacian occupations directly on bedrock

At Abris Blanchard and Castanet there is no doubt that the Aurignacian occupation rests directly on bedrock. While this may be the case for sites on the western side of the vallon, it is less well understood. Though it is possible that there was a major geological event or anthropogenic emptying of any preexisting sediment, this pattern can also be partially explained by a location high on the cliff face. In the absence of human agency, sedimentation of the region's rockshelters occurs mainly through the sloughing of small and large particles of the water-soluble limestone during seasonal freeze-thaw cycles. A high rockshelter in a constrained valley would be more susceptible to aeolian and water transport as it would be both more exposed and the significant drop-off at the mouth would remove material. Thus, in these shelters at least some of the material could, over time, have been removed from the shelter, leaving only bedrock and the similar material from the shelter ceiling.

e. Implications for larger study

The Castel-Merle example, while in some ways specific to the vallon, illustrates that erosion and fluvial action are key factors influencing the region's modern topography. Additionally, if this study is representative, than there may be systematic biases in site visibility and preservation based on spatial and topographic location. Thus this study helps to address the very real effects that the assumptions of minimal taphonomic bias and topographic continuity have on the preceding analyses. Thus, this case study contributes directly to the larger study of late Middle and Early Upper Paleolithic settlement in the Vézère Valley.

1. Taphonomic bias is minimal

The assumption of minimal taphonomic bias states that, all things being equal, there is not one type (chronological or functional) of site that is more likely to be preserved. While this assumption is always troublesome for landscape archaeology, it was thought that for the Vézère Valley, with its long and intense history of research, there would be a representative sample of sites for most periods. This may still be the case, but the question of site visibility plays an important role. If, as the Castel-Merle case study demonstrates, there is a significant erosional infill of the low-lying vallon bases, then many sites could be deeply buried in these areas. Additionally, if the elevations of dissolution-prone limestone layers is consistent across the region, the Castel-Merle pattern may be broadly applicable. Alternatively, the hypothesized Castel-Merle pattern of eUP occupied shelters high up the cliff face and potential earlier occupations deeply buried, may be a unique case. Depending on levels of erosional infill in other areas any ground-level shelters would be systematically visible or not. Regardless, there may be more deeply buried occupations in dry valleys. Thus, the already rich prehistory of the region may be even richer than previously thought. This could potentially be related to the significant differences in sediment types preserving MP and eUP sites found in the preceding chapter.

2. Modern topography is an acceptable analog for the Paleolithic topography

This case study also demonstrates that a lack of significant tectonic events does not meant that the modern topography serves as an accurate analog for the Paleolithic topography. Instead, operating under this assumption again excludes the large impacts caused by erosion and fluvial action. More specifically, if, as the previous study indicates, the Castel-Merle Vallon was only thinly covered by sediment during the Paleolithic, then up to 10 meters of sediment has been deposited in the intervening time. This magnitude of cover is sufficient not only to hide many sites, but also to dramatically change some of the variables used in the larger study. Most saliently of these, the viewshed is heavily impacted by nearby landscape features (Wheatley and Gillings, 2002) and slight changes in the local topography could greatly impact what is visible from a particular site. However, as the majority of the variables used in the larger study are relative and not absolute, the impacts of moderate, potentially systematic, topographic changes may be minimal. Thus, while the modern topography may not be a perfectly accurate representation of the Paleolithic topography, it does seem to serve as an acceptable proxy.

Addressing these issues in the larger study

These factors clearly affect the larger landscape analysis of this dissertation. In order to assess these effects, one must first determine if the Castel-Merle Vallon is representative of the region's other dry valleys. While a full study of the depositional history of each of the study area's dry valleys is outside the scope of this project, the degree of similarity to Castel-Merle can be addressed in the context of important landscape characters. In particular, the preceding study highlighted the importance of colluvial deposition and erosion in shaping the post-Paleolithic topography of the region. Thus, by analyzing the region’s hydrology via the digital elevation model (discussed in Chapter 4), one can interpret if other regions were as prone to these factors.

To complete this model, the hydrological modeling tools in Spatial Analyst module of ESRI ArcInfo were used to create raster images representing the flow direction and flow accumulation for each pixel of the study area. These models were then built into vector models of topographically-derived drainage paths. Points at the mouths of 50 randomly selected dry valleys were chosen and optimized to represent the area with the highest water flow. A watershed analysis then shows how much area contributes to water flow from the mouth of each vallon (Figure 6-11). When the total area drained through the mouth of each vallon in plotted it is apparent that many of these areas could be subject to significant erosional infill. The area of the plateau drained by the Castel-Merle Vallon is approximately 1 km^2. Compared to the a mean value of 4.7 km^2 for these 50 points, the area drained through Castel-Merle is actually quite low. This suggests that there are areas with even more potential for erosional infill and thus the burial of archaeological sites. Although this analysis is preliminary, many of these potential zones can be located by examining the confluence of many drainage paths (Figure 6-11).

f. Conclusions

The above example from the Castel-Merle Vallon illustrates some significant restrictions on the interpretation of the larger project's data. This is not to say that these previously under-studied biases have rendered the spatial patterns found in the preceding chapter irrelevant. Areas where there is a higher likelihood of infill are predictable, and do not appear to have greatly changed the overall pattern. However, even if there is bias in the some of these analyses, the statistical techniques addressed in the preceding chapter reduce the impact of problematic areas on the final model. Thus, despite the undeniable effects of taphonomy and geological processes on this region, the dataset appears robust enough to support the conclusions drawn. The following chapter will then compile these results in the light of this dissertation's guiding questions and the broader context of settlement in the Paleolithic.

Figures and Tables: Chapter 6

Table 6-1: Summary data for electrical resistivity study

Transect Number	Active Electrodes	Interval	Total Length	Location
1	64	1 m	63 m	Next to cliff face
2	112	2 m	222 m	East of the road
3	64	2 m	126 m	West of the road
4	64	4 m	252 m	Base of vallon, through stream channel

Table 6-2 Sites of the Castel-Merle complex

Name	Techno-complexes	Key References
Abri Blanchard I	Aurignacian	(Didon, 1911a, 1911b, 1912; Montandon, 1913; Peyrony, 1948, 1949; de Sonneville-Bordes, 1960; Marshack, 1970)
Abri Blanchard II	Mousterian Gravettian	(Peyrony, 1909)
Abri Castanet	Aurignacian	(Peyrony, 1909, 1935; de Sonneville-Bordes, 1960; White, 2008; Sisk, 2010; White et al., 2010)
Abri Labattut	Aurignacian Gravettian Solutrean	(Breuil, 1927; de Sonneville-Bordes, 1960; Mormone, 1983)
Abri des Merveilles	Mousterian (MTA) Mousterian (Quina) Gravettian	(MacCurdy, 1926, 1927, 1931; Delage, 1936)
Abri Reverdit	Magdalenian	(Delage, 1935)
Abri Rochers d'Acier	Aurignacian? Gravettian	(Delage, 1927, 1935, 1947)
La Souquette	Aurignacian Solutrean Magdalenian	(Delage, 1938, 1939; de Sonneville-Bordes, 1960; Rigaud, 1982; Castel and Madelaine, 2003)

Table 6-3: Summary data for each electrical resistivity transect

Transect	Model	Range (Ω.m)	Inversions	RMS error	Notes
1	a	30 - 400	5	4.6	To north is a very resistive area surrounded by less resistive material. Resistive areas are near the surface, with less resistive material beneath. Less resistive areas may represent karstification with possible sand or clay infill.
	b	30 - 900	4	3.8	
2	a	30 - 400	4	9.2	High RMS error means many anomalies. Several high resistance areas near the surface with lower resistivity below. This makes the bedrock difficult to determine, but the northern section appears to show bedrock.
	b	30 - 900	4	9.2	
3		30 - 400	5	1.8	Resistivity increases gradually with depth. Well defined boundary between limestone and low resistivity areas. Bedrock follows topography, decreasing to the north, 4 - 7 m deep.
4	Raw	30 - 400	4	1.7	The depression in 4Raw is most likely from recent excavations. Bedrock follows topography, decreasing to the north, 4 - 10 m deep.
	Treated	30 - 400	5	1.8	

Table 6-4: Penetrometer data

Sample	Penetrometer Used	Location (Transect; Electrode)	Maximum Depth (m)
PD1	Light	1; 45	0.4
PD2	Light	1; 32/33	~0.1
PD3	Light	1; 26/27	0.5
PD4	Light	1; 20	0.7
PD5	Light	1; 7	0.5
P1	Heavy	3; 19/20	6.9
P2	Heavy	3; 30/31	7.1
P3	Heavy	3; 41/42	6.3
P4	Heavy	4; 57/58	8.3
P5	Heavy	2; 83	2.8
P6	Heavy	2; 74	0.7
P7	Heavy	2; 56	2.5
P8	Heavy	2; 18/19	0.3

Table 6-5: Correlation between penetrometer samples and electrical resistivity data

Transect	Sample	Penetrometer Depth	Resistivity at depth (ohm)	Correlation	Comment
1	PD1	0.4	> 300	Excellent	
	PD2	~0.1	> 300	Good	Over low resistance area
	PD3	0.5	240	Moderate	Resistivity depth ~ 1.3 m
	PD4	0.7	280	Excellent	
	PD5	0.5	>280	Good	Over low resistance area
2	P5	2.8	225	Poor	Anomaly
	P6	0.7	>300	Moderate	
	P7	2.5	>300	Poor	Anomaly
	P8	0.3	170	Poor	
3	P1	6.9	280	Excellent	
	P2	7.1	>300	Moderate	Resistivity depth ~ 5 m
	P3	6.3	>300	Good	Resistivity depth ~ 6.5 m
4	P4	8.3	>300	Good	Resistivity depth ~ 7.5 m

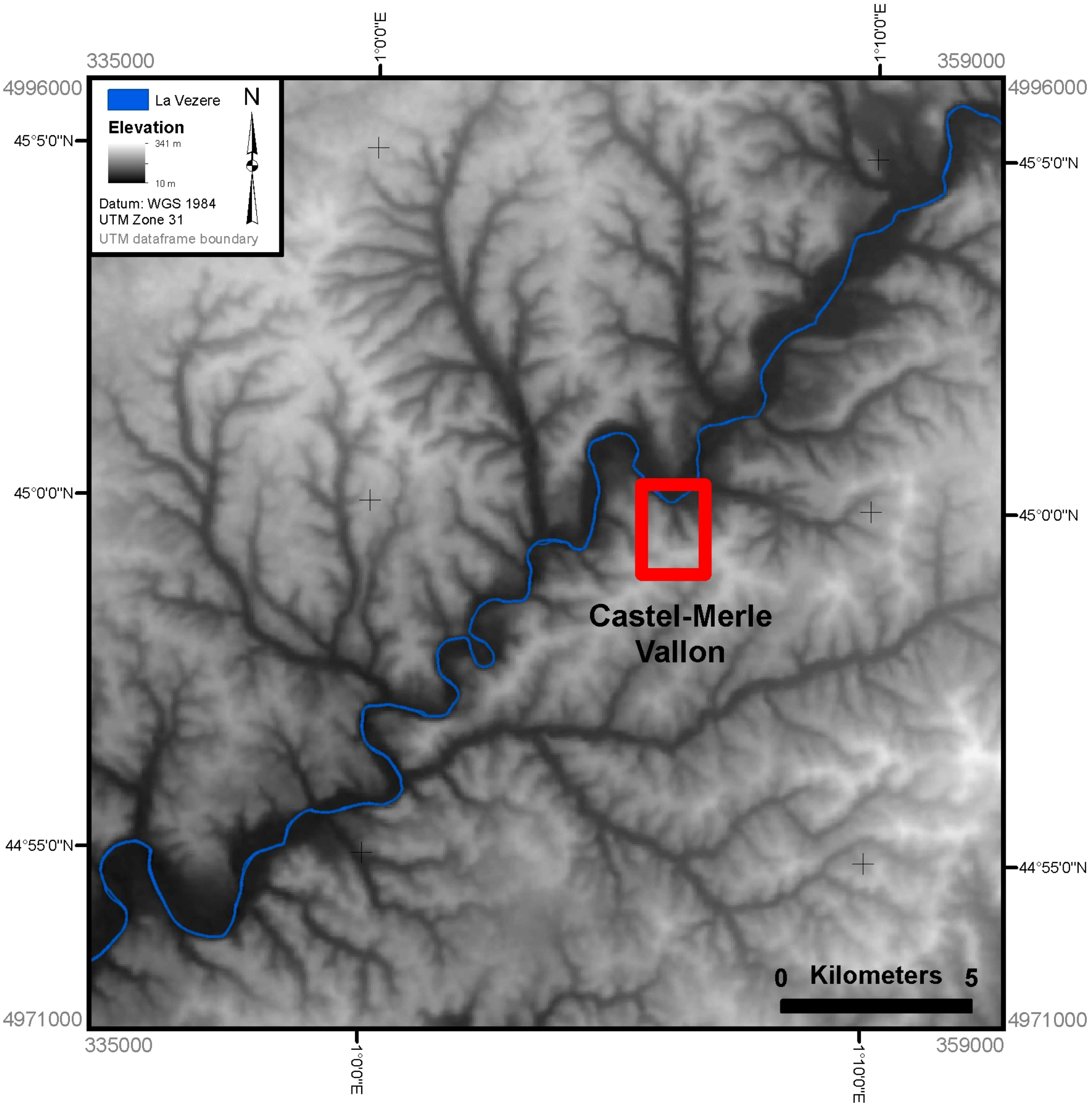


Figure 6-1: Location of the Castel-Merle Vallon

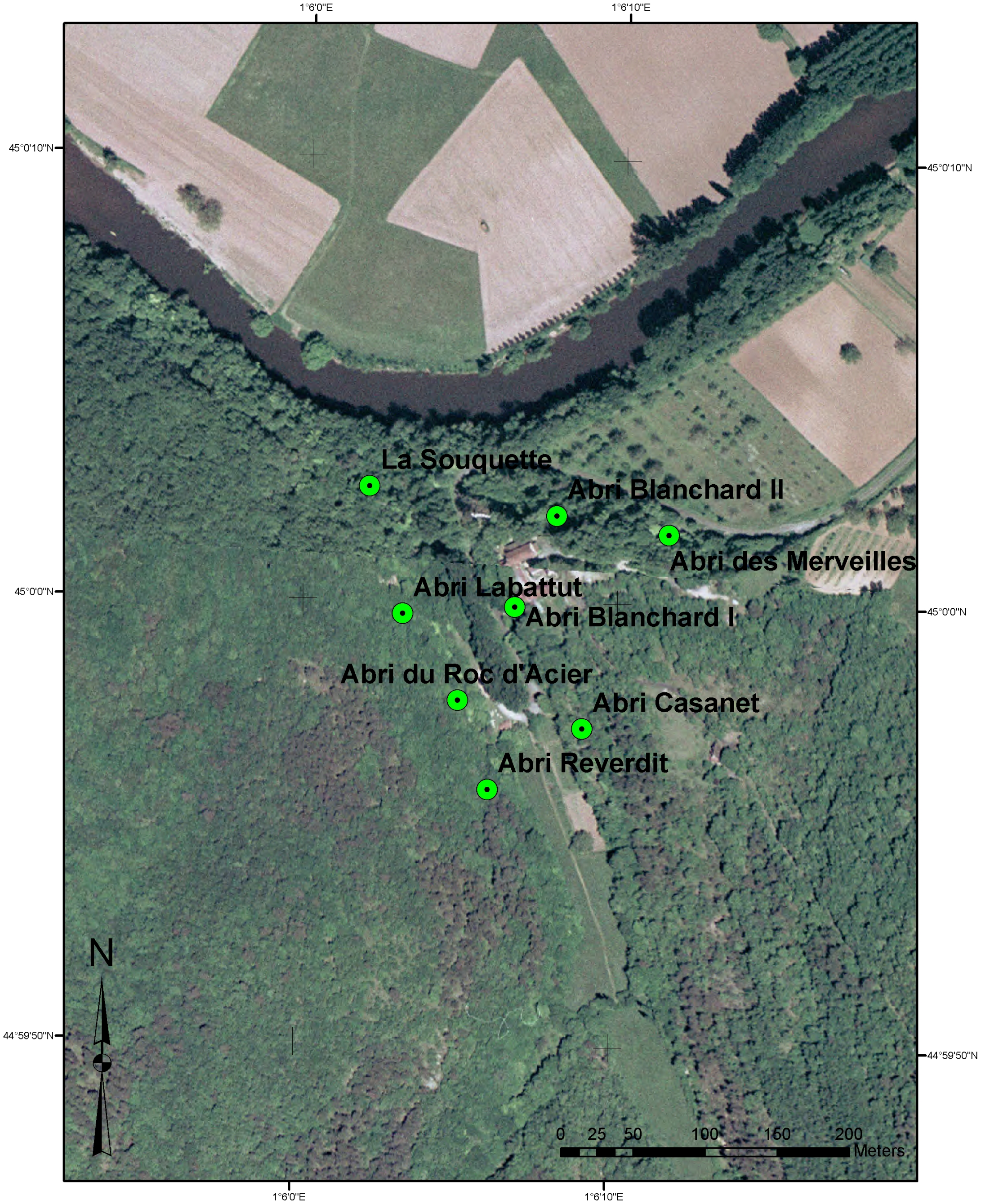


Figure 6-2: Map of relevant sites in the Castel-Merle Vallon.

