TEMPORALITIES IN STONE PROVISIONING IN THE MIDDLE PALEOLITHIC STONE ARTIFACT RECORD OF THE CAVE OF PECH DE L'AZÉ IV IN SOUTHWEST FRANCE; INSIGHTS INTO THE VARIABILITY IN NEANDERTAL LANDSCAPE USE

Zeljko Rezek

A DISSERTATION

in

Anthropology

Presented to the Faculties of the University of Pennsylvania

in

Partial Fulfillment of the Requirements for the

Degree of Doctor of Philosophy

2015

Supervisor of Dissertation

Harold L. Dibble

Professor of Anthropology

Graduate Group Chairperson

Clark L. Erickson

Professor of Anthropology

Dissertation Committee

Deborah I. Olszewski	Adjunct Associate Professor of Anthropology
Theodore G. Schurr	Professor of Anthropology
Shannon P. McPherron	Senior Researcher in Anthropology
C. Dana Tomlin	Professor of Landscape Architecture

TEMPORALITIES IN STONE PROVISIONING IN THE MIDDLE PALEOLITHIC STONE ARTIFACT RECORD OF THE CAVE OF PECH DE L'AZÉ IV IN SOUTHWEST FRANCE; INSIGHTS INTO THE VARIABILITY IN NEANDERTAL LANDSCAPE USE

ACKNOWLEDGEMENTS

This work was made possible by the help of many great people and academic organizations. In the first place, I would like to thank my advisor Harold Dibble for his guidance and tremendous intellectual support for pursuing the research subject of this dissertation. Fieldwork and conversations with Harold and with Shannon McPherron were instrumental in my adoption of some of the analytical and methodological approaches. Of a great help was them granting access to the data used in this analysis.

I would also like to thank my committee members, Deborah Olszewski, Theodore Schurr, and Dana Tomlin, for their feedback, comments and criticism, and especially for their patience. People who were not part of my committee, but had their part in shaping some of the thoughts presented here are Simon Holdaway, David Braun, Matthew Douglass, and Sam Lin.

I am grateful to the University of Pennsylvania (Department of Anthropology) and The University of Pennsylvania Museum of Archaeology and Anthropology (Luis J. Kolb Society of Fellows) for their financial support.

A great deal of acknowledgements for the support of academic and non-academic nature goes to my close colleagues and friends during my graduate study, (in chronological order) Utsav Schurmans, Radu Iovita, Shawn Hyla, Vera Aldeias, Sam Lin, and Annie Chan.

Finally, I owe my deepest gratitude to my family. For what it's worth, this work is for them.

ABSTRACT

TEMPORALITIES IN STONE PROVISIONING IN THE MIDDLE PALEOLITHIC STONE ARTIFACT RECORD OF THE CAVE OF PECH DE L'AZÉ IV IN SOUTHWEST FRANCE; INSIGHTS INTO THE VARIABILITY IN NEANDERTAL LANDSCAPE USE

Zeljko Rezek

Harold L. Dibble

Interpretation of variability in the Middle Paleolithic stone artifact record continues to be one of the major research questions in the Pleistocene archaeology of Europe. Current interpretations of this variability are shifting from culture-historical explanations towards ones related with Neandertal use of the landscape in economic sense: strategies of mobility and resource procurement. These interpretations nonetheless reduce this behavior to one meaning behind a particular set of techno-typological traits in the stone artifact record. Contributing to this problem is the conventional concept of this record as comprised of archaeological assemblages defined on the basis of natural interfaces and perceived as emic entities that contain functionally associated artifacts of time-averaged behavioral events. This dissertation investigates temporalities of processes related to stone provisioning by Neandertals during their use of the cave of Pech de l'Azé IV in south-west France to contribute to understanding the variability in their landscape use from Marine Isotope Stage (MIS) 5 until MIS 3 in this region. This stone artifact sequence is sampled by the same number of stone artifacts, following the general history of their accumulation. The analysis examines behavioral processes of stone movement, blank production, tool

selection, and tool management, and the dynamics among these processes is used to infer the degree of variability in the use of this place and the degree of variability in the use of stone as components of variability in landscape use. The results show certain patterns in the association between different degrees of variability in landscape use and the three isotope stages and the record of particular techno-typological attributes. During MIS 5, the degree of variability in landscape use fluctuated more than during post-MIS 5 times, when the variability in this behavior was constantly higher. Low variability in landscape use left the record with higher incidences of Levallois elements, while moderate or high variability in this behavior produced the record that is technologically less uniform. Also, until MIS 3, there was a cyclical pattern in the degree of variability in landscape use. Finally, this dissertation argues for the abandonment of the concept of assemblage in stone artifact archaeology.

Table of Contents

List of Tables

CHAPTER 7

List of Figures

CHAPTER 6

CHAPTER 7

Chapter 1: Introduction

The region of southwest France has been one of the most prominent for studying the behavior of Neandertals during the Late Pleistocene. It is characterized by a long tradition of paleoanthropological research, numerous stratified deposits with stone artifact records, equally abundant faunal record in a relatively good state of preservation, and extensive absolute dating of Late Pleistocene contexts, together with a relatively high number of hominin skeletal remains. All of these factors have made this region exceptional in providing data from which insights into Neandertal stone tool technology (e.g., Boëda, 1995; Bordes, 1950, 1961, 1981; Delagnes & Meignen, 2006; Dibble & McPherron, 2006; Dibble, 1987; Pelegrin, 1990; Rolland & Dibble, 1990; Turq et al., 2008; Turq, 1992), pyrotechnology (Goldberg et al., 2012; Sandgathe et al., 2011), settlement dynamics and stone raw material acquisition (e.g., Féblot-Augustin, 1999; Geneste, 1989; Mellars, 1996; Park & Féblot-Augustin, 2010; Patou-Mathis, 2000; Turq, 1992), subsistence strategies (e.g., Bocherens, Drucker, Billiou, Patou-Mathis, & Vandermeersch, 2005; Burke, 1993; Chase, 1986, 1999; Costamagno, Meignen, Beauval, Vandermeersch, & Maureille, 2006; Grayson & Delpech, 2003; Lalueza, Péréz-Perez, & Turbón, 1996; Patou-Mathis, 1993; Rendu, Costamagno, Meignen, & Soulier, 2012a), and symbolic behavior (e.g., Chase & Dibble, 1987; D'Errico, Zilhão, Julien, Baffier, & Pelegrin, 1998; Dibble et al., 2015; Farizy, 1990; Gargett et al., 1989; Hublin, Spoor, Braun, Zonneveld, & Condemi, 1996; Rendu et al., 2014; Zilhão, 2007) have been obtained.

This region, known as the Aquitaine Basin, is bordered by the Massif Armoricain and the Massif Central in the north and east, respectively, and by the Pyrénées in the south. This is the birth-place of 'Mousterian', at first a geological and then a cultural analytical unit (Bordes & Bourgon, 1951a; Bordes, 1953, 1961a, 1981; Commont, 1909; de Mortillet, 1872; Lartet & Christy, 1875; Peyrony, 1920), which was named after the rockshelter of Le Moustier near the Dordogne River. The now classic Bordes-Binford debate (Binford, 1973; Bordes, 1953, 1975, 1981) over variability in the European Mousterian was largely founded on the stone artifact record recovered in this region.

Interpretation of variability in the Mousterian or Middle Paleolithic stone artifact record continues to be one of the major research questions in Pleistocene archaeology of Europe. Today, we have moved from the interpretation of this variability as reflecting different traditions in the production of stone tools (Bordes, 1953, 1975, 1981) or different stone tool functions and uses (Binford, 1973) to one that associates the stone artifact record of Neandertals in southwest France with strategies of mobility and resource procurement, that is, their use of landscape (in an economic sense) during different paleoenvironmental conditions of the Late Pleistocene (Delagnes & Rendu, 2011; Morin, Delagnes, Armand, Castel, & Hodgkins, 2014; Pettitt, 2003; Rolland, 2001; see also Dibble & Rolland, 1992; Mellars, 1965, 1969, 1996; Rolland & Dibble, 1990; Rolland, 1981). In general, it can be noted that the trajectory of interpretation of Mousterian variability has shifted from culture-historical explanation towards the one related with Neandertal behavior of evolutionary significance, i.e., their adaptation to the environment.

The most comprehensive models that relate the Neandertal stone artifact record in southwest France with their land use are those proposed by Pettitt (2003) and Delagnes and Rendu (2011). Both of these models rely on, and argue for, temporal sequencing of some of the most conspicuous typo-technological features of the Middle Paleolithic stone artifact record, such as those known under the names of 'Levallois system' (or techno-complex) of stone tool production, 'Quina system', 'Discoid-deniticulate system', and the 'Mousterian of Acheulian Tradition' (MTA) (Delagnes & Meignen, 2006; Discamps, Jaubert, & Bachellerie, 2011; Jaubert, Bordes, & Gravina, 2011; Mellars, 1965, 1969, 1996; Morin et al., 2014). The Levallois system of Marine Isotope Stage (MIS) 5 (130 – 75 ka) would be replaced by the Quina system of MIS 4 (75-60 ka), which would, with the beginning of MIS 3 (60 ka), be replaced by Discoidal-Denticulate technocomplex or with MTA (Guérin et al., 2012, 2015; Guibert et al., 2008b; Richter, Dibble, et al., 2013; Richter, Hublin, et al., 2013; Vieillevigne, Bourguignon, Ortega, & Guibert, 2008).

In his model, Pettitt (2003) interprets Levallois products as generally flexible stone tools, and proposed that the adaptation of Neandertals during MIS 5 involved high mobility. After this stage, Neandertal land use involved limited mobility due to more geographically restricted resources and harsher climate of MIS 4 and 3, as reflected by low flexibility of Quina items produced in locally available stone (Pettitt, 2003). In contrast, in interpreting the variability in of Neandertal stone artifact record, Delagnes and Rendu (2011) focused more on differences in retouch and use-life potential of stone tools and on the complexity of reduction sequences in different technological systems. They proposed that the Neandertal adaptation to

the environment and resource distribution of MIS 5 would entail lower mobility and be not unlike Binford's (1980) 'forager' model of landscape use. In MIS 4 and MIS 3 this would change into high mobility and specialized exploitation of particular taxa, such as reindeer (*Rangifer tarandus*), associated with Quina record, or steppe bison (*Bison priscus*) and horse (*Equus ferus caballus*) associated with Discoidal-denticulate record, or red deer (*Cervus elaphus*) and steppe bison, associated with MTA record (Delagnes & Rendu, 2011; Discamps et al., 2011; Morin et al., 2014).

These recent advancements in interpreting the Neandertal stone artifact record in southwest France add to the known extent of Mousterian typo-technological variability (e.g., Morin et al., 2014), and they improve our understanding of some of its formation processes. However, the degree to which they represent a true departure from the approach to the stone artifact record as inherent in Bordian systematics and in both Bordes' and Binford's interpretation of the variability in this record can be disputed. In both models of Neandertal landscape use, the variability in Neandertal stone artifact record is reduced to one particular meaning behind a particular technological system and/or particular set of typological features. Bordes' meaning related to culture-history and Binford's meaning related to function, thus, have been replaced by the meaning related to the concept of time-averaged (Behrensmeyer & Schindel, 1983; Behrensmeyer, 1982; Stern, 1993, 1994, 2008) behavioral strategies (Bettinger, 1991; M. C. Nelson, 1991; Torrence, 1989). As Holdaway and Wandsnider (2006) argued, a 'strategic' interpretation of behavior inevitably leads to the view of past land use and settlement dynamic as being highly stable over considerable spans of time during

the history of occupation of a particular region (Murray, 1997, 2008; see also Rossignol & Wandsnider, 1992). This perspective also renders Neandertal occupation of southwest France as being devoid of variability and historically static between one 'steady' system of land use, regarded as characteristic for a period of particular MIS, until the other.

As it will be argued in this dissertation, such a 'strategic' approach to the interpretation of stone artifact record is only a part of the problem in relating the variability in Middle Paleolithic stone record to variability in Neandertal behavior. The other part is more fundamental, but also increasingly more complex, and it is related to the understanding and interpretation of the ontology of archaeological record. The conventional understanding of the stone artifact record is that it is comprised of assemblages as discrete units in time and space. Since these assemblages of stone artifacts are defined on the basis of natural interfaces, their legitimacy is often left unquestioned. This is a result of the perception of the concept of assemblage from a depositional aspect as comprised of material remains functionally associated in a single summation of activities, and from the aspect of classification, as a natural emic unit.

But as recently revealed by Turq et al. (2013), the Middle Paleolithic stone artifact record in southwest France is fragmented along spatial, temporal, and social domains. In their study, the analysis of stone movement, reduction, and recycling showed that this record was structured over the landscape due to independent stone artifact production, transport, (re)use, and discard events, which raises questions about what is it that is sampled at particular places across the landscape

by conventionally defined assemblages, and how should the record sampled by these assemblages be interpreted.

One of those places in southwest France is the cave of Pech de l'Azé IV, which is where we come to the aim of this dissertation. Excavated by Bordes from 1970 through 1977 (Bordes, 1975, 1978, 1981) and subsequently by Dibble and McPherron from 2000 through 2003 (Dibble & McPherron, 2006; Dibble, Raczek, & McPherron, 2005; Dibble, Berna, et al., 2009; Goldberg et al., 2012; McPherron, Dibble, & Goldberg, 2005; McPherron, Soressi, & Dibble, 2001; McPherron & Dibble, 1999; Sandgathe et al., 2011; Turq et al., 2008, 2011) this cave yielded both stone artifacts and fauna remains that have been among the samples used intensively in these recent interpretations of Mousterian variability and Neandertal landscape use (Delagnes & Meignen, 2006; Delagnes & Rendu, 2011; Discamps et al., 2011; Morin et al., 2014). In fact, Bordes himself used the stone artifact record from this place for his development of the systematics of French Mousterian (Bordes, 1981, 1984), together with the record from other places. The Pech de l'Azé IV sequence has been placed and dated into the period from MIS 5c to MIS 3, spanning from the basal layer 8 to layer 3 (McPherron et al., 2012; Richter, Dibble, et al., 2013; Sandgathe et al., 2011). According to the classic systematics of French Mousterian (Bordes & Bourgon, 1951a; Bordes, 1950a, 1953, 1961a, 1981), Pech de l'Azé IV exhibits Typical Mousterian, Asinipodian, Quina Mousterian and MTA (Dibble & McPherron, 2006; McPherron & Dibble, 1999).

The aim of this dissertation is to contribute to insights about the variability in Neandertal landscape use in southwest France from MIS 5 into MIS 3 by exploring the stone artifact record of Pech de l'Azé IV. More precisely, this dissertation will investigate temporalities (Ingold, 1993; Lucas, 2005; Murray, 1997; Olivier, 2011; Thomas, 1996) in processes of stone provisioning to infer the degree of variability in the use of this place and the degree of variability in the use of stone as components of variability in landscape use.

Four processes of stone provisioning will be examined. These include stone movement, flake production, flake (or tool) selection, and flake (or tool) management or stone use-life extension. The analytical methods used in examination of these processes can be most closely regarded as following the 'reduction thesis' framework (Shott & Nelson, 2008; Shott, 2003, 2005) used in various geographical and temporal contexts (e.g., Andrefsky, 2006, 2008; Clarkson & Lamb, 2006; Dibble, 1987, 1995; Frison, 1968; Hiscock & Clarkson, 2005; Holmes, 1894; Jelinek, 1976; Kuhn, 1992a, 1991; McPherron, 1994; Potts, 1991; Rolland & Dibble, 1990) supported by recent advances in experimentation about stone fragmentation and flake formation (Dibble & Rezek, 2009; Dibble, Schurmans, Ioviţă, & McLaughlin, 2005; Douglass, Holdaway, Fanning, & Shiner, 2008; Lin, Rezek, Braun, & Dibble, 2013).

As mentioned above, the interaction of these four processes, that is, the similarity or differences in their temporalities, will be used to infer the degree of variability in landscape use between and within three isotope stages. This will make it possible to evaluate the recently proposed models about temporal patterning of

Neanderthal land use strategies (Delagnes & Rendu, 2011; Pettitt, 2003). Lastly, by projecting the results of this analysis on Mousterian systematics, the question of Mousterian variability will be re-examined.

Where this dissertation differs from traditional approaches is that it does not employ units of analysis based on assemblages as empirically and traditionally defined on the basis of geological stratification. In line with the discussion about the ontology of the archaeological record, this dissertation will adopt an 'assemblageless' approach to the stone artifact record of Pech de l'Azé IV and its sampling. The stone artifact sequence will be partitioned by samples that are composed of the same amount of stone artifacts, and which generally follow the history of artifact accumulation at this place. It will be argued that such approach is more appropriate not just to the stone artifact record and its formation as a phenomenon, but also to the analysis of the interaction between different behavioral processes and to the research inquiries of this dissertation in general.

In terms of its organization, the dissertation is divided into eight chapters. After the *Introduction,* the *Neanderthal landscape use and the question of Mousterian in southwest France* reviews those two subjects to the extent that they are relevant for this dissertation. Next, the *Assemblage definition and the ontology of the archaeological record* chapter discusses the definition of assemblages as analytical units and outlines a new concept for the archaeological record. This concept will serve as the rationale for sampling the Pech de l'Azé IV stone artifact sequence as performed in this dissertation. The fourth chapter is about chronostratigraphy and

the stone artifact record of the place of Pech de l'Azé IV. At the end, the same chapter will discuss the theoretical concept of place use from the perspective of stone artifact record. Chapter 5 discusses the sampling process of this record, with a detailed description of each step in generating samples for the analysis. The *Analysis* in Chapter 6 presents the results of the analyzing processes of stone provisioning, together with the methods used in this analysis. The seventh chapter examines the results from the previous chapter, and together with some additional analysis relevant to temporalities of investigated processes brings together all of the results to discuss the variability in the use of Pech de l'Azé IV and to present some insights about the variability in the use of landscape. Finally, the concluding chapter summarizes the study, and offer some guidance for future research.

Chapter 2: Neanderthal landscape use and the question of the Mousterian in southwest France

2.1 *Moustérien*

Our general concept of European, Asian and African prehistory derives from the tripartite division of Scandinavian antiquity by Thomsen (1837) into the Stone, Bronze and Iron Ages (see Daniel, 1950; Trigger, 2006). Looking at artifacts predominantly from France, 19th century French scholars initiated a distinction between the artifacts made of polished stone and stone artifacts made by chipping, which led them to separate *de période de la pierre polie* from *de période de la pierre taillée* (see de Mortillet, 1883). However, this distinction was much more strongly articulated by Lubbock (1865) who, on the basis of the record across Western and Northern Europe, divided the oldest of Thomsen's Ages into the Old Stone Age, as the period of chipped stone and now extinct fauna, and the New Stone Age, as the period of polished stone. For this purpose, he coined the terms *Palaeolithic* and *Neolithic* to denote those two subdivisions respectively (Lubbock, 1865).

Soon afterwards, the French researchers Lartet and de Mortillet developed two different systems for the division of the Paleolithic. While both of them based their classifications on the material found mainly in the caves of southwest France, their approach to the classification of *de période de la pierre taillée* differed, due their research backgrounds. As a paleontologist, Lartet (Lartet & Christy, 1875) used animal type fossils for one of the earliest classifications of the Paleolithic into the Cave Bear Age, the Age of Woolly Mammoth and Rhinoceros, and so on. By contrast,

de Mortillet (1872) developed his chronological system on the basis of observable characteristics of the archaeological objects made of flint and bone. It was De Mortillet's chronology that has served as a framework on which succeeding subdivisions were built, such as those of Commont (1909) and Breuil (1913).

De Mortillet's chronological scheme for the Paleolithic had four epochs, each of which being named after the first site where the material used to define it had been recovered. These were *époque de Saint-Acheul*, *époque de Moustier*, *époque de Solutré*, and *époque de Madeléine*, where "*époque de Moustier* [was] *caractérisée par des pointes de pierre retaillées d'un seul côté [...] et par de grands racloirs [...]. Le véritable grattoir fait default*" (de Mortillet, 1872, p. 434). Moreover, de Mortillet here proposed abbreviated terms to be used for denoting these epochs, and following the tradition in geology to name the period after the type site, one of the Paleolithic *époques* started to be referred to as *Moustiérien* (de Mortillet, 1872, p. 435). Subsequently, this term was modified into *Moustérien*.

It should be noted that, in French schemes, *de période de la pierre taillée* was in use until the adoption and extensive use of *Paléolithique* by de Mortillet (1883) in his *Le Préhistorique Antiquité de l'Homme*. In the expanded edition of this work, under the name of *Le Préhistorique Origine et Antiquité de l'Homme*, he later placed (Chellen and) Acheulien into *Paléolithique Inférieur* (*Lower Paleolithic*), Mousterian into *Paléolithique Moyen* (*Middle Paleolithic*), and Solutrien and Magdalenien into *Paléolithique Supérior* (*Upper Paleolithic*) (de Mortillet & de Mortillet, 1900). De Mortillet was both a geologist and archaeologist, and, in developing this general tripartite framework for the Paleolithic, he took the concept of stratigraphy present

in the division of Quaternary into Lower, Middle and Upper, laid out by French geologists at that time (Daniel, 1950, p. 123; de Mortillet & de Mortillet, 1900). Moreover, de Mortillet continued to follow the unilinear evolutionary approach in the notion of (prehistoric) societies in general, which was prevalent in the anthropology and archaeology of the second half of 19th century (Trigger, 2006, pp. 149–156). It is unclear, however, whether it was the concept of stratigraphy or unilinear evolutionism that had greater impact on the nomenclature adopted in this tripartite division for Paleolithic groups, going from *inférieur*, through *moyen,* to *supérieur* (de Mortillet & de Mortillet, 1900). De Mortillet's tripartite division of the Paleolithic of Western Europe was later extended to the Pleistocene archaeological record of the rest of the continent, Western Asia and North Africa, and it is still in use today.

2.2 Towards the Bordian definition of Mousterian variability

De Mortillet (1872) defined *Moustérien* to be characterized by the presence of points, scrapers (end-scrapers excluded) and general unifacial tools. Yet, de Mortillet, as well as Lartet and Christy (1875), were aware of the existence of variability within Mousterian. The first attempt to systematize the whole Mousterian record in France was made by Commont (1909), who divided the Mousterian into four groups: Mousterian of Warm Fauna, Ancient Mousterian, Middle Mousterian and Upper Mousterian. This scheme was based on stratigraphic succession at several sites, although still framed as a chronological unilineal evolutionary system (Sackett, 1982). Ultimately, the systematics that serve as a

basis for the current taxonomy of Mousterian was made by Peyrony (1920), and using different intellectual grounds.

A short digression must be made here in order to understand the background of Peyrony's division of the Mousterian. At the end of 19th century, interest in ethnicity in Europe led to the increased use and application of the concept of culture in archaeology, which culminated in the so called culture-historical approach in the archaeology of the first half of 20th century (Trigger, 2006, pp. 232–331). The approach to the history of humanity as following a progressive unilinear evolution was gradually replaced with perspective that allowed the development of a scheme of synchronous, but diverse cultures. In Paleolithic archaeology, *Moustérien* started to be viewed less as a geological *time period* in which the variability of its material was accounted for as a result of a diachronic evolution in the sense of de Mortillet, and more as a *culture* or cultural manifestation of the Middle Paleolithic, where the variability of its record could be viewed as the result of different, but parallel material expressions or traditions (see Sackett, 1982).

This is essentially the background paradigm of Peyrony's (1920) division of Mousterian. His classification rested on a notion of synchronous and independent traditions within the Mousterian and, at the same time, reflected the application of the concept of an index fossil (*fossile directeur*) taken from paleontology, which presupposes that there is a characteristic type of artifact upon which each of the traditions can be recognized (see Rolland & Dibble, 1990; Sackett, 1982). Peyrony's classification consisted of two Mousterian groups or variants. Those were Mousterian of Acheulian Tradition and Typical Mousterian. *Moustérien de tradition*

acheuléenne was identified on the basis of a presence of bifaces (and backed knives) as a type artifact. Since those were evocative of the handaxes of the Acheulian, this Mousterian variant was thought to be a derivative of a technological tradition coming from that earlier period. *Moustérien typique,* on the other hand, was recognized as a variant predominantly with a high frequency of scrapers (*racloirs*). On similar grounds, Breuil and Koslowski (1932) made their division of Mousterian into Tayacian and Levalloisian (and 'Cave Mousterian') as parallel phyla that developed rather independently from Lower Paleolithic industries. Nevertheless, it was Peyrony's simpler two-type classification that had more impact upon the current taxonomy of Mousterian.

2.3 Mousterian taxonomy

The final classification system of Mousterian was formed by Bordes (1950a, 1950b, 1953, 1961, 1981; Bordes & Bourgon, 1951a). Bordes expanded Peyrony's division of Mousterian by three more variants, and established the Mousterian systematics that are current in the research of the Middle Paleolithic in Western and Central Europe up to the present day.

Although in developing his Mousterian taxonomy, he continued to use the concept of *fossile directeur* to a very limited degree, Bordes was generally opposed to basing different Mousterian variants upon a single diagnostic tool type. Nevertheless, scrapers remained as a principal category of tools for examining Mousterian variability. This category was identified as characteristic of the Mousterian since de Mortillet (1872). The variability in scraper frequency in stone

artifact assemblages was also considered by Peyrony (1920) when laying the grounds for current Mousterian taxonomy.

However, more serious attention to the variability in relative abundance of scrapers within Mousterian started from Bordes' notion that the overall distribution of frequency of scrapers in Middle Paleolithic assemblages across France follows a general trimodal pattern (Bordes, 1953). As Mellars (1996) suggests, this pattern likely was taken by Bordes as an *a priori* justification for classifying the Mousterian into at least three distinct assemblage groups. To a considerably less degree, the so-called Levallois technology was taken by Bordes as a technological basis for the differentiation of the Mousterian.

The high regard that Levallois technology has in the study of the Mousterian even to this day can be traced back to Commont (1913). As Monnier (2006) points out, after Commont (even before Peyrony) noted that handaxes can also be found within Mousterian assemblages, there emerged a need to establish another index fossil for the distinction between the Acheulian and Mousterian, since both of these industries contain the same stone artifact categories – handaxes and retouched flakes. Commont's interest in flake technology led him to identify that index fossil in the Levallois technology (Commont, 1913). As in the case of scrapers, in measuring Mousterian variability, Bordes adopted the significance of this technology for describing Mousterian variability that had already been established prior to his own classification system.

The primary approach that was used by Bordes in the description of Mousterian variability was the application of quantitative methods. First, this was

possible due to the construction of the list of 63 standard types of stone tools for the Middle (and Lower) Paleolithic developed by Bordes (1961b, 1981). In that type list, each of those types was established on the basis of its explicit morphological and technological attributes. Even before the time of de Mortillet, the study of Mousterian stone artifacts launched several of their specific morphologies as distinctive types, most notably scrapers. However, it was not until Bordes that the overall variability of that material became significantly more comprehensive and standardized. Most of these types are present in virtually all Mousterian assemblages.

Secondly, in the description of assemblages of stone artifacts, Bordes introduced the concept of indices, that is, percentages of stone artifacts with particular typological and technological features (Bordes, 1984, pp. 131–133). For example, one of the typological indices is the Scraper Index, which is calculated as a percentage of scrapers relative to the total type count. Similarly, the Levallois Index, as one of the technological indices, is measured by dividing the number of flakes, blades and points produced using Levallois technique by the total number of unifacial artifacts within an assemblage.

Using this rationale, by quantifying the relative frequency of standardized tool types and the relative incidences of technological features within an assemblage, one can categorize Mousterian assemblages into different groups. As already mentioned, in one of his original descriptions of Mousterian variability, Bordes (1950a, 1953; Bordes & Bourgon, 1951a) divided the Mousterian into three groups based on the frequency of scrapers. Ultimately, he expanded the

classification of the Mousterian industry of Western Europe into five different variants (Bordes, 1961a, 1981, 1984). These include (1) *Quina Mousterian,* which is characterized by a high percentage of scrapers and a low Levallois Index; (2) *Ferrassie Mousterian*, which is characterized by a high percentage of scrapers and a high Levallois Index; (3) *Typical Mousterian*, which is characterized by a moderate percentage of scrapers (and notched tools) and varying Levallois Index; and in this respect, it differs from the Peyrony's (1920) *Moustérien typique;* (4) *Denticulate Mousterian*, which is characterized by a low percentage of scrapers, high percentage of notched tools and varying Levallois Index; and (5) *Mousterian of Acheulian Tradition*, which is characterized by the presence of cordiform bifaces and varying Levallois Index. If the percentage of scrapers in an assemblage of this variant is moderate, then it is known as Mousterian of Acheulian Tradition Type A. If the percentage of scrapers is low and the frequency of notched tools is high, then an assemblage is labeled as a Type B of this Mousterian variant.

As previously mentioned, the Mousterian of the Acheulian Tradition was also identified by Peyrony (1920) on the basis of bifaces. Here, in the Bordian scheme, this variant essentially reflects either the Typical or Denticulate Mousterian, depending on the frequency of scrapers and notched tools, but with the presence of bifaces. In any case, it is this presence of bifaces within a Mousterian assemblage through which the application of the old concept of *fossile directeur* has persisted in the identification of the industrial variant. In this respect, the Mousterian of Acheulian Tradition may represent an exceptional case in the taxonomy of

Mousterian industries, since this type is defined exclusively on the presence of 'type-fossil' forms (Bordes, 1961a, 1961b; Mellars, 1996).