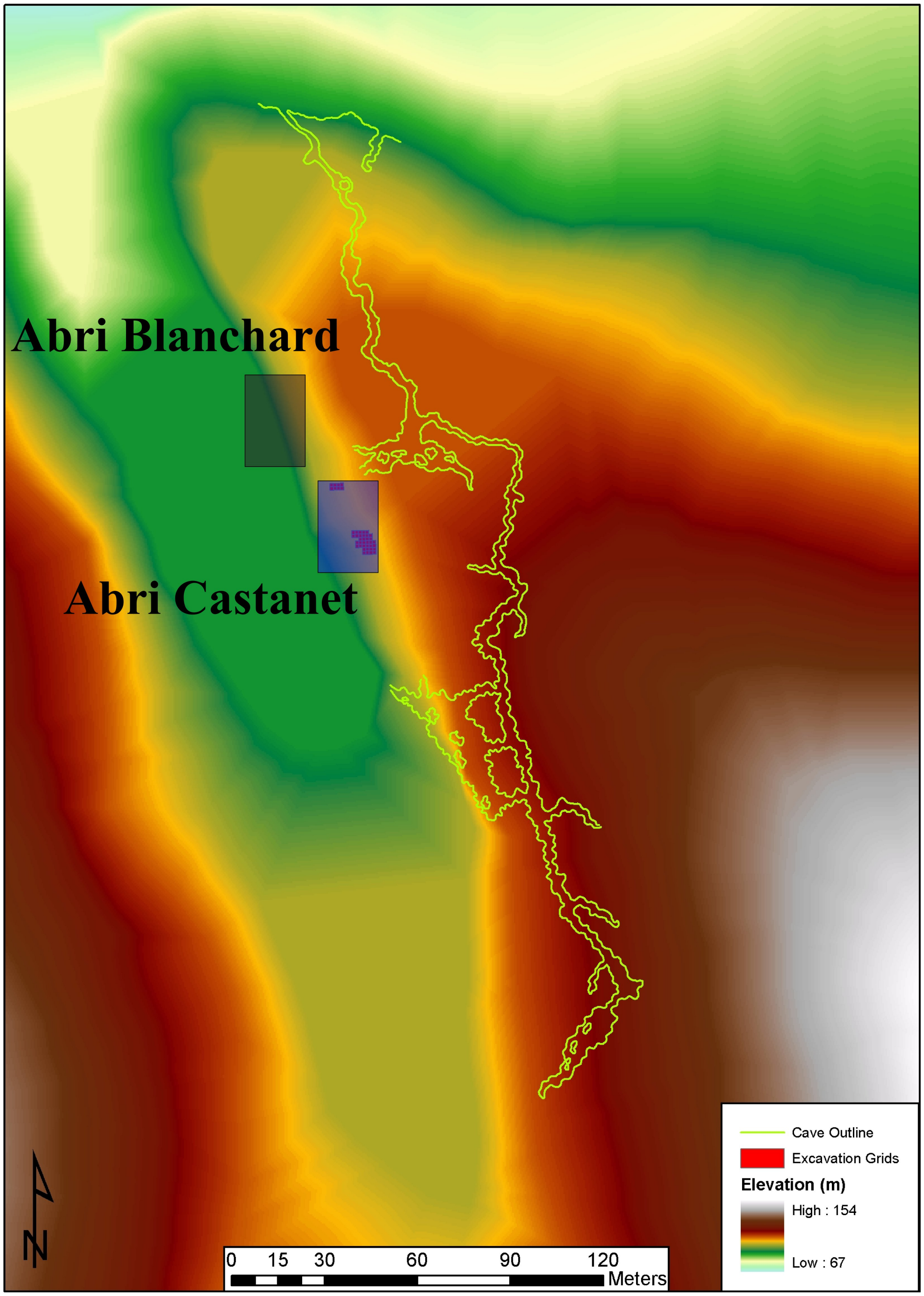


Figure 6-3: Provisional plot of the karstic cave system in east cliff face of the Castel-Merle Vallon

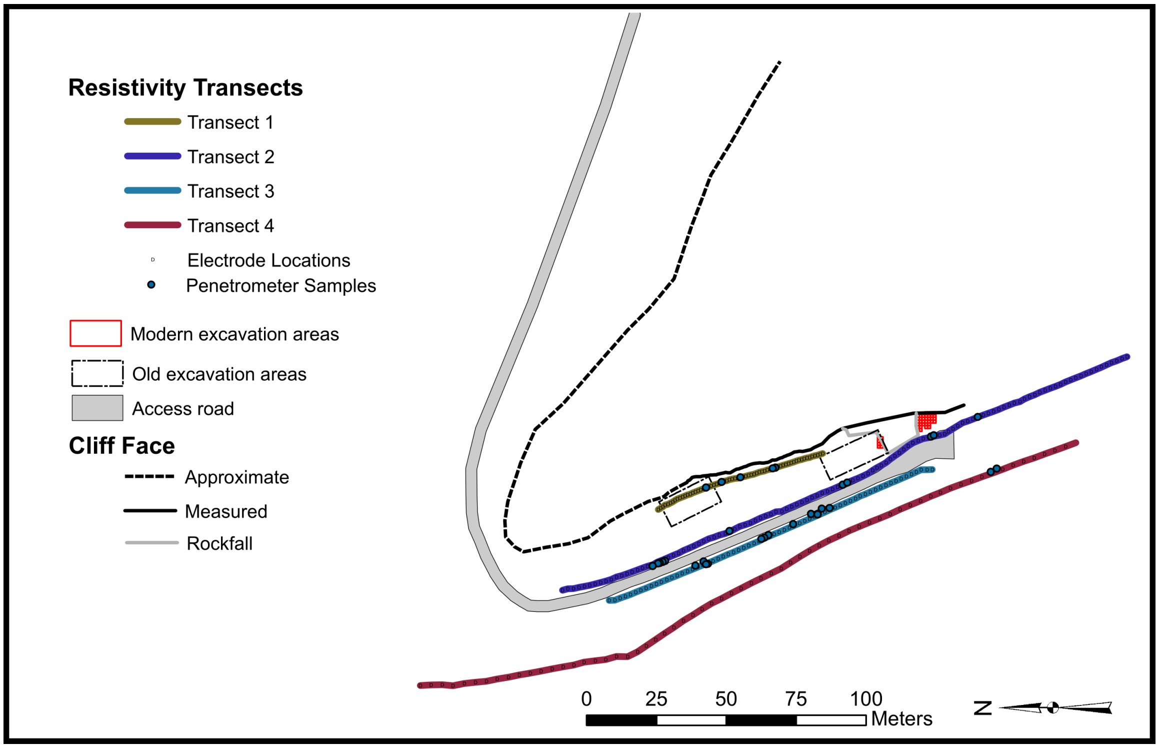
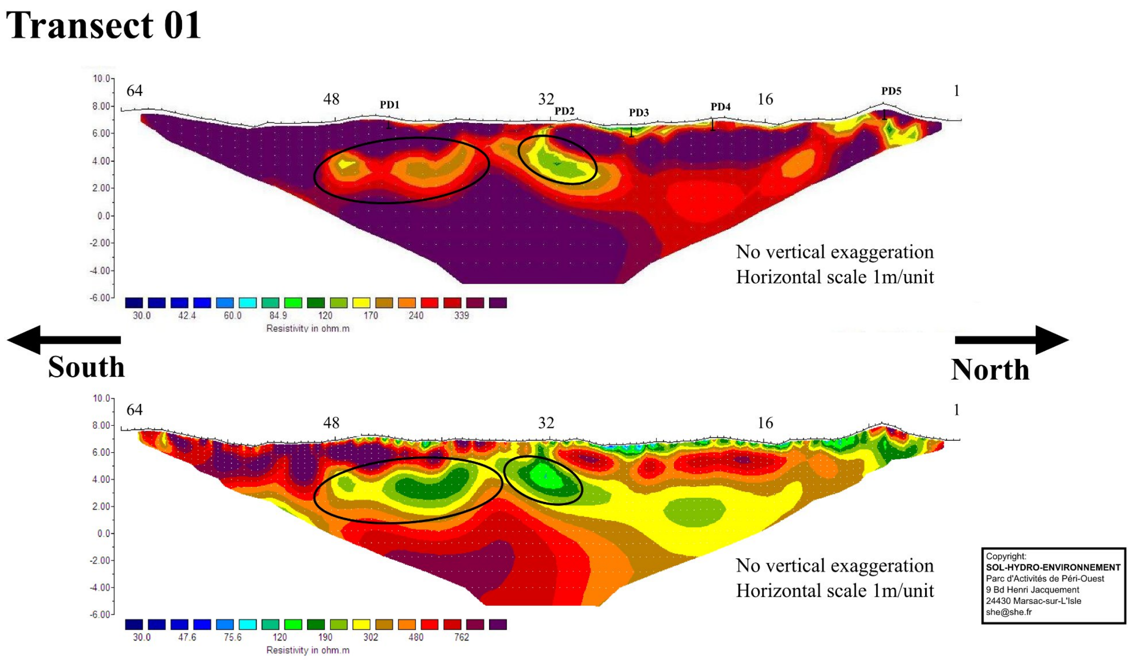


Figure 6-4: Location of resistivity transects and penetrometer samples in the Castel-Merle Vallon.



No vertical exaggeration
Horizontal scale 1m/unit

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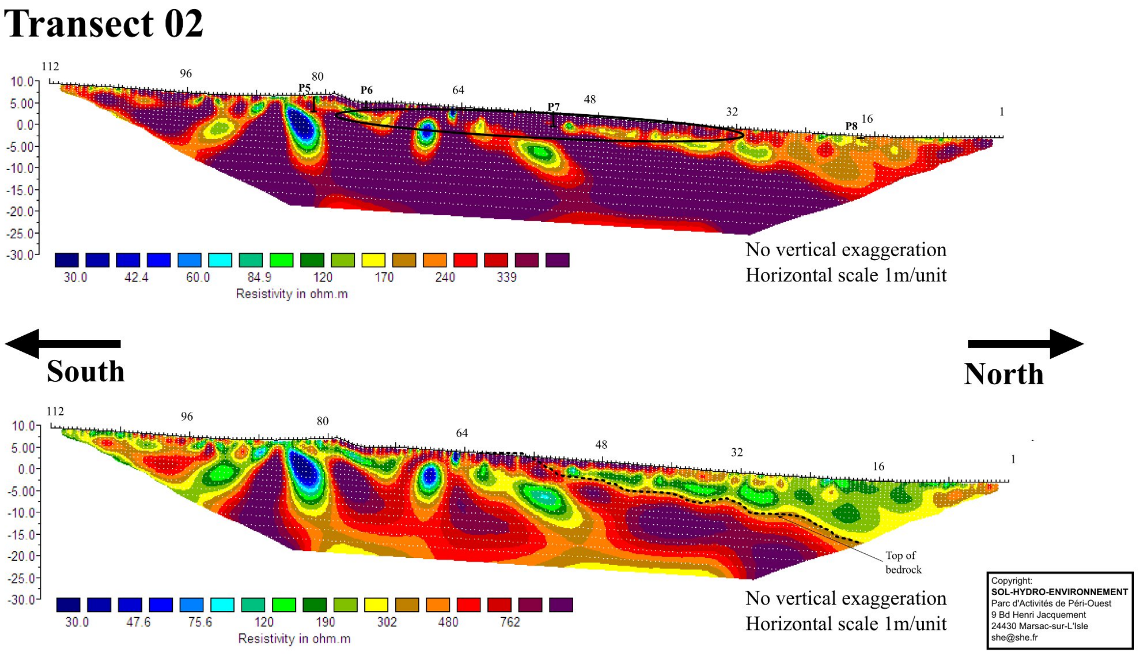
Figure 6-5: Resistivity profile of Transect 01 with penetrometer depths and locations plotted. The upper profile is with a standard resistivity range. The lower profile is with an expanded range.



No vertical exaggeration
Horizontal scale 1m/unit

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Figure 6-6: Resistivity profile of Transect 02 with penetrometer depths and locations plotted. The upper profile is with a standard resistivity range. The lower profile is with an expanded range.

Transect 03

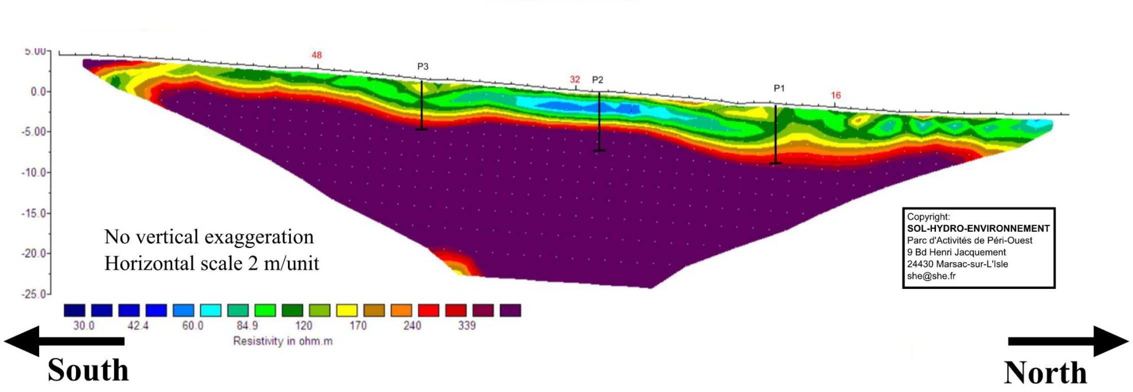


Figure 6-7: Resistivity profile of Transect 03 with penetrometer depths and locations plotted. The standard resistivity range was used.

Transect 04

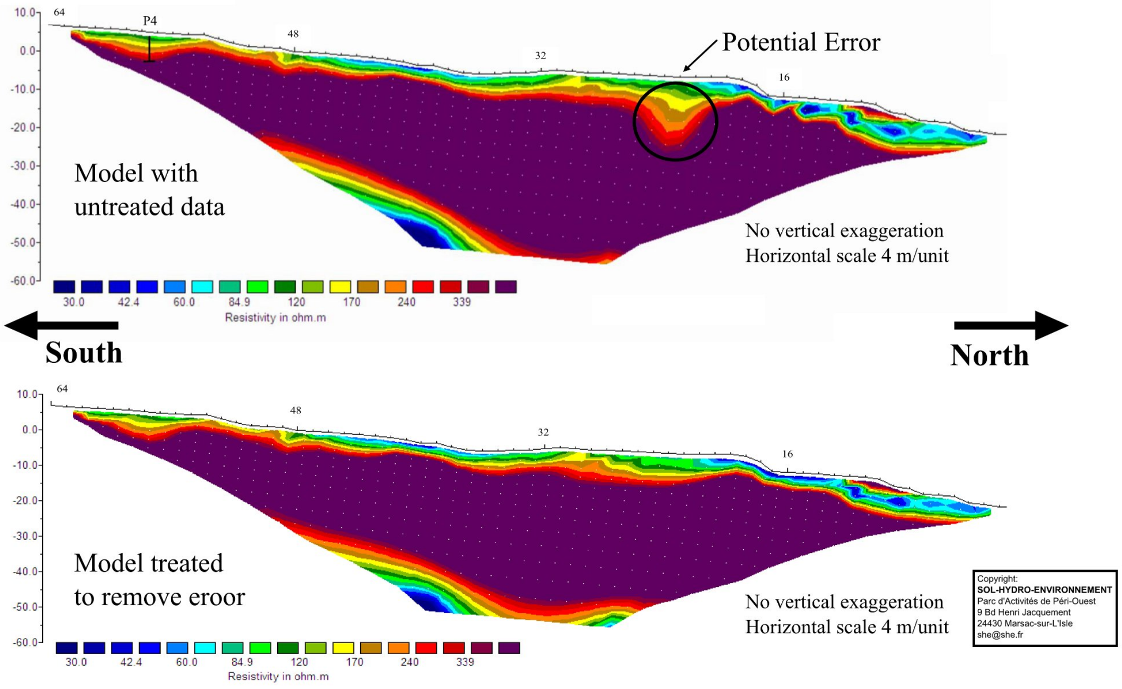


Figure 6-8: Resistivity profile of Transect 04 with penetrometer depth and location plotted. The upper profile is raw data with an apparent error. The lower profile removes the erroneous data. Both are with a standard resistivity range.

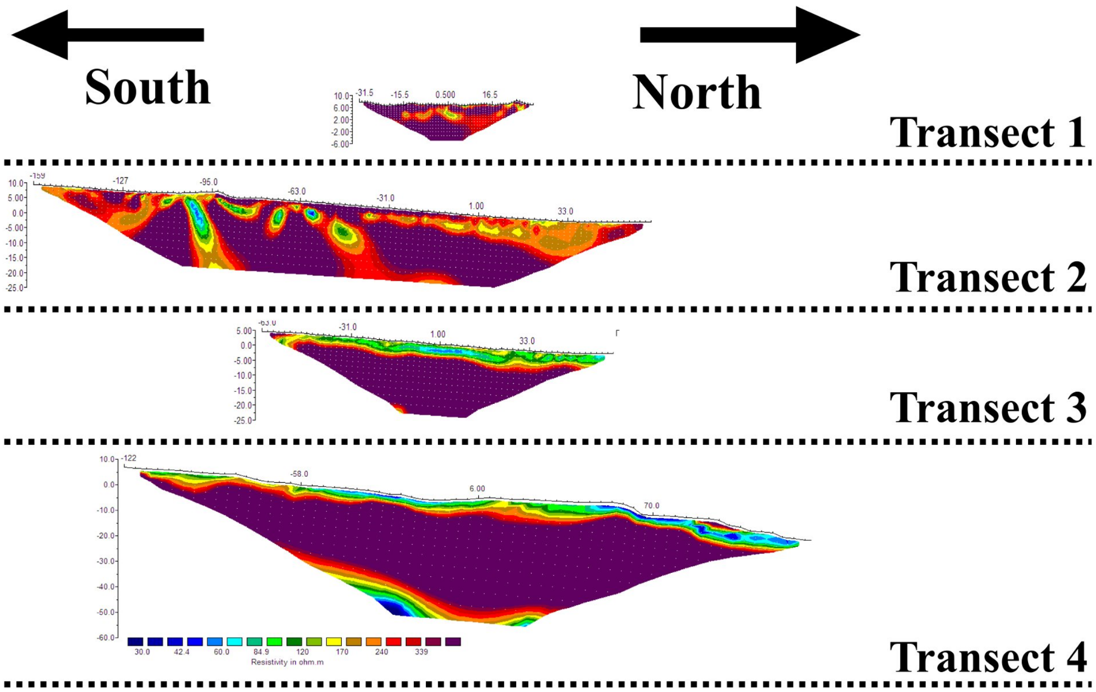


Figure 6-9: Representative profiles for each of the resistivity transects projected at the same scale.

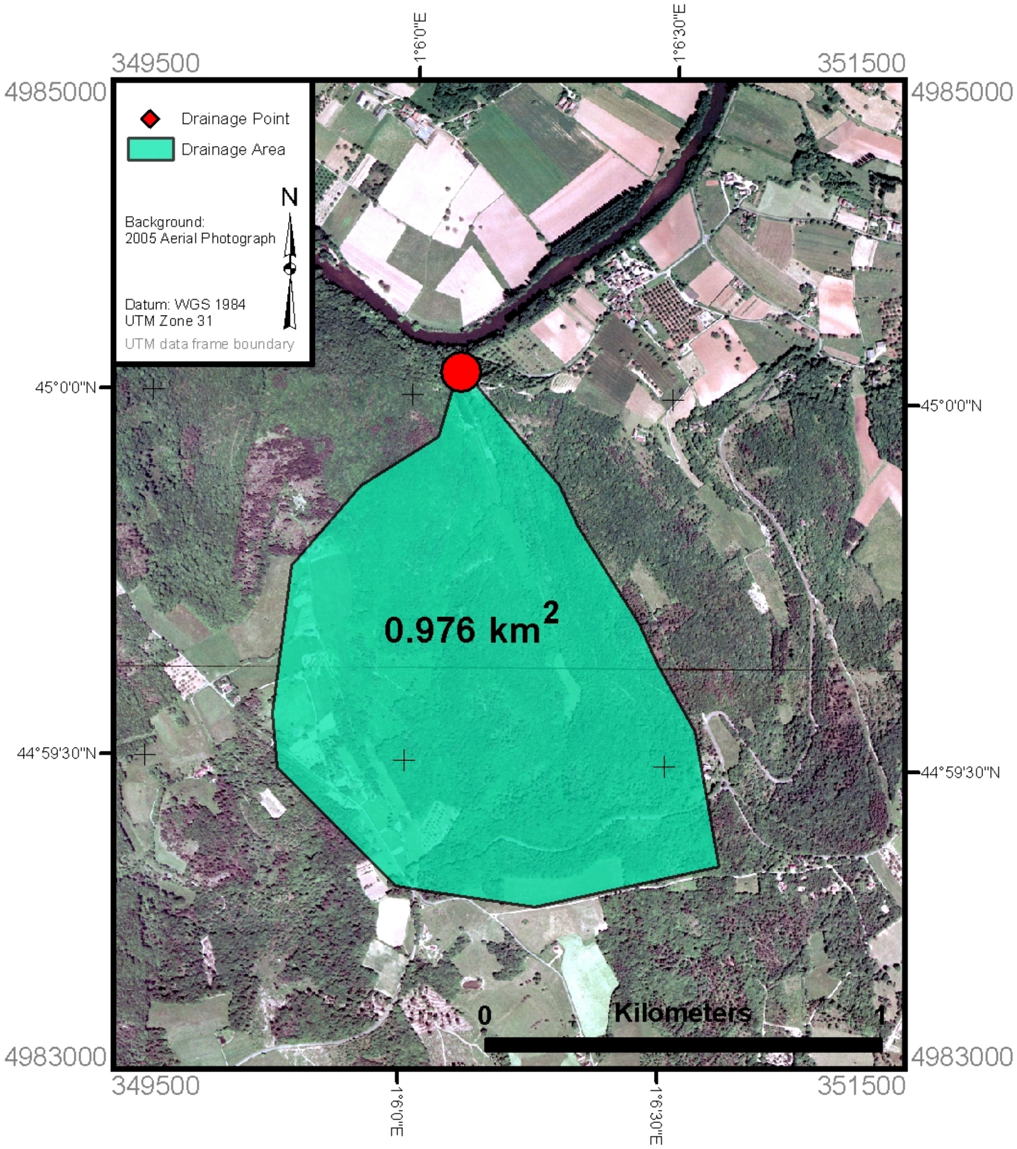
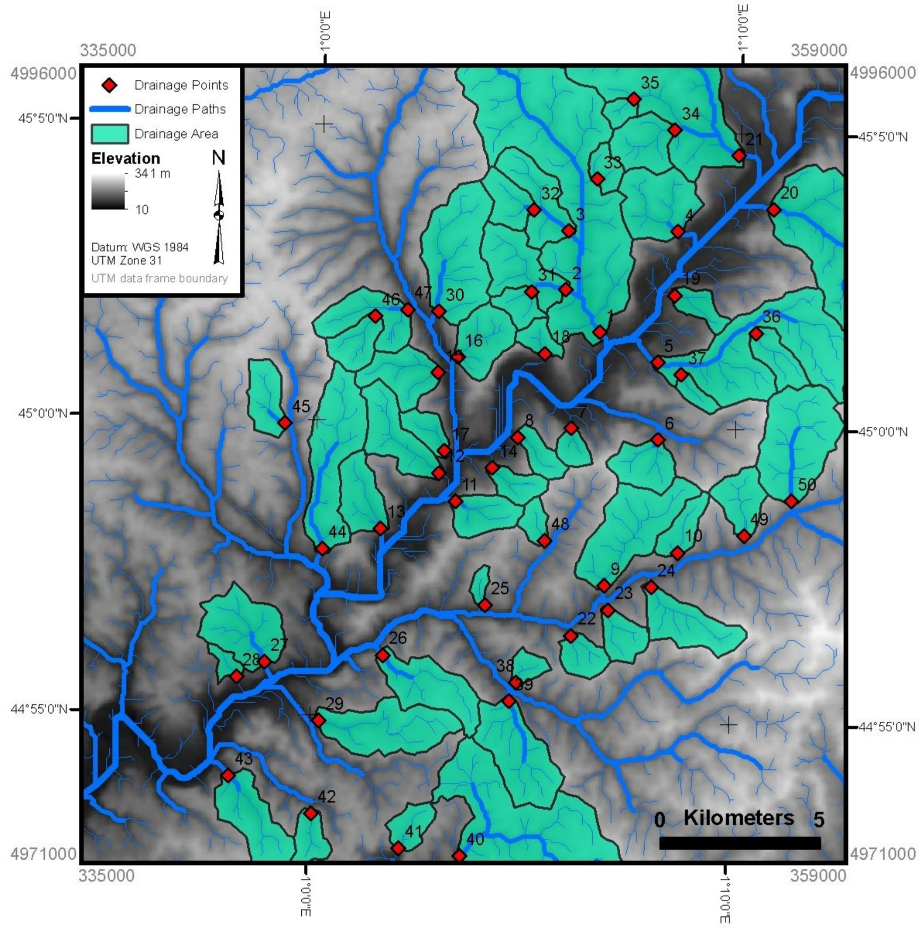