2.4 Interpretations of the Mousterian

De Mortillet's division of the Paleolithic into four (or five) epochs was strictly its geochronological division into periods of time (see Daniel, 1950, pp. 122–130). *Moustérien* started to be imbued with the notion of culture or industry from Breuil (1913) and Peyrony (1920). However, it was Bordes again who ventured into the interpretation of the Mousterian based on its variability (Bordes, 1953).

Traditionally, there have been two major interpretations of the variability of Mousterian industries. They are largely known under the name of the 'Bordes-Binford debate'. Bordes (1953, 1975, 1981) proposed that the variation should be explained on the basis of the ethnicity of past hunter-gatherers. Different variants of the Mousterian would be products of groups with different cultural traditions within the same species. Moreover, these groups could be contemporaneous, but restricted in communication with each other. Thus, we can have a Quina-type group and a Denticulate-type group occupying different sites contemporaneously.

By contrast, Binford (1973) approached this problem by developing his systemic 'functional' model of industrial variability. According to this model, different assemblages would be a result of a particular interplay of different activities related directly to the pertinent ecological conditions (for a full overview of Bordes-Binford debate, its implications and connotations, see Wargo, 2009).

In addition to Bordes and Binford, other researchers contributed to this debate. Accordingly, Mellars (1967, 1986, 1996), in contrast with Bordes and Binford, raised warnings about the asynchrony of some of the Mousterian types (like Quina occurring after the Ferrassie, and Mousterian of Acheulian Tradition being the youngest of all Mousterian types) and introduced some demographic factors that would potentially contribute to the variability of the Mousterian, as well. Rolland and Dibble (1990) have also argued that the principal factors underlying Mousterian variability are raw material availability and the intensity of occupation.

2.4.1 Neanderthal landscape use in southwest France during the Late Pleistocene

More recently, the variability of the Middle Paleolithic record in southwest France recently has been associated with variations in the paleoenvironment (Delagnes & Rendu, 2011; Pettitt, 2003; Rolland, 2001). These associations continue to argue for the proposed temporal patterning of technological and typological qualities in that record (Delagnes & Meignen, 2006; Discamps et al., 2011; Faivre et al., 2014; Jaubert et al., 2011; Mellars, 1965, 1996; Morin et al., 2014; Rolland, 1988). For example, assemblages of MIS 5 with higher frequencies of Levallois were succeeded by Quina assemblages of MIS 4, after which came assemblages that exhibit features of the MTA production system and the discoid-denticulate system of MIS 3 (but see Guérin et al., 2012, 2015; Guibert et al., 2008; Richter, Dibble, et al., 2013; Richter, Hublin, et al., 2013; Vieillevigne et al., 2008). In these studies, it was advocated that different qualities of this patterned record reflect different adaptive

strategies of mobility and resource procurement within the changing landscape during the Late Pleistocene.

This interpretation of Mousterian variability and the infered variation in Neanderthal landscape use will be discussed further below. What follows is an introduction on the shifts in climate and paleoenvironments during the most of the Late Pleistocene in southwest Europe, as background information necessary for the discussion about Neanderthal landscape use.

Like in the rest of Europe, from Marine Isotope Stage (MIS) 5 (MIS after Lisiecki & Raymo, 2005) until the late MIS 3 there was a major shift in the paleoclimate of southwest France (Anklin et al., 1993; Gibbard & van Kolfshoten, 2004; Petit et al., 1999; Taylor et al., 1993; Winograd, Landwehr, Ludwig, Coplen, & Rigg, 1997; see also Genty et al., 2010; Laville et al., 1983; Wohlfarth et al., 2008). During MIS 5, paleoenvironmental conditions were generally warm and wet, with prevailing mixed deciduous and conifer forests, as inferred from pollen records in deep-sea cores taken from the Bay of Biscay (Sánchez Goñi et al., 2008) and in lake cores from Bouchet lake in the Haute-Loire (Reille & de Beaulieu, 1990). The dominant fauna recovered in the stratified contexts of this isotope stage were those adapted to temperate conditions, namely red deer and roe deer (e.g., Armand, 1998; Banes & Dorigny, 2005; Dibble et al., 2009; Laquay, 1981; Laville et al., 1983).

At the transition to MIS 4, generally around 75 kya, the climate shifted to very cold and dry conditions, with prevailing grassland (or shrubland) environment (Laville et al., 1983; Reille & de Beaulieu, 1990; Sánchez Goñi et al., 2008). The biozone of MIS 4 that has been recovered in the deposits of caves and rockshelters

of southwest France (and other areas in Europe) is dominated by reindeer, while bison and horse make up a minor biostratigraphic zone of this stage (e.g., Briki-Hereich, Duran, Saos, Gregoire, & Moigne, 2005; Costamagno et al., 2006; Delpech, 1996; Discamps et al., 2011; Goldberg et al., 2012; Jaubert et al., 2008; Laquay, 1981; Paletta, 2005; Turq et al., 2008). The latter two ungulate species, are the more prevalent in deposits of MIS 3 (from approximately around 60 kya), when open grassland expanded even more at the expense of boreal forests (David & Fosse, 1999; Guadelli, 1987; Jaubert et al., 2008; Laville et al., 1983; Paletta, 2005; Rendu et al., 2012; Richards et al., 2008).

As mentioned above this variation in paleoenvironments during the Late Pleistocene has recently been linked to variability in the Mousterian stone artifact record through models of Neandertal landscape use. The most elaborate and comprehensive of such models were those proposed by Pettitt (2003) and Delagnes and Rendu (2011). These authors, respectively, proposed two opposing models of interaction between Mousterian technologies and subsistence-settlement dynamics of Neandertals. In both models (in the latter more than in the former), however, some elements characteristic of the concept of technological organization, which developed in North American tradition of stone artifact archaeology (e.g., Andrefsky, 1991; Bamforth, 1986; Binford, 1978, 1979, 1980; Kelly, 1983, 1988; Kuhn, 1992, 1994; M. C. Nelson, 1991; Parry & Kelly, 1987; Torrence, 1983) and of the interpretation of stone artifact variability, were employed. Here, the variability in Mousterian stone artifact record is seen as a means of Neandertal adaptation in their use of landscape or territory, that is, in their strategies of resource

procurement. Variations in landscape use and mobility patterns, thus, have been introduced as a considerable source of technological variability in French Mousterian. Identical developments have also been advanced for the Middle Paleolithic archaeology of Rhône Valley between Massif Central and Alps in southeastern France (e.g., Daujeard & Moncel, 2010; Daujeard et al., 2012; Moncel & Daujeard, 2012).

A degree of diachronic patterning within the French Mousterian has long been observed. In particular, Mellars (1965, 1967, 1986, 1988, 1992, 1996), who, on the basis of Mousterian stratified contexts of southwest France, proposed that there is a pattern of succession in which Levallois-rich Ferrassie type Mousterian is succeeded by Quna Mousterian with a lower incidence of Levallois products, which is then overlaid by the Mousterian of Acheulian Tradition (MTA). Further chronological patterning related to the frequency of the Levallois technique was presented by Rolland (1988). In this view, several assemblages from this region document the rise in the incidence of Levallois technique from MIS 6 till the end of MIS 5, and a decline from the MIS 5-4 transition ('Ferrassie-Quina transition', according to Mellars, 1969) until the late Mousterian of MIS 3 (see also Bordes, 1972; Callow & Webb, 1981; Jaubert et al., 2011; Le Tensorer, 1978). In addition, it has been recognized that the Quina Mousterian, which is characterized by highly cortical and relatively thick products with triangular cross-section and invasive retouch (Bourguignon, 1997; Dibble & Lenoir, 1995; Hiscock, Turq, Faivre, & Bourguignon, 2009; Lenoir, 1986; Turq, 1989, 1992), is largely associated with the paleoenvironmental conditions characteristic of MIS 4 (Binford, 1989; Bordes, 1981;

Delagnes et al., 1999; Delpech, 1996; Guadelli, 1987; Meignen, 1988; Mellars, 1969, 1996; Rolland, 1981; Turq, Antignac, & Roussel, 1999), which has been confirmed with through absolute dating (Discamps et al., 2011; Faivre, 2008; Guérin et al., 2012; Guibert et al., 2008; Jaubert, Hublin, McPherron, & Soressi, 2010; Richter, Dibble, et al., 2013; Richter, Hublin, et al., 2013). The Quina system has also been documented in some layers dated into MIS 3 (Guérin et al., 2012; Guibert et al., 2008; Richter, Dibble, et al., 2013; Richter, Hublin, et al., 2013).

According to Féblot-Augustin (1993) and Geneste (1985) in cases of movement of stone artifacts over greater distances (more than 20 km) in the landscape those artifacts are predominantly of the Levallois system. Since Levallois *sensu lato* (Boëda, 1994, 1995) produces flakes with mass distributed more economically and makes flakes relatively larger and thinner (see papers in Dibble & Bar-Yosef, 1995; Eren & Lycett, 2012; Van Peer, 1992), Pettitt (2003) argued that it was presumably more convenient to carry large (enough to fulfill a variety of tasks, or to take a variety of modifications) and relatively lighter Levallois blanks around the landscape, than bulky Quina items or short and asymmetrical blanks produced with the discoidal technological system (Boëda, 1993; Mourre, 2003; but see Bordes, 1961b). Furthermore, Pettitt (2003) referred to studies of Turq (1985, 1989, 1990), which showed that in sites in the region of the Perigord of southwest France that were included in his study Quina technology was mostly executed on raw material that was available locally (less than 5 km in distance).

Drawing on a degree of chronological patterning of some technological aspects present in the Middle Paleolithic stone artifact record of northern Europe

and southwest France (Mellars, 1988; Rolland, 1988), Pettitt (2003) suggested that the transition from MIS 5 into MIS 4 marked a change in Neandertal mobility from higher to relatively lower and with restricted range. According to Pettitt (2003), in southwest France, as in northern Europe, hominins began integrating more purposefully the technology with their mobility and resource procurement strategies during MIS 6. Until MIS 4, these technologies (predominantly consisting of Levallois *sensu lato*) would be more appropriate for flexible mobility strategies, which were, in general, wide-ranging due to more dispersed faunal resources in relatively unfamiliar environments.

By contrast, according to Pettitt (2003), the relatively hostile environments of MIS 4 would have dictated more limited mobility. During MIS 5, more mobile technological solutions would allow more flexible responses to unpredictable resource distribution, while in the latter conditions, an *ad hoc* Quina stone artifact production on local raw material would suffice, as would the curation of a single tool, like in the form of a biface - the *fossile directeur* of the MTA - , over a shorter range of its transport (Pettitt 2003).

The model of settlement dynamics and landscape use related with Middle Paleolithic technological systems in southwest France as proposed by Delagnes and Rendu (2011) is quite the opposite. Without citing Pettitt's (2003) proposed model of Neandertal landscape use in the same region, Delagnes and Rendu (2011) provided an interpretation of Mousterian technological variability as reflecting variation in mobility strategies and responses to diverse hunting practices. Like Pettitt (2003), they too consider the stratigraphic succession of Levallois/laminar,

Quina, MTA, and discoidal-denticulate flaking systems (see Delagnes & Meignen, 2006) in Mousterian sequences from southwest France to argue for these systems' temporal patterning.

Delagnes and Rendu (2011) emphasize the immediate usability and expedient retouch modifications of products of Levallois and laminar production system. The reduction sequence of this system is rather long and elaborate, executed in a single place, as documented in some reduction sequence studies and refitting examples coming from northwestern France (Delagnes, 1993; Lazuén & Delagnes, 2014). Due to their relatively smaller volume and sharp edges, the blanks produced by this method supposedly have limitations in their resharpening and recycling, which would translate to such end-products being of short use-life and produced for a single purpose. All of this would for Delagnes and Rendu (2011) be diagnostic of low transportability and of demand for greater stone raw material supply.

The association of Levallois and laminar stone artifact technology with a variety of non-migratory biomass, assumingly available year-round, would indicate that before MIS 4 the predominant landscape use strategy was the one that didn't require high mobility, since Neandertal groups would occupy raw material and other resource patches across the landscape and employ a non-selective hunting. Delagnes and Rendu (2011) labeled this resource procurement strategy as 'forager' *sensu* Binford (1979, 1980; but see Parry & Kelly, 1987), where stone artifact technology would not necessarily be geared towards items that are highly transportable and of a long use-life (Delagnes & Rendu, 2011).

Quina items, on the other hand, were potentially multi-purpose, since their volume allows them to be used as (retouched or unretouched) flakes or cores for the production of smaller flakes (Bourguignon, Delagnes, & Meignen, 2006; Geneste & Plisson, 1996; Meignen & Vandermeersch, 1987). Investment in core preparation is low, but it results in products with high maintenance or recycling potential, that is, with a high curation rate and long use-lives (Bourguignon et al., 2006; Bourguignon, 1997; Faivre, 2008; Hiscock et al., 2009; Park, 2007). These facts imply that the Quina system is of a great flexibility and a high transportability, and that it can be employed to reduce risk of low raw material supply in the landscape (Hiscock et al., 2009; Rolland, 2001).

The Quina Mousterian is predominantly associated with fauna dominated by reindeer (Briki-Hereich et al., 2005; Britton et al., 2011; Costamagno et al., 2006; Delpech, 1996; Jaubert et al., 2008; Laquay, 1981; Niven et al., 2012; Paletta, 2005), which is a migratory species with predictable seasonal displacements. This association implies that during MIS 4 Neandertals employed a potentially high mobility strategy in exploiting a migratory prey of a particular taxon (reindeer) with predictable migratory routes (Delagnes & Rendu, 2011). However, others have suggested that hunting predominantly reindeer may not be a result of the deliberate single-species hunting specialization, but rather an obligate response to whatever resources (of large ungulates) were available in the environment during those particular times (Costamagno et al., 2006; Delpech, 1999; Discamps et al., 2011; Grayson & Delpech, 2003; Niven et al., 2012; Rendu et al., 2012).

Nevertheless, in such a landscape use strategy, as proposed to be reflected by Quina technology (Delagnes & Rendu, 2011), various places across the landscape would be used as either 'butchery sites', 'camp sites', 'residential camps', or some other types of task-specific sites, within a settlement system that, as labeled by the authors, is more or less 'logistical' (Rendu et al., 2012). According to Delagnes and Rendu (2011), such a strategy corresponds to a 'collector' strategy for hunter-gatherer mobility and landscape use (*sensu* Binford, 1979, 1980; but see Parry & Kelly, 1987). In many elements similar settlement organization that would be characteristic for Quina Mousterian was also proposed by Rolland (2001), but not mentioned by Delagnes and Rendu (2011) in their proposed model of Neanadertal landscape use.

Similar high-mobility and logistic landscape use practices would remain dominant until the end of Middle Paleolithic (at around 35 kya) (Delagnes & Rendu, 2011), but with predominant focus on bison and horse hunting (David & Fosse, 1999; Guadelli, 1987; Guibert et al., 2008a; Paletta, 2005; Rendu, 2010; Richards et al., 2008). In the period from MIS 4, an alternative technology to Quina technology is proposed to be the discoidal-denticulate system (Delagnes & Meignen, 2006; Delagnes & Rendu, 2011), in which the flaking method, as in Quina, is not elaborate, but characterized with higher adaptability to raw-materials of lower quality (Jaubert & Farizy, 1995; Locht & Swinnen, 1993; Pasty, 2000). This system produced multi-purpose blanks with low durability in terms of their use-life (and curation rate) (Thiébaut, 2005; Thiébaut et al., 2012) relative to the duration of use-life of Quina items, but with higher versatility. Such compensation would suggest that the

products of discoid technological system were transported to the extent as much as the products of the Quina technological system (Delagnes & Rendu, 2011).

Finally, the MTA, which seems to occur at the end of Middle Paleolithic (Airvaux & Soressi, 2005; McPherron et al., 2012; Richter, Dibble, et al., 2013) would be positioned between Levallois/laminar system on one side and Quina and dicoidal-denticulate system on the other in terms of the degree of mobility and nature of the settlement dynamic, according to Delagnes and Rendu (2011). The main argument for the higher mobility strategy represented by the MTA, as opposed to the Levallois or laminar systems, according to Delagnes and Rendu (2011) lies in the long and elaborate reduction process of single tools, -- bifaces. In addition, MTA exhibits preferential use of high-quality flint from sources that are not 'local' to the places where MTA bifaces have been recovered (Geneste, 1985; Soressi & Hays, 2003; Soressi, 2004). Furthermore, MTA bifaces are proposed to be of a long use-life and durability potentially used either or both as tools and cores (Boëda, Fontugne, Valladas, & Ortega, 1996; Claud, 2008; Soressi & Hays, 2003; Soressi, 2004), being highly transportable during 'provisioning of individuals' (Kuhn, 1994, 1995) with these items. Other technological elements within the MTA assemblages are seen as more expedient, and this aspect, together with the apparent non-selective hunting predation (that is seen in the potential absence of correlation between the MTA system and particular dominant taxa), would suggest that the MTA system reflecting a rather distinct strategy of landscape use and somewhat higher mobility during the MIS 3 (Delagnes & Rendu, 2011; Soressi, 2004).

2.5 The aim of this dissertation

Within this recent approach to interpreting the variability in the Middle Paleolithic stone artifact record of southwest France (Delagnes & Rendu, 2011; Pettitt, 2003; see also Djindjian, 2012), Neandertal behavior has been explained using the concept of 'strategies' (Bettinger, 1991; M. C. Nelson, 1991; Torrence, 1989) or adaptive responses to the particular ecological conditions occurring during the Late Pleistocene. Due to the deep-time during which these artifacts accumulated, and therefore given their time-averaged nature (Behrensmeyer & Schindel, 1983; Behrensmeyer, 1982; Stern, 1994), these strategies can be assumed to represent repeated and more-less consistent behaviors over time, that is, within the respective MIS periods. Holdaway and Wandsnider (2006) argued that 'strategic' interpretation of behavior leads to the view of past hunter-gatherer landscape use and settlement dynamic as being devoid of variability over considerable spans of time during the history of occupation of a particular region. 'Strategic' interpretation of behavior also depicts Neandertal occupation of southwest France as being historically static between one relatively steady system of landscape use until the other (Holdaway & Wandsnider, 2006; Murray, 1997, 1999; Rossignol & Wandsnider, 1992). More detailed discussion about these issues, and how they pertain to the aim of this dissertation, require a re-examination of the ontology of stone artifact record.

The overall and immediate objective of this dissertation research is to infer the degree (low vs high) of variability in the use of one place in southwest France, Pech de l'Azé IV (hereafter Pech IV) in the Dordogne, as well as the degree (low vs

high) of variability in the use of stone over the landscape as reflected by the record at this place, within individual isotope stages from MIS 5 through MIS 3. The goal of this research is to contribute to the understanding of the degree (low vs high) of variability in Neanderthal landscape use during the Late Pleistocene in southwest France (and to evaluate the recently proposed models of this use [Delagnes & Rendu, 2011; Pettitt, 2003]), and to re-examine the question of the Mousterian as an analytical unit.

The degree of variability in the use of Pech IV and the degree of variability in stone use will be inferred on the basis of interaction between temporalities of behavioral processes related to stone provisioning during different environmental conditions of the Late Pleistocene. Throughout this dissertation, and with respect to the stone artifact record only, the degree of variability in place use will be inferred on the basis of *the interaction between the intensity of stone movement (import and export of various stone objects) and the intensity of blank production (intensity of flaking: production of stone objects at the place)*. The degree of variability in the use of stone will be inferred on the basis of *the interaction between the intensity of stone movement (import and export of various stone objects) and the intensity of stone object use-life extension.*

The sampling of the stone artifact record of Pech IV will not follow the traditional partitioning of the archaeological record into assemblages defined on the basis of geological sequence. Instead, samples of defined sample size will be generated in a non-conventional approach to the stone artifact sequence that has been recovered during the excavations by Bordes (1975, 1978), and more recently

by Dibble and McPherron (Dibble, Raczek, et al., 2005; Turq et al., 2011). Here too, the rationale for such an approach to sampling the archaeological record requires a discussion about assemblage definition and the ontology of the archaeological record. This is the topic of the following chapter.

Chapter 3: Assemblage definition and the ontology of the archaeological record

3.1 Assemblage definition

Both individual artifacts and assemblages of artifacts are the basic units of analysis in archaeology. The definition of empirical assemblages is inextricably bounded with archaeological context. The context of archaeological finds represents the medium for uniting those finds together into one analytical entity. In Paleolithic archaeology, the (smallest) envelope of sediment, is usually taken as the context for defining an assemblage (Goldberg & Berna, 2010; Stein & Farrand, 2001; Stern, 1993, 1994). In principle, due to the observable differences in color, texture and grain size of sediments on a macro scale, archaeological material is associated into distinct units that are then analytically processed as behaviorally meaningful.

"Units are the means by which we partition and specify a range of variability that is relevant for particular research questions" (Ramenofsky & Steffen, 1998b, p. 3). As Ramenofsky and Steffen (1998b) noted almost two decade ago, despite the fundamental importance of units as tools of measurement at any level of archaeological research, theoretical evaluation of units in archaeology has been far from being sufficiently represented in the literature. The major reasons for this lack of concern may be related to the power of traditions in methodology for classifying archaeological phenomena. For example, partitioning and sampling the archaeological record by means of assemblages imbued with an intrinsic cultural, functional or chrono-evolutionary meaning, is a practice (derived from

paleontology) that marked the commencement of the Paleolithic archaeology (de Mortillet, 1872; Lartet & Christy, 1875).

It is also possible that, as Dunnell (1986, p. 149) noted, when researchers do see it as important, they consider the definition of their analytical units as not having significant ramifications for the discipline's primary goals, i.e., those that are related to deciphering past behavior. Nevertheless, when archaeological systematics and the definition of analytical units have undergone an evaluative discussion, most often that discussion focuses on the classification and typology of artifacts or assemblages once they are isolated from the archaeological record (Adams & Adams, 1991; Dunnell, 1971, 1986; Hill & Evans, 1972; Klejn, 1982; see papers in Whallon & Brown, 1982). The major concern has always been focused on typological assemblages. It has been only recently that the construction of analytical units related to sampling or grouping the material in space and time, notably assemblages and sites, are receiving more attention and theoretical review (Dunnell, 1992; Murray, 1999b; Ramenofsky & Steffen, 1998a; Rossignol & Wandsnider, 1992; Stern, 1993; Sullivan, Mink, & Uphus, 2007). Perhaps not surprisingly, the majority of such discussions about analytical units, which, in order to be defined, require partitioning along the spatial and the temporal dimensions of the archaeological record, are from studies directly associated with stone artifacts, as the component of the archaeological record that is empirically widest in space and go deepest in time.

By their content, analytical units can be either empirical or conceptual (ideational, abstract) (O'Brien & Lyman, 2002; Ramenofsky & Steffen, 1998b). Empirical units derive from direct observation and measurement of physical

phenomena and they vary according to the scale of the phenomena being investigated (Dunnell, 1971, pp. 145–161). In archaeology, the most common empirical units used are those at the scale of observable attributes, individual artifacts and features, and higher level units such as assemblages and sites. Conceptual units, on the other hand, are tools of our own construction that allow us to measure, describe and compare the variability in empirical units for a particular purpose. Sometimes labeled as theoretical units (Dunnell, 1971, 1986) they are imposed on, rather than extracted from, empirical reality (Dunnell, 1986, p. 152). On the basis of the scale of the measurement, conceptual units can be nominal (e.g. stone tool types, technological systems, settlement and mobility systems, kinship systems, cultures, etc), ordinal, interval and ratios. The selection of the kinds of empirical and conceptual units that are appropriate in a particular research investigation is, or at least should be, driven by theory (Dunnell, 1971; Ramenofsky & Steffen, 1998b).

Besides the theory that makes them relevant for the scale of investigation, the construction of units involves their *definition*. The two types of definition commonly used to define units in archaeology are extensional and intentional, and both of them can be used in the definition of empirical and conceptual units (Dunnell, 1971, pp. 16–17; O'Brien & Lyman, 2002). Extensional definition involves defining a unit by specifying its extension, that is, every entity or object that has been placed within that unit. For example, an extensional definition of the conceptual unit 'Mousterian industry' would be the listing of all industries that have been classified under the denomination of 'Mousterian' in Europe, North Africa,

Near East and Arabia (like 'Typical Mousterian', 'Maghrebian Mousterian', 'Tabun C', etc). Likewise, the extensional definition of an empirical unit of 'the assemblage of the site of Pech de l'Azé IV' would be a list of all of the finds from this site. Intentional definitions are usually developed from concepts (not conceptual units!) and they explicate the necessary conditions, *significata*, for membership in a unit (for more on theory of definitions see Robinson, 1962). An example of an intentionally defined conceptual unit is 'Mousterian of Acheulian Tradition' which is defined as a Mousterian industry (of Western Europe) characterized by the presence of cordiform bifaces (Bordes, 1961b, 1981; Peyrony, 1920). The empirical unit of 'the assemblage of Pech de l'Azé IV' can be defined intentionally as archaeological material recovered from the site of Pech de l'Azé IV.

3.2 The notion of assemblage

From an archaeological perspective, an assemblage as a conceptual unit perhaps can be intentionally defined as *a group of discrete objects found in the same depositional context*. Its empirical counterpart has to have a designation of the location and the scale of the depositional context where it is coming from, such as a particular layer or site. Here, it is clear that the definition of units of the more inclusive scale than that of a discrete object is faced with the problem of drawing the boundaries in the spatial and temporal dimensions of the archaeological record (Dunnell, 1971). As can be inferred from Dunnell's (1971) attempt to classify the archaeological phenomena of various scales of inclusiveness, adding anything more to the intentional definition of the conceptual unit of assemblage (as above) will

consequently affect this unit's ontology and the interpretation of its archaeological context. Merely for the sake of the discussion about the classification of different scales of phenomena, in Dunnell (1971, p. 151), an assemblage is equated with an 'occupation', as an assumed "… product of a single group of people at that particular locality deposited over a period of continuous residence comparable to other such units in the same study". On the other hand, Stern (1994, 2008), considers an assemblage as a "minimum archaeological stratigraphic unit", that is, a minimum chronological resolution within a depositional sequence. According to Stern (1993, 1994), since in this way an assemblage is equated with a minimal chrono-stratigraphic depositional segment, an assemblage itself represents an accumulation of archaeological material in time, and the interpretations of such an accumulated unit must take into account its time-averaged quality (Behrensmeyer, 1982).

Assemblages as analytical units attain reification within sedimentary envelopes in stratified deposits, "as though natural limits give legitimacy naturally" (Shott, 2008, p. 46). Once they are isolated as entities of fixed size, composition, and boundaries in space and time during fieldwork, they usually become treated as cohesive ensembles in subsequent analyses (but see, for example, McPherron et al., 2005). In order to elicit some of the inherent connotations in such a concept of assemblage, this concept should be subjected to the same ontological evaluation like the concept of the archaeological record.

3.3 The ontology of the archaeological record

Substantial investigations of the concept of the archaeological record began with Schiffer's (1972) interest in its processes of formation (see Lucas, 2012). By developing a model which viewed the life cycle of 'elements' which are participating in a 'behavioral system' before they enter into the 'refuse' and become the object of archaeological investigation, Schiffer (1972) made the distinction between systemic context and archaeological context of archaeological record. The nature of the distinction between these two types of contexts was particularly explored in his debate with Binford (Binford, 1981; Schiffer, 1985), which revolved around the notion of the 'Pompeii Premise'.

The 'Pompeii Premise' is a concept of the archaeological record as a static deposit of more or less synchronous events (Ascher, 1961, 1968). Either conceived of as a passive record of material traces of past cultural and anthropological processes (Binford, 1964), or as a text that can be used and re-used actively in the interpretation of its contextual meaning (Hodder, 1989) (conception of the archaeological record through physical or textual form [e.g., Patrik, 1985]), the archaeological record is viewed as a static and integral unity (Murray, 1997, 2008). In Ascher's (1968) dynamic view of the archaeological record, it is never formed, and what archaeologists do is interrupt the process of its formation, rather than disturbing "the remains of a once living community, stopped as it were, at a point in time" (Ascher, 1961, p. 324).

Both Binford (1981) and Schiffer (1985) agreed that the 'Pompeii Premise' is an erroneous notion implicit in archaeological research. However, while Schiffer

(1985) regarded the archaeological record as a distorted reflection of a past 'behavioral system' due to various cultural and non-cultural transformational processes that act on artifacts in their transition into archaeological context, in Binford's view (1981), cultural processes cannot distort the archaeological record, but are an integral part of it. Conceivably, and as emphasized by Murray (1999a, 2008), one of the most important outcomes of this debate was the attention drawn to the temporal dimension of the archaeological record and artifact deposition.

One of the interpretative frameworks most commonly employed in the archaeology of hunter-gatherers has been ethnography. Extant hunter-gatherer societies are studied in order to develop models for connecting their material traces with various processes related to their activities (e.g., Binford, 1978, 1980). However, as Bailey (1983) emphasized, the application of ethnographic models to the interpretation of the past hunter-gatherer record are useful only if time is considered to be 'flat' and history is ignored. This 'tyranny of the ethnographic record' (Wobst, 1978) has persistently fostered the essentialist concept of the archaeological record (Holdaway & Wandsnider, 2006; Murray, 1999a). Assemblages, thus, are considered as having an essence -- an inherent composition that is necessary for the integrity of the assemblage as an entity imbued with an intrinsic meaning (Murray, 1999a, 2008). In most cases, this meaning has been interpreted through the dichotomy of juxtaposing different groups versus different activities. The Bordes-Binford debate is perhaps the best known example of this dichotomy.

This is a human time scale perspective (Stein, 1993, 2000) on the assemblage, which is at the core of the 'Pompeii Premise' (Ascher, 1961). It calls into question the compatibility of models based on (social) studies using observational scales not exceeding a lifetime of the observer to the nature of the Pleistocene archaeological record which is one of a large scale (Bailey, 2008; Holdaway & Wandsnider, 2008; Murray, 1997, 2008; Wandsnider, 1996). Forty years ago, Isaac (1972, see also 1981) suggested that the long time depth represented in the Paleolithic record requires different kinds of explanation than more recent periods. For Stern (1993, 1994, 2008), assemblages from Pleistocene contexts are time-averaged samples of past human activity. Archaeological material formed over a prolonged period of time within a single depositional context may originate from various cultural systems and behavioral contexts (Stern, 1994, 2008). Along similar lines, Bailey (1981, 1983, 2007) elaborated the palimpsest perspective on the archaeological record (introduced by Binford [1981]), which "refers to a superposition of successive activities, the material traces of which are partially destroyed or reworked because of the process of superposition" (Bailey, 2007, p. 203).

3.4 A new concept of the archaeological record

Many have called attention to geological processes behind the accumulation of artifacts found in the same depositional context (e.g., Butzer, 1982; Davidson & Shackley, 1976; Pyddoke, 1961; Schiffer, 1972; Stein & Farrand, 2001). But, there is much more to this, and the dimensions of time and space in the formation of the

archaeological record involve various processes entwined with the use-lives of individual artifacts and with transformations of that same record over a landscape scale due to social agencies. The effort to explain the mechanisms leading to collectives of stone artifacts should employ a bottom-up perspective and examine such collectives from the position of single artifacts and the role that single artifacts have in constituting the archaeological record. Through the flux of their affordances, stone artifacts as objects have their own history; a biography (Appadurai, 1986; Gosden & Marshall, 1999; Hodder, 2012; Olsen, 2010). At the end, the question is not how artifacts end up in the archaeological record, but something quite the opposite: how the archaeological record is formed and composed through the individual life of each artifact.

This process has been in the center of North American formation theory that will be invoked here once again. Regrettably though, in the major treatises revolving around this theory, this subject has been approached conceptually and principally more from the standpoint of record distortion, erasure, and deformation than its formation. This perspective was taken from the start by Ascher (1968) with his concern upon the survival of the record "along the route of increasing disorder" (p. 52) and "process of decomposition" (Ascher, 1961, p. 324). Schiffer (1972, 1983, 1985, 1988) further refined this position with his introduction of qualitative changes that the record goes through, and which successively transform the systemic inventory of a "Pompeii-like assemblages of de facto refuse" (1985, p. 18). At the same time, by considering such qualitative changes as part of the past cultural dynamics itself, Binford (1981) extended the scope of the systemic context onto the

events that, he would argue, Schiffer would see as part of the distortion process of the record (Lucas, 2012, pp. 95–104; Murray, 1999a; Shott, 1998). According to Binford, "the archaeological record is therefore not a poor or distorted manifestation of ethnographic 'reality', but most likely a structured consequence of the operation of a level difficult, if not impossible, for an ethnographer to observe directly" (Binford, 1981, pp. 182–183).

It is unclear how far Binford was truly willing to go with such notion of the archaeological record. It seems that the true ground for the difference between Binford and Schiffer was in the unfortunate dynamic-static antinomy that was imposed by Schiffer (1975a) and in specifying the exact point of transition between these two states in such a view of the archaeological record. At the bottom line, Schiffer was not excluding formation processes from behavioral interpretations (1985), nor, according to Shott (1998), was he interested only in short-term events. Somewhat unclearly, Binford (1981, p. 200) too considered the record to be a static phenomenon and viewed it through the lenses of entropy.

Albeit in a more subtle way, the presence of entropy is also present in Bailey's call for embracing the temporal resolution of the archaeological record and to study long-term behavioral processes responsible for its formation (Bailey, 1981, 2007, 2008; see also Binford, 1981; Foley, 1981). For Bailey (1981), as we move far back in time, the archaeological record becomes of a decreasing resolution. Such consideration is a result of his preoccupation with the amount of absolute time in the record (Bailey, 2008; Murray, 1999a; Shanks & Tilley, 1987), or more precisely, with the increasing margin of error in dating the older contexts. That is why, for

Bailey, the ethnographic timescale is not appropriate for understanding the archaeological record, because short-term behavior is largely inaccessible under the deep veil of time.

But as Lucas (2005) argues, rejecting the ethnographic scale for interpretation of archaeological record is misleading insofar as this is done on the premise of incommensurability of absolute timescale and not on the basis of incomparable scale of events and processes (and the formation theory of Schiffer and Binford described above falls into the same trap: conflating the amount of behavioral events with the amount of absolute time). Therefore, the issues of precision in deducing the absolute age does not necessarily make an Oldowan context to be of a lower behavioral resolution or in a state of entropy more than a scatter of tools abandoned by a member of Hadza at the moment of writing these lines.

Accordingly, and in comparison to ethnographic record, to characterize the archaeological record merely as a palimpsest is to a great extent a misdirection, one that most often leads to its apprehension as reflecting a time-averaged accumulation generated either through diachronic sequencing of unrelated episodes of activity (Crawford, 1953; Hodder & McAnnany, 2009) or through a complete mixture of episodes of activity in the sense of Bailey's (2007) 'cumulative palimpsest' (see Lucas, 2012, pp. 118–120). Characterization of the archaeological record as a palimpsest may ultimately result in an even greater worship and pursuit for 'immaculate' single-event episodes. For even a closed find combination (a concept known from Worsaae, 1849) or a "secure find" (Montelius, 1903, p. 11) of a single

event of deposition, or, more prosaically, a 'living floor', is a palimpsest ('temporal' *sensu* Bailey, 2007) of events of manufacture, use, movement, discard, and deposition through social and natural space and time, as convincingly revealed by Olivier (1999) in his presentation of the Celtic princely grave in Hochdorf.

Such thinking about the archaeological record in terms of accumulation and the dynamics of events, as constitutional elements of various social and natural processes, rather than in terms of the passage of time, is what really leads us into a different concept of the archaeological record. The dynamics of such events, responsible for the circulation of stone artifacts though time and space, is the formative agent behind artifact accumulations. This metaphysics can perhaps be best examined by invoking three ideas, which in themselves, and more or less directly, all have significant implications on the theory of archaeological record formation.

One of these ideas is Chapman's (2000) fragmentation thesis. Interpreting the fragmented state of clay figurines found in the contexts of the early farming communities in southeastern Europe, Chapman (2000) and Chapman and Gaydarska (2007) argued that the state of this record is a product of events of deliberate fragmentation of such objects, and circulation, deposition and reuse of their fragments as a way of instituting social associations between individuals or groups and the settlement (or places with specific function within the settlement). According to this thesis, the nonexistence of some fragments in depositional contexts would not necessarily mean that the record is incomplete, but rather that it is fragmented along the spatial and social dimensions.

The fragmented character of the stone artifact record in the context of the Middle Paleolithic of southwest France as revealed by Turq et al. (2013) is conceptually very similar to Chapman's fragmentation thesis. Through such fragmentation, objects (or fragments) are circulating through temporal, spatial and social domains, in a constant flux of forming new associations. Therefore, the fragmentation itself creates the record. Of course, in the case of the Middle Paleolithic, the symbolic process behind the fragmentation or segmentation of the clay figurine record is replaced by processes related to stone material and stone tool economy on the scale of the landscape. In the latter, such fragmentation of the record also most likely (but not necessarily!) occurred over a longer period of time. But regardless, all of these differences just point to the variability of kinds of processes behind the formation of the archaeological record, as well as to events, either short- or long-term, as the formative agents of the record as a phenomenon.

Such a spatio-temporal array of activities or events over a landscape scale that forms (the structure) of the archaeological record is what Ingold (1993) referred to when developing his concept of a 'taskscape'. This is a second idea that has direct implications for the view of the archaeological record as proposed here, and the one which proceeds from the empirical observation of fragmented character of the record towards the theoretical explanation behind such fragmentation. Ingold's concept of 'taskscape' is both temporal and spatial. To a large degree it relies on time as being imminent in the passage of events (the so-called 'A-series' by McTaggart, 1908; see also Gell, 1992), rather than being positioned over social 'tasks' (that is, events and actions) as an astronomical transcendence. The concept of

a ‘taskscape’, grounded on the imminence of time, is what enabled Ingold (1993) to move towards the temporality of a landscape or the temporality of archaeological record (Murray, 1997; Olivier, 2011; Thomas, 1996).

Perhaps the most useful theoretical explanation for assemblage formation, and for the fragmented character of the record as manifested by the concept of ‘taskscape’ and by the temporality of landscapes, is the theory of social assemblage formation by DeLanda (2006). DeLanda interprets all social phenomena (such as institutions, nations, etc.) as synthetic, rather than essentialist, social assemblages that are (re)defined on the basis of their disposition of any kind towards other entities in their social landscape (see also Latour, 2005). Such assemblages or associations become materialized due to temporal, spatial and social circulation of their component parts. Such collectives are also characterized by ‘relations of exteriority’ (Deleuze & Guattari, 1987), meaning that “a component part of an assemblage may be detached from it and plugged into a different assemblage in which its interactions are different” (DeLanda, 2006, p. 10).

Projecting such a view of the formation of social entities onto formation of archaeological record, a stone artifact, thus, is and was a component part of various associations or entanglements (Hodder, 2012) in the past based on its affordances relative to the changing historical context during its use-life. Like *spolia*, -- re-used parts of Roman stone structures and sculptures during the late antiquity and the early Middle Ages --, stone artifacts have been re-associated into different collectives due to their historicized capacities. Related to this, the mechanisms behind the associations of objects or entities of various scales are intertwined

through, what DeLanda (2006) termed, 'territorialization' and 'deterritorialization', that is, stabilizing or destabilizing the collectives on the basis of fluidity of contextual disposition of objects (see also Lucas, 2012, pp. 199-214). Probably the most conspicuous example of 'territorialization' (following 'deterritorialization') would be a burial, while the movement of stone artifacts would be an obvious case of 'deterritorialization' (leading to 'territorialization').

As DeLanda (2006, p. 11) notes, "the reason why the properties of a whole cannot be reduced to those of its parts is that they are the result not of an aggregation of the components' own properties but of the actual exercise of their capacities. These capacities do depend on a component's properties, but cannot be reduced to them since they involve reference to the properties of other interacting entities". This is how DeLanda strips assemblages away totalistic and essentialist constructions that would be based on the presence of certain properties of their components, or, in our case, the presence of a particular stone tool type. For him, "taxonomic essentialism relies on a very specific approach to yield its reified generalities: it starts with finished products …" (DeLanda, 2006, p. 28).

To avoid this reification, DeLanda proposes to shift the focus from form to historical processes behind the formation of social entities. "The identity of any assemblage at any level of scale is always a product of a process (territorialization, […]) and it is always precarious, since other processes (deterritorialization […]) can destabilize it" (DeLanda, 2006, p. 28). Furthermore, "… unlike taxonomic essentialism, the ontology of assemblages is flat, since it contains nothing but differentially scaled individual singularities …" (DeLanda, 2006, p. 28). This is at the

core of the concept of archaeological record as proposed here: collections of biographies of individual stone artifact.

Using DeLanda's rhetoric, assemblages are, therefore, phenomena generated by processes of (de)territorialization, which can be regarded as essentially those of fragmentation of the archaeological record. The mechanisms behind these processes are those related to behavioral events occurring across the fluid taskscape over time and space, including the post-depositional life of stone objects. Stone artifacts as objects are therefore event-transgressive, and they acquire their attributes through potentially significant number of processes of (de)territorialization (see Dunnell, 1992, p. 34). The depositional associations (provenience) within which they are found is one of those attributes.

Moreover, the processes of (de)territorialization are also those related to our own sampling of the record during the excavation, and according to the employed archaeological practice and research design. As Lucas presents (2012) presents, the flux of associations of stone artifacts, and the process of stabilization of these associations, continues during archaeological interventions (largely fieldwork). This occurs even after such interventions, via circulation of artifacts between and within museums and research labs (see Dibble, McPherron, et al., 2009 regarding the misconstruction of associations between Middle Paleolithic stone artifacts from the Combe Grenal collection, and their incongruity with associations of those same artifacts as defined during Bordes' excavation of that cave).

Such a concept of the archaeological record bridges the division between pre-deposition and deposition on one side, and deposition and post-deposition on the other, reconciling, in a sense, Binford with Schiffer. In this concept of the archaeological record, Schiffer's 'transforms' do not echo the concern about the 'original' or 'pristine' anymore; now they manifest the mechanisms of DeLanda's (de)territorialization as the dynamics of archaeological record formation. Since (de)territorialization can occur over any time scale building up the temporality of a process, such as, for example, provisioning of stone objects by selecting immediately from the produced population of blanks (e.g., Jones & White, 1988, p. 68) or by post-depositional scavenging of stone accumulated during previous occupations (e.g., Hayden, 1979, p. 168; Tindale, 1965, p. 161), the proposed concept of the stone artifact record also overcomes the opposition between short-term and long-term behavior (Bailey, 1983, 2008). The stone artifact record is thus an accumulation or an aggregate of temporalities (Ingold, 1993; Thomas 1996; Murray, 1997; Lucas, 2005; Olivier, 2011) of various behavioral and natural processes.

The entire archaeological record is an accumulation of such temporalities , and samples extracted from the archaeological record in a variety of ways within the archaeological practice are accumulations in themselves. The emphasis in this concept of the stone artifact record is on the temporality of processes of deposition and accumulation. For this reason, sampling the record either with assemblages defined conventionally or with any other kinds of samples will generate units of analysis that are not essentialist but synthetic. What this means is that in this concept of the archaeological record, and in contrast to the traditional Harris'

(1989) approach to stratigraphy, there are no natural (in any sense) interfaces. In approaching stratigraphy through this concept of the record, the focus is not placed in the order of interfaces and mere sequence of units, but in unit *formation* (see Stein, 2000).

The view on sampling the stone artifact record in this dissertation, and in the process of sampling the Pech IV record in particular, is that such sampling should be defined in the best way to help engage with the particular research questions. If required by the research question, sampling the stone artifact record at times may equal a find combination in closed or singular depositional context, such as a geological layer. However, geological and topographic interfaces used to define 'components' and 'sites' (in archaeological terms) *a priori* should not be given a monopoly in defining empirical units and stone artifact associations, nor should they prevent the generation of samples, that is, sampling the archaeological record, using frames that are independent of these natural features in the landscape (see Murray, 1997, 2008).

This is precisely what Dunnell (1992) argued for in his seminal discussion about the notion of site. "The archaeological record is more or less continuous distribution of artifacts or on near the surface of the planet, not a collection of sites waiting to be found" (Dunnell 1992, p. 34). Constraints in the definition of a group of artifacts as analytical units have been largely imposed by 'sites' and 'assemblages'. In principle, they come from the implicit and erroneous notion that 'sites' and 'assemblages', either in form of closed depositional contexts or in the appearance of high-density concentrations of stone artifacts, exist naturally and independently of

archaeologists. Of no smaller fallacy is another implicit notion that these geological or topographical features themselves are the very agents of artifact deposition, rather than just places within the landscape where artifacts get deposited due to true agents of stone artifact accumulation: behavioral and natural processes (Schlanger, 1992). As Murray (1997, p. 453) noted, "the recent changes in our comprehension of the Pleistocene records are tailor-made for supporting the notion that there is nothing natural about those units, and for clarifying the related point that there is nothing natural about their interpretations either".

Subsequently to this, in this dissertation, the units of analysis for studying the variability in the use of stone and place of Pech de l'Azé IV will not follow the traditional definition and notion of assemblage. Instead, the sampling of the stone artifact sequence at this place will follow the concept of the archaeological record as outlined above. In concordance with the research question of examining the temporalities of processes related to stone provision, Pech IV sequence will be analyzed with the samples that are comprised of (about) 1,000 stone artifacts, generally following the history of their accumulation.

Since the research focus of this dissertation is inferring the degree of variability in the use of Pech IV and the degree of variability in the use of stone within and between different isotope stages, the number of samples of artifacts deposited during the same MIS should be adequate for this analysis. At the same time, the samples should be of a size that will encompass sufficient quantities of various categories of stone artifacts for comparisons that are based on those categories. In relation to the quantity of stone artifacts in Pech IV sequence and the

research subject pursued in this dissertation, a sample size of 1,000 stone artifacts is here argued to appropriate for this research. Following the concept of the archaeological record as presented above, these samples will be treated merely as analytical units, and referred to as 'accumulations', devoid of any essentialist notions that have been contaminating 'assemblages'. The sampling process is described in Chapter 5. The next chapter presents the place of Pech de l'Azé IV and its stone artifact record.

Chapter 4: Pech de l'Azé IV and variability in place use

4.1 The location and the history of excavation of Pech de l'Azé IV

Pech de l'Azé IV (Pech IV) is a collapsed cave at about 2.5 km southeast of the town of Sarlat-la-Canéda in the department of Dordogne (Figure 4-1) in southwest France. It is one of the four locations in the range of about 200 meters around the same hill that have documented deposits of the Pleistocene age (McPherron & Dibble, 1999; McPherron et al., 2001). These locations, Pech de l'Azé I, II, III, and IV, were excavated by various researchers as early as the first half of the 19th century (Bordes & Bourgon, 1950, 1951b; Bordes, 1954, 1955; Capitan & Peyrony, 1909; Lartet & Christy, 1864; Vaufrey, 1933).

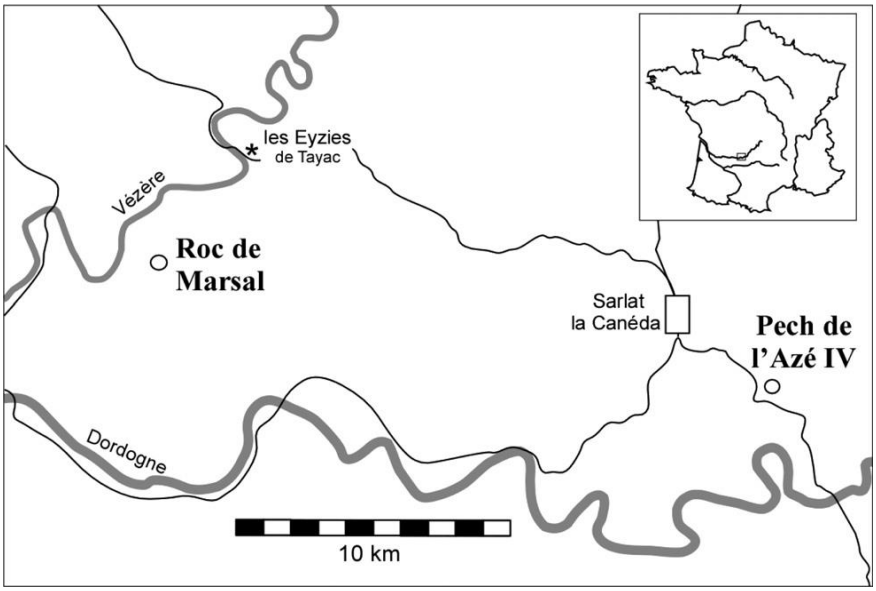

Figure 4 - 1: Location of Pech de l'Azé IV in southwest France, with reference to towns of Sarlat-la-Canéda and Les Eyzies-de-Tayac, and to the Roc de Marsal Middle Paleolithic sequence.

With some breaks in the sequence, Pech de l'Azé II was occupied between MIS 6 and 3 (Grün, Mellars, & Laville, 1991; Grün, Yan, McCulloch, & Mortimer, 1999; Schwartz & Blackwell, 1983). Its stone artifact record exhibits some form of early Mousterian with bifaces, which was known by Bordes as the 'Acheuléen méridional' (or southern Acheulian, as distinct to the Acheulian of northern France) (Bordes, 1966, 1971; see also Mourre & Colonge, 2007), followed by Typical Mousterian in the upper part of the sequence (Bordes & Bourgon, 1950, 1951a; Bordes, 1955, 1971). The archaeological record of Pech de l'Azé III corresponds to the lower part of the Pech de l'Azé II sequence (Bordes & Bourgon, 1950, 1951a; Bordes, 1955, 1971), while Pech de l'Azé I, dated into MIS 3 (Soressi, Jones, Rink, Maureille, & Tillier, 2007) exhibits Mousterian of Acheulian Tradition (MTA) (Bordes, 1954; Soressi, 2002; Soressi et al., 2002; Vaufrey, 1933). The stone artifact record recovered from these locations, especially from Pech de l'Azé I and II, was used extensively in the development of Mousterian taxonomy (Bordes & Bourgon, 1951a; Bordes, 1954, 1971, 1975, 1978, 1981).

Although Pech IV was discovered and tested by Bordes in 1952 (Bordes, 1954, 1955), it was an amateur archaeologist named Mortureux who did the first excavations by opening a trench 1 m wide and 9 m long from 1953 to 1956 (Bordes, 1975). Bordes excavated Pech IV in eight field seasons from 1970 to 1977 (Bordes, 1975, 1978). He expanded Mortureux's trench in front of the limestone cliff, and opened a rectangular excavation area of 7 m by 6 m against the cliff (Bordes, 1975, 1978). In total, he opened 52 m^2, and excavated the most of these squares until the bedrock, with the maximum depth of 4.5 m below the surface (Bordes, 1975, 1978;

McPherron & Dibble, 1999; McPherron et al., 2001) (Figure 4-2). Excavations of Pech IV were the second largest excavations undertaken by Bordes (second to Combe Grenal) in terms of the number of field seasons and the amount of excavated archaeological material (McPherron & Dibble, 1999; McPherron et al., 2001). Bordes recovered about 90,000 stone artifacts and around 30,000 faunal remains during his excavations of Pech IV (Dibble, Raczek, et al., 2005).

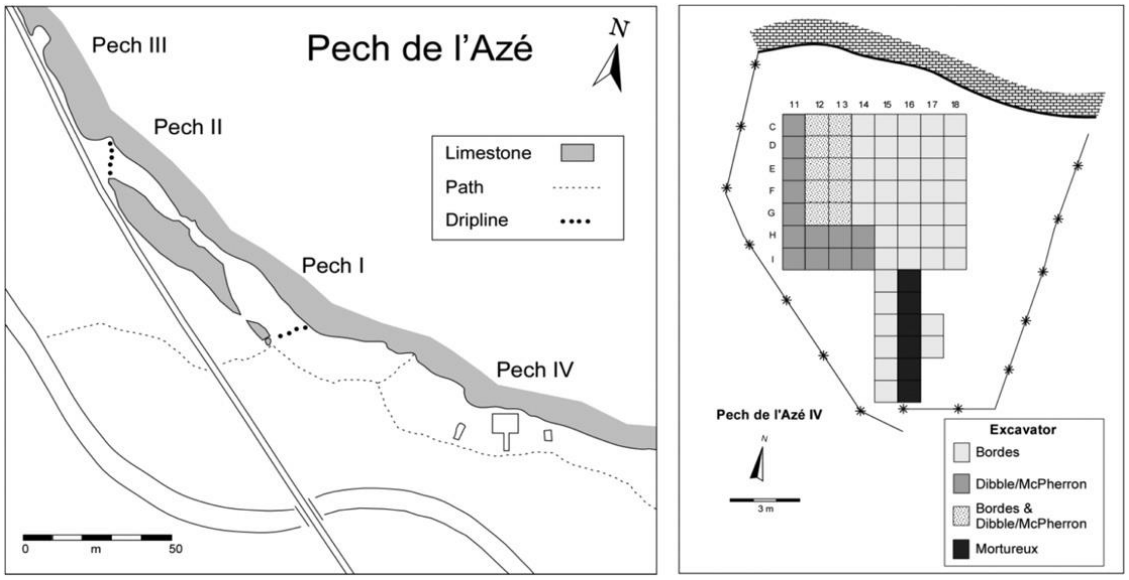

Figure 4 - 2: Complex of Pech de l'Azé locations with Middle Paleolithic deposits. Pech de l'Azé IV is one of four locations on the southern perimeter of the same hill (Pech de l'Azé). On the left is the plan of Mortureux' trench (1953-1956), excavation units by Bordes (1970-1977), and Dibble and McPherron (2000-2003).

Dibble and McPherron expanded the excavation in the western part of Bordes' excavation area (Figure 4-2) (Dibble, Raczek, et al., 2005; Turq et al., 2008, 2011). During these excavations, which lasted from 2000 to 2003, the whole excavation area was expanded by a new line of square units (C11-I11) excavated to

the bedrock (Dibble, Raczek, et al., 2005; Turq et al., 2011). Moreover, some of the old square-units opened by Bordes were also excavated to the bedrock (Dibble, Raczek, et al., 2005). The major goals of these new excavations were obtaining samples for absolute dating of the sequence, conducting sedimentology analysis for the purpose of reconstructing formation processes and paleoenvironments, and document more comprehensively the depositional context of the stone artifacts and faunal material recovered during Bordes' excavations (Dibble, Raczek, et al., 2005; McPherron et al., 2001).

In their excavations, Dibble and McPherron utilized Bordes' grid system but implemented different standards for point-provenienced finds. Unlike Bordes' excavations where finds that were provenienced individually had no cut-off in size, in these new excavations, stone artifacts and faunal remains that were provenienced individually (or point-provenienced) were those with a maximum dimension equal to or are larger than 2.5 cm (finds smaller in size were collected with the sediment from the same and limited excavation area in a bucket, sharing, thus, the provenience of that bucket) (Dibble, Raczek, et al., 2005). By counting only individual point-provenienced finds only, these excavations recovered an additional 20,000 stone artifacts and 23,000 faunal remains[1].

Dibble and McPherron also undertook extensive measures of the organization and curation of Bordes' collection that was stored at the Université du Bordeaux I (Dibble, Raczek, et al., 2005; McPherron & Dibble, 1999). During this work, they assigned the proper stratigraphic unit for a considerable amount of

[1] Information retrieved from the Pech IV database

material using original Bordes' field notebooks that were kept in the Musée d'Aquitaine in Bordeaux (Dibble, Raczek, et al., 2005; McPherron & Dibble, 1999). In addition, using the entries in the Bordes' notebooks, Dibble and McPherron digitized the provenience info (x, y, and z coordinates, level assignment, etc.), as well as basic typological and technological data for every artifact or bags of artifacts from Bordes' collection (Dibble, Raczek, et al., 2005; McPherron & Dibble, 1999). In this way, the provenience and analytical data of Pech de l'Azé IV artifacts recovered during excavations of both Bordes and Dibble/McPherron were merged into the same database (Figure 4-3).

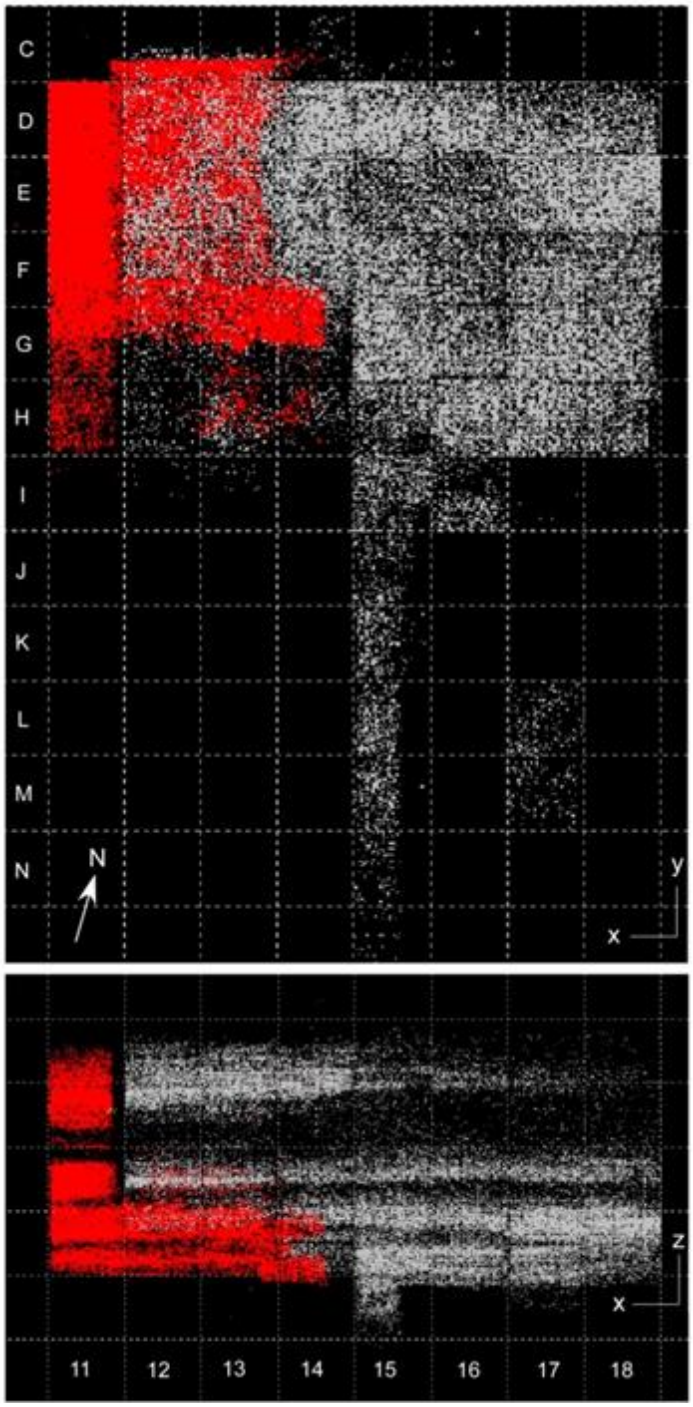

Figure 4 - 3: Plan and front views on point-provenienced individual stone artifacts and faunal remains of Pech IV. Points in grey are finds recorded by Bordes, while points in red are those recorded during the excavations by Dibble and McPherron. Provenience data of finds recovered by Bordes were entered in the database by Dibble and McPherron using Bordes' notebooks.