Figure 6-10: Hydrological model of the Castel-Merle vallon



Point ID	Area (km2)
1	25.058
2	4.079
3	3.523
4	4.606
5	11.400
6	2.603
7	0.976
8	1.387
9	6.449
10	1.677
11	2.325
12	3.744
13	2.864
14	1.456
15	3.130
16	3.104
17	1.360
18	1.084
19	1.356
20	16.033
21	40.201
22	1.599
23	1.784
24	3.727
25	0.477
26	4.252
27	4.717
28	0.696
29	5.489
30	7.258
31	1.358
32	2.037
33	1.156
34	2.938
35	0.769
36	1.986
37	0.815
38	0.905
39	5.487
40	17.072
41	1.524
42	1.466
43	4.068
44	6.933
45	2.304
46	1.964
47	3.440
48	0.957
49	2.403
50	7.206

Figure 6-11: Hydrological model of the study area.

Figure 6-12: Water flow in the Castel-Merle Vallon following heavy rain. View to the South towards the plateau. Photo courtesy of A. Clark.

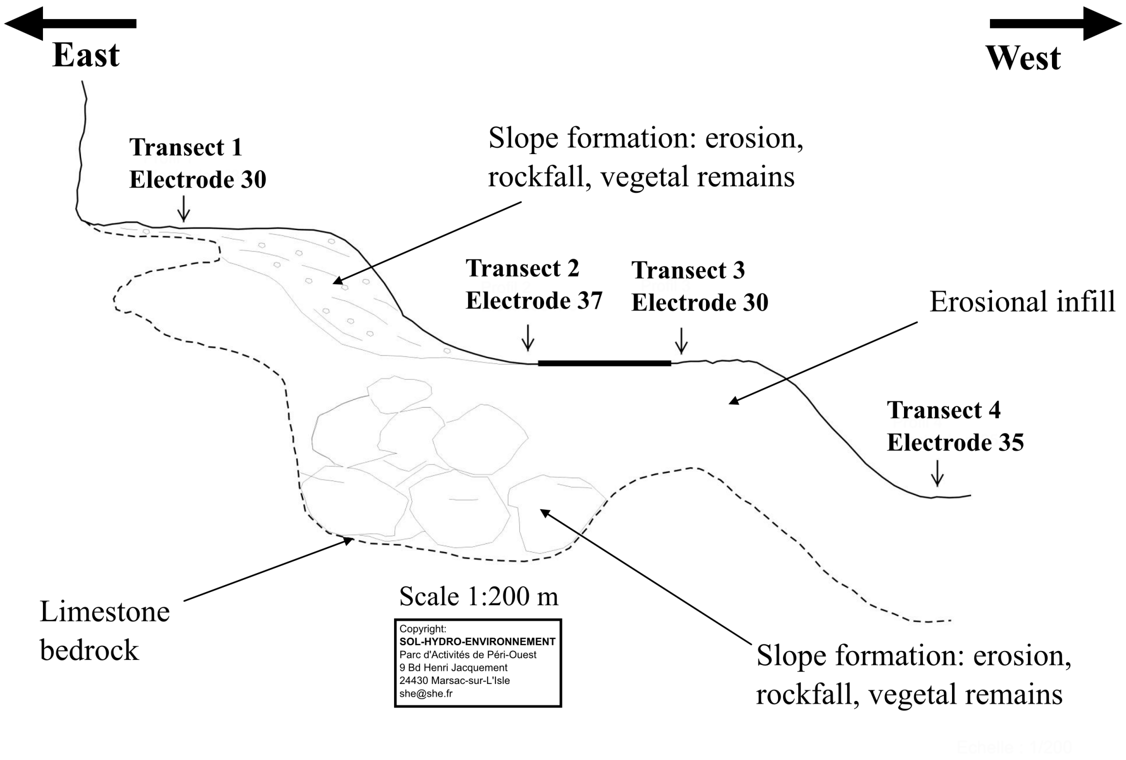


Figure 6-13: Proposed profile of the Castel-Merle subsurface based on the 4 resistivity transects

Figure 6-14: Examples of *blocs anneaux*: Discovered in the backdirt from the Peyrony excavations. Photographs courtesy of R. Bourrillion

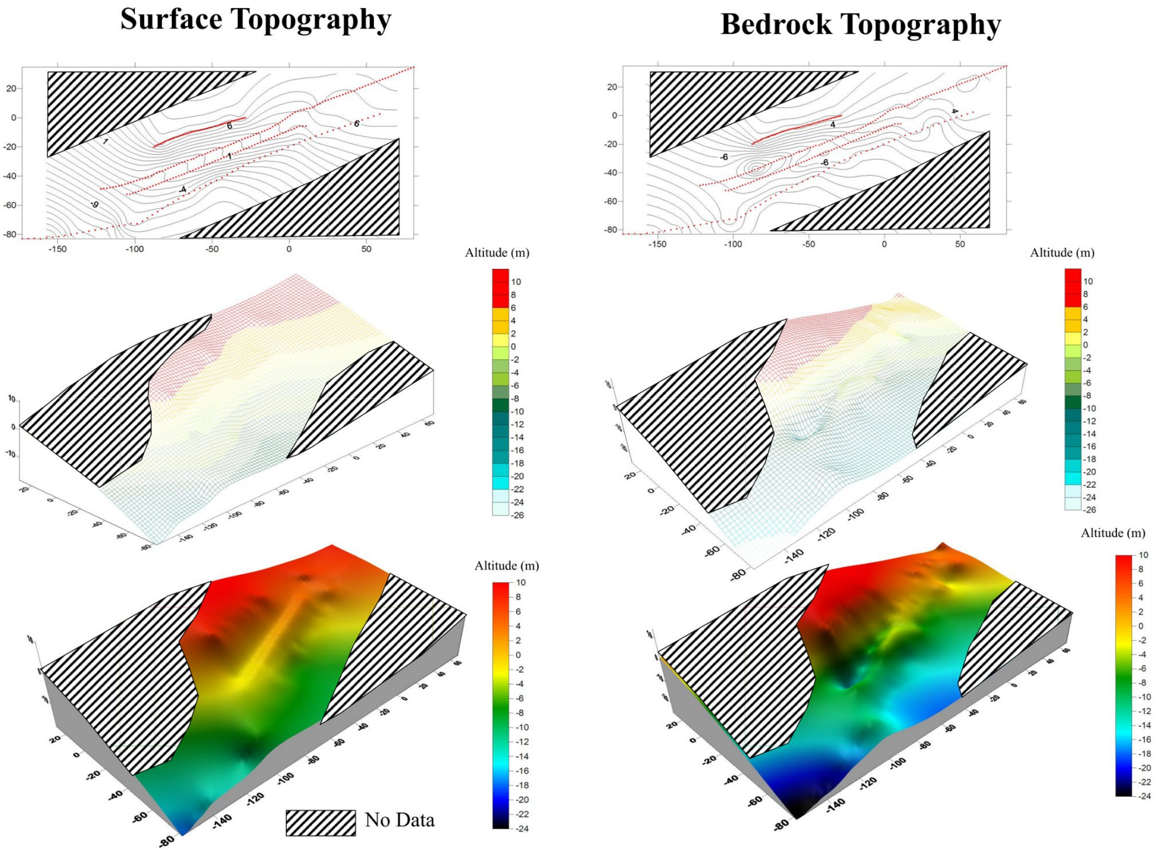


Figure 6-15: Interpolation of surface and bedrock topography. Surface topography is based on more than 8,000 measurements with a Total Station and theodolite. Bedrock topography is based on magnetic resistivity measurements.

Chapter 7: Conclusions

a. Introduction

This dissertation tested a number of factors related to Paleolithic site locations and how they can relate to settlement and subsistence. Traditional GIS-based landscape analysis and novel methodological approaches (aspects of the viewshed analysis, MaxEnt) were used to investigate Paleolithic settlement in the Middle Vézère Valley from the modern record and landscape. But in addition to methodological advances, this dissertation also addressed key differences between Neanderthal and *Homo sapiens* populations by systematically measuring variation in site location between the Middle and Upper Paleolithic. Working within a small area with a high density of sites, landscape characters hypothesized to be important controls on settlement were isolated, measured and statistically tested. However, this was a complicated process using analogy and, in some cases, assumption to interpret the observed patterns. In order to assess the success of this project in the broader context of Paleolithic archaeology, the descending research questions outlined in Chapter 3 will not be revisited.

b. Summary of results and return to the guiding research questions

1. *Do any differences between the Middle and Upper Paleolithic reflect characteristics of the global or species-level models?*

This question was well addressed in this work. There do appear to be aspects of the global and species-level models of Paleolithic settlement that hold true for this region. All sites show a preferential orientation to the South, and some Middle Paleolithic sites were potentially in depressions. Maps of modern vegetation zones show that Middle Paleolithic sites are often found in areas that were likely near ecoclines in the Paleolithic. Sites seem to be preferentially located in areas with a good overview of the landscape, particularly with high percentages of plateau area visible. All of this can be distilled into a view of the Middle Paleolithic as an adaptation designed to exploit a wide variety of resources. Population densities appear to have been low, although this is non-conclusive. There may be a real problem of time averaging across the longer span of the MP. With this possibility, it is then no surprise to find that these sites seem well suited to allow a small group of mobile hunter-gatherers to maximally exploit a wide variety of environments through a chronological and climatic variation.

Early Upper Paleolithic sites do not appear to be tied to these heterogeneous environments. Instead, there is a clear and unambiguous focus on the river. Sites are located closer to the river, at low elevations, in areas with high variability in slope and in close proximity to natural shallows in the Vézère. Although it was not studied here, it should be noted that many of the early Upper Paleolithic sites in the region are spatially expansive. This can all be distilled into a picture of the early Upper Paleolithic in the Vézère valley as more concentrated adaptation to a particular resource. From this dataset, it is impossible to directly infer the nature of this resource, but it appears to be related to the river or the shallow fords across it. In the absence of substantial evidence for fishing or the exploitation of river resources, this may well be migrating reindeer herds that others have postulated. If this is correct, it would fit well with Finlayson's (2004) model of *Homo sapiens* adaptation, although in this context these sites may be a seasonal adaptation revisited annually to exploit these resources rather than a long-term hunting camp.

2. *Are there significant differences in settlement among the techno-complexes of the Upper Paleolithic (Châtelperronian, Aurignacian, Gravettian) in the Vézère Valley?*

One point that quickly becomes apparent from a close examination of the data yielded by this project is a distinct similarity among the techno-complexes of the early Upper Paleolithic. While there are a few differences in the magnitude of relationships, when compared with the Middle Paleolithic, the Aurignacian and Gravettian stand as a consistent pattern. Other work has isolated key differences between these time periods and following Upper Paleolithic techno-complexes of the Solutrean and Magdalenian (e.g. White, 1985), but it appears that the high incidence of sites with both Aurignacian and Gravettian levels in this sample makes determining statistical patterns difficult. This is a topic that could greatly benefit from future work.

3. *When Middle Paleolithic data is of sufficient resolution to determine techno-complexes, are there significant differences among them?*

Unfortunately, the sample size and resolution of the Middle Paleolithic sample used by this project is insufficient to address this question. Because of a lack of specific and well-published attributions, too few MP sites were able to be definitively placed into any techno-complex except for the Mousterian of Acheulean tradition (MTA). Even this sample size was very small, with only nine sites included. All of these nine sites also preserved evidence of another techno-complex, further reducing the likelihood of discovering a statistical difference between the MTA sample and any of the others. However, this may well be a result of using too rigorous of a selection criteria. Many other MP sites have been preliminarily placed in the MTA. Thus, it is entirely likely that further examination of collections and the literature may expand this sample and reveal intra-Middle Paleolithic variation in settlement strategies.

4. *Does the Châtelperronian more resemble the early UP (Aurignacian / Gravettian) or the MP?*

The sample of 13 Châtelperronian sites was able to be statistically differentiated from the the lumper Middle Paleolithic sample in raw and mean elevation and the ratio of valley to plateau visibility. In all of these cases, it falls in with the Aurignacian and Gravettian. In contrast, with several of the categorical measures of landscape character and variability (mainly soil classes and modern vegetation zones) the Châtelperronian sites do more closely resemble the Middle Paleolithic, exhibiting a reduced variability and a similar preference of flat areas and south-facing slopes.

This pattern should not, however, be taken as conclusive. First, the sample size is relatively small for the Châtelperronian, decreasing the statistical power of categorical variables. More saliently, there were no uniquely Châtelperronian sites in the sample. In fact, each of the 13 Châtelperronian sites also preserved either Aurignacian or Gravettian material. Because of these overlapping data points, it is statistically far more likely that these groups would fall out together. Thus, this may be more of a pattern of coincidence than a true characterization of the Châtelperronian settlement pattern. Questions on integrity of the Châtelperronian as a true techno-complex are far beyond the scope of this project, but the lack of Châtelperronian sites without an overlying early Upper Paleolithic techno-complex is striking. Furthermore, the Châtelperronian sample has a higher mean elevation than the rest of the early Upper Paleolithic, and while non-significant, this comparison is potentially important ($p = 0.056$). Without a larger sample size of Châtelperronian sites this remains a trend, but the possibility of different site location patterns exists.

c. Broader context

Whether site location differences between the Middle and early Upper Paleolithic truly represent different settlement and subsistence adaptations is a hard question to answer. Projects like this one speak of possibilities and seek to provide a framework into which more detailed data can be placed. But even though the interpretations discussed throughout this work are based on archaeological and ethnographic models that may fully capture the nature of Paleolithic subsistence adaptations, the overall patters observed here compare reasonably well with Middle and early Upper Paleolithic settlement data from other well-studied regions.

Recent syntheses of Middle Paleolithic / Neanderthal behavior from throughout Europe and the Levant have highlighted the variability of these populations (e.g. Stiner, 2001; Wallace and Shea, 2006; Shea, 2007; Adler and Bar-Oz, 2009). Different technological strategies and settlement patterns seem to suggest highly adaptable populations changing their strategy in response to particular climatic or environmental conditions. While there are some indications of change through time towards particular technological adaptations or increased population density (Meignen et al., 2006), this adaptation seems to be largely stable (Ambrose and Lorenz, 1990; Dietl et al., 2005; Shea, 2007). Although this study did not address variability within the techno-complexes, the finding of many MP sites in varied environments and with good overviews of the landscape does fit with the majority of other data.

Studies of early Upper Paleolithic (or Late Stone Age) settlement tend to be more variable in their findings (e.g. Ambrose and Lorenz, 1990; Kusimba, 1999). Many have stressed the focused nature of and concluded that resource intensification is the likely cause (Mellars, 2004). This intensification is often presented as a product of increasing population size and demographic pressure (Stiner, 2001). However, it is also apparent that, at least in some cases, dietary breadth actually increases in the early Upper Paleolithic (Grayson and Delpech, 1998; Richards et al., 2001) and that patterns showing focus on a particular species in the UP may be the product of taphonomy and selective excavations (Grayson and Delpech, 2002). While this may seem to refute the findings of this dissertation, in fact there is no reason to assume that this would not be the case for a denser eUP occupation. These is little debate that the technological toolkit of the eUP was more diverse than the MP. A higher population density and access to projectile weapons can then help explain any issues of dietary breadth and resource intensification.

d. Future directions

This project has been successful at distinguishing differences Middle and early Upper Paleolithic site patterning in the Vézère Valley. These patterns can then be interpreted in the light of how humans and other primates use resources and settle the landscape. This project took initial steps at this, but there remains significant work to be done. First, more work on the region's geology and the importance of erosion and colluvial action are needed to fully understand the potential for taphonomic bias. Second, a better understanding of the character of smaller open-air MP sites is crucial to understanding what, if any, variability is found among these sites. To this end, a survey project on the plateaus of the Vézère Valley is well merited, and given the ever increasing return to dense forest cover, would be quite timely.

Third, and perhaps most important, the findings and interpretations found here are meant to serve only as a framework for more detailed data about individual sites. The database generated here needs to be expanded to include faunal and lithic data from individual excavations, as well as better information of the environmental backdrop from pollen and paleontological data. It is only through this sort of investigation that we can begin to understand the real evolutionarily significant differences, if any, between the settlement patterns shown by Middle and early Upper Paleolithic populations.

e. Concluding remarks

Frequently, Paleolithic archaeologists suffer from a myopia of specialization. Too often is one particular source of data (lithics, faunal remains, etc.) used to extrapolate broadly on the life-ways of Paleolithic hominins. This is particularly true in the analysis of settlement, where archaeologists often use one line of evidence (methodological or chronological) to interpret the settlement dynamics of entire species. In the formation and analysis of this project, I hope to have avoided some of this trend. Beginning with a detailed, quantifiable, study of settlement patterns in a constrained area provides only one datum. Many more are needed to characterize the strategies of an entire species or techno-complex. The results presented here are not meant to be expanded broadly without consideration for the idiosyncrasies of local environment or taphonomy. However, I hope that this work will stand as a step along the path to a more complete understanding of the nature and variability of Paleolithic settlement.

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Appendix A: Annotated Site Database

This appendix contains the raw data and measurements that were used in this project's analyses. These data are presented in a single table of values organized into rows by site. The table is large and complicated, so first is a key to each of the fields is presented. Each column code is identified and described with the relevant units for any measures. This is followed by the table itself, which is by necessity, split onto several pages. The site identifier (ID) and the column heading are preserved across these multiple pages.