4.2 Geological context of Pech IV

The cliff face at Pech, like the other hills in the region, formed due to erosion of Jurassic and Cretaceous limestone during the period from the Oligocene to Pliocene, with the substantive dissolution of this limestone during the periglacial conditions of the Quaternary (Salomon & Astruc, 1992). Bordes described Pech IV as a collapsed cave or *abri* (Bordes, 1955, 1975). However, the 2000-03 excavations disclosed that, when the occupation of Pech IV began, its morphology was more like in a form of a small cave (Turq et al., 2011). The new excavations also revealed that Pech IV may have been interconnected with caves of Pech I and Pech II by a large tube-like passage from a pre-Quaternary phreatic system, curving along the southern side of the hill (Turq et al., 2011).

There are several lines of evidences suggesting this possibility, Perhaps the most prominent of these is that the sediment deposits of Pech IV generally follow the same slope (north-south downward) of the bedrock, a feature generally characteristic for sedimentation processes in caves where flowing water runs and transports sediments out of the karst phreatic system (Turq et al., 2011). In addition, elongated stone artifacts and faunal bones tend to be oriented from east to west, which indicates a potential existence of an internal flow (of a low energy) through Pech I, II and IV (Turq et al., 2011). At some point, the connection to Pech I and Pech II partially eroded away, while further weathering of the southern wall created an overhang (Turq et al., 2011).

The recent excavations at Pech IValso recovered fragments of stalagmites, as well as of small travertine deposits formed at drip lines that moved through time

following the recess of the cave/cave mouth towards the north (Turq et al., 2011). Such roof-fall, episodes were recorded in several layers throughout the stratigraphy (Turq et al., 2011). As a consequence of Pech IV being part of this phreatic system, the stratified deposits of the Pech IV extend further westward (Turq et al., 2011). The 2000-03 excavations also revealed a crack in the bedrock, possibly leading to a chamber in limestone beneath the bedrock floor of Pech IV (Turq et al., 2011), that followed this same orientation.

The stratigraphy of Pech IV consists of eight major geological units (Table 4-1, Figure 4-5). At their thickest, the deposits are about 4.5 m deep (Goldberg et al., 2012; Turq et al., 2011). Extensive information about the sedimentology and formation processes of Pech IV deposits was published in Turq et al (2012), and a short summary about the geological context of this cave that is mostly taken from this publication is presented below.

As inferred through micromorphological thin sections of sediments, the sediments of Pech IV are primarily comprised of coarse fraction that is of geologic (as opposed to anthropogenic) origin. This fraction largely contains quartz, glauconite, carbonate sand, and limestone fragments. Thin sections also revealed that fragments of limestone have been actively dissolving, thereby contributing quartz sand to the sediments. This observation also suggested that the coarser sediments derived locally and internally due to dissolution of quartz-rich limestone bedrock (Turq et al., 2011).

A significant component of the fine fraction of sediments also derived from weathering of the limestone into its insoluble components (Turq et al., 2011).

However, the fine fraction of deposits above layer 7 contains silt and clay size grains of iron and manganese oxides that most likely originated from soils mantles above the cave or cave, filtering through cracks in the bedrock (Turq et al., 2011). In layers 8 and 7, as well as in 6, the fine fraction of sediments is abundant with ashes (Goldberg et al., 2012; Turq et al., 2011). This finding, together with documented combustion features (most likely hearths) in these lower layers, and with large amount of animal burned bone fragments, indicate a considerable anthropogenic input in forming these lower deposits, especially the layer 8 (Dibble, Berna, et al., 2009; Goldberg et al., 2012; Sandgathe et al., 2011; Turq et al., 2011).

Layer 8 consists of multiple superimposed levels that are comprised of clayish sand, ash and charcoal (Dibble, Berna, et al., 2009; Goldberg et al., 2012; Turq et al., 2011). The composition of this layer suggests that during the earliest occupation of Pech IV the occupation activities took place directly on the surface of the bedrock and included the deposition of anthropogenic material related to burning and mixed with cave detritus (Dibble, Berna, et al., 2009; Turq et al., 2011).

Layer 7 is a relatively thin layer of coarse sand that was subjected to severe processes of solifluction, a down-slope movement of sediments imbued with water usually under conditions of colder climate, with evidences of cryoturbation (Goldberg et al., 2012; Turq et al., 2011).

By contrast, Layers 6, 5 and 4 are comprised of silty sand with limestone fragments of varying size and quantity (Goldberg et al., 2012; Turq et al., 2011). These bloks of limestone, or *éboulis,* represent the collapse and recess of the cave/cave roof.

The roof collapse seen in layer 6 (Figure 4-4), and the subsurface pedogenic origin of some sediment materials (which would percolate through the fissures in bedrock) around these limestone blocks, indicate the thinning and recession of the cave overhang during the deposition of this layer (Turq et al., 2011). The presence of burned bones in layer 6 suggests that the occupation continued to include anthropogenic combustion activities, albeit less intensive or at a different location within this place, as compared to such activities documented in layer 8 (Turq et al., 2011). After the event of the roof fall of the cave during the deposition of layer 5, documented by limestone blocks in that layer (Figure 4-4), the overhang started to retreat, indicated by limestone fragments through layer 4 (Figure 4-4 (Turq et al., 2011).

Layer 3 is a thick layer of coarse and sandy texture, with re-deposited limestone fragments, and locally formed breccias that most likely resulted due to shifting drip-lines of the overhang (Goldberg et al., 2012; Turq et al., 2011). This layer is the uppermost of the Pleistocene sequence (Goldberg et al., 2012; Sandgathe et al., 2011; Turq et al., 2011). After the final collapse of the roof (layer 1), erosion of the hill-slope covered the sequence with colluvial accumulations and dark brown organic clayish sand (Turq et al., 2011).

Layer 7 excluded, the analysis of artifact orientation, and their condition in terms of their edge damage and fragmentation, together with analysis and observations of sedimentology, indicate that Pleistocene deposits at Pech IV were not significantly affected by postdepositional processes (Turq et al., 2011). Here it needs to be mentioned that, on the macroscale of observation, the distribution of

limestone blocks and clasts in the lower part of a limited area of layer 5 could be suggestive of the process of solifluction (Turq et al., 2011).

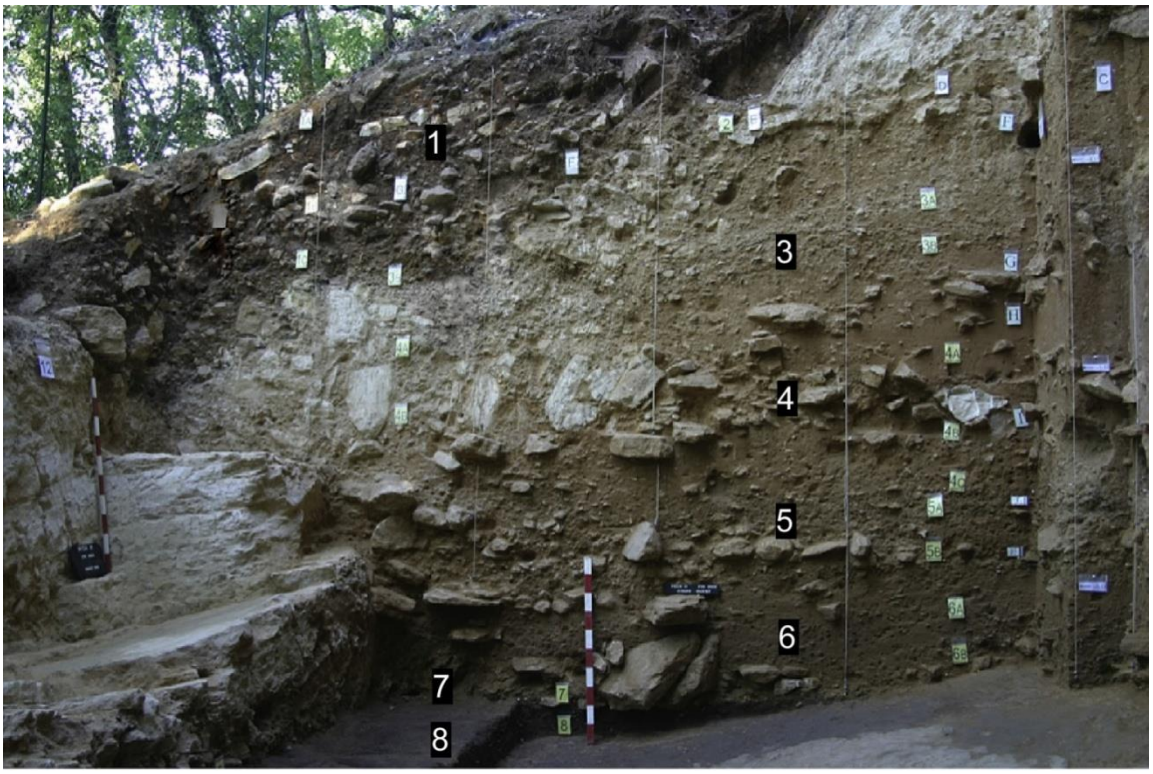

Figure 4 - 4: The western profile of the Pech IV sequence after the excavations by Dibble and McPherron. Some square-units (lower left) were not excavated to the bedrock. Numbered are major geological units, except layer 2, which represents the fill of the localized channel that passed through the top of layer 3 (and 4) and that was formed by flowing water from the overhang (as stretched out before the deposition of layer 1) (Turq et al., 2011).

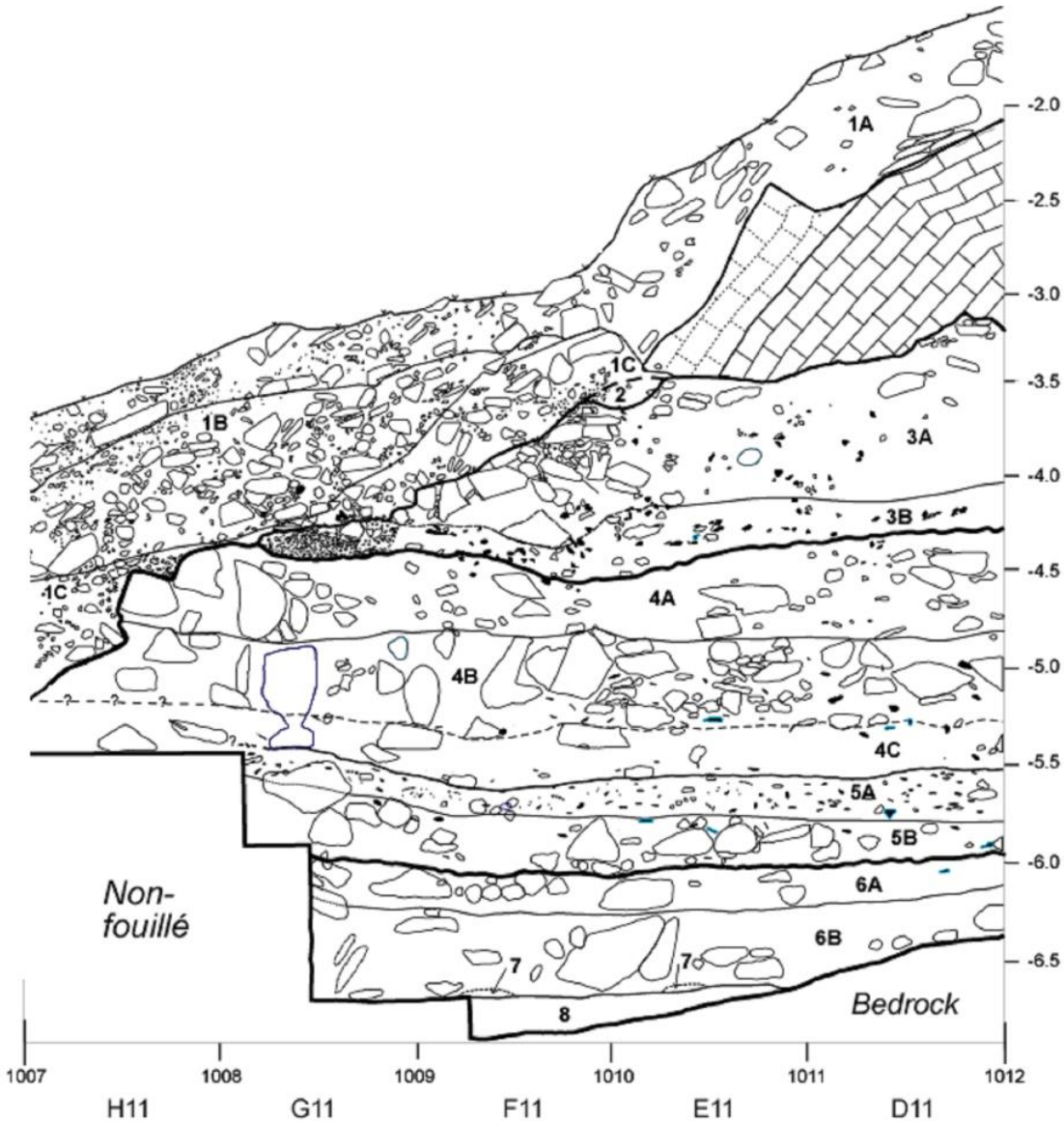

Figure 4 - 5: A drawing of the western profile of the Pech IV sequence after excavations by Dibble and McPherron. Major geological units were further subdivided on the basis of vertical differences in texture and the nature and morphology of clasts and grains within them (Turq et al., 2011). Indicated are these sublevels of major geological units, as well as y and z coordinates of the local grid system.

4.3 Chronological framework and paleoenvironmental context of the Pech IV sequence

The major geological indicators of changes in climate and environment in the Pech IV sequence are those that are observable only on the macroscopic scale (Bordes, 1975; Dibble, Berna, et al., 2009; Goldberg et al., 2012; Sandgathe et al., 2011; Turq et al., 2011). According to Turq et al. (2012), this comes to be a result of the Pech IV deposits predominantly consisting of coarse sediment fractions. Since coarse grain sediments contain less clay and silt-size particles that would inhibit water drainage, such sediments are less prone to freeze-thaw effects, consequentially obscuring all but the most macroscopic signatures of climate changes and formational environment of the sequence from the geological perspective (Turq et al., 2011). The macroscopic indicators are the limestone fragments that were deposited due to episodes of the cave retreat, and along with some clastic components of a smaller size they indicate periods of colder and drier climate within the history of sequence formation (Laville, Rigaud, & Sackett, 1980).

The available information regarding the paleoenvironmental context of the Pech IV sequence, as well as the dating of its deposits, is structured according to geological layers (Dibble, Berna, et al., 2009; Goldberg et al., 2012; Laquay, 1981; Richter et al., 2010; Richter, Dibble, et al., 2013; Sandgathe et al., 2011).

Layer 8 fauna is dominated by red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*) and wild pig (*Sus scrofa*), species which indicate the presence of a temperate wooded environment (Dibble et al., 2009; see Laquay, 1981). The recent thermoluminescence (TL) dating of layer 8 yielded a weighted mean date of 96±5 ka (Dibble, Berna, et al., 2009; Richter, Dibble, et al., 2013). It should be mentioned that

the first chronometric study of the Pech IV sequence using the TL method on heated flints from Bordes' excavations was reported by Bowman et al. (1982). Those dates, which were based only on a single sample per layer, were interpreted as underestimating the firing age and being too young (Bowman et al., 1982; Richter, Dibble, et al., 2013). In any case, taken together with fauna evidence, the recent TL date mentioned above places Layer 8 largely into the period of MIS 5c, when climate conditions were warm and humid (Anklin et al., 1993; Gibbard & van Kolfshoten, 2004; Taylor et al., 1993; Winograd et al., 1997).

By contrast, due to being severely affected by postdepositional processes, layer 7 has a few remaining faunal remains. On the basis of the chronological placement of layer 8 and 6, it could potentially be correlated with MIS 5b (Goldberg et al., 2012; Sandgathe et al., 2011).

The faunal composition of layer 6 is similar to that of layer 8, suggesting a correlation with relatively temperate environment (Sandgathe et al. 2011; see Laquay, 1981). However, an average TL date for samples taken in the upper part of this layer (in sublevel 6A) was 70.9±3.5 kya (Richter et al., 2010), which would place it into MIS 4, which was generally cold period (Anklin et al., 1993; Gibbard & van Kolfshoten, 2004; Taylor et al., 1993; Winograd et al., 1997). Sandgathe et al. (2011) emphasized that, due to the faunal composition that would exclude the relation of this layer with cold climate, the absolute dates for layer 6 are most likely incorrect, and instead it should probably be placed into the MIS 5a period (see also Richter, Dibble, et al., 2013).

Layer 5 marks the major change in the local fauna. Within this layer, there is a decrease in roe deer and wild pig, and an increase in reindeer (*Rangifer tarandus*) (Goldberg et al., 2012; Sandgathe et al., 2011). The lower part of this layer (sublevel 5B) is still dominated by red deer, which, together with considerable quantity of wild pig, red deer and an example of the Irish Elk (*Megaloceros giganteus),* indicates a temperate environment of open woodlands (Goldberg et al., 2012; Laquay, 1981; Sandgathe et al., 2011). By contrast, in sublevel 5A, the disappearance of wild pig and roe deer is coupled with a marked increase in reindeer (Goldberg et al., 2012; Sandgathe et al., 2011). A weighted average TL date for layer 5(A) is 74±5 ka (yielding a range from 84 to 64 ka, with 2-σ) (Richter, Dibble, et al., 2013). This date is consistent with faunal evidence placing the lower part of layer 5 into MIS 5(a) and the upper part into MIS 4 (Richter, Dibble, et al., 2013; Sandgathe et al., 2011; see Lehman, Sachs, Crotwell, Keigwin, & Boyle, 2002; Taylor et al., 1993; Winograd et al., 1997).

In layer 4, reindeer is a dominant species, while the percentages of roe deer and red deer is low, indicating the placement of this layer into MIS 4 (Sandgathe et al., 2011; Laquay, 1981). TL dates reported for the lower part of this layer by Richter et al. (2013) push both the upper and lower limits of layer 4 into MIS 5a and MIS 3, respectively. However, these dates are based only on two samples, due to the small amount of heated stone artifacts in this layer (Richter, Dibble, et al., 2013). Furthermore, the chronometric dating of layer 3, as discussed below, confines the final deposition of layer 4 most plausibly into the end of MIS 4 (Richter, Dibble, et al., 2013).

The faunal composition in layer 3 is characterized by a decrease in reindeer, which is still a dominant species in the sublevel 3B, and the small amounts of roe deer and reed deer (Bordes, 1975; McPherron et al., 2012). Bone samples taken from this layer for the accelerator mass spectrometry (AMS) radiocarbon dating indicated that the deposition of layer 3 started prior to the current limit of radiocarbon calibration around 50 ka BP and ended around 45 ka cal BP (McPherron et al., 2012). These dates are in general agreement with the limited TL dating (Richter, Dibble, et al., 2013), electron-spin resonance (ESR) dates (Turq et al., 2011), and the composition of the fauna, in placing layer 3 into the period of MIS 3 (Goldberg et al., 2012; McPherron et al., 2012; Richter, Dibble, et al., 2013; Sandgathe et al., 2011; Turq et al., 2011). According to these dates for layer 3, the Pleistocene occupation of Pech IV most likely ended sometime during the course of MIS 3 (McPherron et al., 2012).

4.4 The stone artifact sequence

The area around Pech de l'Azé is composed of the Upper Cretaceous deposits of Turonian (from about 94 Ma [Gradstein, Ogg, & Smith, 2004]), Coniacian, Santonian, and part of Campanian stages (Campanian ending around 72 Ma [Gradstein et al., 2004]) (Demars, 1982; Geneste, 1988; Seronie-Vivien & Seronie-Vivien, 1987; Turq et al., 2011, 1999). All three Senonian (Coniacian, Santonian, and Campanian) deposits yield abundant outcrops of flint in the immediate vicinity of Pech (Dibble, Berna, et al., 2009; Turq et al., 2011). Coniacian and Santonian flint sources are present in the limestone slopes of the hill, as well as in the valleys of

Dordogne river and Enéa tributary (both in the primary and secondary contexts of *álterites*), up to a distance of 8 km from Pech caves and caves (Dibble, Berna, et al., 2009; Turq et al., 2011). Campanian flint outcrop was located at higher elevations above the town of Sarlat, located 7 km from Pech (Dibble, Berna, et al., 2009; Turq et al., 2011). The Enéa Valley is also a source of quartz and quartzites, and other rocks coming from the upstream part of the basin (Turq et al., 2011, 1999). In addition, this valley is a source of chalcedony, which formed in Enéa's Cretaceous beds (Turq et al., 2011, 1999). Calcedony outcroppings can also be found in Cenozoic limestone near Dordogne about 8 km to the south (Dibble, Berna, et al., 2009; Turq et al., 2011).

At Pech IV, about 95% of the stone artifacts are made of raw materials that are available locally, with light and dark varieties of Senonian flints predominating throughout the sequence (Turq et al., 2011). The whole sequence is relatively coherent in terms of the proportions of locally available stone raw materials (Turq et al., 2011). The raw material that was obtained farthest away from this area is 'Bergerac' flint, which is available more than 50 km to the west (Geneste, 1985; Turq, 1989; Turq et al., 2011). However, its insubstantial percentage throughout the sequence (Turq et al., 2011) makes tenuous any potential raw material analysis that would be based on the dichotomy between exploitation of local versus exploitation of 'non-local' stone raw materials.

Stone artifacts from both the Bordes collection and Dibble/McPherron collection of Pech IV were published to a varying extent in Bordes (1975), McPherron and Dibble (1999), Dibble and McPherron (2006), Dibble et al. (2009),

and in Turq et al. (2011). In addition, this record was described to some degree in Dibble and McPherron (2007), McPherron et al. (2001, 2005), and in Turq et al. (2008).

Using the typological and technological criteria of Bordian systematics, layer 8 is characterized as being high in scrapers (of single, double, and convergent forms) and low in notches and denticulates. Its stone artifact record has a relatively high Levallois component, and can be classified as Typical Mousterian (Bordes, 1978; Dibble, Berna, et al., 2009; McPherron & Dibble, 1999; Turq et al., 2011). Dibble et al. (2009) reported on the relatively low intensity of utilization of stone in this layer, since the number of blanks to cores and the number of retouched pieces to the number of unretouched flakes are low. According to cortex ratio and the amount of fully cortical complete blanks, layer 8 contains all elements from reduced nodules, suggesting that there was relatively little importation or exportation of stone artifacts during the occupations of layer 8 (Dibble, Berna, et al., 2009; Turq et al., 2011, p. 33).

In layer 7, the stone artifacts are heavily rolled and battered (McPherron & Dibble, 1999; Turq et al., 2011). The postdepositional processes acted on stone artifacts from this layer to such an extent that they are not suitable for any technological (and typological) analysis (Dibble & McPherron, 2006; Goldberg et al., 2012; Turq et al., 2011).

Bordes (1975) termed the stone artifact record from layer 6 'Asinipodian'. The stone artifacts from this layer are characterized by several techniques that were used for small flake production, such as Kombewa, Levallois, and truncating-faceting

(Dibble & McPherron, 2006, 2007). While common in this layer, the Levallois component consists of flakes and cores of smaller dimensions (Dibble & McPherron, 2006; McPherron & Dibble, 1999; Turq et al., 2011). The relative percentage of notches and denticulates is somewhat higher than seen in layer 8, but the ratios of blanks to core and retouched artifacts to unretouched flakes are relatively low, suggesting a low intensity of utilization of stone resources (Dibble & McPherron, 2006; McPherron & Dibble, 1999; Turq et al., 2011).

The stone artifact record of layer 5 can be also classified as Typical Mousterian (Bordes, 1978; McPherron & Dibble, 1999; McPherron et al., 2001; Turq et al., 2011). However, within layer 5 (from sublevel 5A), the percentage of scrapers relative to denticulates increases (with a side-scraper as the dominant form). This trend is followed by a decrease in Levallois and slight increase in ratios of blank to core and retouched to unretouched flakes (McPherron & Dibble, 1999; Turq et al., 2011).

By the time of layer 4, the material is very rich in scrapers (with more convergent and transverse forms) and associated with low use of Levallois (McPherron & Dibble, 1999; Turq et al., 2011). In addition, unretouched and retouched flakes are the largest in the sequence (McPherron & Dibble, 1999; Turq et al., 2011). While most of the stone artifacts from this layer exhibit affinities with Typical Mousterian (Bordes, 1975, 1978; McPherron et al., 2001), the top of layer 4 can be attributed to Quina (Turq et al., 2011). Layer 4 has the highest ratios of blank to core and retouched to unretouched flakes (McPherron & Dibble, 1999).

Finally, the presence of some bifaces and backed knives in layer 3 affiliates this stone artifact record with MTA (Bordes, 1975; McPherron et al., 2005, 2001; McPherron & Dibble, 1999; Turq et al., 2011). The frequencies of scrapers and Levallois blades are low, while the frequencies of notches and denticulates are relatively high (Turq et al., 2011). By partitioning this layer vertically into segments of the same thickness, McPherron et al (2005) showed that the frequency of notches is relatively constant throughout the deposition of this layer, while the frequency of scrapers decreases from the bottom to the top of the layer. In this layer, the blank-to-core and retouched-to-unretouched flake ratios are low (McPherron & Dibble, 1999).

4.5 Variability in place use and stone 'reduction thesis'

As mentioned already, this dissertation will examine the degree of variability in the use of Pech IV, from the perspective of its stone artifact record. By documenting the degree (low vs high) of this variability throughout the sequence of this place, and integrating it with the degree (low vs high) of variability in the use of stone, the goal is to contribute to the discussion about the degree (low vs high) of variability in Neandertal landscape use between and within the three isotope stages. With respect to the stone artifact record only, the degree of variability in place use will be inferred on the basis of interaction between the intensity of stone movement (import and export of various stone objects) and the intensity of blank production (intensity of flaking: production of stone objects at the place). The degree of variability in the use of stone will be inferred on the basis of interaction between the

intensity of stone movement (import and export of various stone objects) and the intensity of stone object use-life extension.

In the research of stone artifact archaeology, variability in place use and variability in stone use have been actively studied within two research frameworks developed in North American archaeology. The first of these frameworks is 'technological organization' (Bamforth, 1986, 1991; Binford, 1979, 1980; M. C. Nelson, 1991; Shott, 1986; Torrence, 1983), with complex development history. According to Carr and Bradbury (2011), one of the main strands that had considerable influence on the premises of this framework came from the theoretical and ethnographic work of Binford (1978, 1979, 1980, 1981, 1982), who turned attention to "the organizational alternatives within a technology which may be manipulated differently to affect acceptable adaptations to differing situations" (Binford, 1979, p. 255). Of similar importance to the development of this framework has been the growing interest in stone artifact technology and experiments, which touched on the discussion of technological strategies for production and maintenance of stone tools (e.g. Collins, 1975; Magne, 1985). This led to the elaboration of the stone artifact technology model that starts from stone acquisition and, through stone tool manufacture, use and maintenance, ends in the discard and physical distribution of that record (see also Holmes, 1890) (the methodological and theoretical use and implications of this model should not be confused with the *chaîne opératoire* approach to stone artifact technology that employs the same trajectory [Geneste, 1985; Leroi-Gourhan, 1964; Pelegrin, 1984]).

Merged with behavioral ecology (Bird & O'Connell, 2006; Smith, 1979; Winterhalder & Smith, 2000), and often with optimal foraging theory (Smith, 1983; Winterhalder & Smith, 1981), this stone artifact technology model became the central focus of technological organization, which is defined by Nelson (1991, p. 51) as "the selection and integration of strategies for making, using, transporting, and discarding tools and the materials needed for their manufacture and maintenance". These strategies are the result of a combination of technology and mobility within a conceptualized hierarchy (Carr & Bradbury, 2011, p. 312; M. C. Nelson, 1991, p. 59). They are affected by and responsive to economic and/or social constraints that are governed by environmental conditions (most often translated as raw material availability and food resource distribution) (e.g. Andrefsky, 1994; Bamforth, 1986; Bleed, 1986; Jeske, 1989; Kelly, 1988; Kuhn, 1992; Roth & Dibble, 1998; Torrence, 1983). Therefore, technological organization reflects an interplay between a variety of activities and decision-making that is associated with management of risk, costs and benefits (Bamforth & Bleed, 1997; Bamforth, 1991; Bousman, 1993; Elston, 1990; M. C. Nelson, 1990, 1991; Torrence, 2001).

The study of these strategies can lead to an assessment and modeling of adaptation to the environment. Perhaps the most widely employed model has been the one that dichotomizes between 'expedient' and 'curated' technological strategies (Bamforth, 1986; Parry & Kelly, 1987) and associates them respectively with 'foraging' and 'collecting' (Binford, 1979, 1980) practices of landscape use. This model will not be used in the interpretation of the result in this dissertation, because (1) this is just a hypothesized model that has not been tested (nor it was

conceived by Binford [1980] as a universal model for landscape use in all contexts of hunter-gatherers), and, more importantly, and (2), it represents an overly simplistic interpretative model of landscape use that does not allow exploration of the variability in such behavior but to instead reduce it to two predetermined categories (Carr & Bradbury, 2011, pp. 311–312; Holdaway & Douglass, 2011; M. C. Nelson, 1991, pp. 62–66; Surovell, 2009, pp. 10–11). In any case, within this framework for studying strategies that guided the technological component of human behavior, variability in place use and variability in stone use have been integrated reciprocally with mobility and stone material economy (Binford, 1979, 1980; Elston, 1990; Kelly, 1983, 1988; Parry & Kelly, 1987).

Another framework of archaeological research in which variability in place and stone use has taken the central focus is so-called 'accumulations research' (Varien & Mills, 1997). Here, the main goal has been to understand the dynamics of accumulation of the archaeological record for addressing questions of general anthropological interest. One of the earliest examples of such research were Nelson's (1909) and Gifford's (1916) studies of the occupation spans of Native American shell mounds in California. During the 1960s and 1970s, and in concordance with the intellectual framework in archaeological research of that time and the development of interest in formation processes (Ascher, 1961, 1968; Binford, 1978, 1979, 1980, 1981; Schiffer, 1972, 1975a, 1976, 1985, 1987), modeling the accumulation of the archaeological record included formal mathematical models generated on the basis of ethno- and experimental

archaeology (David, 1972; Schiffer, 1975b; Hayden & Cannon, 1983; Mills, 1989; Murray, 1980; and others).

The relationship between time, accumulation of artifacts and population size has been even formulated as a 'discard equation' (David, 1972; Schiffer, 1975b). In contrast to the earliest examples of accumulations research where determining the duration of site occupation was the goal of the research (Cook, 1946; Gifford, 1916; C. G. Nelson, 1909), in later studies the occupation span served as a variable, and the dynamics between artifact discard and duration of occupation have been explored for estimating population size (e.g . Powell, 1988) for reconstructing mobility patterns and changes in land use strategies (Kohler & Blinman, 1987; Varien, 1996), and for assessing the complexity of social organization (Nelson, Kohler, & Kintigh, 1994; Price & Brown, 1985).

Accumulations research has explored the relationship between variables of artifact use-life and place occupation span, that is, time. One of the observable phenomena that emerged from this kind of research is related to the effects that this relationship had on artifact frequencies in the record. As Varien and Mills (1997, p. 144) pointed out, such studies, among other things, demonstrated that variability in assemblage composition can be caused by variation in artifact use-life or by variation of site occupation span, and not by differences in the activities performed at the site (see also Dibble & Rolland, 1992; Rolland & Dibble, 1990; Shott, 1989, 2003). This is at the core of the 'Clarke Effect', as labeled and defined by Schiffer (1987, pp. 54–55) the "statistical tendency for the variety of discarded artifacts to increase directly with a settlement's occupation span." Long-term occupations

would contain a greater diversity of artifact forms, and the frequency of these forms in both longer and shorter occupation spans may reflect a random process rather than site function (see Shott, 2010). According to Schiffer (1975a), the relationship between the length of occupation and artifact use-life will have a considerable effect on the structure of the stone artifact record found at that place (see also Surovell, 2009; Wandsnider, 1996). With the increase in the occupation span relative to the use-life of an artifact, the chance that an artifact will be discarded at that place due to its increased wear will be higher. The probability of discard is smaller if there is an increase in the use-life of artifact in relation to place occupation span (Schlanger, 1990; Shott & Sillitoe, 2005; Shott, 1989; Varien & Potter, 1997).

In this dissertation, the degree of variability in the use of place of Pech IV and in the use of stone will be inferred by using the 'reduction thesis' (*sensu* Shott, 2003, 2005; also Shott & Nelson, 2008) approach to its stone artifact record. In this approach, various measures related to reduction of stone will be used as proxies for the behavioral processes of stone movement, economy of stone material resources and production of stone objects, intensity of stone (objects') utilization, and those affecting the use-life and life histories of stone objects (see papers in Andrefsky, 2008; Shott & Sillitoe, 2005; Shott, 2005). In this respect, this analytical approach to the stone artifact record is conceptually associated with phenomena that have been of interest within the frameworks of both the technological organization and the accumulations research (see above).

Such an approach has emerged with numerous researchers studying the record left in stone by toolmakers from various cultural and temporal contexts (e.g.,

Andrefsky, 2006, 2008; Clarkson & Lamb, 2006; Dibble, 1987, 1995; Frison, 1968; Hiscock & Clarkson, 2005; Holmes, 1894; Jelinek, 1976; Kuhn, 1992a, 1991; McPherron, 1994; Potts, 1991; Rolland & Dibble, 1990; Shiner, Holdaway, Allen, & Fanning, 2007). Furthermore, this approach is the foundation in one of the interpretations of Mousterian variability. It was proposed that the intensity of tool utilization was a potential source of variability in Middle Paleolithic record of southwest France (Rolland, 1981, 1988), and that there is an association of typological makeup of Mousterian assemblages with the increase in tool (scraper) reduction (Dibble, 1984, 1987, 1988, 1991, 1995) and 'intensity of occupation' (Dibble & Rolland, 1992; Rolland & Dibble, 1990).

Before the 'reduction thesis' can be applied to the Pech IV stone artifact record to examine the variability in the use of this place and in the use of stone, Pech IV sequence has to be partitioned into analytical units. The sampling of this sequence is presented in the next chapter.

Chapter 5: Sampling

5.1 The sampling concept

In this analysis, there will be no partitioning of the stone artifact record of Pech de l'Azé IV into separate assemblages according to layers. The reasoning for this approach was presented in Chapter 3, in the discussion about the concept of the stone artifact record that is adopted in this dissertation. Moreover, and in accordance with the emphasis on the accumulation of stone artifacts rather than on accumulation of sediments, the use of the word 'sequence' will refer not to the sequence of strata (except when specified) but instead to the vertical sequence of stone artifacts.

The samples created in the approach described below will be treated merely as analytical units, or units of observation. By no means will there be an attempt to refer to such samples as distinct 'occupation episodes' on the ethnographic scale (see Chapter 3). A sample created in the manner described in this chapter represents an accumulation of stone artifacts during various and indefinite time units, and/or indefinite number of behavioral events related to particular behavioral processes in the history of the use of the place of Pech IV. In this respect, the samples created can (and most likely will) be different in the amount of time that passed for the accumulation of the artifacts that each of these samples contain.

However, such conditions are inherent in all methods used to group individual artifacts into empirical assemblages in Pleistocene contexts, especially in the traditional method where the sequence is partitioned using sedimentary

envelopes that are observable on a macro scale. Such a condition will not likely be resolved largely due to the reasons related with (post-) depositional processes and the resolution of absolute dating of such contexts. Yet, the objective here is to document Pleistocene sequences as place use histories (Holdaway & Wandsnider, 2006, 2008; Rossignol & Wandsnider, 1992; Schlanger, 1992), and, by using the example of Pech IV in this dissertation, to evaluate such sequences in a way which will enable emancipation of analytical units for the study of behavior, and variability in this behavior, through time from geological units and from history that relates primarily to the deposition of geologically derived sediments (Holdaway & Wandsnider, 2008; see McPherron et al., 2005).

The sequence of stone artifacts that will be sampled in this study is comprised of both Bordes' and Dibble/McPherron collections (see Chapter 4), integrated by Dibble and McPherron into one database (Dibble, Raczek, et al., 2005). The categories of stone artifacts that will be included in the analysis are limited to complete and proximal flakes, complete and proximal retouched artifacts, and complete cores, all of which in their maximum dimension equal to or are larger than 2.5 cm, because artifacts of such dimension were individually provenienced during excavations by Dibble and McPherron (see Chapter 4). The categories of stone artifacts that will not be included in this analysis are shatter, medial and distal flakes, medial and distal retouched artifacts, and some others. Medial, distal and proximal pieces potentially represent fragments of the same individual artifacts. Therefore, including only the proximal (those that exhibit platform) fragments of flakes and retouched artifacts is assumed to be a strategy that will make calculations

based on numbers of flakes and retouched artifacts more accurate and unbiased (see Hiscock, 2002).

Since the research focus is inferring the degree of variability in the use of Pech IV and the degree of variability in the use of stone within and between different isotope stages, the number of samples of artifacts deposited during the same MIS should be adequate for the analysis that will allow these inferences. At the same time, the samples should be of a size that will encompass sufficient quantities of various categories of stone artifacts for comparisons that are based on those categories. In relation to the quantity of stone artifacts and the research subject pursued in this dissertation, an *a priori* decision was made that each sample will be comprised of about 1,000 artifacts.

The stone artifact record is distributed in a space in an irregular manner, with a geomorphology of sediments/layers that is undulating and sloped, resulting in the sequence potentially not being of the same thickness throughout its 3D-space. Therefore, when specifying a boundary of a sample in such distributional 3D-space of an asymmetrical form, one cannot choose a particular absolute elevation value at which the boundary would be placed throughout the horizontal distribution, as such 'slicing' would not correspond to the local geomorphology of the sequence. What must first be done is to adjust the absolute elevation value of every artifact to the local geomorphology. This adjustment will be made by calculating their relative elevation within their respective layers, because geological layers can be taken as proxies for local geomorphology within the cave deposit. Therefore, the geological layers, or more precisely their vertical and horizontal distributions, will be here

used to adjust the vertical positions of artifacts and make them relative to the geomorphological settings around their provenience.

In addition to differences in the local geomorphology, the vertical distribution of stone artifacts is not regular throughout the thickness of their sequence. Accordingly, if samples of the same size would be taken at the same vertical intervals throughout the sequence, it is very likely that, in parts of the sequence where the material is denser, some of the artifacts would be left out of the sampling. Since the sample size is the same for all samples, the sections (both vertical and horizontal) of the sequence with more artifacts require that more samples be taken from those sections, as opposed to portions of the sequence with less material or those representing a hiatus in terms of the deposition of stone artifacts. As described further below, geological layers will also be used here as units for controlling this difference in the vertical distribution of stone artifact record, which will be then partitioned by quantiles into the samples of the same sample size. Therefore, in this sampling, the specified total number of samples will be distributed according to the differences in the incidence of artifacts throughout the Pech IV sequence. As a result, more samples will be defined in portions with higher densities of artifacts.

The sampling procedure, therefore, consists of two major steps. The first is to specify the relative vertical position of all stone artifacts within the sequence, while the second is to make the actual generation of samples. The entire sampling process will be performed by using *ArcGIS* software. What follows is the description of each step in the sampling process, but also the rationale behind of all of those steps.

5.2 Sampling

Computing the relative vertical position of stone artifacts

In order to adjust the absolute elevation of artifacts to the local geomorphology, we must quantify the differences in the morphological properties of the sequence, that is, differences in thickness and slope throughout their respective layer in both x and y directions at the same time. To be able to quantify those differences, the vertical positions of all artifacts that share the same local geomorphological characteristics within the layer have to be attached to each of those artifacts. For this step, we need a medium through which this information can be transferred among the artifacts. This medium will be a cell grid that covers the entire horizontal distribution of the data set. By joining all artifacts to the cell grid, it will be possible for each cell in the grid to extract the data from all of the artifacts that will project onto or will be joined to the respective cell (Figure 5-1). In this way, it will become further possible for each artifact to be attached the data of other artifacts with which it shares the same cell.

This cell grid will essentially be used for acquiring control over the differences in local geomorphology. By inspecting the geomorphology of strata at Pech IV in the database, it was decided that the length of each of the cells in this cell grid will be 0.5 m. It was estimated that the area of 0.25 m^2 for each of those cells will be sufficient to detect variability in local geomorphology. There will be four cells in a single 1 m^2 unit created during the Pech IV excavation (Figure 5-2). These cells will heretofore be referred to as 'subunits'.

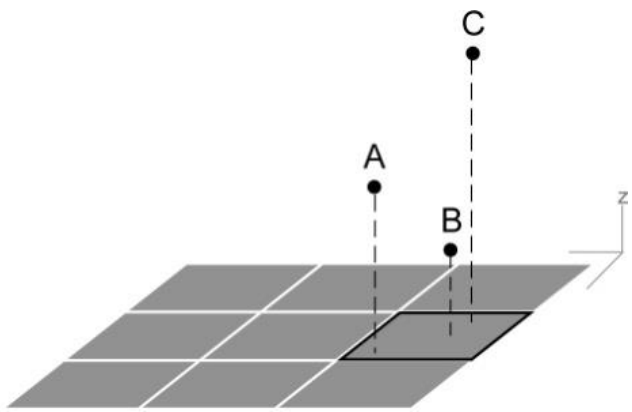

Figure 5 - 1: A dataset of three points joined to the cell grid. By using the cell grid as a medium, the data in points A and B, for example, can be attached to the point C through the shared cell in that grid.

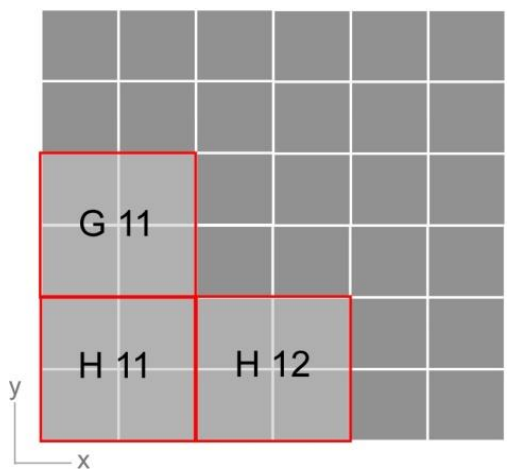

Figure 5 - 2: Plan view on a portion of the grid system used at Pech IV with the cell grid created during the sampling process. Each cell is of 0.25m² and it represents one of the four subunits in a unit. Here we see, for example, each of the units G11, H11 and H12 partitioned into four subunits.

The following analysis is performed using the *ArcGIS* software.

- ArcToolbox > Data Management Tools > Feature Class > **Create Fishnet**

(with an origin of x=999 and y=1000, and cell width and height of 0.5) (Figure 5-3).

This step creates a polygon shapefile *Grid* which, due to the specified origin coordinates, covers the entire horizontal distribution of the point dataset. The origin of the cell grid is specified as x=999, because this is the x-coordinate of the furthest point in the west in the dataset, and as y=1000, because the y-coordinate of the southernmost point in the dataset is 1000.108.

The origin (0, 0, 0) of the grid used at Pech IV was placed about 1,000 m southwest from this place, and about 4 m above the surface layer. Because of this positioning, the elevation values for all artifacts appear as in negative numbers.

- In the attribute table of *Grid* polygon shapefile, **add field** 'SubUNIT' to create a unique integer number for every cell in the grid.

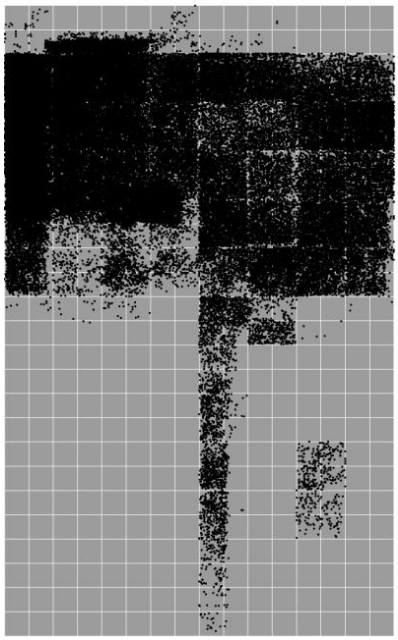

Figure 5 - 3: A plan view of the total point data set (n=128,406) from Pech IV projected on the created cell grid.

➢ In the field 'SubUNIT', equate 'SubUNIT" with 'FID' using **Field Calculator** (Figure 5-4). Here, 'FID' stands for the 'feature ID', and, in this case, is a unique ID for all polygons (features), which represent cells in the cell grid. 'FID' is assigned automatically upon the creation of a shapefile. By doing this, every cell representing a subunit receives a unique ID number. In the following procedure, this ID number will be used several times for joining data from various created data tables.

FID	Shape *	SubUNIT
0	Polygon	0
1	Polygon	1
2	Polygon	2
3	Polygon	3
4	Polygon	4
5	Polygon	5
6	Polygon	6
7	Polygon	7
8	Polygon	8
9	Polygon	9
10	Polygon	10
11	Polygon	11
12	Polygon	12
13	Polygon	13
14	Polygon	14
15	Polygon	15
16	Polygon	16
17	Polygon	17
18	Polygon	18
19	Polygon	19
20	Polygon	20
21	Polygon	21

Figure 5 - 4: An excerpt from the attribute table of *Grid* polygon shapefile. Every subunit (cell) is numbered with its unique id number.

Since each of the layers in the geological sequence has its own geomorphology, and since there can be differences in slope and undulation between layers within the same subunit (cell), it is necessary to further partition the sequence within the same subunit into layer-subunits (Figure 5-5). The dimensions

of each layer-subunit depend on the thickness of the particular layer in the respective subunit, as well as on its slope. This partitioning allows for better control over local geomorphology, not just of the sequence but also within it. In the definition of layer-subunits, we use geological layers. Each of them represents a segment within the sequence that has been formed more or less in the same manner in terms of the matrix (sediment) derivation, its deposition and accumulation, and the post-depositional agents that mechanically and chemically acted upon that matrix.

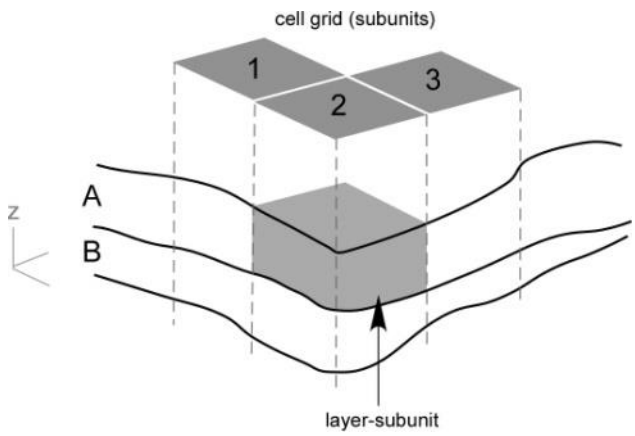

Figure 5 - 5: As isometric view of the sequence of two layers with projected subunits. The sequence of layers A and B is partitioned within the imaginary columns of subunits into layer-subunits. A layer-subunit indicated in the figure, thus, belongs to layer A and the subunit 2.

The point shapefile containing the provenience information of all the points from Pech IV will be labeled as *Dataset.* This file contains 128,406 points that were recorded during the excavation of Pech IV by both Bordes and more recently by Dibble and McPherron (Dibble, Raczek, et al., 2005; McPherron & Dibble, 1999; Turq et al., 2011) (see Chapter 4). The points in this shapefile represent all cases of stone artifacts, remains of fauna, sediment-buckets, and some other recorded archaeological and geological material. Out of these records, and as already

mentioned, only stone artifacts will be sampled and analyzed. However, in the definition of the local geomorphology, points of all other recovered material (namely, bone fragments and sediment-buckets) will be used along with points of stone artifact provenience, to define more precisely the local geomorphological conditions of the sequence.

- Within the point shapefile labeled as *Dataset*, **join** polygons (cells, subunits) from *Grid* to *Dataset* points based on spatial location, so such that each point in *Dataset* acquires the 'SubUNIT' ID number of the subunit that falls inside.

This will create a point shapefile *DatasetGrid* (Figure 5-6).

- In the attribute table of the shapefile *DatasetGrid*, **add field** 'LaySubUNIT' to specify the layer-subunit for each of the points in the next step.

In the field 'LaySubUNIT', concatenate values of layer and the ID number of subunit using the expression ' [Layer] & "-" & [SubUNIT] ' in **Field Calculator**.

Now that data set has been appropriately partitioned within its entire 3D-space, we can proceed with defining the local geomorphology for each layer-subunit. For this step we need to know three things: (1) the absolute elevation of the highest point in a layer-subunit, (2) the absolute elevation of the lowest point in the same

layer-subunit, and (3) the thickness of the layer-subunit, as calculated by using the elevations of these two points.

UNIT	ID	COLLECTION	WORDCODE	Layer	X	Y	Z	SubUNIT	LaySubUNIT
F11	6713	SPMHLD	TAMIS	8	999.7069	1009.372	-7.002	289	8-289
F11	6733	SPMHLD	MINERAL	5	999.7670	1009.166	-6.036	289	5-289
F11	6734	SPMHLD	MINERAL	5	999.7670	1009.166	-6.036	289	5-289
F11	6735	SPMHLD	MINERAL	5	999.7670	1009.166	-6.036	289	5-289
F11	6736	SPMHLD	MINERAL	5	999.7670	1009.166	-6.036	289	5-289
F11	6737	SPMHLD	MINERAL	5	999.7670	1009.166	-6.036	289	5-289
F11	6775	SPMHLD	OS	8	999.5830	1009.359	-6.933	289	8-289
F11	6779	SPMHLD	OS	8	999.711	1009.330	-6.954	289	8-289
F11	6813	SPMHLD	SILEX	5	999.599	1009.327	-5.71	289	5-289
F11	6838	SPMHLD	SILEX	6	999.7429	1009.450	-6.165	289	6-289
F11	6842	SPMHLD	SILEX	8	999.7189	1009.301	-6.815	289	8-289
F11	6845	SPMHLD	SILEX	8	999.9559	1009.333	-6.956	289	8-289
F11	6849	SPMHLD	SILEX	8	999.7100	1009.333	-6.936	289	8-289
F11	6910	SPMHLD	MINERAL	6	999.5900	1009.482	-6.389	289	6-289
F11	6911	SPMHLD	MINERAL	6	999.5900	1009.482	-6.389	289	6-289
F11	6912	SPMHLD	MINERAL	6	999.5900	1009.482	-6.389	289	6-289
F11	6923	SPMHLD	SILEX	6	999.5269	1009.031	-6.332	289	6-289
F11	6924	SPMHLD	SILEX	6	999.5269	1009.031	-6.332	289	6-289
F11	6925	SPMHLD	SILEX	6	999.5269	1009.031	-6.332	289	6-289
F12	691	Bordes	T	3	1000	1009.179	-4.14	289	3-289
F12	2059	Bordes	F	4	1000	1009.469	-5.55	289	4-289
G11	2356	SPMHLD	OS	6	999.6740	1009.008	-6.388	289	6-289
G11	2464	SPMHLD	OS	6	999.8640	1009.005	-6.427	289	6-289
F11	5650	SPMHLD	OS	6	1000.070	1009.168	-6.471	290	6-290
F12	21	Bordes	F	3	1000.479	1009.419	-3.66	290	3-290
F12	22	Bordes	F	3	1000.419	1009.429	-3.65	290	3-290
F12	23	Bordes	F	3	1000.409	1009.409	-3.66	290	3-290
F12	25	Bordes	F	3	1000.460	1009.280	-3.65	290	3-290
F12	76	Bordes	F	3	1000.5	1009.020	-3.7	290	3-290
F12	77	Bordes	F	3	1000.450	1009.030	-3.69	290	3-290
F12	169	Bordes	F	3	1000.44	1009.080	-3.74	290	3-290
F12	172	Bordes	F	3	1000.13	1009.450	-3.71	290	3-290

Figure 5 - 6: An excerpt from the attribute table of *DatasetGrid* point shapefile. For each point (n=128,406) its layer-subunit ('LaySubUNIT) is specified by merging values of its layer in 'Layer' field with the number of its subunit.

To determine the maximum and the minimum elevation of the set of points within each of the respective layer-subunits:

➢ In the attribute table of *DatasetGrid*, **Summarize** the minimum and maximum z-coordinate ('Z' field) in the 'LaySubUNIT' field.

This will create a new dbf table *DatasetGrid_summarized* with the minimum and maximum elevation values of the set of points per each layer-subunit (Figure 5-7).

OID	LaySubUNIT	Cnt_LaySub	Min_Z	Max_Z
473	5-376	148	-6	-5.7
474	5-377	120	-6	-5.63
475	5-378	84	-6.02	-5.63
476	5-379	99	-6	-5.63
477	5-380	30	-5.98	-5.45
478	5-381	48	-6	-5.64
479	5-382	42	-5.99	-5.65
480	5-383	27	-5.98	-5.69
481	5-386	227	-5.961	-5.517
482	5-387	231	-5.979	-5.571
483	5-388	107	-6.006	-5.591
484	5-389	60	-5.979	-5.563
485	6-120	5	-6.3	-6.19
486	6-152	5	-6.26	-6.03
487	6-168	40	-6.27	-5.99
488	6-184	9	-6.23	-6.04
489	6-200	29	-6.45	-6.03
490	6-201	18	-6.47	-6
491	6-202	23	-6.47	-6.12
492	6-203	13	-6.3	-6
493	6-216	26	-6.42	-6
494	6-217	16	-6.31	-6.01

Figure 5 - 7: An excerpt from the *DatasetGrid_summarized* table. For each layer-subunit a minimum and a maximum z-coordinate for all the points in that layer-subunit are specified, as well as the total number of points in it (field 'Count_LaySubUNIT'). Negative elevation values are a product of the coordinate system that was used at Pech IV during the excavation. Elevation values are given in meters.

As already mentioned, the sampling will involve only the stone material. Therefore, a new table was made, labeled as *Lithics.* It contains all individual stone

artifacts (≥ 2.5 cm), except those categorized as shatter, and medial and distal flakes; 38,221 cases in total.

- Within *Lithics* point shapefile, **join** polygons (subunits) from *Grid* to *Lithics* points based on spatial location, so that each point will be given the 'SubUNIT' value of the subunit that falls inside.

This will create a point shapefile *LithicsGrid.*

- In the attribute table of *LithicsGrid*, **add field** 'LaySubUNIT' to specify the layer-subunit for each of the artifacts. In the field 'LaySubUNIT', merge values of layer and subunit using the expression '[Layer] & "-" & [SubUNIT] ' in **Field Calculator.**

After this step, all of the cases in the lithic table have had their layer-subunit specified. Alternatively, the step above may not be necessary, since the cases of stone artifacts could have been extracted from the *DatasetGrid* point shapefile, where all points from Pech IV are already joined to their layer-subunit. However, the difference between cases of stone artifacts in the *DatasetGrid* shapefile and the *Lithics* table is that, in the latter table, these artifacts also have the data generated from their descriptive typo-technological analysis. Using this additional step will produce a final table at the end of the sampling procedure with appended typo-

technological data for all of the stone artifacts across all of the samples, instead of appending this data sample by sample after the samples have been generated.

As mentioned, the goal of this step in acquiring the control of local geomorphology is to transfer the information about the local geomorphological conditions to all of the stone artifacts, which will allow finding the relative position of each artifact within its respective layer-subunit. For these reasons, a layer-subunit will now serve as a medium for transferring the elevation data of the highest and the lowest point that it contains (among all of the points that is contains, and by using the *DatasetGrid_summarized* table), as well as its thickness, to each stone artifact of that respective layer-subunit.

- Within *LithicsGrid* dbf table, **join** attributes from the *DatasetGrid_summarized* table based on 'LayeSubUNIT' field.

This will join values of the minimum and maximum elevation (extracted from the entire *Dataset*) within the respective layer-subunit to each of the points (of only stone artifacts) in *LithicsGrid* table.

- **Export** this joined attribute table as a new dbf table *LithicsGrid1.*

- In the attribute table of *LithicsGrid1*, **add field** 'LSUthick' (as for 'layer-subunit thickness'), and using **Field Calculator** calculate for each point the

thickness of its layer-subunit by using this layer-subunit's minimum and maximum elevation values (Figures 5-8 and 5-9).

As mentioned already, all categories of finds were included to find the minimum and maximum elevation values for layer-subunits (*DatasetGrid* shapefile above, in Figure 5-6).

- **Add field** 'relElevat' (as for relative elevation) (Figure 5-8), and using **Field Calculator** calculate for each point its relative elevation within the thickness of its layer-subunit, with the expression '(([Z]-[Min_Z]) / [LSUthick]) * 100'.

The relative elevation of a stone artifact within its layer-subunit is expressed as a percentage of the thickness of that layer-subunit (going from the bottom of the layer) at which the artifact is positioned. This gives a range of relative elevation for all stone artifacts between 0 and 100 (Figures 5-8 and 5-9).