Table A- 1: Key to the variables included in the site database

Code	Variable	Description
ID	ID	Site ID used for indexing
INDEX_NA	Index Name	Index Name: Omits Abri or Grotte and removes non-English characters
FULL_NA	Full name	Full name of each site
SITE_COM	Site complex	Name of the site complex, if applicable
VISITED	Visited	Whether the site was visited and recorded with the GPS
TYPE	Site Type	The type of site
REFS	References	Selected references to the site in the literature. Includes gazetteers listing the site
LP	Lower Paleolithic	Binary: 1 = Lower Paleolithic material reported from the site
MP	Middle Paleolithic	Binary: 1 = Middle Paleolithic material reported from the site
EUP	Early Upper Paleolithic	Binary: 1 = Early Upper Paleolithic material reported from the site
MTA	MTA	Binary: 1 = Mousterian of Acheulean Tradition material reported
CHAT	Châtelperronian	Binary: 1 = Châtelperronian material reported from the site
AURIG	Aurignacian	Binary: 1 = Aurignacian material reported from the site
GRAV	Gravettian	Binary: 1 = Gravettian material reported from the site

X_UTM	X coordinate	X coordinate of the site point (WGS1984: UTM Zone 31N)
Y_UTM	Y Coordinate	Y coordinate of the site point (WGS1984: UTM Zone 31N)
ELEV_P	Point Elevation	Elevation of the site extracted from the raster DEM (m above sea level)
ELEV_X	Area Elevation Average	Average elevation for 200 meters around site point
ELEV_STD	Area Elevation Variability	Standard deviation of all elevation values around site point
SLOPE_P	Point Slope	Slope of the site point (degrees)
SLOPE_X	Area Slope Average	Average slope for 200 meters around site point
SLOPE_STD	Area Slope Variability	Standard deviation of all slope values around site point
ASPECT_P	Point Aspect	Aspect of the site point (circular degrees)
ASPECT_AX	Area Aspect Average	Angular mean of all aspect values within 200 meters of site point
ASPECT_AV	Area Aspect Variability	Angular variance of all aspect values within 200 meters of site point
RIVER_ED	Distance to River	Euclidean distance to nearest major river (kilometers)
RIVER_SW	Weighted Distance to River	Slope weighted distance to nearest major river (Units are relative)
SPRING_ED	Distance to Springs	Euclidean distance to nearest modern spring (kilometers)
SPRING_SW	Weighted Distance to Springs	Slope weighted distance to nearest modern spring (Units are relative)
FORDALL_ED	Distance to All Fords	Euclidean distance to nearest known or estimated ford (kilometers)
FORDALL_SW	Weighted Distance to All Fords	Slope weighted distance to known or estimated ford (Units are relative)
FORDREAL_E	Distance to Known Fords	Euclidean distance to nearest known ford (kilometers)
FORDREAL_S	Weighted Distance Known Fords	Slope weighted distance to nearest known ford (Units are relative)
CORINE_P	CORINE	Numeric designator of the CORINE landcover class (Level 3) of the site
SOIL_P	Soil Type	Soil type of the site point
VALPLA_P	Valley / Plateau	The Valley/Plateau classification for the site point
VEG3_P	Veg3 classification	The 3 part modern vegetation zone of the site point
NDVI	NDVI	Normalized Difference Vegetation Index: Scale of vegetation density/health from multi-spectral satellite images
VSA_RAW	Raw viewshed area	The total area visible from the site point (square kilometers)
VSA_RAW_X	Area viewshed average	The average of all viewshed measurements within 200 m of the site (km^2)

VSA_RAW_ST	Area viewshed variability	The standard deviation of the area visible measurements in 200 m of site
VSRAT_RAW	Raw viewshed ratio	Percentage of “Valley” class visible from the site point
VSA_OPT	Optimal viewshed area	The largest area visible from any point within 200 meters of the site point (km^2)
VSRAT_OPT	Optimal viewshed ratio	Percentage of “Valley” class visible from the optimal point
VSA_CUM	Cumulative viewshed area	The area visible from any point within 200 meters of the site point (km^2)
VSRAT_CUM	Cumulative viewshed ratio	Percentage of “Valley” class visible from the area within 200 meters of site
VSA_RAW_X_F	Area viewshed average filtered	The average of all viewshed measurements within 200 m of the site (km^2) after filtering out extreme elevations.
VSA_RAW_ST_F	Area viewshed variability filtered	The standard deviation of the area visible measurements in 200 m of site after filtering out extreme elevations.
VSA_OPT_F	Optimal viewshed area	The largest area visible from any point within 200 meters of the site point (km^2) after filtering out extreme elevations.
VSRAT_OPT_F	Optimal viewshed ratio	Percentage of “Valley” class visible from the optimal point after filtering out extreme elevations.
VSA_CUM_F	Cumulative viewshed area	The area visible from any point within 200 meters of the site point (km^2) after filtering out extreme elevations.
VSRAT_CUM_F	Cumulative viewshed ratio	Percentage of “Valley” class visible from the area within 200 meters of site after filtering out extreme elevations.
FILTER_PER	Percent retained after filter	Percent of cells in that were retained after filtering out extreme elevations.

Table A-2: All site data and landscape variables used in this project

ID	INDEX_NA	FULL_NA	SITE_COM	VISITED	TYPE	REFS
SRA076	Audi Superieur	Abri Audi Superieur		Yes	Abri	54
SRA192	Audi Inferieur	Second Abri d'Audi		Yes	Abri	54
SRA178	Bagnegrole	Bagnegrole		No		2
SRA188	Balutie	La Balutie	Regourdou	Yes		45
SRA036	Bel Air	Bel Air		No		18
GPS022	Belcayre Haute	Belcayre Haute		Yes		16, 34
SRA017	Bil Bas	Abri du Bil Bas		No	Abri	34
SRA080	Bitou	Bitou		No		46
SRA073	Blanchard I	Abri Blanchard I	Castelmerle	Yes	Abri	22, 34, 54
SRA197	Blanchard II	Abri Blanchard II	Castelmerle	Yes	Abri	34, 37
SRA128	Blanchonnerie	La Blanchonnerie		No		
SRA034	Boredon	Boredon,Bos Redon		No		2
SRA015	Boulou Bas	Abri du Boulou Bas		No	Abri	34
SRA234	Cacaro	Abri de Cacaro		No	Abri	34
SRA031	Capudie	Capudie		No		13
SRA030	Carmensac	Carmensac		No		31
SRA001	Casserole	Abri Casserole	Sur Les Roches	Yes	Abri	21, 32, 34
SRA081	Castanet	Abri Castanet	Castelmerle	Yes	Abri	34,42,538,59
SRA016	Cazelle	Abri de Cazelle		No	Abri	34, 46, 54
SRA014	Cellier	Abri Cellier		Yes	Abri	34, 44, 54
SRA156	Chadourne	Abri Chadourne		No	Abri	4
SRA075	Chambre	La Chambre		No		
SRA146	Champ Pages	Champ Pages		Yes		24
SRA035	Combe Negre	Combe Negre		No		
SRA024	Cro le Biscop	Cro le Biscop		No		34, 48, 49
SRA189	Cro Magnon	Abri de Cro Magnon	Chambre d'Ane	Yes	Abri	28, 34
SRA194	Croze à Gontran	Grotte de la Croze A		No	Cave	34
SRA148	Eglise de Guilhem	Eglise de Guilhem		No		
SRA045	Entre Pivieres et Capudie	Entre Pivieres Et Capudie		No		

ID	INDEX_NA	FULL_NA	SITE_COM	VISITED	TYPE	REFS
SRA154	Esclafer	Abri Esclafer		No	Abri	12
SRA180	Facteur	Abri du Facteur	La Foret	Yes	Abri	19, 34, 57
SRA209	Fargues	Les Fargues	La Rigaudie	No		1
SRA018	Fatouret	Grotte de Fatouret		No	Cave	34
SRA013	Faurelie I	La Faurelie I		Yes		34
SRA105	Ferrassie	Abri de la Ferrassie		Yes	Abri, Cave	9, 26, 41
SRA021	Fongal	Abri de Fongal		Yes	Abri	34
SRA238	Font-de-Gaume	Grotte de Font-de-Gaume	Font de Gaume	Yes	Cave	34
SRA228	Fromagerie	La Fromagerie	La Fromagie	No		46
SRA206	Galinat	Galinat		No		
SRA241	Laussel	Grand Abri de laussel		Yes	Abri	8, 34
SRA119	Grand Castang	Grand Castang		Yes		2
SRA203	Graviére du Verdier	Graviére du Verdier		No		
SRA190	Grotte de la Combe	Grotte de la Combe		Yes	Cave	34
SRA196	Jardel I	Abri Jardel I		Yes	Abri	34
SRA047	Oreille d'Enfer	Grotte de l'Oreille d'Enfer	Gorge d'Enfer	Yes	Cave	34
SRA078	Labattut	Abri Labattut	Castelmerle	Yes	Abri	7, 33, 54
SRA091	Langle	Langle 1, Langle 2		No		34, 48
SRA195	Langle 3	Langle 3		No		
SRA048	Lartet	Abri Lartet	Gorge d'Enfer	Yes	Abri	39
SRA097	Laugerie-Haute	Laugerie-Haute-Est		Yes	Abri	3, 47
GPS018	Laussel	Laussel		Yes		8, 27, 50
SRA248	Le Chambon	Le Chambon	Le Chambon	No		
SRA059	Lespinasse	Lespinasse		No		
SRA182	Maillol	Maillol	Maillol	No	Open	
SRA090	Maisnaigre	Maisnaigre		Yes		5, 54
SRA193	Malbarrat	Grotte de Malbarrat		Yes	Cave	34
SRA056	Manestrugeas	Manestrugeas		No		6
SRA007	Merveilles	Abri des Merveilles	Castelmerle	Yes	Abri	29, 34
SRA137	Metairie	Abri de la Metairie	Belcayre	No	Abri	34
SRA072	Micoque	La Micoque		Yes		23, 43, 56

ID	INDEX_NA	FULL_NA	SITE_COM	VISITED	TYPE	REFS
SRA028	Moustier	Le Moustier, Chez delbos		Yes		38, 46
SRA103	Moustier, Upper	Superieur du Moustier		Yes	Abri	38, 55
SRA138	Mouthe	Grotte de la Mouthe		Yes	Cave	11, 34
SRA221	Musée	Abri du Musée		Yes	Abri	21
GPS003	MP site Valloujoux	Near Valloujoux		Yes		
SRA084	Pages	Abri Pages	Le Ruth	Yes	Abri	34
SRA096	Pasquet	Abri Pasquet	Gorge d'Enfer	Yes	Abri	11, 34
SRA176	Pataud	Abri Pataud		Yes	Abri	35
SRA207	Pech de Bertrou	Pech de Bertrou		No		
SRA246	Pech Saint-Sourd	Pech Saint-Sourd	Le Pech	Yes		34
SRA032	Pechboutier	Pechboutier		No		
SRA131	Penoterie	La Penoterie		No		
SRA089	Petit Abri de la Ferrassie	Petit Abri de la Ferrassie		No		9, 41
SRA121	Plaine	La Plaine		No		
SRA215	Poisson	Abri du Poisson	Gorges d'Enfer	Yes	Abri	39
SRA037	Queyrel	Queyrel or Queirel		No		
SRA116	Regourdou	Le Regourdou		No		30, 52
SRA245	Renne	Abri du Renne	Belcayre	Yes	Abri	34
SRA006	Reverdit	Abri Reverdit,des Roches	Castelmerle	Yes	Abri	
SRA157	Rochers de l'Acier	Rochers de l'Acier	Castelmerle	Yes		14, 15, 34
SRA244	Rochette	La Rochette		Yes		17, 20, 36,51
SRA185	Rouquette	La Rouquette		No		
SRA122	Site du Faux	Site du Faux		No		
SRA008	Souquette	Abri de la Souquette	Castelmerle	Yes	Abri	10, 54
SRA088	Sous le Roc	Sous le Roc		No		34
SRA071	Trou du Bechou	Trou du Bechou		No		
SRA003	Tuiliere	Abri de la Tuiliere		No	Abri	34
SRA219	Turq	Grotte de la Turq	Pechnoir	No	Cave	
GPS002	Valloujoux	Valloujoux		Yes	Open	
SRA086	Vidal	Grotte Vidal		No	Cave	40
SRA204	Vignaud	Vignaud		No	Abri	25, 34

ID	LP	MP	EUP	MTA	CHAT	AURIG	X_UTM	Y_UTM	ELEV_P	ELEV_X	ELEV_V	SLOPE_P	SLOPE_X	SLOPE_V	ASPECT_P	ASPECT_AX	ASPECT_AV
SRA076	0	1	1	1	0	0	343442	4977838	109	99.2	0.35	33.2	15.8	0.66	175	82	71.1
SRA192	0	0	1	0	0	0	343442	4977808	75	90.5	0.37	26.6	14.8	0.73	174	80	72.8
SRA178	0	1	0	0	0	0	345708	4972629	174	178.0	0.04	3.1	5.4	0.51	239	39	82.2
SRA188	0	1	1	1	1	1	356405	4990157	153	141.6	0.16	20.0	11.5	0.56	192	80	70.3
SRA036	0	1	0	0	0	0	348785	4981783	238	231.5	0.03	2.2	4.6	0.62	90	175	54.8
GPS022	0	0	1	0	0	1	350814	4986608	96	87.0	0.13	8.4	8.7	0.51	243	136	36.7
SRA017	0	0	1	0	0	1	342028	4978539	82	90.6	0.20	14.7	12.6	0.31	358	225	97.0
SRA080	1	1	0	0	0	0	347407	4972495	179	170.6	0.06	5.8	6.2	0.65	68	218	88.5
SRA073	0	0	1	0	0	1	350360	4984699	89	93.0	0.17	8.6	10.7	0.49	353	263	66.6
SRA197	0	1	1	1	0	0	350360	4984749	80	86.4	0.19	10.3	9.5	0.55	348	267	62.1
SRA128	0	1	0	0	0	0	348132	4993327	251	248.5	0.02	3.6	4.8	0.37	333	263	64.5
SRA034	0	1	0	0	0	0	346741	4973000	166	167.8	0.01	2.7	2.4	0.52	225	307	52.1
SRA015	0	0	1	0	0	1	344981	4981314	63	61.9	0.14	1.4	5.6	0.74	169	134	27.8
SRA234	0	0	1	0	0	0	352081	4976595	142	150.0	0.07	9.4	7.8	0.42	175	95	52.3
SRA031	0	1	0	0	0	0	345060	4972855	186	184.5	0.05	8.2	5.1	0.44	241	9	67.2
SRA030	0	1	0	0	0	0	345446	4974631	168	170.7	0.04	4.2	3.7	0.31	325	313	10.8
SRA001	0	0	1	0	0	1	343302	4977809	91	81.7	0.38	28.1	15.4	0.65	193	57	101.8
SRA081	0	0	1	0	0	1	350399	4984598	98	104.2	0.13	6.2	12.1	0.43	263	267	60.1
SRA016	0	0	1	0	0	1	347225	4978205	97	105.7	0.21	17.7	11.3	0.53	194	40	99.6
SRA014	0	0	1	0	0	1	346674	4984050	79	78.8	0.28	15.8	10.7	0.72	94	162	34.3
SRA156	0	1	0	0	0	0	343362	4977788	79	83.9	0.37	25.8	15.0	0.71	177	64	93.1
SRA075	1	0	0	0	0	0	344697	4972408	185	184.3	0.01	3.1	2.3	0.59	285	259	63.5
SRA146	0	1	1	0	0	0	346652	4983750	58	63.1	0.10	0.4	5.2	0.96	45	178	54.8
SRA035	0	1	1	0	0	0	346343	4974323	174	174.3	0.02	3.1	2.6	0.62	165	76	69.5
SRA024	0	0	1	0	1	1	344608	4978517	72	84.6	0.19	4.1	10.5	0.63	157	112	38.7
SRA189	0	0	1	0	0	1	343025	4978251	74	80.2	0.27	12.4	12.1	0.39	250	45	111.5
SRA194	0	0	1	0	0	1	342729	4978594	77	78.0	0.25	14.3	9.8	0.52	253	24	93.1
SRA148	1	1	1	0	0	0	343216	4977030	131	124.6	0.33	37.5	20.1	0.51	309	306	10.9
SRA045	0	1	0	0	0	0	344703	4972067	189	185.2	0.04	4.4	5.0	0.50	76	160	39.6
SRA154	0	1	0	0	0	0	343582	4977837	99	95.1	0.35	33.6	14.9	0.69	169	98	44.2
SRA180	0	0	1	0	0	1	346590	4982340	81	90.9	0.25	11.3	13.8	0.48	349	302	21.7

ID	LP	MP	EUP	MTA	CHAT	AURIG	X_UTM	Y_UTM	ELEV_P	ELEV_X	ELEV_V	SLOPE_P	SLOPE_X	SLOPE_V	ASPECT_P	ASPECT_AX	ASPECT_AV
SRA209	1	0	0	0	0	0	351096	4979533	158	149.6	0.13	13.4	11.9	0.47	158	118	22.7
SRA018	0	0	1	0	0	0	345250	4976422	155	157.8	0.07	12.7	7.9	0.51	101	216	83.7
SRA013	0	0	1	0	0	1	338649	4983268	104	114.0	0.20	17.7	11.6	0.50	224	56	101.6
SRA105	0	1	1	1	1	1	337338	4979678	114	119.9	0.11	9.1	11.8	0.47	242	39	74.6
SRA021	0	0	1	0	0	1	348708	4984483	99	103.7	0.21	20.8	12.8	0.39	202	37	91.6
SRA238	0	0	1	0	1	1	344479	4977595	91	110.1	0.24	17.3	17.9	0.44	229	15	69.8
SRA228	0	1	0	0	0	0	352715	4994847	163	161.9	0.08	9.8	7.9	0.35	17	266	64.7
SRA206	0	1	1	0	0	0	353343	4982674	222	219.4	0.03	2.2	5.4	0.46	0	219	86.2
SRA241	0	1	1	0	1	1	350667	4978874	100	109.3	0.17	13.7	9.6	0.54	157	115	21.3
SRA119	1	1	0	0	0	0	345055	4972144	169	164.0	0.09	10.7	7.4	0.45	117	133	7.0
SRA203	1	0	0	0	0	0	347252	4978936	92	95.8	0.18	13.5	8.8	0.60	179	88	59.9
SRA190	0	1	1	0	1	1	342943	4975512	135	142.6	0.21	14.5	14.7	0.50	193	75	84.1
SRA196	0	0	1	0	0	1	348521	4984844	75	85.0	0.31	19.1	12.8	0.54	283	350	41.0
SRA047	0	0	1	0	0	0	342068	4978559	76	83.7	0.22	11.5	12.9	0.34	353	225	97.6
SRA078	0	0	1	0	0	1	350200	4984770	83	95.2	0.27	19.0	13.3	0.56	26	238	103.8
SRA091	0	1	1	0	0	0	344686	4980142	62	69.0	0.19	6.6	7.9	0.46	238	28	100.5
SRA195	1	0	0	0	0	0	344405	4980449	57	63.1	0.12	6.7	6.1	0.44	241	5	60.9
SRA048	0	0	1	0	1	1	342078	4978569	77	81.0	0.23	13.2	12.7	0.37	358	225	97.6
SRA097	0	0	1	0	0	1	342337	4979596	83	77.0	0.28	24.0	10.6	0.71	162	129	13.9
GPS018	0	0	1	0	1	1	350643	4978853	102	108.8	0.17	14.9	10.0	0.54	154	118	18.6
SRA248	0	1	0	0	0	0	356042	4993192	71	73.4	0.05	2.8	3.3	0.97	209	138	42.6
SRA059	0	1	0	0	0	0	346042	4982516	73	70.6	0.10	5.4	4.3	0.41	180	94	50.1
SRA182	0	1	1	0	0	0	344601	4981297	69	76.7	0.27	17.7	9.7	0.74	180	89	58.2
SRA090	0	0	1	0	0	1	351989	4988155	154	146.0	0.11	10.4	9.1	0.38	179	87	63.0
SRA193	0	0	1	0	0	1	349050	4978805	101	107.7	0.21	17.7	11.2	0.57	194	64	91.1
SRA056	0	1	1	0	0	0	343562	4977837	103	96.6	0.35	33.7	15.0	0.70	172	97	45.8
SRA007	0	1	1	1	0	0	352917	4993996	163	156.9	0.09	5.9	8.9	0.33	60	180	57.8
SRA137	0	0	1	0	0	1	350409	4984648	97	98.3	0.15	7.3	11.5	0.43	280	271	55.8
SRA072	1	1	1	0	0	0	350841	4986215	80	69.8	0.21	11.6	7.7	0.57	133	169	41.5
SRA028	0	1	1	1	1	1	342763	4980213	87	91.7	0.28	18.1	13.8	0.41	218	43	108.9
SRA103	0	0	1	1	1	1	347155	4984146	70	71.3	0.21	8.8	8.3	0.56	166	81	70.1