COLLECTION	WORDCODE	Layer	X	Y	Z	SubUNIT	LaySubUNIT	Min_Z	Max_Z	LSUthick	relElevat
Bordes	F	4	1000.0	1011.2	-5.63	354	4-354	-5.7	-4.31	1.39	5.03597
Bordes	F	4	1000.4	1011.2	-5.43	354	4-354	-5.7	-4.31	1.39	19.4244
Bordes	F	4	1000.1	1011.1	-5.23	354	4-354	-5.7	-4.31	1.39	33.8129
Bordes	F	4	1000.0	1011.0	-5.44	354	4-354	-5.7	-4.31	1.39	18.7050
Bordes	F	4	1000.3	1011.3	-5.42	354	4-354	-5.7	-4.31	1.39	20.1438
Bordes	F	4	1000.2	1011.4	-5.35	354	4-354	-5.7	-4.31	1.39	25.1798
Bordes	F	4	1000.1	1011.3	-5.33	354	4-354	-5.7	-4.31	1.39	26.6187
Bordes	F	4	1000.5	1011.0	-5.29	354	4-354	-5.7	-4.31	1.39	29.4964
Bordes	F	4	1000.0	1011.0	-5.3	354	4-354	-5.7	-4.31	1.39	28.7769
Bordes	F	4	1000.4	1011.1	-5.38	354	4-354	-5.7	-4.31	1.39	23.0215
Bordes	F	4	1000.2	1011.3	-5.37	354	4-354	-5.7	-4.31	1.39	23.7410
Bordes	F	4	1000.3	1011.0	-5.39	354	4-354	-5.7	-4.31	1.39	22.3021
Bordes	F	4	1000.3	1011.0	-5.52	354	4-354	-5.7	-4.31	1.39	12.9496
Bordes	F	4	1000.2	1011.3	-5.37	354	4-354	-5.7	-4.31	1.39	23.7410
Bordes	F	4	1000.4	1011.4	-5.5	354	4-354	-5.7	-4.31	1.39	14.3884
Bordes	F	4	1000.1	1011.2	-5.45	354	4-354	-5.7	-4.31	1.39	17.9856
SPMHLD	SILEX	5	1000.3	1011.3	-5.77	354	5-354	-5.937	-5.751	0.186	89.7849
SPMHLD	SILEX	5	1000.0	1011.0	-5.787	354	5-354	-5.937	-5.751	0.186	80.6451
SPMHLD	SILEX	5	1000.2	1011.3	-5.886	354	5-354	-5.937	-5.751	0.186	27.4193
SPMHLD	SILEX	5	1000.0	1011.0	-5.878	354	5-354	-5.937	-5.751	0.186	31.7204
SPMHLD	SILEX	5	1000.4	1011.0	-5.885	354	5-354	-5.937	-5.751	0.186	27.9569
SPMHLD	SILEX	5	1000.0	1011.2	-5.781	354	5-354	-5.937	-5.751	0.186	83.8709
SPMHLD	SILEX	5	1000.4	1011.0	-5.846	354	5-354	-5.937	-5.751	0.186	48.9247
SPMHLD	SILEX	5	1000.3	1011.3	-5.751	354	5-354	-5.937	-5.751	0.186	100
SPMHLD	SILEX	5	1000.2	1011.0	-5.814	354	5-354	-5.937	-5.751	0.186	66.1290

Figure 5 - 8: An excerpt from the *LithicsGrid1* table, with cases from the same subunit, but two different layers. For each case of stone artifact (n=38,221), elevations of the highest ('Max_Z') and the lowest ('Min_Z') recorded point (using all categories of finds from *DatasetGrid* shapefile) from the same layer-subunit are joined. The thickness of the layer-subunit ('LSUthick') is calculated based on those two values. In the next step, the relative elevation ('relElevat') for each point in its respective layer-subunit was calculated based on its distance to the lowest point of the same layer-subunit and the thickness of that layer-subunit.

In Figure 5-8, we see that the vertical position of, for example, the first artifact is at about 5% of the thickness value (1.39 m) of this artifact's layer-subunit (4-354). The absolute elevation of the second artifact from the bottom of this excerpt is -5.751 m. Since this position happens to be the highest point in this artifact's layer-subunit 5-354 (as can be seen in 'Max_Z' field), the relative elevation of this artifact is 100%. In another excerpt from the same table, in Figure 5-9, although the fourth artifact is positioned below the last one (comparing their Z-coordinates), it is, nevertheless, closer to the top of the same layer (comparing their

relative elevations), relative to the local geomorphology of this layer in the subunit 104.

COLLECTION	WORDCODE	Layer	X	Y	Z	SubUNIT	LaySubUNIT	Min_Z	Max_Z	LSUthick	relElevat
Bordes	F	8	1003.1	1003.3	-7.53	104	8-104	-7.53	-7.19	0.34	0
Bordes	F	8	1003.2	1003.4	-7.37	104	8-104	-7.53	-7.19	0.34	47.0588
Bordes	F	8	1003.2	1003.2	-7.41	104	8-104	-7.53	-7.19	0.34	35.2941
Bordes	F	8	1003.1	1003.1	-7.28	104	8-104	-7.53	-7.19	0.34	73.5294
Bordes	F	8	1003.0	1003.2	-7.23	104	8-104	-7.53	-7.19	0.34	88.2352
Bordes	F	8	1003.0	1003.0	-7.4	104	8-104	-7.53	-7.19	0.34	38.2352
Bordes	F	8	1003.1	1003.3	-7.19	104	8-104	-7.53	-7.19	0.34	100
Bordes	F	8	1003.1	1003.3	-7.27	104	8-104	-7.53	-7.19	0.34	76.4705
Bordes	F	8	1003.1	1003.0	-7.37	104	8-104	-7.53	-7.19	0.34	47.0588
Bordes	F	8	1003.4	1003.3	-7.26	104	8-104	-7.53	-7.19	0.34	79.4117
Bordes	F	8	1003.1	1003.3	-7.2	104	8-104	-7.53	-7.19	0.34	97.0588
Bordes	F	8	1003.1	1003.1	-7.26	104	8-104	-7.53	-7.19	0.34	79.4117
Bordes	F	8	1003.5	1003.3	-7.35	104	8-104	-7.53	-7.19	0.34	52.9411
Bordes	F	8	1003.5	1003.0	-7.26	104	8-104	-7.53	-7.19	0.34	79.4117
Bordes	F	8	1003.5	1003.4	-7.4	104	8-104	-7.53	-7.19	0.34	38.2352
Bordes	F	8	1003.2	1003.8	-7.22	120	8-120	-7.48	-7.12	0.36	72.2222
Bordes	F	8	1003.2	1003.5	-7.2	120	8-120	-7.48	-7.12	0.36	77.7777
Bordes	F	8	1003.2	1003.6	-7.27	120	8-120	-7.48	-7.12	0.36	58.3333
Bordes	F	8	1003.2	1003.5	-7.27	120	8-120	-7.48	-7.12	0.36	58.3333
Bordes	F	8	1003.4	1003.8	-7.23	120	8-120	-7.48	-7.12	0.36	69.4444
Bordes	F	8	1003.1	1003.5	-7.23	120	8-120	-7.48	-7.12	0.36	69.4444
Bordes	F	8	1003.0	1003.8	-7.46	120	8-120	-7.48	-7.12	0.36	5.55555
Bordes	F	8	1003.1	1003.8	-7.25	120	8-120	-7.48	-7.12	0.36	63.8888

Figure 5 - 9: An excerpt from the *LithicsGrid1* table, with cases from the same layer, but two different subunits. For each case of stone artifact (n=38,221), elevations of the highest ('Max_Z') and the lowest ('Min_Z') recorded point (using all categories of finds from *DatasetGrid* shapefile) from the same layer-subunit are joined. The thickness of the layer-subunit ('LSUthick') is calculated based on those two values. In the next step, the relative elevation ('relElevat') for each point in its respective layer-subunit was calculated based on its distance to the lowest point of the same layer-subunit and the thickness of that layer-subunit.

By using their relative elevation, the vertical positions of stone artifacts will be comparable across all subunits of the same layer, regardless of the differences in the thickness and slope between layer-subunits, that is, across the extend of the layer.

Generating samples

As already mentioned, because the sample size is the same for all samples, parts of the sequence with a higher incidence of stone artifacts require that more samples be taken from those parts. In order to control for the difference in frequency of stone artifacts throughout the Pech IV sequence, the sequence needs to be partitioned into units that will allow tracing this difference. Such frequency-control units can correspond to geological layers, and this strategy will be employed here.

The ratio between the number of samples in a unit of controlling the difference in frequency of artifacts (which here corresponds to a geological layer), and the total number of samples must match the ratio between the number of artifacts in that unit and the total number of artifacts in the whole sequence (Table 5-1). This will allow the distribution of samples across the sequence to match the distribution of artifacts across the same sequence. Since the individual sample will be (at least) of n=1,000, and since the number of stone artifacts that will be sampled is 38,221 in total, the number of samples will be 38 (Table 5-1).

Table 5 - 1: Breakdown of number of samples by layer

Layer	n of stone artifacts	% from the total number of stone artifacts	n of samples[1]
3	11420	29.87	11
4	7048	18.44	7
5	3957	10.35	4
6	12128	31.73	12
8	3668	9.6	4
Total	38221	100	38

[1] The number of samples within a layer equals to ((n of stone artifacts in a layer / total number of stone artifacts) * 38). The number of 38 is derived by rounding of (total number of stone artifacts / sample size)).

In order to distribute a specified number of samples (Table 5-1) in a respective layer such that there will be more samples where the frequency of artifacts is higher, the distribution of artifacts within respective layers will be partitioned by quantiles. The number of quantiles in a layer will be identical to the number of samples in the same layer. By partitioning the distribution of artifacts in a layer by quantiles, this distribution will be partitioned into subsets of equal size, which, in this case, is of about 1,000 artifacts. Just like layers were used as control units for artifacts distribution throughout the entire sequence, quantiles will take the role of such units in layers.

Figures 5-10 through 5-14 present the partitioning of the sequence of stone artifacts (based on their computed relative elevation) from five layers by quantiles into samples of equal size. For example, Figure 5-10 shows the distribution of stone artifacts from Layer 8, partitioned by 4 quantiles into four subsets that are comprised of the same number of stone artifacts. The artifacts are distributed according to their relative elevation (x-axis on this figure) in their respective

subunits. Regardless of the difference in local geomorphology (thickness, slope, and absolute elevation) throughout Layer 8, all stone artifacts that were recorded on the surface of this layer are in this graph positioned around the value of 100 on the x-axis. Those found at the bottom of this layer across all (sub)units are positioned here around the value of 0 on the same axis.

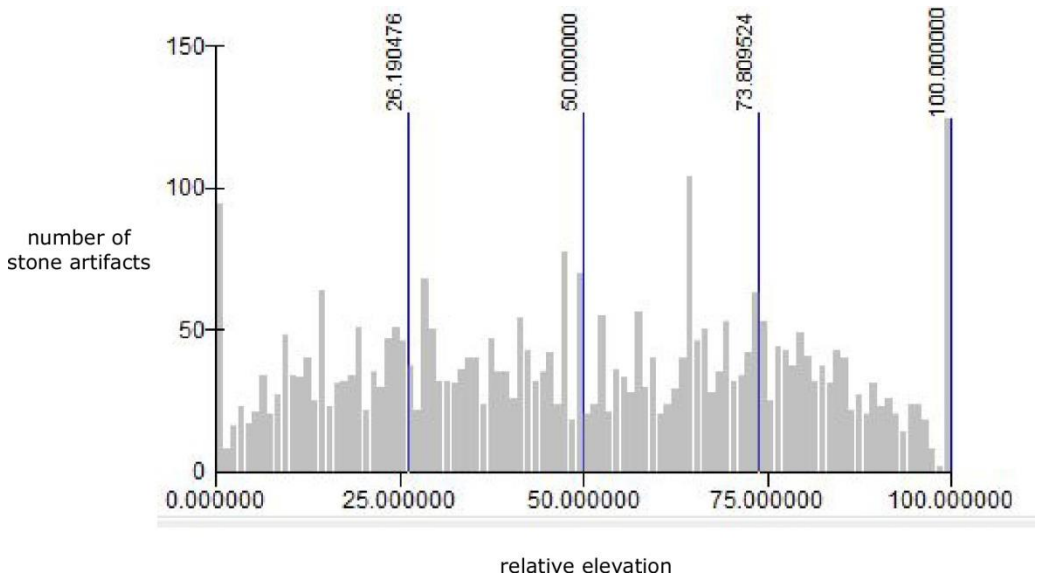

Figure 5 - 10: The distribution of stone artifacts in layer 8 according to their relative elevation values. This distribution is partitioned into four samples of equal size by 4 quantiles. The relative elevation of these quantiles is indicated. For example, the first quantile is positioned at around 26% of the thickness of this layer from its bottom (across all subunits).

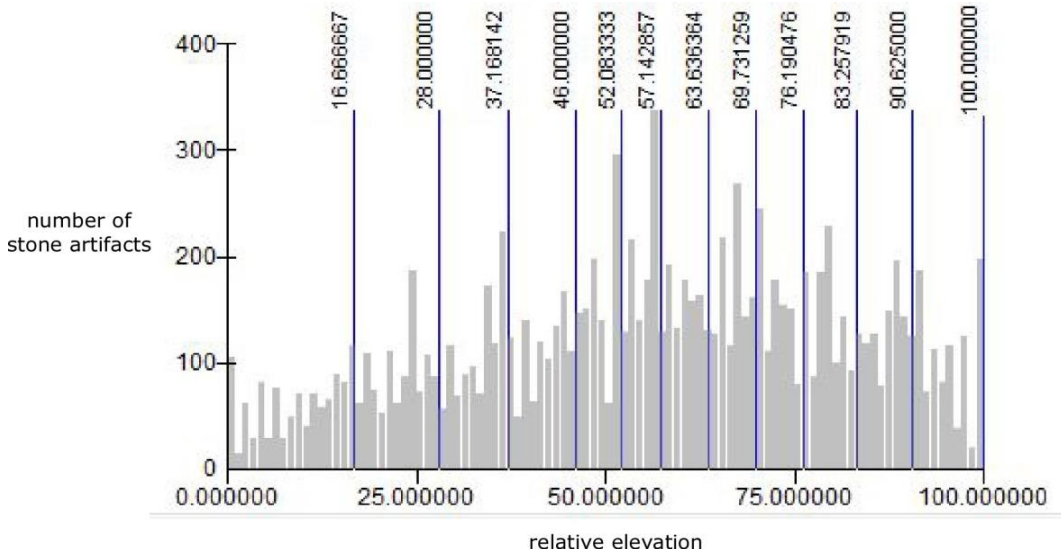

Figure 5 - 11: The distribution of stoneartifacts in layer 6 according to their relative elevation values. This distribution is partitioned by 12 quantiles into 12 samples.

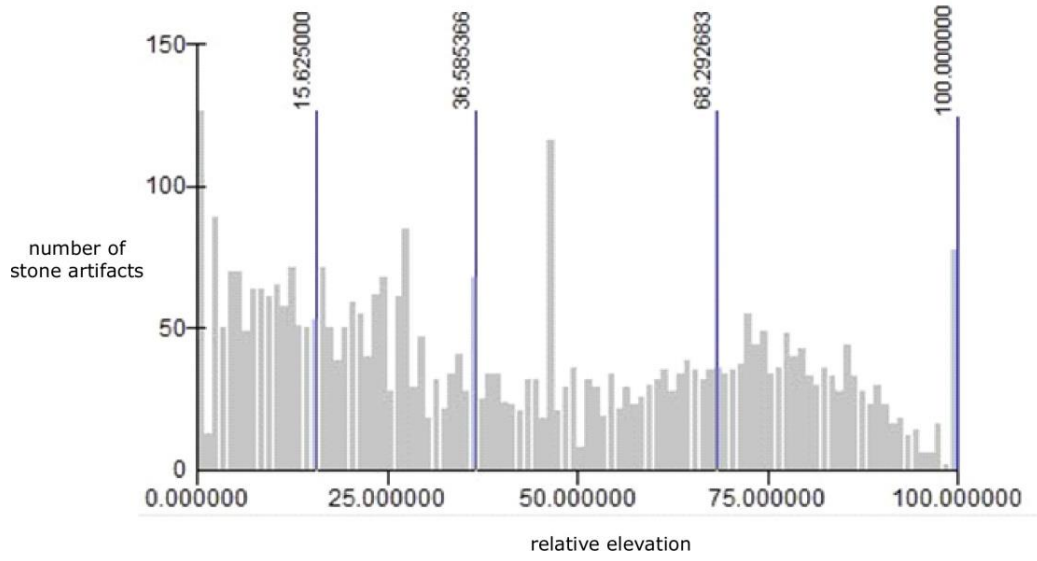

Figure 5 - 12: The distribution of stone artifacts in layer 5 according to their relative elevation values. This distribution is partitioned by 4 quantiles into 4 samples.

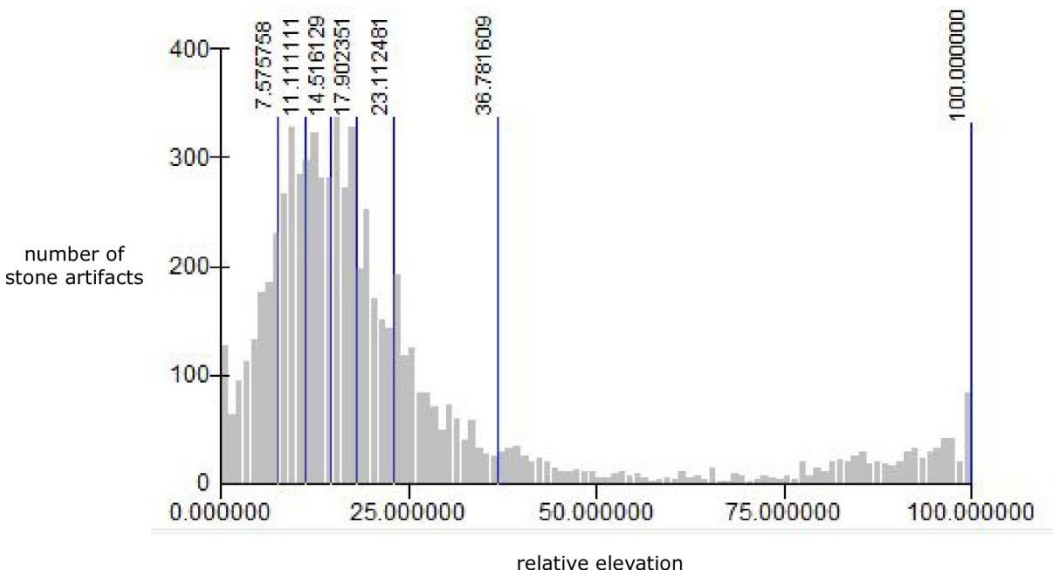

Figure 5 - 13: The distribution of stone artifacts in layer 4 according to their relative elevation values. This distribution is partitioned by 7 quantiles into 7 samples.

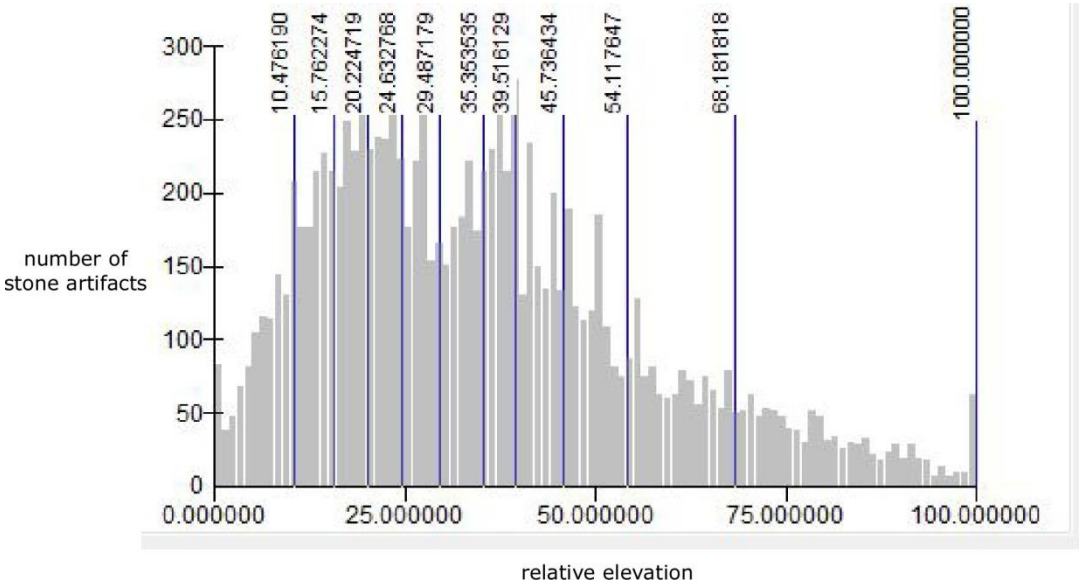

Figure 5 - 14: The distribution of stone artifacts in layer 3 according to their relative elevation values. This distribution is partitioned by 11 quantiles into 11 samples.

Stone artifacts between two quantiles are sampled out as one sample. For example, the lowest sample from layer 3 (Figure 5-14) is composed of artifacts that were provenienced up to 10% of the thickness of their respective layer-subunit. The next sample contains artifacts with a relative elevation between 10 and 16%, and so on. Table 5-2 contains the breakdown of a number of artifacts within each of the samples for Pech IV, and Figure 5-17 is a side view on the sequence with shown artifacts of the three lowermost samples (sample 1, 2, and 3).

Table 5 - 2: The relative elevation values of quantiles in their respective layers, and number of stone artifacts in each of 38 samples as defined by these quantiles.

Layer	sample	Relative elevation (%) of quantiles	N
3	**38**	100	1031
	37	68	1034
	36	54	1025
	35	46	1030
	34	39	1067
	33	35	1032
	32	29	1035
	31	25	1056
	30	20	1035
	29	16	1041
	28	10	1034
4	**27**	100	998
	26	37	998
	25	23	998
	24	18	1003
	23	14	1029
	22	11	1027
	21	8	995
5	**20**	100	992
	19	68	1033
	18	37	944
	17	16	988
6	**16**	100	1005

	15	91	988
	14	83	1017
	13	76	993
	12	70	1018
	11	64	1020
	10	57	1010
	9	52	996
	8	46	1008
	7	37	1006
	6	28	1073
	5	17	994
8	**4**	100	907
	3	74	905
	2	50	940
	1	29	917

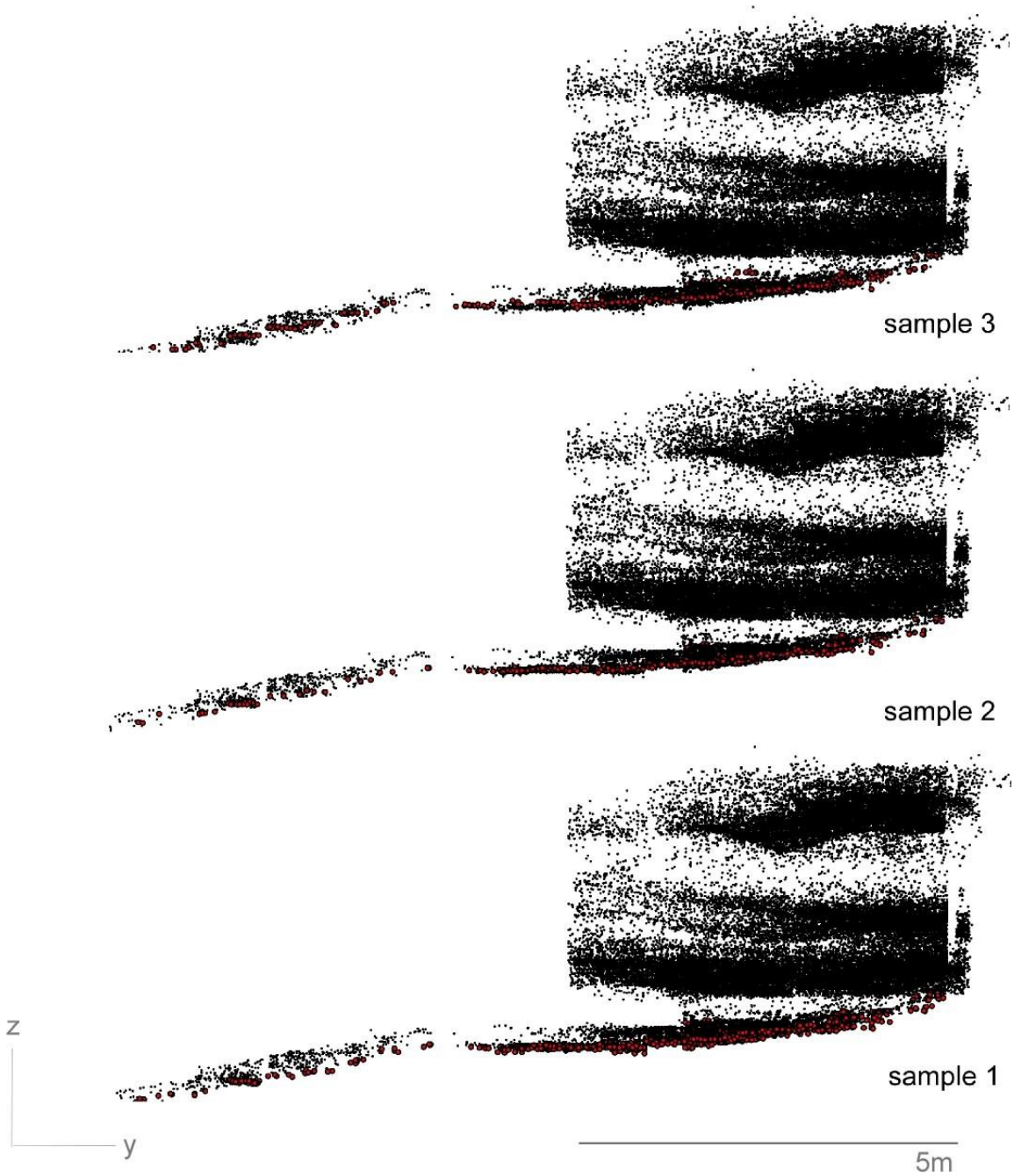

Figure 5 - 15: A side view of the sequence of stone artifacts at Pech IV (n=38,221) with three lowermost samples. Each point represents an individual stone artifact. Points in red are those included in the lowermost three samples, respectively.

The sampling of Pech IV stone artifact record as described in this chapter differs from the conventional method of defining stone artifact assemblages on the basis of geological layers. In this sampling method, the stone artifact sequence was partitioned by samples that are composed of the same amount of stone artifacts, and which generally follow the history of artifact accumulation at this place. The number and the size of the samples were defined *a priori* on the basis of the total number of stone artifacts from this sequence, and according to the research subject of this dissertation. Following the discussion about the ontology of the stone artifact (and archaeological) record in Chapter 3, it is argued that this approach is more appropriate to the goals of this research and to exploring this record as a phenomenon.

In the following chapter, these samples of the stone artifact record of Pech IV will be used to explore the variability in this record in relation to several behavioral processes of stone provisioning from MIS 5 to MIS 3. This will lead to inferences about the degree of variability in the use of this place and the degree of variability in the use of stone within and between different isotope stages, offering insights into the variability in Neandertal landscape use.

Chapter 6: Analysis

6.1 Introduction

As outlined in earlier chapters, the analysis in this dissertation is aimed at exploring the variability of the stone artifact record at Pech IV, in order to assess the dynamics of behavioral practices related to stone provisioning during different environmental conditions of the Late Pleistocene. The analysis is divided into three sections. The first section presents the analysis of the movement of stone objects, the second is about stone reduction and blank production, and the third about stone object selection and management (use-life extension). The analytical methods and variables used for the investigation of each of these processes are described and defined in the respective sections of this chapter.

The stone artifact sequence of Pech IV had accumulated from MIS 5(c) until some point during MIS 3 (Goldberg et al., 2012; McPherron et al., 2012; Richter et al., 2010; Sandgathe et al., 2011; Turq et al., 2011). Because the aim of this research is to examine the variability of this stone artifact record within and between different isotope stages, it is first necessary to present the correlation between the sampled accumulations (as performed in Chapter 5) with isotope stages. Such a correlation is presented in the Figure 6-1, as well as the one between samples --- henceforth, referred to as accumulations --- and the geological layers of Pech IV. These correlations are made based on the association between the layers, inferred paleo-environments (isotope stages), and chronometric dates, as described in Sandgathe et al. (2011), Turq et al. (2011), Goldberg et al. (2012), and Richter,

Dibble et al. (2013). For this study, the most important correlation is the one between accumulations and isotope stages, while that with the layers is indicated to refer where particular accumulations were sampled from within the sequence of Pech IV layers.

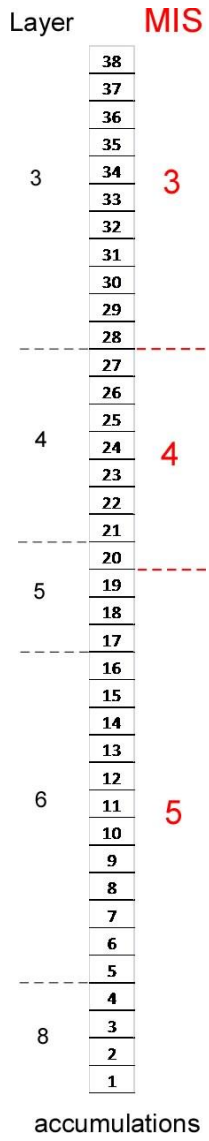

Figure 6 - 1: Correlations between sampled accumulations, marine isotope stages and layers of Pech IV. The placement of the divisions between two subsequent isotope stages on the sequence of sampled accumulations is only approximate.

As is evident from discussions of the Pech IV sequence, its absolute dating, and its sampling in the previous chapters, the lower and the upper boundaries of MIS 4 as projected here on the sampled accumulations are only approximations. Accumulations 19 and 20, and 27 and 28, are not assumed to represent clear-cut transitions from MIS 5 into 4, and MIS 4 into 3, respectively. A total of 3,957 stone artifacts from Layer 5 were sampled in this sampling process, out of which 2,969 were recorded in the lower part of this Layer, sublevel 5B. This left only one accumulation (of 988 artifacts) that could be sampled from the upper part of this Layer (sublevel 5A).

Based on the change in fauna into the one that is viewed as a proxy for colder conditions, and the available absolute dating, this upper part of Layer 5 most plausibly can be placed into MIS 4 (Goldberg et al., 2012; Richter, Dibble, et al., 2013; Sandgathe et al., 2011). The chronometric dating of Layer 3 suggested that the final deposition of Layer 4 most likely occurred at the overall transition between MIS 4 and MIS 3 (McPherron et al., 2012; Richter, Dibble, et al., 2013). This is the reason for placing this transition between the last sampled accumulation from Layer 4 and the first sampled accumulation from Layer 3, even though a geochronological break between these two climatic stages is less evident in the paleo-environmental record of Pech IV than the one between MIS 4 and MIS 5.

6.2 Movement of stone objects

One of the most common approaches to the study of stone artifact movement, as a general proxy for mobility in the past, has been determining the

source and distribution of different raw materials across the landscape and among the places of accumulated stone artifact record. A number of major raw material studies for southwest France have given valuable insights into the economy of procurement of different raw materials (Féblot-Augustin, 1993, 1999; Geneste, 1989; Park & Féblot-Augustin, 2010; Turq, 1990). Such an approach for detecting the degree of movement predominantly relies on the relationship between the raw materials that are available in the immediate vicinity and those that are found at more distant locations.

However, using the quantity of distant stone raw materials to infer the degree of stone movement will inevitably result in interpreting the record in which the amount of such raw materials is low as formed without a significant movement of stone artifacts. As shown in the studies above, the proportion of distant stone raw materials at many places with the accumulated stone artifact record in this region is low, as it is also the case also at Pech IV. This automatically biases the assessment of the stone movement at this place towards an interpretation of low intensity of movement. Another concern here is that the discussion of stone movement in the approaches involving raw material sourcing is reduced to the tracking of the linear movement of the raw material or stone objects across the landscape, without gauging the dynamics of movement at the particular place in that landscape, especially if that involved taking the stone objects *out* of that particular place.

An approach that offers much closer examination of the degree and the nature of movement of stone objects to explore patterns of human mobility is through conjoining studies (e.g. Close, 2000). However, this approach requires, first,

a high visibility of the stone artifact record across the landscape (see also Chiotti, McPherron, Olszewski, Dibble, & Smith, 2007; Olszewski et al., 2010), and, second, that one recovers stone artifacts that have been involved in the fragmentation process of the same stone object (a nodule, a core, or a blank) through time and space, which is something that is largely dependent on the extent and placement of the unit for sampling the record.

The movement of stone artifacts and the mobility of human groups have also been explored extensively through the lenses of the curation concept, as introduced by Binford (1973, 1979). Although the definition and application of this concept in stone artifact studies have varied considerably (for overview see Andrefsky, 2009; Bamforth, 1986) the most common association of curation has been the one with the stone tools that underwent the process of their maintenance, modeling, thus, degrees of mobility on the basis of differential amount of retouch in the stone artifact record (but see Shott, 1989). But here two opposing models of the relationship between the amount of retouched or more 'formally' looking artifacts and the degree of group mobility have been used. On the basis of his ethno-archaeological work, Binford (1979) suggested a relation between a higher degree of retouch and lower mobility, where those groups that were more sedentary would expend their prolonged stay at a place preparing their tools for future use. An alternative model was opposite model was proposed by Parry and Kelly (1987), who suggested that a longer stay at a place would result in the more expedient nature of tool production and management, largely due to higher relative availability of raw material at the place of occupation. But as Holdaway and

Douglass underlined (2011), both models can be correct, depending on the context that involves particular, rather than general, interplay between the uncertainties of resource availability and practices of maintenance of stone tool utility (see Bamforth, 1986; Kuhn, 1992, 1994; M. C. Nelson, 1991; Shott, 1986). The uncritical association between the lack of retouched artifacts and the absence of movement recently has been under increased deconstruction (e.g., Douglass, 2010; Shott & Sillitoe, 2005).

Dibble and colleagues (2005) developed, and Douglass and colleagues (2008) further investigated, a measure for the movement of stone artifacts that is based on quantification of cortex in the stone artifact record (see also Douglass, 2010; Lin, Douglass, Holdaway, & Floyd, 2010). Due to knapping nodules of stone raw material, their cortex becomes distributed in various amounts across produced blanks and cores. Based on the estimated size of the stone nodules, it is thus possible to estimate the amount of cortex that should be present in the record in theory if there was no movement of cortical elements after the discard or deposition of products of nodule reduction. The comparison of this estimate to the amount of cortex that is observed in the record produces a 'cortex ratio'. This value is used to evaluate if the record contains all products of knapping stone (a cortex ratio around 1), if some of the elements with cortex were removed and/or non-cortical elements added (lower than the amount of cortex that in theory should be present, a cortex ratio less than 1), or if the cortical elements were added and/or non-cortical elements were removed (higher than the amount of cortex that in theory should be present, a cortex ratio more than 1). This method for inferring the intensity of movement of

stone artifacts, and, thus, the movement of people in the past, has already been effectively applied in studies related to human mobility in several temporally and geographically different contexts, such as Middle Stone Age of Morocco (Dibble et al., 2012), Neolithic of Egypt (Phillipps, 2012), and mid-to-late Holocene of New South Wales in Australia (Douglass et al., 2008; Douglass, 2010; Holdaway, Douglass, & Fanning, 2012, 2013).

6.2.1 The method

The cortex ratio measurement as outlined in Dibble and colleagues (2005) and Douglass and colleagues (2008) will be used in this study for discussion about differences in movement activity along the sequence of Pech IV. However, unlike in applications of this method in the aforementioned studies, the derived cortex ratio will be discussed here in terms of its relative difference along the Pech IV sequence, not according to the interpretative framework developed experimentally (Dibble, Schurmans, et al., 2005), in which the cortex ratio of '1.0' is the absolute threshold between different scenarios of movement activity. The reason for considering the relative difference of cortex ration along this sequence is that the estimated amount of cortex that should be present in the record of Pech IV if there had been no stone movement, as derived in this study and presented further below, is most likely either over- or underestimation from the true values.

There are three major causes for such over- or underestimation: the theoretical nodule size, its shape, and the amount of cortex on its surface. The critical step in deriving the estimated amount of cortex is estimating the average

size of the original nodule (theoretical nodule size). This value is then used to estimate the cortical surface area of the nodule of such size, and subsequently (as described in more detail below), with the estimated number of nodules, to calculate the theoretical cortex amount that should be present in the record (Dibble, Schurmans, et al., 2005; Douglass et al., 2008). In some of the examples of this method (Dibble, Schurmans, et al., 2005; Douglass et al., 2008), the theoretical nodule size (volume) was calculated by dividing the total volume of the record by the number of cores it contains, and then placed into the equation for calculating the surface area of a sphere to calculate its outer surface presumably covered with cortex. In others (Douglass, 2010; see also Phillipps, 2012), an extensive analysis of geometric properties of the raw material available in the study area was performed to obtain more accurate parameters necessary to calculate the estimated cortex amount.

The application of the cortex method in this dissertation lacks such necessary background raw material research that would ultimately yield more accurate cortex ratios along the sampled accumulations. Nevertheless, since the configuration of the stone raw materials is not considerably different along the entire Pech IV sequence (see Chapter 4), whatever difference exists between the estimated amount of cortex of the theoretical nodule and the accurate amount of cortex of the empirical nodule, this difference is assumed to be proportionally the same throughout the sampled accumulations. Since the same procedure (as outlined below), with its limitations, is applied to all sampled accumulations, this makes valid to explore the existence of *relative difference* in the activity of movement in the Pech IV record.

Definitions of categories and variables used

The list and definitions of the categories of artifacts and the measured variables that are used in the calculation of the cortex ratio are presented below:

- Complete blank: a non-fragmented unretouched or retouched artifact detached from a core.
- Complete blank length: measured from the point of percussion to the most distal end of the artifact.
- Complete blank width: measured at the midpoint and perpendicular to the length axis.
- Proximal fragment: fragment of an unretouched of retouched blank with a platform.
- Proximal fragment length: measured as the longest axis of the artifact.
- Proximal fragment width: measured at the midpoint and perpendicular to the length axis.
- Core length: measured as the longest axis of the artifact.
- Core width: measured at the midpoint and perpendicular to the length axis.
- Core thickness: measured at the intersection of the length and width axis.
- Cortex: measured using two ratio and five interval classes: 0%, 0-10%, 10-40%, 40-60%, 60-90%, 90-99%, 100%.
- Cortical complete flake: unretouched complete blank with more than 10% of the dorsal surface covered in cortex.

Derivation of approximate observed cortex

The largest proportion of the artifacts that were recovered during the excavations by Bordes currently lack cortex data. Nonetheless, the calculated observed cortex amount of an accumulation will encompass all of its artifacts. The observed cortex was first calculated for the subset of artifacts in an accumulation that did have cortex data available (as well as their metrical attributes), and then this value was increased by the difference between the volume of this subset and the volume of the entire respective accumulation (Table 6-1). For this reason, the observed cortex amount of an accumulation is considered to be only as an approximate.

The observed cortex of the subset of artifacts in an accumulation with available cortex data is derived as the sum of cortical surfaces of those artifacts. Cortical surface of an artifact is calculated as a product of its estimated surface area and the percentage of that surface covered in cortex. For complete blanks and proximal fragments the surface area is estimated by multiplying their length by width. Following Douglass and colleagues (2008), estimation of a surface of a core was derived by using the equation for the ellipsoid surface, a shape that is arguably the closest resemblance to the average form of cores. The surface of individual artifacts was then multiplied by the midpoint of the interval used for recording the amount of their cortex (1-9%, 10-39%, 40-59%, 60-89%, 90-99%). For artifacts with either no cortex (0%) or with the entire surface covered in cortex (100%) their

estimated surface area was multiplied by 0 or 1, respectively (Dibble, Schurmans, et al., 2005).

As mentioned in previous chapters, shatter, medial and distal blank fragments recovered in Pech IV were not sampled and included in this study. The sampled accumulations consist of only complete blanks (retouched and unretouched), proximal fragments of blanks, and cores. Since the cortical surfaces of shatter, medial and distal blanks fragments are, thus, left out of the observed cortex summation, any calculation of observed cortex amount in an accumulation will most likely be an underestimation of the amount of cortex in the part of the Pech IV sequence where the accumulation is sampled from. However, if one assumes that the fragmentation intensity of stone artifacts is not significantly different across the entire Pech IV sequence then the differences in the total amount of cortex present on shatter, medial and distal fragments should proportionally correspond to the differences in the total amount of cortex present on complete blanks and proximal fragments across the sequence. The relatively uniform fragmentation intensity across most or all of the sequence, would, thus, make the differences in the observed cortex, as calculated here, still representative, albeit in relative terms. The assessment of stone fragmentation intensity across the sequence can perhaps be performed by quantification of size of artifact accumulations as outlined by Hiscock (2002). In any case, the relative representativeness of the differences in observed cortex amount between the sampled accumulations is another reason why the cortex ratio in this study will be discussed in terms of its relative and not absolute differences across the sampled accumulations.

As mentioned, the observed cortex of an accumulation is calculated from only those artifacts with available cortex data. To approximate the amount (surface) of cortex present in the entire accumulation, the calculated observed cortex amount is multiplied by the difference between the volume of the entire accumulation and the volume of this subset of artifacts with cortex data. The volume of an artifact was calculated as its mass multiplied by the general density of quartz solids (all microcrystalline or cryptocrystalline SiO_2 sedimentary rocks), which is 2.6 g/cm^3 (Berry & Mason, 1959, pp. 474–479). Because the quantity of (cortical) surface is estimated on the basis of (the difference in) the quantity of volume, it is necessary to convert allometric properties of the latter dimension into those of the former by raising the difference between the two volumes (of the accumulation and of the subset of artifacts with cortex data) with the power of 2/3. The observed cortex is then multiplied by this volume-to-surface conversion factor.

Below is the abridged procedure for calculating approximate observed cortex, as used in this study (Table 6-1):

1. Calculating cortical surface of all artifacts with an accumulation that have both cortex and metrical data
    a. For complete blanks and proximal fragments = length * width * (the midpoint of the cortex interval);
    b. For cores = $(4 * Pi * (((ab)^{1.6} + (ac)^{1.6} + (bc)^{1.6})/3)^{1/1.6})$ * (the midpoint of the cortex interval), where a = length/2, b = width/2, and c = thickness/2
2. Calculating the volume of an accumulation, as the sum of the volume of all individual artifacts (the volume of an artifact = mass * 2.6 g/cm^3).

3. Calculating the volume of the subset of artifacts with cortex data in the same accumulation, as the sum of the volume of all individual artifacts (the volume of an artifact = mass * 2.6 g/cm^3).
4. Calculating the volume-to-surface conversion factor (F): (the volume of the entire accumulation / the volume of the subset with cortex data)$^{2/3}$.
5. Calculating approximate observed cortex amount of the accumulation: (sum of cortical surfaces of the artifacts with cortex data in the accumulation) * F

Table 6 - 1: Summary data generated for calculating the approximate observed cortex amount per accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation	MIS	volume (cm^3) of the accumulation	volume (cm^3) of the subset with cortex data	volume-to-surface conversion factor (F)	observed cortex amount (cm^2) on the subset with cortex data	approximate observed cortex amount (cm^2) of the accumulation
1		5832.05	1755.67	2.22631	666.70	1484.28
2		5807.07	1637.37	2.32563	790.55	1838.52
3		5593.58	1662.58	2.24529	873.73	1961.77
4		5153.80	1556.88	2.22117	820.88	1823.31
5		5469.27	1505.03	2.36368	730.25	1726.08
6		5910.98	1432.70	2.57239	915.74	2355.64
7		4809.02	1076.13	2.71307	639.15	1734.06
8		5478.94	1643.20	2.23188	852.78	1903.30
9		5366.05	1383.50	2.46860	917.67	2265.36
10	5	5440.54	1353.74	2.52777	860.34	2174.74
11		6082.66	1988.20	2.10744	1031.82	2174.50
12		6245.95	1897.30	2.21297	993.65	2198.91
13		5798.98	1874.20	2.12336	968.50	2056.47
14		6164.23	1775.50	2.29283	962.97	2207.93
15		6851.85	2172.70	2.15050	1227.36	2639.43
16		6289.30	1808.95	2.29501	970.31	2226.87
17		7243.76	3050.10	1.78005	1339.40	2384.21
18		7107.63	2982.70	1.78406	1179.74	2104.73
19		8124.75	2915.30	1.98039	1406.07	2784.57
20	4	7195.47	2995.80	1.79348	1560.05	2797.93
21		7769.47	3892.00	1.58543	1708.42	2708.57

22		7525.03	3517.50	1.66029	1749.91	2905.35
23		6911.90	2722.30	1.86112	1597.18	2972.54
24		6624.47	2401.20	1.96705	1404.15	2762.03
25		6836.86	2564.90	1.92246	1514.39	2911.36
26		8673.05	3659.70	1.77753	1710.78	3040.97
27		10063.68	4893.80	1.61711	1980.15	3202.13
28		6765.86	3169.40	1.65792	1731.36	2870.46
29		6371.29	3087.90	1.62073	1648.73	2672.14
30		6537.52	3138.00	1.63120	1687.31	2752.34
31		6271.42	2764.60	1.72646	1536.99	2653.55
32		6322.58	2425.80	1.89391	1409.56	2669.58
33	3	6585.51	2529.20	1.89265	1457.63	2758.79
34		6320.29	1598.90	2.50002	895.47	2238.69
35		6458.58	2120.10	2.10146	1315.71	2764.91
36		6642.33	2108.40	2.14904	1183.91	2544.27
37		7656.23	2440.00	2.14330	1439.69	3085.69
38		7528.67	3306.50	1.73075	1836.05	3177.73

Derivation of estimated cortex

As indicated above, the estimated amount of cortex is the amount anticipated to be present in an accumulation if the accumulation represents a complete product of a process of cortical nodule reduction. To calculate this value, we need to estimate what was the cortical surface area of an average-sized nodule in the landscape, and how many nodules would a particular accumulation be indicative of. The cortical surface area of an average-sized nodule is estimated on the basis of the average length of cortical complete flakes found in the respective accumulation (Table 6-2).

Here, it is assumed that differences in nodule size are more likely to be reflected in differences in the size of cortical complete flakes than in the size of any of the non-cortical elements. The reason for this assumption is that the size of cortical flakes will be limited by nodule size, while the size of non-cortical blanks

taken off during the process of reduction will be restricted by the size of what is left of the nodule, that is, the size of a nodule that is already reduced (the core), especially if the nodule is fragmented into more than one core. Hence, as the reduction of a nodule proceeds, the size of non-cortical blanks will be more reflective of the size of the core at that stage of nodule reduction rather than the size of a non-reduced nodule. Moreover, it can hardly be assumed that during the reduction process the goal was to always detach blanks as long as possible given the size of a nodule or a core at hand. In fact, Dibble and McPherron (2006) have already reported on the possibility of deliberate production of blanks of smaller size in layer 6 of Pech IV (see also Bordes, 1975).

A related concern is that during the course of reduction of a single nodule the average size of produced (non-cortical) blanks were not necessarily uniform. This would be especially true if the reduction process of the same nodule was *recurrent* through time and space, meaning that one single nodule went through several spatially and/or temporally discontinuous practices of its reduction. All of this presumably makes the size of non-cortical items deposited at Pech IV, as well as at other places, a less reliable proxy of the differences in the size of flint nodules procured in the landscape (but see Braun, 2006; Douglass, 2010) .

The theoretical nodule size in an accumulation is calculated by raising the average length of cortical complete flakes (those with more than 10% of their dorsal surface covered in cortex) in the same accumulation to a power of 3, such that the *differences* in this length correspond proportionally to the *differences* in the volume. Consequently, this value of the theoretical nodule size itself is to be taken only as a

provisional. Due to the lack of background research on the geometric properties of stone raw materials, the (cor)relation between the average length of cortical complete flakes and the average volume of flint nodules that can be collected today in the area of Pech IV is not known in this study. Under such circumstances, an experiment helping to outline such a correlation would facilitate correction of the provisional value of the theoretical nodule volume. Since no such correction was applied, the theoretical nodule volume for each accumulation, as derived here, is, thus, most likely an underrepresented value of this volume than if it would be calculated by using more sophisticated and systematic method for estimating the theoretical nodule size. Such is the method outlined by Douglass (2010), who relied on experimental work by Braun (2006) which stimated the mass that was taken off during the course of a nodule reduction. However, the application of that method requires a particular set of measurements for cores of Pech IV, such as the frequency of scars, the average platform angle, etc., all of which were not obtained for this study.

The difference in the average length of cortical complete flakes is, hence, used as a proxy for the differences in the theoretical nodule volume. The provisional nodule volume was then used to calculate the surface area of the nodule through the equation for calculating surface area of a sphere with known volume. The use of the equation for the surface area of this particular solid is based on the experimental results of the application of the spherical model in calculating cortex as reported by Dibble and colleagues (2005). The survey of the raw material available in the area would make more accurate the estimation of the shape of the theoretical nodule.

More significantly, such a survey would also provide insights into the average proportion of the nodule surface that is actually covered in cortex and not decertified. Again, due to the lack of raw material research, this study takes the whole surface area of the theoretical nodule to be covered in cortex, which, in turn, potentially overestimates the derived estimated cortex amount in an accumulation.

To proceed, this estimated surface area of an average-size nodule is then multiplied by number of cores in an accumulation to get to the estimated total cortical area that should be present in the same accumulation. This approach follows that of Dibble and colleagues (2005), and Douglass and colleagues (2008), where the number of cores was used as an estimate for the original number of nodules. In this study, such relation is taken as the default one. Even though a single nodule at the end of its reduction can result in more than one core, such a scenario is something that would first need to be investigated more thoroughly, perhaps through a detailed examination of internal cohesiveness of the raw materials on all artifacts like, for example, in the minimum analytical nodule analysis by Larson and Finley (2004).

Finally, below is the abridged procedure for calculating estimated cortex in an accumulation, as used in this study (Table 6-2):

1. Calculating the average length of cortical complete flakes (L).
2. Calculating the provisional volume (V) of the average-sized nodule on the basis of the average length of cortical complete flakes converted into cm: $(L/10)^3$

3. Calculating the estimated surface area (A) of the average-sized nodule, using the equation for surface area of a sphere with known volume: $\pi^{1/3}(6V)^{2/3}$
4. Calculating the estimated cortex amount: A * (number of cores in an accumulation).

Table 6 - 2: Summary data generated for calculating the estimated cortex amount per accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation	MIS	N of cores	average length (L) (mm) of cortical complete flakes	provisional volume (V) (cm^3) of an average-sized nodule	estimated surface area (A) (cm^2) of an average-sized nodule	estimated cortex amount (cm^2)
1		27	38.24	55.918	70.70	1909.02
2		33	39.42	61.256	75.14	2554.60
3		34	40.61	66.973	79.74	2711.16
4		28	37.81	54.053	69.12	1935.45
5		73	38.64	57.691	72.19	5269.97
6		89	36.49	48.587	64.38	5794.30
7		59	36.77	49.714	65.37	4445.36
8		103	38.12	55.393	70.26	7236.92
9		82	37.97	54.721	69.69	5784.36
10	5	75	38.78	58.312	72.71	5453.09
11		89	39.48	61.536	75.36	6782.78
12		87	38.75	58.168	72.59	6605.50
13		77	39.76	62.845	76.43	6343.63
14		61	40.32	65.543	78.60	4873.29
15		86	41.44	71.164	83.03	7472.96
16		63	40.59	66.879	79.67	5417.25
17		68	43.22	80.728	90.32	6141.42
18		44	40.59	66.854	79.65	3504.42
19		40	41.67	72.355	83.96	3694.11
20		43	41.10	69.432	81.68	3512.24
21		35	43.95	84.911	93.41	3362.72
22		27	44.23	86.503	94.57	2553.46
23	4	31	42.73	78.008	88.27	2736.51
24		22	42.71	77.909	88.20	2028.61
25		23	42.69	77.811	88.13	2115.02
26		25	42.75	78.128	88.37	2209.14
27		30	39.91	63.545	77.00	2309.87

28		24	36.51	48.679	64.46	1611.56
29		42	37.05	50.867	66.38	2787.94
30		24	36.81	49.873	65.51	1572.28
31		34	36.62	49.108	64.84	2204.58
32	3	24	38.27	56.032	70.80	1770.01
33		34	37.90	54.457	69.47	2361.89
34		32	35.79	45.844	61.93	2291.58
35		32	36.02	46.722	62.72	2132.58
36		43	36.39	48.201	64.04	2753.69
37		58	37.42	52.402	67.71	3927.08
38		39	38.00	54.859	69.81	2722.54

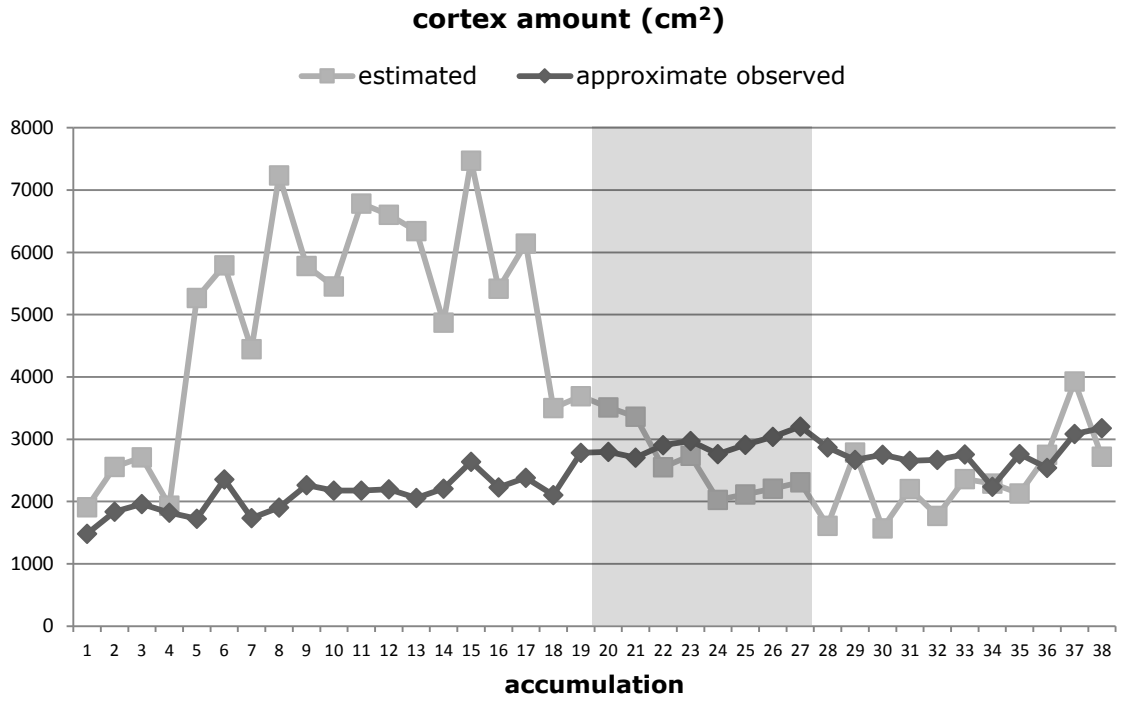

Figure 6 - 2: The amounts of approximate observed and estimated cortex per accumulation. The area shaded in light-grey represents accumulations from MIS 4; its boundaries are approximate.

6.2.2 The results

The differences between the approximate observed and the estimated cortex amount, as calculated here, are the greatest in the accumulations of MIS 5, or more

precisely, in those from the later period of this stage (most likely 5a [Goldberg et al., 2012; Sandgathe et al., 2011; Turq et al., 2011])(Figure 6-2). Here, the amount of estimated cortex greatly exceeds the amount of approximate observed. In the earlier sub-stage (most likely 5c), which is represented in this sequence by its lowest layer (Layer 8) (Dibble et al., 2009; Goldberg et al., 2012; Sandgathe et al., 2011; Turq et al., 2011) and sampled here with accumulations 1-4, this difference is smaller and it seemingly resembles such difference in the portion of the sequence that marks the transition from MIS 5 in to 4. The sequence of accumulations deposited during MIS 4 is presented in Figure 6-2, as well as in all other figures below, highlighted in light-grey. As mentioned before, it is not assumed that accumulations 19 and 20, and 27 and 28, represent clear transitions from one climatic stage into another. In any case, sometime during MIS 4, the relation between the two amounts of cortex changes, and from that point forward, in almost all sampled accumulations, the amount of approximate observed cortex exceeds the amount of estimated cortex (but with smaller difference between these two amounts than in pre-MIS 4 accumulations).

As already described, the theoretical (estimated) cortex amount for each accumulation is most likely either over- or underestimated. Nevertheless, since the estimated cortex amount, as well as the observed cortex amount, was calculated in the same way for all accumulations, the difference between these two cortex amounts in all of the accumulations should be subject to proportionally the same over- or underestimation. As such, these differences across the sampled accumulations can be investigated in relative terms. For this reason, the values of the two cortex amounts were first log transformed (since the distribution of the

estimated cortex values is not normal), and then these log-transformed values were converted (Table 6-3) into standardized z-scores relative to their respective distributions (the value of the approximate observed amount relative to the distribution of approximate observed cortex amounts throughout the entire sequence, and the value of the estimated amount relative to the distribution of estimated cortex amounts throughout the entire sequence). In this way it is possible to inspect in which accumulations from the Pech IV sequence, are the greatest discrepancies between the approximate observed and the estimated cortex.

Table 6 - 3: Summary data generated in transforming the approximate observed and the estimated cortex amounts, and converting these transformed values into standardized z scores, per accumulation. The boundaries of MIS 4 (light grey shading) are approximate.

accumulation	MIS	log(10) approximate observed cortex amount	z-score of log approximate observed cortex amount	log(10) estimated cortex amount	z-score of log estimated cortex amount
1		3.17	-2.61	3.28	-1.14
2		3.26	-1.44	3.41	-0.54
3		3.29	-1.09	3.43	-0.41
4		3.26	-1.49	3.29	-1.11
5		3.24	-1.79	3.72	0.96
6		3.37	-0.10	3.76	1.16
7		3.24	-1.76	3.65	0.61
8		3.28	-1.26	3.86	1.62
9		3.36	-0.31	3.76	1.15
10	5	3.34	-0.53	3.74	1.03
11		3.34	-0.53	3.83	1.48
12		3.34	-0.47	3.82	1.43
13		3.31	-0.84	3.80	1.34
14		3.34	-0.45	3.69	0.80
15		3.42	0.52	3.87	1.68
16		3.35	-0.40	3.73	1.02
17		3.38	-0.03	3.79	1.28
18		3.32	-0.71	3.54	0.12
19		3.44	0.81	3.57	0.23

20		3.45	0.84	3.55	0.12
21		3.43	0.66	3.53	0.03
22		3.46	1.04	3.41	-0.54
23	4	3.47	1.16	3.44	-0.39
24		3.44	0.77	3.31	-1.01
25		3.46	1.05	3.33	-0.93
26		3.48	1.29	3.34	-0.84
27		3.51	1.57	3.36	-0.74
28		3.46	0.97	3.21	-1.49
29		3.43	0.59	3.45	-0.36
30		3.44	0.75	3.20	-1.54
31		3.42	0.55	3.34	-0.84
32		3.43	0.58	3.25	-1.30
33	3	3.44	0.76	3.37	-0.70
34		3.35	-0.38	3.36	-0.76
35		3.44	0.77	3.33	-0.91
36		3.41	0.32	3.44	-0.38
37		3.49	1.37	3.59	0.35
38		3.50	1.53	3.43	-0.40
	average	3.38		3.52	
	sd	0.08		0.21	

As can be seen from Table 6-3 and in Figure 6-3, in almost all of the sampled accumulations, there is a discrepancy in the amount of approximate observed and the amount of estimated cortex, relative to the distributions of these two amounts throughout the sequence. The discrepancy in the z scores is here visible if the z score of one variable is positive, while of the other is negative. In an accumulation exhibiting z-scores that are both either positive or negative (their raw values don't have to be equal), the two cortex amounts are in the same direction from the mean cortex amount in their respective distributions. For example, the log approximate observed cortex and the log estimated cortex in the accumulation 18 are 3.32 and 3.54, respectively, making the standardized scores of these two values (according to

the means and standard deviations of their respective distributions) -0.71 and 0.12 (Table 6-3).