ID	LP	MP	EUP	MTA	CHAT	AURIG	X_UTM	Y_UTM	ELEV_P	ELEV_X	ELEV_V	SLOPE_P	SLOPE_X	SLOPE_V	ASPECT_P	ASPECT_AX	ASPECT_AV
SRA138	0	1	1	0	1	1	347075	4984147	73	69.1	0.19	5.4	7.7	0.62	200	63	86.6
SRA221	0	1	1	0	0	0	343801	4976524	145	147.9	0.04	3.1	4.7	0.58	142	265	59.3
GPS003	0	1	0	1	0	0	343262	4977759	63	68.0	0.36	15.4	12.2	0.82	201	49	105.6
SRA084	0	0	1	0	1	1	354874	4986632	117	119.3	0.08	10.3	6.1	0.54	339	296	30.4
SRA096	0	0	1	0	0	1	346482	4983732	74	83.3	0.26	16.5	11.2	0.56	65	184	63.1
SRA176	0	0	1	0	0	1	342119	4978708	58	67.3	0.33	17.1	13.2	0.63	82	212	82.1
SRA207	0	1	0	0	0	0	343173	4977930	70	80.1	0.41	20.8	15.2	0.59	248	27	100.1
SRA246	0	0	1	0	0	1	344601	4976447	186	185.7	0.03	4.1	4.3	0.55	191	346	43.0
SRA032	0	1	0	0	0	0	341069	4977008	77	75.5	0.33	21.7	12.2	0.65	178	90	57.3
SRA131	0	1	0	0	0	0	345618	4973750	172	167.2	0.06	8.9	5.9	0.44	73	238	94.3
SRA089	0	1	0	0	0	0	352843	4994547	193	188.1	0.03	2.4	6.2	0.59	63	198	70.0
SRA121	0	1	0	0	0	0	337338	4979678	114	119.9	0.11	9.1	11.8	0.47	242	39	74.6
SRA215	0	0	1	0	0	1	346006	4973156	178	177.2	0.03	2.1	3.4	0.51	337	265	63.0
SRA037	0	1	0	0	0	0	342084	4978679	69	73.6	0.30	17.2	13.8	0.54	100	208	82.5
SRA116	0	1	1	0	0	0	346182	4972105	182	185.3	0.05	5.9	5.3	0.46	90	150	21.3
SRA245	0	0	1	0	0	1	356599	4990725	202	194.9	0.06	7.8	6.9	0.51	344	276	51.1
SRA006	0	0	1	0	0	1	350802	4986136	73	72.1	0.20	8.6	7.7	0.51	120	162	31.3
SRA157	0	0	1	0	0	1	350339	4984569	102	108.3	0.15	9.8	12.4	0.44	73	240	79.7
SRA244	0	1	1	0	1	1	350339	4984609	97	105.1	0.15	8.3	12.5	0.42	69	249	76.6
SRA185	0	1	0	0	0	0	350492	4985691	85	81.7	0.19	10.2	7.8	0.51	131	137	8.7
SRA122	0	1	0	1	0	0	342727	4977213	69	64.6	0.19	10.1	6.4	0.52	113	127	14.2
SRA008	0	0	1	0	0	1	346516	4972352	179	176.0	0.06	9.1	6.6	0.38	87	171	45.5
SRA088	0	0	1	0	0	1	350201	4984810	75	88.3	0.28	11.6	12.4	0.65	43	243	100.1
SRA071	0	1	0	0	0	0	347871	4984809	82	84.2	0.23	17.2	8.8	0.72	87	182	61.3
SRA003	0	0	1	0	0	0	347075	4984147	73	69.1	0.19	5.4	7.7	0.62	200	63	86.6
SRA219	0	1	0	0	0	0	347906	4984249	69	68.6	0.19	15.5	6.7	0.64	87	156	23.3
GPS002	0	1	1	0	0	0	349050	4974071	149	152.0	0.07	4.8	6.2	0.51	207	26	80.3
SRA086	0	0	1	0	0	0	354699	4986563	114	117.5	0.08	3.8	6.1	0.61	315	299	27.6
SRA204	0	1	1	0	0	1	343173	4977930	70	80.1	0.41	20.8	15.2	0.59	248	27	100.1

ID	RIVER_ED	RIVER_SW	SPRING_ED	SPRING_SW	FORDALL_ED	FORDALL_SW	FORDREAL_E	FORDREAL_S	CORINE_P	SOIL_P	VALPLA_P	VEG3_P	NDVI
SRA076	0.32	3.51	0.30	2.83	0.37	3.84	0.37	3.84	311	C4b	V	F	145
SRA192	0.31	2.64	0.28	2.04	0.36	2.97	0.36	2.97	311	FC	V	F	142
SRA178	5.14	16.58	0.54	1.66	5.64	16.69	5.64	16.69	231	C4a	V	F	123
SRA188	1.68	5.83	1.17	6.88	1.97	5.82	10.85	18.17	311	C4b	V	S	152
SRA036	2.00	11.58	0.62	2.01	2.26	12.90	2.26	12.90	311	C5c	P	F	108
GPS022	0.15	1.87	2.07	5.77	1.57	4.74	4.28	10.64	311	C4b	V	F	156
SRA017	0.19	2.15	0.03	0.00	0.57	3.17	0.57	3.17	311	FC	V	F	153
SRA080	6.30	17.95	0.58	2.67	6.70	18.06	6.70	18.06	242	C4b	V	F	154
SRA073	0.15	1.36	1.89	6.77	0.19	1.44	2.88	7.62	311	C4b	V	F	151
SRA197	0.09	0.77	1.91	6.25	0.14	0.88	2.90	7.07	311	C4b	V	F	142
SRA128	6.59	19.16	1.04	5.36	7.07	20.00	9.51	24.37	242	A	P	F	121
SRA034	5.48	16.42	0.56	1.32	5.89	16.53	5.89	16.53	242	C5a	V	F	97
SRA015	0.07	0.12	0.91	1.81	0.19	0.28	0.19	0.28	211	C4b	V	F	156
SRA234	7.63	19.20	0.47	1.77	8.09	19.53	8.09	19.53	311	C4b	V	S	156
SRA031	4.64	15.58	0.74	2.97	5.18	15.69	5.18	15.69	311	C4b	P	S	117
SRA030	3.39	12.07	0.20	0.67	3.80	12.18	3.80	12.18	242	C5a	V	F	119
SRA001	0.17	2.46	0.17	1.83	0.25	2.68	0.25	2.68	311	C4b	V	F	96
SRA081	0.24	1.82	1.89	7.39	0.27	1.90	2.88	8.08	311	C4b	V	F	144
SRA016	2.89	8.87	0.69	3.39	3.37	9.20	3.37	9.20	311	C4b	V	F	161
SRA014	0.24	1.40	1.21	3.43	0.56	1.69	0.56	1.69	311	C4b	V	F	140
SRA156	0.23	1.90	0.21	1.97	0.27	2.12	0.27	2.12	311	FC	V	F	106
SRA075	4.89	15.04	0.72	2.38	5.48	15.15	5.48	15.15	242	C4b	P	F	105
SRA146	0.04	0.01	0.95	2.12	0.54	0.47	0.54	0.47	231	Fz	V	F	149
SRA035	4.27	15.26	0.64	1.95	4.64	15.37	4.64	15.37	242	C4b	V	F	133
SRA024	0.78	3.22	0.45	1.59	1.15	3.55	1.15	3.55	311	Fz	V	F	146
SRA189	0.21	1.74	0.52	2.28	0.49	2.03	0.49	2.03	311	FC	V	F	152
SRA194	0.32	1.64	0.60	2.57	0.31	1.82	0.31	1.82	311	C4b	V	F	147
SRA148	0.13	3.67	0.51	5.36	0.62	5.28	0.62	5.28	311	C4b	V	N	144
SRA045	5.20	15.86	0.65	3.40	5.79	15.97	5.79	15.97	311	C4b	P	F	162
SRA154	0.46	3.15	0.43	2.51	0.49	3.48	0.49	3.48	311	C4b	V	F	138
SRA180	0.09	0.94	0.54	4.89	0.28	2.25	0.28	2.25	242	C4b	V	F	160

ID	RIVER_ED	RIVER_SW	SPRING_ED	SPRING_SW	FORDALL_ED	FORDALL_SW	FORDREAL_E	FORDREAL_S	CORINE_P	SOIL_P	VALPLA_P	VEG3_P	NDVI
SRA209	5.14	19.10	0.97	5.62	5.38	19.43	5.42	19.43	311	C5a	V	S	163
SRA018	2.20	9.28	0.51	3.33	2.46	9.62	2.46	9.62	311	FC	V	S	155
SRA013	5.24	9.93	1.33	3.99	5.57	9.98	5.57	9.98	311	C5a	V	F	159
SRA105	3.88	8.26	0.07	0.25	4.36	15.07	4.36	15.07	311	FC	V	S	150
SRA021	0.42	3.56	0.24	2.03	1.30	5.06	1.30	5.06	311	C5a	V	F	147
SRA238	1.25	3.65	0.49	3.42	1.36	3.99	1.36	3.99	311	C4b	V	F	152
SRA228	3.88	9.45	0.59	4.56	4.15	10.01	12.19	24.94	242	A	V	N	141
SRA206	3.56	11.56	2.20	10.35	3.74	12.93	5.80	18.11	242	C5c	P	F	118
SRA241	5.36	14.48	0.21	0.93	5.51	14.81	5.51	14.81	311	C4b	V	F	159
SRA119	5.26	16.36	0.33	1.61	5.85	16.48	5.85	16.48	231	C4a	V	S	161
SRA203	2.35	7.51	1.19	3.58	2.93	7.84	2.93	7.84	311	Fz	V	F	155
SRA190	1.39	7.89	0.75	4.93	2.14	8.00	2.14	8.00	311	FC	V	S	158
SRA196	0.17	1.85	0.36	3.45	1.42	3.86	1.42	3.86	311	C4b	V	F	154
SRA047	0.16	1.75	0.00	0.40	0.54	2.78	0.54	2.78	311	C5a	V	F	154
SRA078	0.06	0.69	1.77	7.06	0.17	0.98	2.76	7.02	311	C4b	V	F	163
SRA091	0.15	0.84	1.00	5.21	0.21	1.06	0.21	1.06	211	C5a	V	F	144
SRA195	0.19	0.55	1.32	4.03	0.30	0.52	0.30	0.52	211	C	V	F	146
SRA048	0.15	1.75	0.03	0.58	0.54	2.78	0.54	2.78	311	C5a	V	F	153
SRA097	0.09	1.38	0.07	1.16	0.43	1.80	0.43	1.80	311	FC	V	F	143
GPS018	5.34	14.20	0.18	0.75	5.50	14.54	5.50	14.54	311	C4b	V	F	159
SRA248	0.71	0.79	1.24	1.59	1.21	1.35	12.65	16.27	242	Fy	V	F	127
SRA059	0.26	1.04	0.49	2.16	0.36	1.56	0.36	1.56	242	C4b	V	F	124
SRA082	0.03	0.54	1.27	3.49	0.23	1.55	0.23	1.55	311	C4b	V	F	157
SRA182	0.63	5.51	0.61	4.88	0.78	5.63	6.20	14.29	313	C5a	V	S	157
SRA090	3.89	10.53	0.70	4.71	4.42	10.86	4.42	10.86	242	Fz	V	F	155
SRA193	0.43	3.15	0.40	2.59	0.49	3.48	0.49	3.48	311	C4b	V	F	141
SRA056	3.12	8.70	1.28	8.91	3.45	9.26	11.52	24.19	242	C5a	V	F	125
SRA007	0.21	1.95	1.91	7.30	0.25	2.03	2.92	8.21	311	C4b	V	F	155
SRA137	0.15	1.50	2.10	5.33	1.43	3.38	4.05	8.56	242	Fz	V	F	157
SRA072	0.69	2.96	0.54	2.72	0.67	3.01	0.67	3.01	313	C4b	V	F	145
SRA028	0.30	1.33	1.11	3.42	0.30	1.45	0.30	1.45	242	C4b	V	F	136

ID	RIVER_ED	RIVER_SW	SPRING_ED	SPRING_SW	FORDALL_ED	FORDALL_SW	FORDREAL_E	FORDREAL_S	CORINE_P	SOIL_P	VALPLA_P	VEG3_P	NDVI
SRA103	0.30	0.90	1.20	3.03	0.32	1.10	0.32	1.10	242	C4b	V	F	125
SRA138	0.89	6.40	1.26	6.59	1.32	6.91	1.32	6.91	243	C4b	V	F	156
SRA221	0.13	1.02	0.13	0.69	0.17	1.15	0.17	1.15	112	FC	V	F	99
GPS003	2.28	4.68	1.98	4.22	2.48	5.65	7.79	14.71	242	C4b	V	N	160
SRA084	0.13	1.10	0.97	3.36	0.73	1.56	0.73	1.56	231	C4b	V	F	156
SRA096	0.06	0.39	0.09	1.07	0.58	1.42	0.58	1.42	231	FC	V	F	158
SRA176	0.13	1.50	0.27	1.95	0.27	1.79	0.27	1.79	112	FC	V	F	103
SRA207	1.62	9.06	0.64	5.51	1.92	9.57	1.92	9.57	243	C5a	P	F	150
SRA246	0.30	2.29	1.63	4.07	0.30	2.35	0.30	2.35	311	C4b	V	F	141
SRA032	4.17	15.54	0.49	2.35	4.63	15.65	4.63	15.65	242	C4b	V	N	124
SRA131	3.57	10.15	0.78	5.93	3.85	10.71	11.98	25.64	242	A	P	F	119
SRA089	3.88	8.26	0.07	0.25	4.36	15.07	4.36	15.07	311	FC	V	S	150
SRA121	4.88	16.04	1.11	2.04	5.35	16.15	5.35	16.15	242	C5a	V	F	97
SRA215	0.09	1.32	0.06	0.68	0.61	2.33	0.61	2.33	311	FC	V	F	148
SRA037	5.85	17.86	0.32	2.24	6.34	17.97	6.34	17.97	324	C4b	P	F	164
SRA116	1.48	8.04	0.90	7.21	1.56	8.25	11.36	21.46	313	C5a	P	F	117
SRA245	0.18	1.33	2.18	5.00	1.33	3.22	3.96	8.39	242	Fz	V	F	158
SRA006	0.27	1.81	1.83	7.64	0.29	1.90	2.82	8.08	311	C4b	V	F	159
SRA157	0.24	1.68	1.84	7.48	0.27	1.76	2.83	7.94	311	C4b	V	F	160
SRA244	0.48	1.82	2.37	5.88	0.84	2.28	3.47	7.45	242	Fy	V	F	159
SRA185	0.28	1.22	0.04	0.23	0.58	1.87	0.58	1.87	242	C4a	V	F	149
SRA122	5.81	17.96	0.61	3.00	6.29	18.07	6.29	18.07	231	C5a	V	N	122
SRA008	0.03	0.17	1.77	6.20	0.14	0.58	2.78	6.54	311	C4b	V	F	159
SRA088	0.39	1.62	0.66	2.86	1.05	2.73	1.05	2.73	311	C4b	V	F	159
SRA071	0.30	0.90	1.20	3.03	0.32	1.10	0.32	1.10	242	C4b	V	F	125
SRA003	0.27	0.76	0.54	2.14	0.60	1.63	0.60	1.63	242	Fz	V	F	158
SRA219	6.66	19.59	1.35	5.66	6.94	19.92	6.94	19.92	311	C4b	V	F	157
GPS002	2.15	4.40	1.81	3.72	2.37	5.36	7.58	14.42	242	C4b	V	F	161
SRA086	0.13	1.50	0.27	1.95	0.27	1.79	0.27	1.79	112	FC	V	F	103
SRA204	0.13	1.50	0.27	1.74	0.27	1.79	0.27	1.79	112	FC	V	F	131

ID	VSA_RAW	VSA_RAW_X	VSA_RAW_ST	VSRAT_RAW	VSA_OPT	VSRAT_OPT	VSA_CUM	VSRAT_CUM	VSA_R_X_F	VSA_R_ST_F	VSA_OPT_F	VSR_OPT_F	VSA_CUM_F	VSR_CUM_F	FILTER_PER
SRA076	1.88	1.48	1.27	91	10.60	84	13.26	82	1.47	1.56	7.26	92	9.40	88	42
SRA192	2.01	1.29	1.30	96	10.60	84	12.83	83	0.74	0.49	3.67	96	4.59	95	64
SRA178	1.03	0.94	1.61	63	7.98	10	13.71	32	0.94	1.51	7.98	10	13.71	32	100
SRA188	5.87	1.38	1.22	66	9.31	60	12.18	61	1.65	1.86	9.31	60	11.40	59	70
SRA036	21.13	10.38	0.65	16	26.04	14	32.44	18	10.38	6.72	26.04	14	32.44	18	100
GPS022	5.88	5.07	0.62	66	12.81	70	15.78	70	5.08	3.19	12.81	70	15.78	70	97
SRA017	1.39	2.58	0.38	86	5.13	74	8.04	74	2.38	0.84	5.13	74	7.17	75	87
SRA080	4.90	2.14	0.65	34	8.21	49	13.39	54	2.17	1.39	8.21	49	13.39	54	98
SRA073	7.74	5.34	0.51	84	12.97	79	16.25	78	4.96	2.38	12.15	81	15.45	78	93
SRA197	6.81	5.06	0.45	86	12.99	79	15.29	78	4.67	1.79	10.20	82	13.99	79	93
SRA128	4.75	7.30	0.70	0	17.58	19	28.06	14	7.30	5.12	17.58	19	28.06	14	100
SRA034	1.69	2.54	0.39	20	5.27	37	9.07	38	2.54	0.99	5.27	37	9.07	38	100
SRA015	3.55	2.46	0.42	81	5.83	82	7.18	83	2.46	1.03	5.83	82	7.18	83	100
SRA234	0.83	0.97	0.61	56	2.62	35	4.74	30	0.95	0.58	2.62	35	4.59	31	97
SRA031	4.45	3.97	1.17	53	16.91	32	25.54	42	3.97	4.63	16.91	32	25.54	42	100
SRA030	1.03	0.81	0.82	45	4.23	16	9.44	29	0.81	0.66	4.23	16	9.44	29	100
SRA001	1.49	0.85	0.65	95	2.57	94	5.90	85	0.81	0.59	2.57	94	4.78	93	43
SRA081	4.68	5.17	0.65	73	13.30	81	17.29	78	4.82	3.18	12.96	81	16.14	78	93
SRA016	1.20	1.06	0.83	76	5.31	62	6.41	60	0.86	0.61	3.13	69	4.40	68	79
SRA014	5.31	4.11	0.40	79	8.75	70	11.50	72	3.71	1.20	7.67	74	8.99	73	82
SRA156	1.30	0.93	1.17	96	10.63	84	12.60	85	0.76	0.55	4.03	96	5.97	95	74
SRA075	4.41	4.75	0.51	45	10.07	36	19.06	44	4.75	2.43	10.07	36	19.06	44	100
SRA146	3.01	2.98	0.20	79	4.36	75	6.48	78	2.97	0.58	4.36	75	6.39	78	99
SRA035	4.33	2.73	0.71	20	7.11	29	9.61	32	2.73	1.95	7.11	29	9.61	32	100
SRA024	1.19	1.25	0.58	96	4.12	79	5.03	81	1.04	0.44	2.39	91	3.47	87	80
SRA189	1.73	1.00	0.74	98	4.02	88	5.36	90	0.86	0.55	2.55	96	3.83	95	82
SRA194	1.30	1.09	0.49	99	2.80	92	5.38	86	1.09	0.56	2.80	92	4.67	86	89
SRA148	12.42	3.94	1.02	79	19.05	72	26.86	69	5.15	4.06	15.68	75	22.05	73	40
SRA045	8.09	7.86	0.67	25	23.95	47	30.74	55	7.86	5.23	23.95	47	30.74	55	100
SRA154	2.53	1.77	1.14	97	10.52	85	13.32	82	1.50	1.23	5.78	95	8.14	88	44
SRA180	4.09	2.43	0.76	80	9.71	68	12.28	70	1.91	1.25	5.58	76	8.74	73	84

ID	VSA_RAW	VSA_RAW_X	VSA_RAW_ST	VSRAT_RAW	VSA_OPT	VSRAT_OPT	VSA_CUM	VSRAT_CUM	VSA_R_X_F	VSA_R_ST_F	VSA_OPT_F	VSR_OPT_F	VSA_CUM_F	VSR_CUM_F	FILTER_PER
SRA209	7.09	5.07	0.75	36	13.94	30	16.08	37	5.72	3.68	13.94	30	16.07	37	86
SRA018	1.10	1.00	0.65	56	4.01	23	4.97	25	0.95	0.54	3.25	21	4.27	26	98
SRA013	1.11	1.22	0.66	89	3.95	72	5.15	70	0.91	0.49	2.55	78	3.29	81	75
SRA105	0.75	0.71	1.36	99	5.32	87	7.95	85	0.58	0.74	3.57	97	6.68	89	94
SRA021	4.13	1.41	1.45	76	8.55	72	9.76	72	1.05	1.48	6.41	74	8.28	74	83
SRA238	0.59	1.07	1.58	89	8.70	81	11.48	78	0.49	0.48	3.13	92	5.63	84	68
SRA228	1.30	0.77	0.50	37	2.13	24	3.92	24	0.77	0.39	2.13	24	3.92	24	100
SRA206	12.88	6.65	0.62	19	24.99	22	27.09	21	6.65	4.12	24.99	22	27.09	21	100
SRA241	0.78	1.00	0.86	91	3.76	59	5.16	55	0.65	0.49	2.73	68	3.47	67	79
SRA119	4.60	4.13	0.75	79	11.74	51	16.64	62	4.19	3.08	11.74	51	16.64	62	98
SRA203	2.15	1.61	0.51	71	4.50	67	6.27	69	1.50	0.70	4.01	68	5.21	73	86
SRA190	1.65	1.52	1.23	85	8.93	47	16.33	47	0.84	0.89	4.66	78	5.80	79	53
SRA196	3.72	1.67	0.76	82	5.69	80	9.22	79	1.78	1.45	5.69	80	6.60	79	70
SRA047	1.30	2.39	0.38	89	5.13	74	7.38	75	2.22	0.80	4.62	74	6.69	76	87
SRA078	7.42	7.25	0.48	83	14.70	75	18.83	75	5.37	1.97	11.47	81	14.07	78	71
SRA091	1.21	0.59	0.74	91	1.63	89	2.80	90	0.59	0.44	1.63	89	2.80	90	100
SRA195	1.18	1.13	0.41	86	2.61	78	4.28	80	1.13	0.46	2.61	78	4.28	80	100
SRA048	1.87	2.33	0.39	88	5.13	74	7.43	76	2.24	0.82	4.62	74	6.81	76	89
SRA097	3.21	3.08	0.44	86	6.88	76	9.02	79	3.06	1.28	6.31	80	8.56	80	94
GPS018	0.70	1.02	0.87	91	3.92	49	5.42	54	0.70	0.54	2.73	68	3.75	62	82
SRA248	2.34	2.90	0.37	82	6.95	75	10.84	75	2.90	1.08	6.95	75	10.84	75	100
SRA059	2.29	1.16	0.54	86	2.99	74	4.41	75	1.16	0.63	2.99	74	4.41	75	100
SRA082	3.00	2.68	0.47	78	7.90	81	9.76	83	2.24	0.50	3.84	79	6.37	83	79
SRA182	14.85	10.73	0.41	68	22.18	55	35.63	64	10.88	4.47	22.18	55	35.60	64	90
SRA090	1.44	1.06	0.90	81	4.73	68	6.53	65	0.72	0.67	3.51	75	4.82	72	78
SRA193	2.81	1.84	1.14	96	10.52	85	13.41	82	1.66	1.28	5.78	95	8.28	88	38
SRA056	4.79	4.28	0.51	49	10.91	38	12.45	40	4.44	2.14	10.91	38	12.45	40	94
SRA007	5.20	5.19	0.58	75	12.98	81	16.69	78	5.08	2.97	12.98	81	16.22	78	98
SRA137	7.23	4.81	0.43	74	9.14	72	12.18	70	5.09	1.91	9.14	72	12.18	70	92
SRA072	2.58	1.36	0.85	89	7.42	72	9.16	71	1.43	1.20	7.23	73	7.86	74	72
SRA028	3.34	2.59	0.49	73	6.56	75	9.01	76	2.46	1.10	5.61	77	8.07	78	93

ID	VSA_RAW	VSA_RAW_X	VSA_RAW_ST	VSRAT_RAW	VSA_OPT	VSRAT_OPT	VSA_CUM	VSRAT_CUM	VSA_R_X_F	VSA_R_ST_F	VSA_OPT_F	VSR_OPT_F	VSA_CUM_F	VSR_CUM_F	FILTER_PER
SRA103	4.16	2.46	0.50	77	6.37	72	8.76	77	2.41	1.17	6.37	72	8.39	77	98
SRA138	0.86	1.11	1.28	61	7.30	54	13.47	69	1.11	1.42	7.30	54	13.47	69	100
SRA221	1.63	0.84	0.63	97	2.47	96	4.41	88	0.86	0.55	2.47	96	3.75	94	81
GPS003	1.89	1.11	0.85	65	5.41	51	6.99	52	1.11	0.94	5.41	51	6.99	52	100
SRA084	3.73	4.02	0.39	77	8.44	73	10.82	73	3.29	0.80	5.64	73	7.08	76	76
SRA096	1.95	2.10	0.71	90	9.06	71	9.89	72	1.59	0.78	3.61	90	4.67	87	81
SRA176	1.86	0.89	0.82	97	3.52	94	5.89	86	0.93	0.68	2.82	93	4.10	92	71
SRA207	6.59	4.21	1.03	64	16.90	53	26.10	54	4.21	4.35	16.90	53	26.10	54	100
SRA246	7.20	4.03	0.55	96	11.96	90	14.65	90	3.46	1.56	8.86	95	11.88	92	81
SRA032	3.40	2.66	0.92	26	9.07	20	12.41	28	2.66	2.46	9.07	20	12.41	28	100
SRA131	13.15	7.91	0.58	33	15.74	35	19.26	39	7.91	4.58	15.74	35	19.26	39	100
SRA089	0.75	0.71	1.36	99	5.32	87	7.95	85	0.58	0.74	3.57	97	6.68	89	94
SRA121	3.54	3.05	0.56	33	8.30	24	10.91	27	3.05	1.71	8.30	24	10.91	27	100
SRA215	2.72	2.19	0.65	90	9.06	71	9.93	72	1.88	0.89	4.60	84	5.83	80	87
SRA037	4.41	7.89	0.41	23	17.20	51	24.10	49	7.89	3.21	17.20	51	24.10	49	100
SRA116	27.10	8.89	0.74	50	27.43	42	40.57	47	9.26	6.64	27.43	42	40.57	47	94
SRA245	5.93	5.25	0.43	72	10.63	73	12.71	71	5.25	2.24	10.63	73	12.71	71	100
SRA006	6.45	5.66	0.68	81	14.57	76	17.69	76	4.82	3.25	12.93	79	15.89	78	89
SRA157	6.46	5.74	0.63	81	14.32	77	17.44	77	4.96	3.04	12.94	79	15.67	79	89
SRA244	7.85	6.05	0.31	75	12.83	73	14.39	73	6.05	1.88	12.83	73	14.39	73	100
SRA185	1.85	1.45	0.68	85	5.98	95	8.04	91	1.45	0.98	5.98	95	8.04	91	100
SRA122	7.26	6.33	0.61	21	20.72	39	23.53	43	6.33	3.89	20.72	39	23.53	43	100
SRA008	5.43	6.48	0.50	82	14.14	77	18.09	75	4.85	1.69	10.20	82	13.21	78	73
SRA088	4.82	4.67	0.26	81	7.11	73	8.98	75	4.62	1.17	7.05	75	8.87	75	97
SRA071	4.16	2.46	0.50	77	6.37	72	8.76	77	2.41	1.17	6.37	72	8.39	77	98
SRA003	3.48	2.82	0.27	81	5.22	81	6.80	80	2.82	0.77	5.22	81	6.80	80	100
SRA219	1.27	0.69	0.65	52	2.21	24	4.45	43	0.69	0.45	2.21	24	4.45	43	100
GPS002	2.18	1.14	0.67	66	5.20	53	6.87	53	1.14	0.76	5.20	53	6.87	53	100
SRA086	1.86	0.89	0.82	97	3.52	94	5.89	86	0.93	0.68	2.82	93	4.10	92	71
SRA204	1.86	0.90	0.77	96	3.52	94	6.03	85	0.94	0.67	2.82	93	4.09	93	72

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Appendix B: Methodological Details

i: Data from the SRA

Although already in a GIS format, these data did require some treatment. They were projected in a uniquely French coordinate system. Furthermore, they represented sites as circles which did not accurately conform to published or observed site size. Finally, these data were not annotated beyond site name and a very rough estimate of chronology (eg Middle/Upper Paleolithic).

During the course of this project, this database was updated to include all of the fields listed in Appendix A as well as references to the available literature for each site. As part of a data-sharing agreement with SRA, a copy of this document, along with the raw data pertaining to site location will be sent to the SRA for incorporation into the regional archaeological database.

ii. Sampling mean and variability around each site

To full address the central tendency of the area surrounding each site, a Python script to calculate the mean and variance of each pixel within a radius of site location was developed. In essence, this script creates a buffer around each site, subsets the input raster, calculates statistics on the remaining part and adds the calculated values to the database. Different algorithms are needed for categorical data. Instead of statistics, this outputs a separate table with columns denoting the frequency of each class in the area surrounding the site. The Python scripts used to perform these calculations can be found in Code Extract 1 and Code Extract 2

iii. DEM Creation

The elevations in ASTER gDEM were accurate in a relative sense, but were approximately 8.25 meters lower than the known topographic points from the IGN topographic map. Thus, the first step was to reduce the cell values of the ASTER to match the known elevations. After this, isolated points of high and low elevation areas from the the topographic maps were digitized for inclusion in the DEM. The original ASTER gDEM was then vectorized into a point shapefile. Points where the surfaces did not agree were preferentially given values from from the IGN map. Additionally, some areas (e.g. small vallons) that were below the resolution of the gDEM were added. Next, a Triangulated Irregular Network (TIN), or vector-based topographic representation was used to check for areas of inaccurate or unrealistic topography. Finally, the modified distribution of point was interpolated into a corrected version of the Aster DEM.

There are a number of different interpolation algorithms to interpolate a surface from topographic data. For archaeological applications the most well known are Spline, Krige, and Inverse Distance Weighting methods. Each has a different set of restrictions and assumptions and is best applied to certain types of landscapes (Hageman and Bennett, 2000).

An interpolation is an estimation of the true topography of the landscape, therefore its accuracy must be measured as well. The accuracy of the DEM used in this project was assessed both by verifying elevations and features on other imagery sources (high resolution satellite imagery and cadastral maps) and by using the Spatial Statistics tool in ESRI ArcGIS to measure the Root Meas Square (RMS) error of a series of known elevations against the predicted elevations from the DEM. For these data, an Ordinary Krige with a spherical semivariogram model gave the most accurate DEM. A plot of locations in the final DEM against known heights is found in Figure 4-9 and the final DEM in Figure 4-8.

iv. Extent rectangles

Many of these analyses require measures of landscape characters for the area surrounding each site. Thus, the extent used in analyses must be larger than the extent of sites. In this project, most landscape characters are sampled in a 200-meter radius around each site. However, the viewshed analyses require a DEM at least 10 km larger than the study area. Thus, three different spatial extents were used:

Site Extent: The full extent of sites used in this area. This is the true study area for this project.

Analysis Extent: A rectangle 1 km larger in all directions than the site extent. Most spatial layers that require average values (e.g. slope, soil types) were created to this extent.

Topo Extent: A rectangle 10 km larger in all directions than the site extent. The DEM was created to this extent because the viewshed calculations require the larger area.

Table B - 1 shows the coordinates and area of these extents and Figure B -1 shows the area encompasses by each.

v. Aspect circular stats

Aspect, or the orientation of a location, was calculated in the ArcGIS 10 Spatial Analyst Toolbox. This tool returns a raster map where the only pixel value is the angular measure of the orientation of each cell. Aspect is an angular measurement, so the normal average and variability measures are inapplicable. To explain, the angular measures of 359° and 1° should have a correct average of 0°, but the mean taken in a standard way ([359 + 1] / 2) give the incorrect result of 180°. Instead the angular measures must be converted to points on the unit circle and trigonometric principles used to take an average. There is some variation is the equations used for these measures (e.g. Gaile and Burt, 1980; Batschelet, 1981; Fisher, 1993). For this project, the Angular Mean was calculated using the formula:

$$\bar{\theta} = atan2\left(\frac{\sum_{j=1}^{n}\sin(\theta_j)}{n}, \frac{\sum_{j=1}^{n}\cos(\theta_j)}{n}\right)$$

and the Angular Standard Deviation:

$$\sigma_\theta = \sqrt{-2\cdot\ln\left(\frac{\sum_{j=1}^{n}\cos(\theta_j - \bar{\theta})}{n}\right)}$$

Both of these equations follow measures presented in Gaile and Burt (1980: 12-18). The average and standard deviation were calculated for all cells within 200 meters of the site location point. The Python function used to apply these formulae to raster data can be found in Code Extract 3.

vi. Satellite Information

This project utilizes imagery and data primarily from two satellite systems, Landsat and ASTER. A brief discussion of each of these satellites and the type of data available from each follows. The resolution and wavelengths sampled varies between these satellites (Table B-2)

The Landsat project consists of a series of seven satellites operating nearly continuously since 1972. The earliest satellites (Landsat 1 - 3) carried an instrument called the Multi Spectral Scanner (MSS) which sampled the globe in the three standard visible light bands (red, green, and blue) and well as one near infrared band. Data from these satellites have, at best, a 75 m resolution. The next generation of Landsat satellites (4 – 5) continued with the MSS instrument, but added the highly useful Thematic Mapper (TM), which samples seven bands (three visible, three near infrared, and one thermal) at a resolution of 30 m. The most recent Landsat satellite

(7) uses the Enhanced Thematic Mapper (ETM+) scanner. This scanner contains all of the TM bands, with an additional thermal infrared band and a single panchromatic (black and white) band. All of the bands in the ETM+ have a 30-meter resolution except the thermal infrareds (6a and 6b) with a resolution of 60 m and the panchromatic band (8) with a 15 m resolution. The increased resolution of the panchromatic band allows it to be combined with the visible light bands (1-3) to artificially "sharpen" the color image to 15 m resolution (Parcak, 2009: 72; ERDAS, 2010: 162-163).

Landsat TM data have been the most widespread and easily available since the beginning of private and academic use of imagery, and thus a number of indices based upon reflectivity ratios among the various bands have been devised for vegetation and geologic signatures (Parcak, 2009: 92-94; ERDAS, 2010: 500-502). This project uses indexed imagery mainly as a method for standardizing analogies with published paleo-flora and fauna, and as a method for incorporating modern landscape characters into a model of factors influencing site location choice. Most salient among these is the Transformed Normalized Difference Vegetation Index (a ratio based on the near infrared [band 4] and the visible light in the blue spectrum [band 4]). Other indices of more limited utility include clay minerals (which can affect erosion potential, band 5 / band 7) and a multi-component type of landcover index, Tasseled Cap, that restructures the image into a number of bands each representing a different aspect of spectral variation. The most useful of these are the bands representing "luminosity," "moisture," "vegetation," and "haze." The last of these can be used to reduce the effects of atmospheric interference on the image (Kauth and Thomas, 1976: 45).

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) was launched in late 1999 as a joint Japanese-American project. It measures 14 bands in the visible and infrared spectra. Resolution is 15 m in the visible and near infrared spectra (bands 1, 2, 3n, 3r), 30 m in the middle, or short-wave, infrared spectrum (bands 4 - 9), and 90 m in the thermal infrared spectrum (bands 10 – 14). The ASTER sensor samples surface reflectivity in significantly smaller bands than does Landsat. Additionally, with ASTER's 15 m spatial resolution it is possible to sample ground cover with spatial accuracy and with a finer resolution spectrally (Abrams et al., 2002: 9-10). Unfortunately, the relatively recent advent of ASTER imagery means that there is less support or technological finesse than there is for Landsat imagery. Thus, there are fewer well-understood, or automated, indices for ASTER imagery (but see San et al., 2004). In this project, ASTER data were used mainly to validate Landsat classifications, to test variation across seasons, and to generate relative elevations.

Both the Landsat and ASTER images were then processed in a number of standard ways to gain the maximum of information about modern landcover. While the landcover is undeniably different today than it was in the Paleolithic, these processes were designed to yield data about potential eco-clines across the landscape. As these boundaries are usually the result of geological, solar, and topographic features, the modern classes should reflect, if not the actual type of environment, potential locations where different eco-zones may have been present.

vii. 3 part modern veg zones

The modern vegetation zones were deliminated based on the final DEM and rasters generated from it representing slope and aspect. Classification was performed by recoding each of the rasters into a binary variable and then combining the three into a raster with three classes representing each zone. Slopes above 8 degrees were given a value of 1 and those below a value of 0. The Elevation was recoded so those areas above 220 meters above sea-level (uplands) or below 110 meters above sea-level (low lying valleys) were given a value of 0 and areas in between given a 1. The aspect was recoded so all south-facing pixels (90º to 270º) were given a value of 2 and north-facing a 1 (-90º - 90º). Vegetation zones were then calculated using the following equation:

Slope_reclass * Elevation_reclass * Aspect_reclass = Vegetation zone [0, 1, 2]

Table B-3 summarized the component values and what type of terrain each of these three final codes represents. All reclassification was performed with the Map Algebra component of ArcGIS. A majority filter with 3x3 kernel was then used to remove small misclassified areas. This filter examines the 8 pixels around each pixel and then reassigns the pixel value to the most common surrounding value.

ix. Viewshed calculations

Viewshed analysis uses a DEM to estimate what is visible from a discrete location on the map. This is calculated by analyzing which cells would or would not be blocked by another cell given specified observer and target heights (Wheatley and Gillings, 2002: 179-184). Most standard GIS packages yield the resulting data as binary rasters of visible or not visible. However, because the calculation is based solely on the underlying DEM and it is potentially biased, there has been a recent argument that viewsheds should not be viewed as a boolean system, but instead as a probability of visibility by including a measure of the underlying error in the terrain model (Fisher, 1992, 1995). However, this approach is largely designed for quantifying the visibility of a location from a number of satellite points or from long distances. Because this project is more interested in the visibility of a landscape from a specific location, the standard, less computationally complex, binary measure was used.

Viewshed has been used often in more recent archaeological contexts (e.g. Lake et al., 1998; Jones, 2006; Lambers and Sauerbier, 2006) but has been rarely used in Paleolithic contexts because of presumed topographic changes (but see van Leusen, 1993; Petraglia et al., 2009). For this study, as we are working under the assumption of little significant topographic change, viewshed can give an interesting look into potential characteristics influencing site location choice. In particular, as all of the Paleolithic groups were hunter-gatherers we can assume that at least some of their sites would be situated with a good overview of the habitats of potential prey species.

A viewshed raster was calculated for each site. In these calculations an observer height and a maximum distance are included. The observer height was arbitrarily set at 1.5 meters. The maximum distance is based largely upon the maximum distance at which details of animal movement could be determined. The average human eye can distinguish an object that is greater than one arc minute (0.01667°) of the total field of view. In optimal cases thirty arc seconds (0.00833°) can be perceived (Ogburn, 2006). This translates to an object with a 1-meter maximum dimension being visible from an average distance of 3 km and a maximum of 6.5 km. If the object has a maximum dimension of 2 m, this range expands to an average of 6.5 km and a maximum of 13 km. Given that the optimal case is rare and that visibility at a distance is influenced by other factors (discussed below) the maximum range for this project was set at 10 km; higher than the average range to see a 2-meter object.

The analysis then yields an area of total visible terrain for each site. A measure of what type of terrain is visible is also important because the subsistence strategies, and thus prey species, of the different time periods are expected to differ. The classification of landcover used will be discussed below, but a quantification of how much of each type of landcover is visible was also calculated for each site.

For the viewshed calculation the choice of the initial location is extremely important. Near objects will block the line of sight more profoundly than far objects (Wheatley and Gillings, 2002: 186-187). As discussed previously, the points representing each site may not be perfectly accurate or even representative of the site. Thus, a method for calculating the Optimal Viewshed for an area (here a 200-meter radius) around each site was developed. The code for this Python script (follows) isolates each pixel within the given distance from the site, calculates the viewshed, stores the total area, and returns the a maximum visible area, an average visible area, and standard deviation for the site. It also computes cumulative and multiple viewsheds for the area. The multiple viewshed combines the viewshed data for each pixel of the area into a binary image. This gives an idea of what would be visible from the totality of the 200-meter radius around the site point. The cumulative viewshed follows the same procedure, but returns a sum of how many cells in the original 200-meter radius can see each point. This can then be converted to a surface showing what is visible from a certain percentage of the original area. The ratio of what types of visible landcover are visible was also calculated for the raw optimal and cumulative viewsheds and can be found in Chapter 5. The Python script used in these viewshed calculations can be found in Code Extract 4.

All of these different viewshed analyses were also performed on a filtered data set that excluded any area that was radically different from the individual site point (i.e. areas with an elevation 30 meters higher or lower than the site point). This was done to counteract the possibility of the 200-m radius capturing the top of a cliff-face for rockshelter sites.

Figures and Tables: Appendix B

Table B-1: Extent rectangles used in this study

Extent	Top Left Corner		Bottom Right Corner		Area (km^2)
	UTM	Long / Lat	UTM	Long / Lat	
Site	358000, 4972000	1.202 E, 44.887 N	336000, 4995000	0.916 E, 45.089 N	506
Analysis	359000, 4971000	1.215 E, 44.878 N	335000, 4996000	0.903 E, 45.098 N	600
Topo	368000, 4962000	1.331 E, 44.799 N	326000, 5005000	0.785 E, 45.177 N	1806

Table B-2: Details on the Landsat and ASTER Satellites

ASTER				Landsat ETM +		
Sensor	Band	Wavelength	Resolution	Band	Wavelength	Resolution
				Band 1	0.45-0.52 µm	30 m
VNIR	Band 1	0.52 - 0.60 µm	15 m	Band 2	0.52-0.60 µm	30 m
	Band 2	0.63 - 0.69 µm	15 m	Band 3	0.63-0.69 µm	30 m
	Band 3n	0.76 - 0.86 µm	15 m	Band 4	0.76-0.90 µm	30 m
	Band 3b	0.76 - 0.86 µm	15 m			
	Band 4	1.60 - 1.70 µm	30 m	Band 5	1.55-1.75 µm	30 m
SWIR	Band 5	2.145 - 2.185 µm	30 m	Band 7	2.08-2.35 µm	30 m
	Band 6	2.185 - 2.225 µm	30 m			
	Band 7	2.235 - 2.285 µm	30 m			
	Band 8	2.295 - 2.365 µm	30 m			
	Band 9	2.36 - 2.43 µm	30 m			
TIR	Band 10	8.125 - 8.475 µm	90 m			
	Band 11	8.475 - 8.825 µm	90 m			
	Band 12	8.925 - 9.275 µm	90 m			
	Band 13	10.25 - 10.95 µm	90 m	Band 6	10.4-12.5 µm	60 m
	Band 14	10.95 - 11.65 µm	90 m			

Table B-3: Pixel values in the original data corresponding to the modern vegetation zone classification

Zone	Code	Elevation	Slope	Aspect
Flat areas	0	< 110 m or > 220 m	< 8º	any
North-facing slopes	1	110 - 220 m	> 8º	-90º - 90º
South-facing slopes	2	110 - 220 m	> 8º	90º - 270º

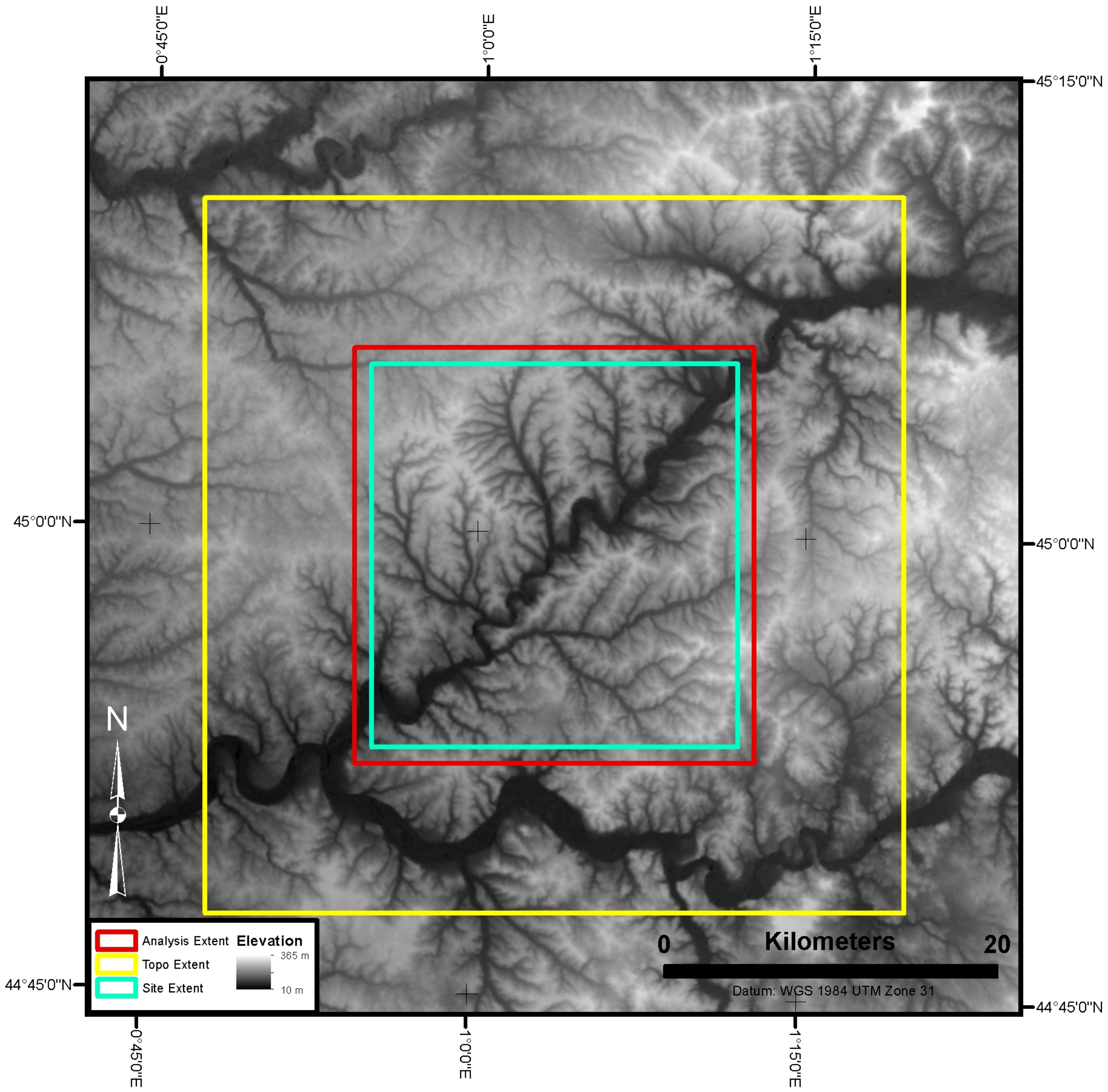

Figure B-1: Map of extent rectangles used in this project

Extracts of code referenced in the text

Code Extract 1: Python script to calculate the mean and variability for the area surrounding each site

```
##------------------------------------------------------------------------------------------------
## ExtractByMask.py
## Created by ML Sisk on: 2011-04-25
## Description: Inputs a folder of rasters images (currently set to Tiff format) and a point
##      shapefile.  Extracts the raster values by a created mask of each polygon then computes
##      the average and standard deviation for a given area surrounding each point
##-----------------------------------------------------------------------------------------------

import arcpy, os

# Check out any necessary licenses
arcpy.CheckOutExtension("spatial")
arcpy.env.overwriteOutput = True

# Input variables:
InputShape = "C:\\DissWorking\\Data\\AllSites_Final.shp"
DistanceToAverage = 200                                             #in meters
DifferentValuesIngnored = True
BufferedShape = "C:\\DissWorking\\Data\\Cache\\AllSites_FinalBuffered.shp"
IndexField = "RESORTID_S"

#Folder variables
rasterFolder = "C:\\DissWorking\\Data\\StatsWork\\DataLayers\\AverageSTATS\\"
scratchPath = "C:\\temp\\Scratch\\"

#Output variables
summaryTablePath = "C:\\DissWorking\\Output\\Proximity_Stats_Table.txt"
MeanString = "_mean"
STDString = "_std"
arcpy.env.workspace = rasterFolder
rasterList = arcpy.ListRasters("*", "TIF")

print "1). Building files for %s layers"%(len(rasterList))
splitPath = os.path.split(summaryTablePath)
logStatsFileHeader = "Site"
for eachRaster in rasterList :               #Creates a header for each of the rasters
    eachCode = str(eachRaster[0:5])
    eachXField = eachCode + MeanString
    eachSTDField = eachCode + STDString
    logStatsFileHeader = "%s;%s;%s"%(logStatsFileHeader,eachXField,eachSTDField)
logFileWriter = open(summaryTablePath, 'w')
logFileWriter.write(logStatsFileHeader + "\n")
logFileWriter.close()
print "     a). Output File built"
if arcpy.Exists(BufferedShape):
    print "     b). Buffer file already exists"
else:
    arcpy.Buffer_analysis(InputShape, BufferedShape, "%s Meters"%DistanceToAverage)
    print "     b). Buffer file created"
print "2). Calculating Frequencies"
total = arcpy.GetCount_management(BufferedShape)
counter = 1

allSitesCURSOR = arcpy.SearchCursor(BufferedShape) #Makes a layer and a sort cursor for each
for eachSite in allSitesCURSOR:                           #Cycles through each point
    eachName = eachSite.getValue(IndexField)
```

```
    print "%8s / %s Site ID: %s"%(counter, total, eachName)
    newSummaryRow = eachName
    selc = "\"%s\" = \'%s\' "%(IndexField, eachName)
    arcpy.MakeFeatureLayer_management(BufferedShape,"bufferedPoints_lyr", selc)
    for eachRaster in rasterList :
        eachCode = str(eachRaster[0:5])
        upXField = eachCode + MeanString             #Remakes the fields in the summary table
        upSTDField = eachCode + STDString
        outName = scratchPath + "\\" + eachName + eachCode
        arcpy.gp.ExtractByMask_sa(eachRaster, "bufferedPoints_lyr", outName)
        meanEach = float(str(arcpy.GetRasterProperties_management(outName, "MEAN")))
        stdEach  = float(str(arcpy.GetRasterProperties_management(outName, "STD")))
        print "%16s: Mean = %.4f   STD = %.4f"%(eachCode, meanEach, stdEach)
        newSummaryRow = "%s;%.4f;%.4f"%(newSummaryRow,meanEach,stdEach )
        arcpy.Delete_management(outName)
    logFileWriter = open(summaryTablePath, 'a')      #Writes this entry in the log file
    logFileWriter.write(newSummaryRow + "\n")
    logFileWriter.close()
    arcpy.Delete_management("bufferedPoints_lyr")
    counter +=1
del allSitesCURSOR
print "\n\nFinished!\n\nHit Enter to exit program"
waiter = raw_input()
```

Code Extract 2: Python script to calculate the frequency of categorical variables the area surrounding each site

```
##------------------------------------------------------------------------------------------------
## Calc_FrequencyExtractByMask.py
## Created by ML Sisk on: 2011-04-25
## Description: Essentially the same as ExtractByMask.py , but creates a table  of the frequency
##     of each categorical variable surrounding each site in the shapefile
##------------------------------------------------------------------------------------------------

import arcpy, os

# Check out any necessary licenses
arcpy.CheckOutExtension("spatial")
arcpy.env.overwriteOutput = True

# Input variables:
BufferedShape = "C:\\DissWorking\\Data\\Cache\\AllSites_FinalBuffered.shp"
IndexField = "RESORTID_S"
valueField = "VALUE"
rasterFolder = "C:\\temp\\Scratch\\"

#Folder variables
scratchPath = "C:\\temp\\Scratch\\"
summaryTablesPath = "C:\\DissWorking\\Output\\"

#Output variables
arcpy.env.workspace = rasterFolder
rasterList = arcpy.ListRasters("*", "TIF")
tempAttTable = scratchPath + "\\tempAttTable.dbf"


print "1). Creating output files"
if arcpy.Exists(BufferedShape):
    print "     a). Buffer file already exists"
else:
    arcpy.Buffer_analysis(InputShape, BufferedShape, "%s Meters"%DistanceToAverage)
    print "     a). Buffer file created"
print "     b). Building frequency tables for %s layers"%(len(rasterList))
#Cycles through the rasters and builds a table for the frequency of each one
for eachRaster in rasterList :
    if os.path.exists(tempAttTable):
        arcpy.Delete_management(tempAttTable)
    eachCode = str(eachRaster[0:5])
    eachTable = summaryTablesPath + "Proximity_Freq_" + eachCode + ".dbf"
    if os.path.exists(eachTable):
        arcpy.Delete_management(eachTable, "")
    eachAttTable = eachRaster + ".vat.dbf"
    if not os.path.exists(eachAttTable) :    #Checks if each raster attribute table exists
        arcpy.BuildRasterAttributeTable_management(eachRaster, "NONE")
    arcpy.Copy_management(eachAttTable, tempAttTable)
    arcpy.AddField_management(tempAttTable, IndexField, "TEXT", "", "", "15", "", "NULLABLE")
    arcpy.CalculateField_management(tempAttTable, IndexField, "\"Total\"", "", "")
    arcpy.PivotTable_management(tempAttTable, IndexField, valueField, "COUNT", eachTable)
    print "    Built frequency table for : %s"%(eachRaster)

print "2). Calculating Frequencies"
total = arcpy.GetCount_management(BufferedShape)
counter = 1
#Makes a layer object for the point data and a cursor to sort it
allSitesCURSOR = arcpy.SearchCursor(BufferedShape)
for eachSite in allSitesCURSOR:
    eachName = eachSite.getValue(IndexField)
    print "%8s / %s Site ID: %s"%(counter, total, eachName)
    selc = "\"%s\" = \'%s\' "%(IndexField, eachName)
```

```
    arcpy.MakeFeatureLayer_management(BufferedShape,"bufferedPoints_lyr", selc)
    for eachRaster in rasterList :
        if os.path.exists(tempAttTable):
            arcpy.Delete_management(tempAttTable)
        eachCode = str(eachRaster[0:5])
        activeTable = summaryTablesPath + "Proximity_Freq_" + eachCode + ".dbf"
        eachClipRaster = scratchPath + "\\" + eachName + eachCode + "_image.tif"
        tempPivotTable = scratchPath + "\\" + eachName + eachCode + "_Pivot.dbf"
        arcpy.gp.ExtractByMask_sa(eachRaster, "bufferedPoints_lyr", eachClipRaster)
        eachAttTable = eachClipRaster + ".vat.dbf"
        if not os.path.exists(eachAttTable) #Checks if each raster attribute table exists
            arcpy.BuildRasterAttributeTable_management(eachClipRaster, "NONE")
        arcpy.Copy_management(eachAttTable, tempAttTable)
        arcpy.AddField_management(tempAttTable, IndexField, "TEXT", "", "", "15", "", "NULLABLE")
        arcpy.CalculateField_management(tempAttTable, IndexField, "\"%s\""%(eachName), "", "")
        arcpy.PivotTable_management(tempAttTable, IndexField, valueField, "COUNT",tempPivotTable)
        arcpy.Append_management(tempPivotTable, activeTable, "NO_TEST","","")
        arcpy.Delete_management(tempPivotTable)
        arcpy.Delete_management(eachClipRaster)
    arcpy.Delete_management("bufferedPoints_lyr")
    del eachSite
    counter +=1
del allSitesCURSOR


print "\n\nFinished!\n\nHit Enter to exit program"
waiter = raw_input()
```

Code Extract 3: Python function to calculate the angular mean and variance of a list of degree measures. The list of angular measures is extracted as in Code Extract 1.

```
## ---------------------------------------------------------------------------------------------
## ExtractAspect.py
## Created by ML Sisk on: 2011-04-25
## Description: Inputs an aspect raster and a point shapefile and calculates the angular mean and
##     angular variance for a given area surrounding each point.
## ---------------------------------------------------------------------------------------------

import arcpy, os, math, numpy

# Check out any necessary licenses
arcpy.CheckOutExtension("spatial")
arcpy.env.overwriteOutput = True

# Local variables:
InputShape =          "C:\\DissWorking\\Data\\AllSites_Final.shp"
aspectRaster =        "C:\\DissWorking\\Data\\StatsWork\\ASPECT_AsterGDem1.tif"
IndexField =           "RESORTID_S"
DistanceToAverage =   200

# Folder Variables
outputPath =          "C:\\DissWorking\\Output\\"
cachePath =            "C:\\DissWorking\\Data\\Cache"

#CreatedVariables
summaryTablePath =    outputPath + "Proximity_Angular_Table.txt"
aspectPoints =                cachePath + "\\aspect_rasteraspoints.shp"
logFileHeader = "%s;%s;%s;%s;%s;%s"%("Site","AngMean","AngVar", "AngSTD","SampleSize","Flat")

#Functions definitions
def angularStats(Angle_List):
#Calculates angular statistics for list on degree measurements
#      Returns a 5 part list in the form [Angular Mean, Angular Variance, Angular STD,
#      MeasuredPixels, FlatPixels]
    n = len(Angle_List)                         #The number of degree measurements
    angMeanDeg = 0.0                                #Clearing old values
    angSTD_Deg = 0.0
    cosSum = 0
    sinSum = 0
    radList = []
    flat = 0
    cosDiffSum = 0.0
    for a in Angle_List:                 #Cycles through each measurement and converts to radians
        if a == -1:                           #To drop what ArcGIS codes as "Flat"
            n = n -1
            flat +=1                            #Keeps a record of how many "Flat" measurements
        else:
            radList.append(math.radians(a))
    if len > 0:                                     #Avoids division by zero errors
        for b in radList:                           #Calculates the sum of the sine and cosines
            cosSum = cosSum + math.cos(b)
            sinSum = sinSum + math.sin(b)
        cosMean = cosSum / n                    #Takes the average sine and cosine
        sinMean = sinSum / n
        arcTan = math.atan2(cosMean, sinMean)
                               #Computes the arcTangent variant for the average sin and cosine
        angMean_Rad = arcTan + math.pi
        for b in radList:                     #Calculates sum of the cos of the mean - each angle
            cosDiffSum = cosDiffSum + math.cos(b - angMean_Rad)
        cosDiffMean = cosDiffSum / n            #Takes the mean of this measurement
        angVar_Rad = 1 - cosDiffMean            #Calculates the angular variance in radians
        angMean_Deg = math.degrees(angMean_Rad)     #Converts everything back to degrees
```

```
        angVar_Deg = math.degrees(angVar_Rad)
        angVar = 0
        return [angMean_Deg, angVar_Deg, angSTD_Deg, n, flat]
    else:
        return 0.0

#Begin actual program

print "1). Building data layers for angular measures"
if not arcpy.Exists(aspectPoints):           #checks if the aspect file has been converted
    print "     a). Calculating raster as points",
    arcpy.RasterToPoint_conversion (aspectRaster, aspectPoints)
    print ":  DONE"
else:
    print "     a). Raster as points file already exits"

logFileWriter = open(summaryTablePath, 'w')
logFileWriter.write(logFileHeader + "\n")
logFileWriter.close()
print "     b). Output File built"

print "2). Calculating Frequencies"
total = arcpy.GetCount_management(InputShape)
counter = 1
arcpy.MakeFeatureLayer_management(aspectPoints,"aspect_lyr")
allSitesCURSOR = arcpy.SearchCursor(InputShape)
for eachSite in allSitesCURSOR:
    eachName = eachSite.getValue(IndexField)
    print "%5s / %s Site ID: %s: "%(counter, total, eachName),
    selc = "\"%s\" = \'%s\' "%(IndexField, eachName)
    arcpy.MakeFeatureLayer_management(InputShape,"eachPointSelected_lyr", selc)
    arcpy.SelectLayerByLocation_management("aspect_lyr","WITHIN_A_DISTANCE", \
       "eachPointSelected_lyr", DistanceToAverage, "NEW_SELECTION")
    pointCURSOR = arcpy.SearchCursor("aspect_lyr")
    aspectList = []
    for eachPoint in pointCURSOR:
        gc = float(str(eachPoint.GRID_CODE))
        aspectList.append(gc)
    eachStatList = angularStats(aspectList)
    print " AngMean = %.3f  AngSTD = %.3f"%(eachStatList[0], eachStatList[2])
    eachLogEntry = "%s;%.4f;%.4f;%.4f;%s;%s"%\
     (eachName,eachStatList[0],eachStatList[1],eachStatList[2],eachStatList[3],eachStatList[4])
    logFileWriter = open(summaryTablePath, 'a')
    logFileWriter.write(eachLogEntry + "\n")
    logFileWriter.close()
    counter +=1
    del eachPoint
    del pointCURSOR
    arcpy.Delete_management("eachPointSelected_lyr")
del eachSite
del allSitesCURSOR

print "\n\nFinished!\n\nHit Enter to exit program"
waiter = raw_input()
```

Code Extract 4: Python script to calculate Raw, Optimal, Cumulative and Multiple viewsheds for each site point.

```
##---------------------------------------------------------------------------------------------
## MasterViewshedCalculator.py
## Created April 23, 2011 by ML Sisk
##     July 27, 2011: Edited to include a measure filtered to avoid very different points
## Description:  Calculates raw, optimal, cumulative and multiple viewsheds for a series of
##     points.  Optionally also calculates the ratio of landcover visible for a binary
##     classifications
## Note:  This program assumes that all of the individual pixel viewsheds have been calculated,
##     it then clips them to a maximum and stores them in a cache. The locations are given below
##----------------------------------------------------------------------------------------- -----

import os, arcpy, numpy, datetime

arcpy.env.overwriteOutput = True
arcpy.CheckOutExtension("spatial")

#Input Variables
OriginalShape = "C:\\DissWorking\\Data\\AllSites_Final.shp"
InputDEM =
"C:\\DissWorking\\Data\\StatsWork\\DataLayers\\AverageSTATS\\Eleva_ASTER_GDEM_TopoExtent.tif"
frequencyRaster = "C:\\DissWorking\\Data\\Cache\\\ValPlat.tif"

#Folder and Temporary File Variables
final_By_SiteBase = "C:\\DissWorking\\Data\\MultVS\\BySite"
allPixelVS = "C:\\DissWorking\\Data\\MultVS\\DEMPixelVS\\"
scratchPath = "C:\\temp\\Scratch"
outputFinalDir = "C:\\DissWorking\\Data\\MultVS\\Outputs\\"
outputFinalImagesDir = outputFinalDir +                    "ImagesProcVS\\"
InputShape = "C:\\DissWorking\\Data\\Cache\\workingShapefileWithElevations.shp"
tempExtractedVS = scratchPath + "\\tempExtractedVS.tif"
clipExtractedVS = scratchPath + "\\clipExtractedVS.tif"
tempAttTable = scratchPath + "\\tempTable.dbf"
#Other Variables
maxVisibleDistance = 10000
scaleFactor = 3.1415926535897931 * maxVisibleDistance * maxVisibleDistance
IndexField = "RESORTID_S"
maximumHeightDifferenceForFilter = 30
minimumHeightDifferenceForFilter = 30
filterOutMuchHigherCells = True
#Debugging Variables
doNotRerun = False
endAfterRuns = -1
logHeaderMake = True
#Output Variables
masterLogFileHeader = "%s;%s;%s;%s;%s;%s;%s;%s;%s;%s;%s;%s;%s;%s;%s"%
("SiteID","rawVS","optVS","optID","cumVS","mean_all","std_all","n","n_filter","opt_filt","optID_f
ilt","cum_filt","mean_filt","std_filt","time")
masterLogFile = outputFinalDir + "VS_Filtered_Output.txt"
errorLogFileHeader = "%s \t\t%s \t\t%s \t\t\t%s"%("Site","ErrorType","File", "Time")
errorLogFile = outputFinalDir + "VS_all_ERRORS.txt"
outputRatioLogFile = outputFinalDir + "VS_RatioVisibleTable.txt"
outputRatioLogHeader = "Site"

#Function definitions
def AreaVisible(inputViewShedRaster):          #Function returns the total square meters visible
    meanRasterValue = float(str(arcpy.GetRasterProperties_management(inputViewShedRaster,/
         "MEAN"))) #Because the viewshed raster is binary this is a percentage of visible cells
    vis = meanRasterValue * scaleFactor                                #Final Measure of visible
    return vis

#builds the master log files
```

```
print "1). Preprocessing"
print "    a). Creating log and output files"

masterLogWriter = open(masterLogFile, 'w')
masterLogWriter.write(masterLogFileHeader + "\n")
masterLogWriter.close()

if not os.path.exists(errorLogFile):
    errorLogWriter = open(errorLogFile, 'w')
    errorLogWriter.write(errorLogFileHeader + "\n")
    errorLogWriter.close()

#Creates a copy of the initial Shapefile and appends the elevation values on it
print "    b). Copying and appending elevations to shapefile"
if not os.path.exists(InputShape):
    arcpy.sa.ExtractValuesToPoints(OriginalShape, InputDEM, InputShape, "", "")

#Begins to loop through each site
cutDown = 0
totalLoop = arcpy.GetCount_management(InputShape)
counter = 0
allSitesCURSOR = arcpy.SearchCursor(InputShape)
print "2). Processing %s site points"%totalLoop
for eachSite in allSitesCURSOR :        #Cycles through each site
    eachName = str(eachSite.getValue(IndexField))
    eachSiteElev = eachSite.getValue("RASTERVALU")
    counter +=1
    calcu = True
    activeSiteFolder = final_By_SiteBase + "\\" + eachName
    indLogFile = activeSiteFolder + "\\Log_Ind_Filtered_" + eachName + ".txt"
    if os.path.exists(indLogFile) and doNotRerun:   #Checks the existance of a log file
        #Activated if it has already been run
        print "%6s / %s Site: %s Already processed: Copying Records"%(counter,totalLoop,eachName)
        print "          To reprocess: Delete: %s"%(os.path.basename(indLogFile))
    #Opens the individual log file
        indLogReader = open(indLogFile, 'r')
        newLine = indLogReader.readline()
        indLogReader.close()
    #Writes that entry to the master log
        masterLogWriter = open(masterLogFile, 'a')
        masterLogWriter.write(newLine)
        masterLogWriter.close()
    else:   #The normal start of calculations
        cutDown +=1
        if cutDown == (endAfterRuns+1):    #This allows cutting down the length of the run
            break
        print "%6s / %s Site: %s  Elev:  %s"%(counter, totalLoop, eachName, eachSiteElev)
        #Variables for each individual site
        each10k_Buffer = activeSiteFolder + "\\" + eachName + "_Buffer_10km.shp"
        pointsToSample = activeSiteFolder + "\\" + "DEM_Points200m_" + eachName + ".shp"
        storageFolderForVS = activeSiteFolder + "\\VS_Clips"
        binaryBasedOnElevation = activeSiteFolder + "\\"+"BinaryElevationFilter_"+eachName+".shp"
        if not os.path.exists(storageFolderForVS):  #Creates the directory for viewsheds
            os.mkdir(storageFolderForVS)
        #builds a list of which individual viewshed points should be sampled for each site
        newPIDS_ToPull = []
        eachLog = activeSiteFolder + "\\Log_DEM_CellList" + eachName + ".txt"
        if os.path.exists(eachLog):  #checks for the existence of a saved list of points a
            print "        a). Log file already exists"
            logFileReader = open(eachLog, 'r')
            for line in logFileReader.readlines():
                temp = line[0:-1]
                nexty = temp.partition(": ")
                rebu = [nexty[0], int(nexty[2])]
                newPIDS_ToPull.append(rebu)
            logFileReader.close()
        else:
            print "        a). Creating Log File of DEM Values to calculate"
            allCellsCURSOR = arcpy.SearchCursor(pointsToSample)
            for eachCell in allCellsCURSOR :
```

```
            eachPID = str(int(eachCell.getValue("NewPID")))
            eachPIDElev = int(eachCell.getValue("GRID_CODE"))
            eachFileName = "vs" + eachPID + ".tif"
            newEntry = [eachFileName, eachPIDElev] #Stores the Entry with its elevation
            newPIDS_ToPull.append(newEntry)
        del eachCell
        del allCellsCURSOR
        logFileWriter = open(eachLog, 'w')
        for newline in newPIDS_ToPull:
            logFileWriter.write(newline[0] + ": " + str(newline[1]) + "\n")
        logFileWriter.close()
#Variables for each run
    x = 0
    x_Filter = 0
    maxArea = 0.0
    allAreas = []
    maxArea_Filter = 0.0
    allAreas_Filter = []
    numberIncluded = 0
    print "        b). Clipping and summing the rasters"
    for eachEntry in newPIDS_ToPull:        #Begin cycling through the individual points
        eachFile = eachEntry[0]
        eachPIDElev = eachEntry[1]
        includeOnFilter = True
        if (eachPIDElev > (eachSiteElev + maximumHeightDifferenceForFilter)) or \
                   (eachPIDElev < (eachSiteElev - minimumHeightDifferenceForFilter)):
            includeOnFilter = False
        eachDEMPixelVS = allPixelVS + eachFile
        eachClippedVSPath = storageFolderForVS + "\\Clip_" + eachFile
        if not arcpy.Exists(eachClippedVSPath) :
           #Recreates any unclipped viewsheds for each site
            try:
                arcpy.gp.ExtractByMask_sa(eachDEMPixelVS, each10k_Buffer , eachClippedVSPath)
            except:
                print "        ERROR: Fix Raster: " + eachDEMPixelVS
                now = datetime.datetime.now()
                errorLogEntry = "%s \t\t%s \t\t%s \t\t%s"%(eachName,"Bad VS  ",\
                          eachFile, now.strftime("%Y-%m-%d %H:%M"))
                eachErrorWriter = open(errorLogFile, 'a')
                eachErrorWriter.write(errorLogEntry + "\n")
                eachErrorWriter.close()
                calcu = False
                break
#processing the area of each and the optimal
        newArea = AreaVisible(eachClippedVSPath)
        if newArea == 0:
            newArea = AreaVisible(eachClippedVSPath)
            if newArea == 0:
                print "        ERROR: Retrying Calculation of Clip_" + eachFile
                arcpy.gp.ExtractByMask_sa(eachDEMPixelVS, each10k_Buffer , eachClippedVSPath)
                newNewArea = AreaVisible(eachClippedVSPath)
                if newNewArea == 0:
                    print "        ERROR: Retry Failed" + eachFile
                    now = datetime.datetime.now()
                    errorLogEntry = "%s \t\t%s \t\t%s \t\t\%s"%(eachName,"Bad Clip",\
                          eachFile, now.strftime("%Y-%m-%d %H:%M"))
                    eachErrorWriter = open(errorLogFile, 'a')
                    eachErrorWriter.write(errorLogEntry + "\n")
                    eachErrorWriter.close()
                    calcu = False
                    break
                else:
                    newArea = newNewArea
        allAreas.append(newArea)    #Appending to the list of all areas
        if newArea >= maxArea:      #saving the current highest viewshed
            optAreaFile = eachFile
            optAreaPath = eachClippedVSPath
            maxArea = newArea
        if x == 0:              #Processing the multiple
            try:
```

```
                    rasterTotal = arcpy.Raster(eachClippedVSPath)
                except:
                    print "        ERROR: Raster calculation failed"
            else:
                rasterNew =  arcpy.Raster(eachClippedVSPath)
                rasterTotal = rasterTotal + rasterNew
            x+=1
            if includeOnFilter :
                numberIncluded +=1
                allAreas_Filter.append(newArea)     #Appending to the filtered list of all areas
                if (newArea >= maxArea_Filter):     #Saving the current highest filtered viewshed
                    optAreaFile_Filter = eachFile
                    optAreaPath_Filter = eachClippedVSPath
                    maxArea_Filter = newArea
                if x_Filter == 0:                   #Processing the filtered multiple
                    try:
                        rasterTotal_Filter = arcpy.Raster(eachClippedVSPath)
                    except:
                        print "        ERROR: Raster calculation failed"
                    x_Filter+=1
                else:
                    rasterNew =  arcpy.Raster(eachClippedVSPath)
                    rasterTotal_Filter = rasterTotal_Filter + rasterNew
                    x_Filter+=1
        if calcu:
            #Names for the output files
            print "        c). Creating output files and logging results"
            optimalOutPath          = outputFinalImagesDir + eachName + "VS_Opt_" +  \
               "_NewPID_" + optAreaFile[2:]
            optimalOutPath_Filter   = outputFinalImagesDir + eachName + "VS_OptFilt_" +\
                 "_NewPID_" + optAreaFile[2:]
            multipleOutPath         = outputFinalImagesDir + eachName + "VS_Mult_" +  ".tif"
            multipleOutPath_Filter  = outputFinalImagesDir + eachName + "VS_MultFilt_" + ".tif"
            CummulatOutPath         = outputFinalImagesDir + eachName + "VS_Cumm_"  + ".tif"
            CummulatOutPath_Filter  = outputFinalImagesDir + eachName + "VS_CummFilt_" + ".tif"
            rawOutPath              = outputFinalImagesDir + eachName + "VS_Raw_Clipped" + ".tif"

            arcpy.gp.ExtractByMask_sa("%s\\VS_RawFixed_%s.tif"%(activeSiteFolder,eachName),\
                each10k_Buffer , rawOutPath)
            outReclassify = arcpy.sa.Reclassify(rasterTotal, "Value", "0 0 0;1 1000 1", "DATA")
            outReclassify.save(CummulatOutPath)
            rasterTotal.save(multipleOutPath)
            arcpy.CopyRaster_management (optAreaPath, optimalOutPath)
            outReclassify_Filter = arcpy.sa.Reclassify(rasterTotal_Filter, "Value", \
               "0 0 0;1 1000 1", "DATA")
            outReclassify_Filter.save(CummulatOutPath_Filter)
            rasterTotal.save(multipleOutPath_Filter)
            arcpy.CopyRaster_management (optAreaPath_Filter, optimalOutPath_Filter)
            del outReclassify
            del rasterNew
            del rasterTotal
            del outReclassify_Filter
            del rasterTotal_Filter
            rawVSArea = AreaVisible(rawOutPath)
            optVSArea = AreaVisible(optimalOutPath)
            cumVSArea = AreaVisible(CummulatOutPath)
            optVSArea_Filter = AreaVisible(optimalOutPath_Filter)
            cumVSArea_Filter = AreaVisible(CummulatOutPath_Filter)
            print "              Raw Viewshed:        %s"% rawVSArea
            print "              Optimal Viewshed:    %s"% optVSArea
            print "              Cumaltive Viewshed:  %s"% cumVSArea
            print "              Number Included in Filter:  %s/%s"%(x_Filter,x)
            print "              Optimal Filter Viewshed:    %s"% optVSArea_Filter
            print "              Cumaltive Filter Viewshed:  %s"% cumVSArea_Filter
            meanVSArea = numpy.average(allAreas)
            stdVSArea = numpy.std(allAreas)
            meanVSArea_Filter = numpy.average(allAreas_Filter)
            stdVSArea_Filter = numpy.std(allAreas_Filter)
#Processing  viewshed values to log and output files
            logOfRaws = activeSiteFolder + "\\Log_Filter_VSAreas_" + eachName + ".txt"
```

```
            logRawWriter = open(logOfRaws, 'w')
            for each in range(0, len(allAreas)):
                first = newPIDS_ToPull[each]
                reID = first[0]
                filtered = 0
                if (first[1] > (eachSiteElev + maximumHeightDifferenceForFilter)) or  \
               (first[1] < (eachSiteElev - minimumHeightDifferenceForFilter)):
                    filtered = 1
                area = allAreas[each]
                logRawWriter.write("%s;%s;%s\n"%(reID,area,filtered))
            logRawWriter.close()
            now = datetime.datetime.now()
            masterLogWriter = open(masterLogFile, 'a')
            entry = "%s;%s;%s;%s;%s;%s;%s;%s;%s;%s;%s;%s;%s;%s;%s"% \
        (eachName,rawVSArea,optVSArea,optAreaFile,cumVSArea,meanVSArea,stdVSArea,x,x_Filter, \
         optVSArea_Filter,optAreaFile_Filter,cumVSArea_Filter,meanVSArea_Filter, \
         stdVSArea_Filter, now.strftime("%Y-%m-%d %H:%M"))
            masterLogWriter.write(entry + "\n")
            masterLogWriter.close()
            eachLogWriter = open(indLogFile, 'w')
            eachLogWriter.write(entry)
            eachLogWriter.close()
#start input of ratio creator
        print "        d). Calculating landcover Ratios"
        eachRatioRow = eachName
        for eachViewshedLayer in \
        [rawOutPath, optimalOutPath,optimalOutPath_Filter,CummulatOutPath,CummulatOutPath_Filter]:
            if logHeaderMake :
                working = eachViewshedLayer.partition("VS_")
                lenth = working[2].find("_")
                layName = working[2][0:lenth]
                outputRatioLogHeader = "%s;%s_val;%s_plat;%s_ratio"% \
               (outputRatioLogHeader,layName,layName,layName)
            tempExtractedVS = arcpy.sa.ExtractByMask(eachViewshedLayer, each10k_Buffer)
            arcpy.Times_3d(tempExtractedVS, frequencyRaster, clipExtractedVS)
            attTable = clipExtractedVS + ".vat.dbf"
            if not os.path.exists(attTable):
                arcpy.BuildRasterAttributeTable_management(clipExtractedVS, "NONE")
                #print "Built new table"
            arcpy.Copy_management(attTable, tempAttTable)
            values = []
            eachAttCURSOR = arcpy.SearchCursor(tempAttTable)
            for eachAtt in eachAttCURSOR:
                values.append(eachAtt.Count)
            del eachAtt
            del eachAttCURSOR
            ratio = ( values[1] / (values[1] + values[2]))
            eachRatioRow = "%s;%.0f;%.0f;%.4f"%(eachRatioRow, values[1], values[2], ratio)
            arcpy.Delete_management(tempAttTable)
        if logHeaderMake:
            ratioLogWriter = open(outputRatioLogFile, 'w')
            ratioLogWriter.write(outputRatioLogHeader + "\n")
            ratioLogWriter.close()
            logHeaderMake = False
        outWriting = open(outputRatioLogFile, 'a')
        outWriting.write(eachRatioRow + "\n")
        outWriting.close()
#end input of ratio creator
del eachSite
del allSitesCURSOR
arcpy.Delete_management(InputShape)
print "Finished!\n\nHit Enter to exit program"
waiter = raw_input()
```