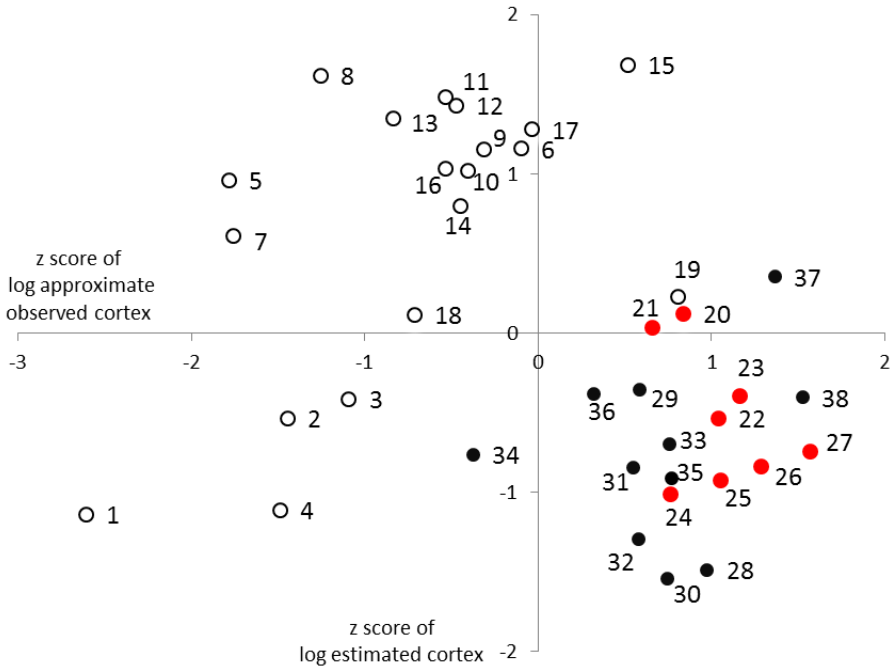

Figure 6 - 3: Z-scores of log approximate observed cortex and log estimated cortex. Points in red and black represent accumulations of MIS 4 and 3, respectively, while points in open circles are those of MIS 5 accumulations.

One of the interesting and clear observations coming from plotting these two values of z scores in Figure 6-3 is the opposite trend between the distributions of the (log) approximate observed cortex and the (log) estimated cortex across the Pech IV sequence (the pattern that can also be discerned in Figure 6-2). While in the majority of accumulations from the pre-MIS 4 part of the Pech IV sequence the amount of (log) approximate observed cortex is less than the mean of this measurement in the entire sequence, the majority of accumulations from MIS 4 and 3 exhibit values of (log) approximate observed cortex that are above this mean. The

opposite is true for the values of (log) estimated cortex. These findings produce two relatively distinct clusters on the plot of z-scores. One is comprised predominantly of accumulations of MIS 4 and 3, with negative z-scores of log estimated cortex amounts and positive z-scores of log approximate observed cortex amounts, while the other is made up of accumulations of MIS 5, with negative z-scores of log approximate observed cortex values and positive z-scores of log estimated cortex values. An equally interesting observation is that those z-scores of the two cortex amounts that correspond to each other, in that they both are either negative or positive, are coming from the same segment of the Pech IV sequence. Those are accumulations 1, 2, 3 and 4, all of which are coming from the same Layer (8).

Table 6 - 4: The cortex ratio per accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation	MIS	approximate observed cortex amount (cm^2)	estimated cortex amount (cm^2)	cortex ratio
1		1484.28	1909.02	0.78
2		1838.52	2554.60	0.72
3		1961.77	2711.16	0.72
4		1823.31	1935.45	0.94
5		1726.08	5269.97	0.33
6		2355.64	5794.30	0.41
7		1734.06	4445.36	0.39
8		1903.30	7236.92	0.26
9	5	2265.36	5784.36	0.39
10		2174.74	5453.09	0.40
11		2174.50	6782.78	0.32
12		2198.91	6605.50	0.33
13		2056.47	6343.63	0.32
14		2207.93	4873.29	0.45
15		2639.43	7472.96	0.35
16		2226.87	5417.25	0.41
17		2384.21	6141.42	0.39
18		2104.73	3504.42	0.60

19		2784.57	3694.11	0.75
20		2797.93	3512.24	0.80
21		2708.57	3362.72	0.81
22		2905.35	2553.46	1.14
23	4	2972.54	2736.51	1.09
24		2762.03	2028.61	1.36
25		2911.36	2115.02	1.38
26		3040.97	2209.14	1.38
27		3202.13	2309.87	1.39
28		2870.46	1611.56	1.78
29		2672.14	2787.94	0.96
30		2752.34	1572.28	1.75
31		2653.55	2204.58	1.20
32		2669.58	1770.01	1.51
33	3	2758.79	2361.89	1.17
34		2238.69	2291.58	0.98
35		2764.91	2132.58	1.30
36		2544.27	2753.69	0.92
37		3085.69	3927.08	0.79
38		3177.73	2722.54	1.17

By observing the cortex ratio across the accumulations in Table 6-4 and Figure 6-4, it can be seen that the differences between the approximate observed and the estimated cortex amounts make this ratio to be the smallest during the (later) accumulations of MIS 5, while the highest cortex ratios are documented in the later accumulations of MIS 4 and the earlier accumulations of MIS 3.

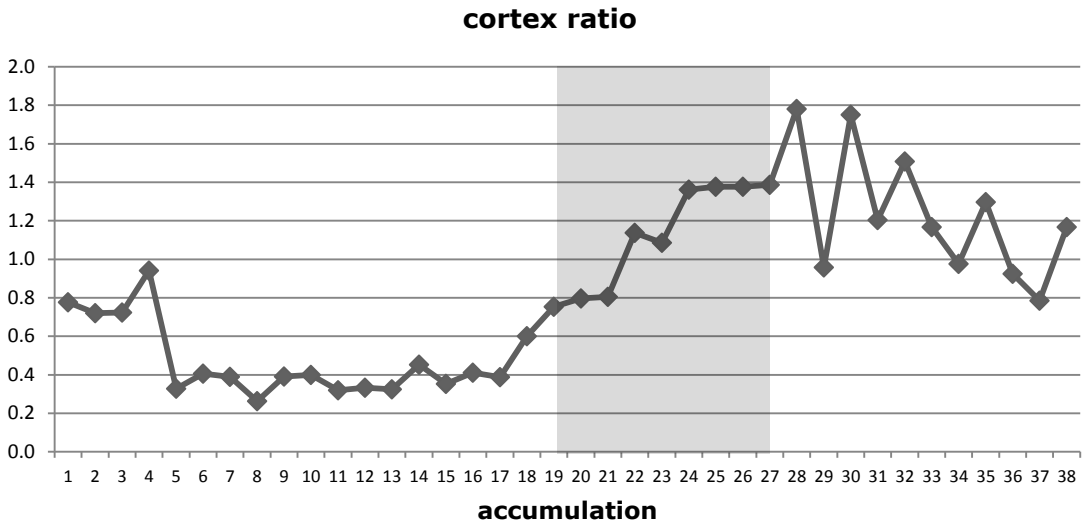

Figure 6 - 4: Cortex ratio values per accumulation. The area in light-grey represents accumulations from MIS 4, and its boundaries are approximate.

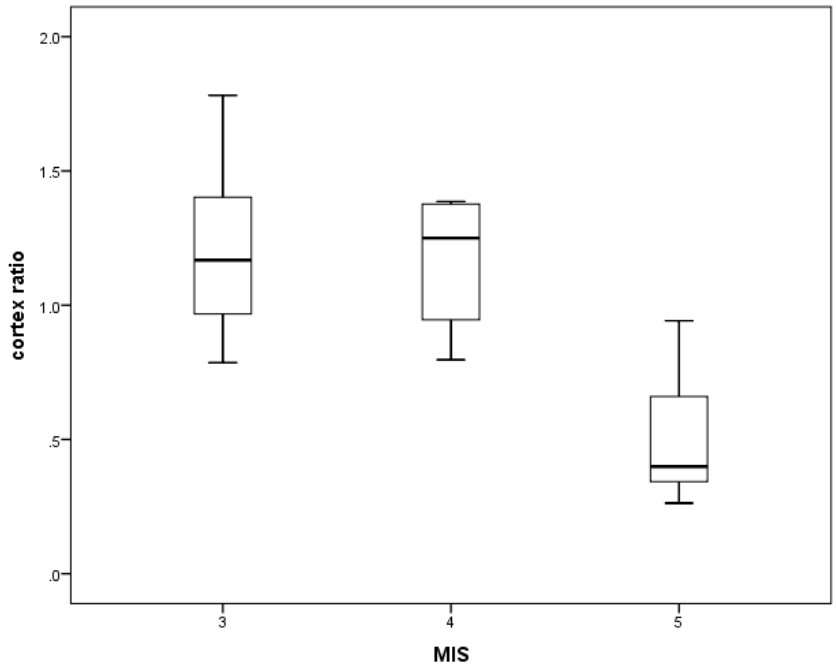

Figure 6 - 5: The distributions of cortex ratio values according to the three climatic stages.

To assess the variances in cortex ratio between these three groups (and, thus, the differences in the distributions of this measurement), and since the distributions of cortex ratio values in MIS 5 and MIS 4 are asymmetrical (Figure 6-5), a Kruskal-Wallis test is applied. Here, the three groups of cortex ratio observations can be regarded as three (statistical) populations of Pech IV approximately corresponding to three different climatic stages. According to the Kruskal-Wallis test, the cortex ratios differ significantly (with an alpha of .05) across the three groups (χ^2=26.561, df=2, p<.001; non-parametric Levene's test of homogeneity in variance [Nordstokke & Zumbo, 2010]) between the three groups, p>.05). At the same time, the differences in the cortex ratio distribution between MIS 4 and 3 is not different (χ^2=.027, df=1, p=.869). According to the estimation of the size of the effect, $\eta^2 = \chi^2/(n-1)$ (where n=38), 71.8% of the variability in the rank scores of cortex ratios throughout the sequence of Pech IV could be accounted for by the three climatic stages.

6.2.3 The interpretation of the results

While the above test shows that there is a difference in the cortex ratio, and, thus, movement, between the three groups of sampled accumulations, it does not offer an explanation of the practices of the movement process along the Pech IV sequence. Likewise is the case with Figure 6-3. Considering the history of the two cortex amounts in the place of Pech IV, it seems that the practices or intensity of movement that are in between two extremes can be detected mostly during the earliest times of the use of this place.

One of the reasons why the test above is not informative about the practices of movement during the each of the climatic stages is that the cortex ratio values, as derived in this study and as already discussed, are most likely either over- or underestimations. Another reason is that, due to the interrelation between cortex and volume, there are two possible explanations for the excess and the deficit of cortex in the record, as measured with the method of cortex ratio.

The excess of cortex can be the result of bringing the cortical elements in and/or of taking the volume (most likely cores) out, while the lack of cortex can be explained by selecting and taking cortical elements out and/or by bringing the volume (non-cortical elements) into the existing record (Dibble, Schurmans, et al., 2005; Douglass et al., 2008). All of this makes the cortex ratio values from this study to possibly reflect several different scenarios of movement activities during the accumulation of Pech IV record. If the theoretical (estimated) cortex amount is underestimated, meaning that all cortex ratio values should be lower, then the lowest cortex ratio values calculated in this study should indicate either larger cortex loss and/or larger amount of volume brought in than they do now. Similarly, higher cortex ratio values should indicate either smaller amount of added cortical elements and/or smaller amount of volume taken out of this place than they indicate now (the higher cortex ratio values would come closer to the value of 1). Conversely, if the theoretical (estimated) cortex amount is overestimated, meaning that all cortex ratio values should be higher, then the lower cortex ratios, as calculated here, should indicate either smaller cortex loss and/or smaller amounts of volume brought into Pech IV than they indicate now (the smaller cortex ratio

values would come closer to the value of 1), while higher cortex ratio values, as calculated here, should indicate either even larger amount of cortical items brought in and/or larger amount of volume taken out than they do now.

To potentially detect the nature of these movement practices, even when the cortex ratio values are derived on the basis of estimated cortex as in this study, it is necessary to closely examine the relationship between cortex and volume in sampled accumulations, both between and within different climatic stages.

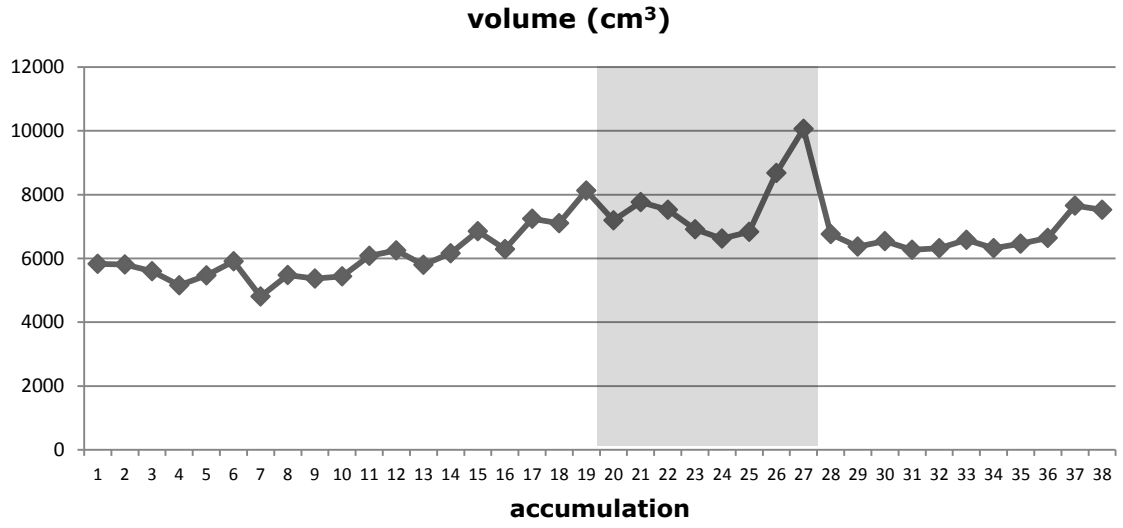

Figure 6 - 6: Volume per accumulation (from Table 6-1). The area in light-grey represents accumulations from MIS 4, and its boundaries are approximate.

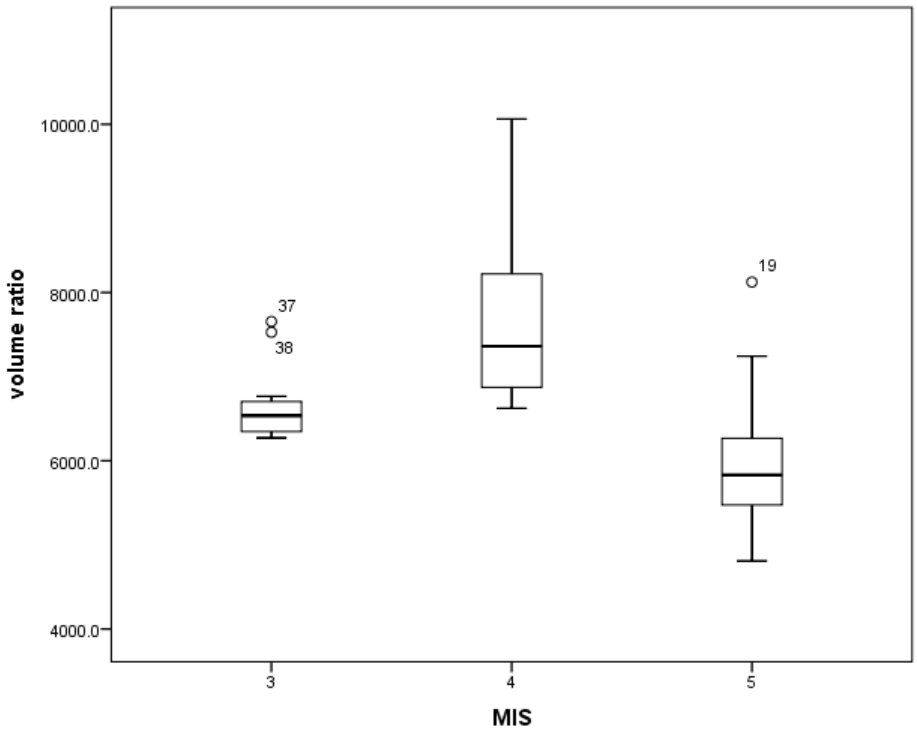

Figure 6 - 7: The distributions of volume according to the three climatic stages.

As seen in Figures 6-6 and 6-7, there is a general difference in volume of the sampled accumulations between different climatic stages (Kruskal-Wallis χ^2=16.400, df=2, p<.001; non-parametric Levene's test of homogeneity in variance, p>.05). The volume is also different between MIS 3 and 4 (χ^2=6.982, df=1, p=.008), and between MIS 3 and MIS 5 (χ^2=7.946, df=1, p=.005). But the more important question is whether a correlation (either positive or negative) between volume and cortex ratio can be detected. Such a correlation would mean that there were similar mechanisms behind the import or export of volume and cortex operating across the entire sequence, as well as within the respective stages.

Analysis of covariance (ANCOVA) (Figure 6-8) between the log-transformed values of these two variables (Table 6-5) confirms the difference in the cortex ratio

between the three stages (F=26.78, df=2, 34, p<.001; Levene's test of the equality in variances, p>.05; homogeneity of regression test, p=.635). It also shows that there is no correlation between this variable and volume within any of the stages. According to the effect size (η^2), 61.2 % of the variability in the cortex ratio across the sequence could be explained by the climatic stages, while only 0.5 % of this variability could be explained by volume. In other words, the knowledge of volume and the respective stage will not allow for a better prediction of the cortex ratio than the knowledge of the respective stage alone.

Table 6 - 5: Summary data generated by transforming the volume and the cortex ratio values per accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation	MIS	log(10) volume	log(10) cortex ratio
1		3.77	-0.11
2		3.76	-0.14
3		3.75	-0.14
4		3.71	-0.03
5		3.74	-0.48
6		3.77	-0.39
7		3.68	-0.41
8		3.74	-0.58
9		3.73	-0.41
10	5	3.74	-0.40
11		3.78	-0.49
12		3.80	-0.48
13		3.76	-0.49
14		3.79	-0.34
15		3.84	-0.45
16		3.80	-0.39
17		3.86	-0.41
18		3.85	-0.22
19		3.91	-0.12
20		3.86	-0.10
21	4	3.89	-0.09
22		3.88	0.06

23		3.84	0.04
24		3.82	0.13
25		3.83	0.14
26		3.94	0.14
27		4.00	0.14
28		3.83	0.25
29		3.80	-0.02
30		3.82	0.24
31		3.80	0.08
32		3.80	0.18
33	3	3.82	0.07
34		3.80	-0.01
35		3.81	0.11
36		3.82	-0.03
37		3.88	-0.10
38		3.88	0.07

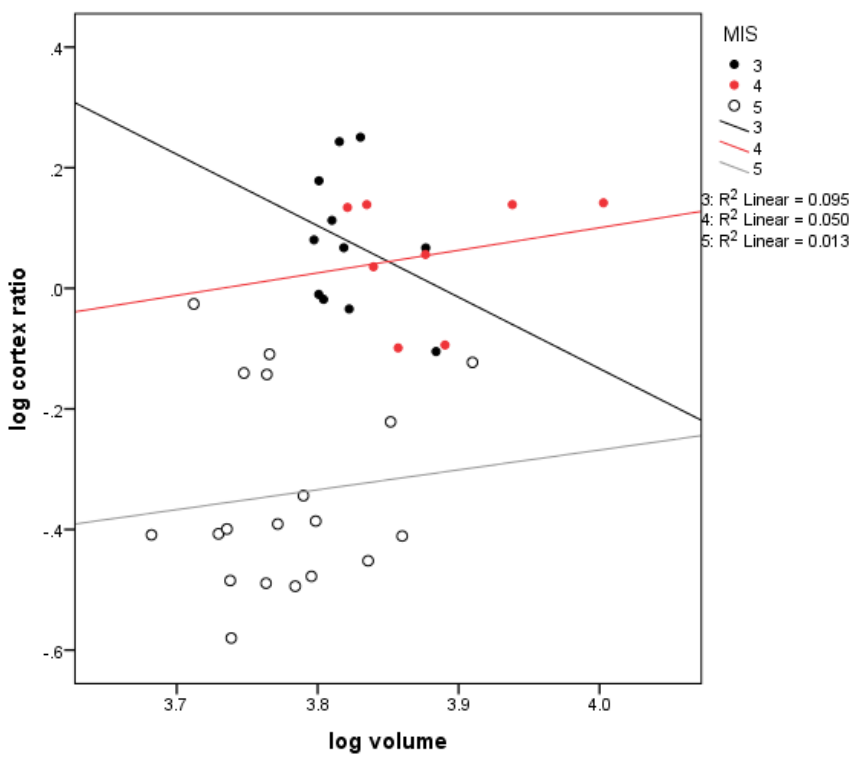

Figure 6 - 8: A scatterplot of log volume and log cortex ratio in the accumulations of their respective MIS.

What the results of ANCOVA indicate is that the relation between volume and cortex is not straightforward, and that there is variability in factors underlining this relationship within all three stages. To more closely examine this variability, which has direct implications for interpretation of the nature of movement across the sequence, it is important to look at differences in the quantity and the size of cores across the sampled accumulations, as well as the proportional difference between cortical and non-cortical flakes. Relative to other categories of stone artifacts, cores are elements with relatively higher volume to surface (potentially covered in cortex) ratio. The change in the size of a core will entail a proportionally greater increase in its volume than in its surface. Therefore, the volume in the stone artifact record will be more susceptible to the import or export of cores than of other categories of stone artifacts.

Table 6-6 and 6-7 and Figures 6-9, 6-10, 6-11, and 6-12 present summary core data and the ratio between non-cortical and cortical (with more than 10% of their dorsal surface covered in cortex) complete flakes, which will all be examined to gauge the relationship between volume and cortex.

Table 6 - 6: Summary data related to cores and blanks per accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation	MIS	N of cores	N of blanks [1]	blank-to-core	N of cores used for average core volume [2]	average core volume (cm^3) [3]
1	5	27	890	32.96	23	14.51
2		33	906	26.65	30	13.13
3		34	871	25.62	34	11.95
4		28	878	31.36	26	12.13
5		73	921	12.62	62	8.70
6		89	983	10.92	72	8.98

7		59	937	13.78	49	7.41
8		103	905	8.79	75	10.12
9		82	913	11.00	68	8.08
10		75	935	12.47	52	9.35
11		89	930	10.33	79	9.13
12		87	927	10.19	74	10.87
13		77	910	10.96	60	8.81
14		61	955	15.40	48	9.47
15		86	898	9.98	76	12.87
16		63	937	13.78	52	10.63
17		68	919	13.51	60	13.17
18		44	900	20.45	34	17.48
19		40	989	22.48	40	21.58
20		43	947	22.02	41	16.23
21		35	959	26.64	35	24.79
22		27	1000	37.04	25	23.58
23	4	31	998	32.19	29	16.28
24		22	980	42.61	22	18.77
25		23	973	40.54	23	18.71
26		25	973	38.92	25	25.58
27		30	968	32.27	27	39.34
28		24	1008	40.32	23	20.13
29		42	999	23.79	40	13.62
30		24	1011	42.13	24	21.46
31		34	1021	30.03	31	18.62
32		24	1009	40.36	23	14.55
33	3	34	998	29.35	32	20.05
34		32	1029	27.81	29	22.41
35		32	994	29.24	30	20.43
36		43	981	22.81	42	18.83
37		58	976	16.83	56	24.07
38		39	991	25.41	35	26.92

[1] Non-retouched and retouched complete and proximal pieces.
[2] Those with recorded mass (which is used to calculate volume)
[3] Calculated as core mass divided by the density of quartz solids of 2.6 g/cm^3
.

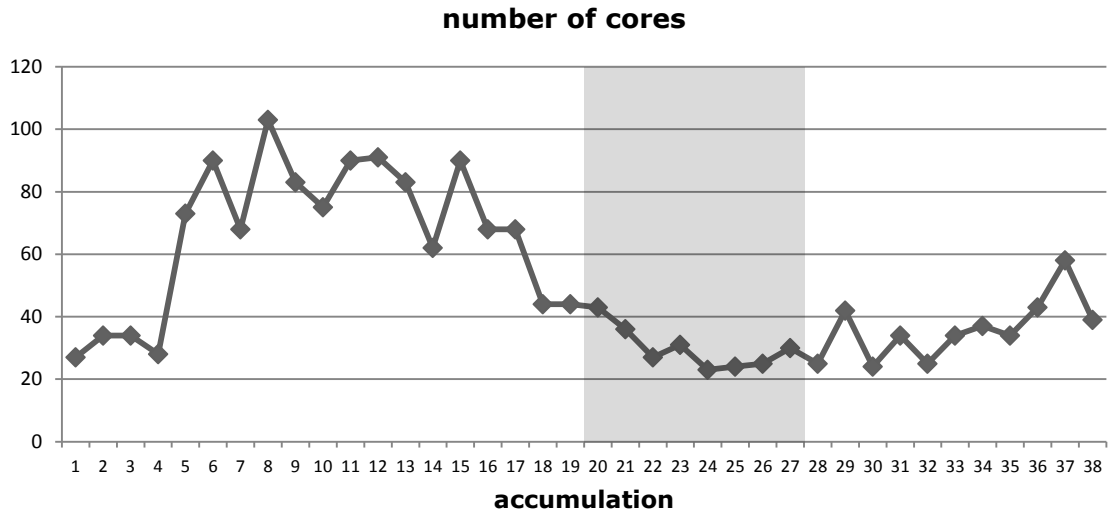

Figure 6 - 9: The number of cores per accumulation. The area in light-grey represents accumulations from MIS 4, and its boundaries are approximate.

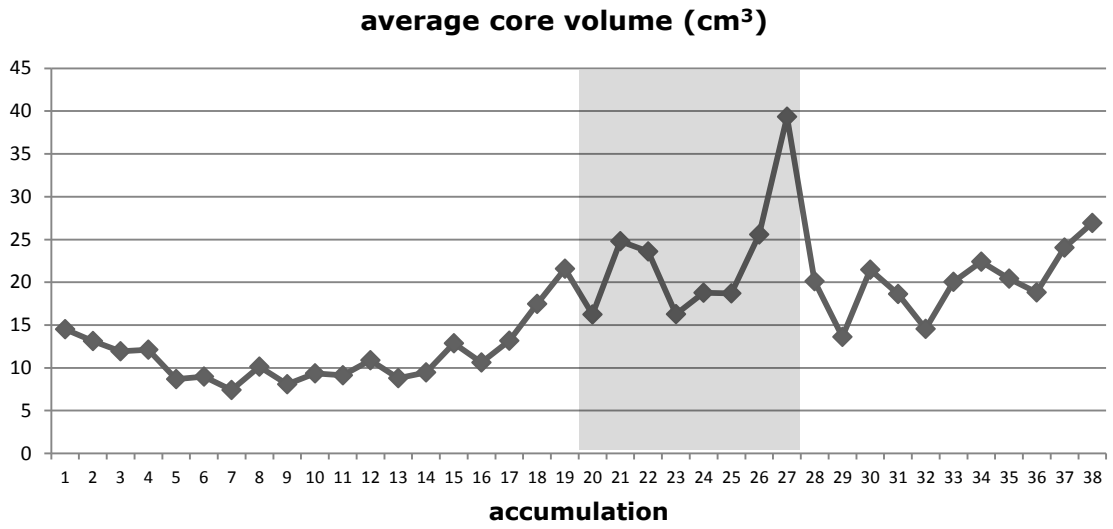

Figure 6 - 10: Average core volume per accumulation. The area in light-grey represents accumulations from MIS 4, and its boundaries are approximate. When testing the average core volume, there was no partitioning the record of a single stage according to sampled accumulations, but all cores (with the available mass data that is necessary to calculate their volume) of a respective stage were sampled into one group representing this stage.

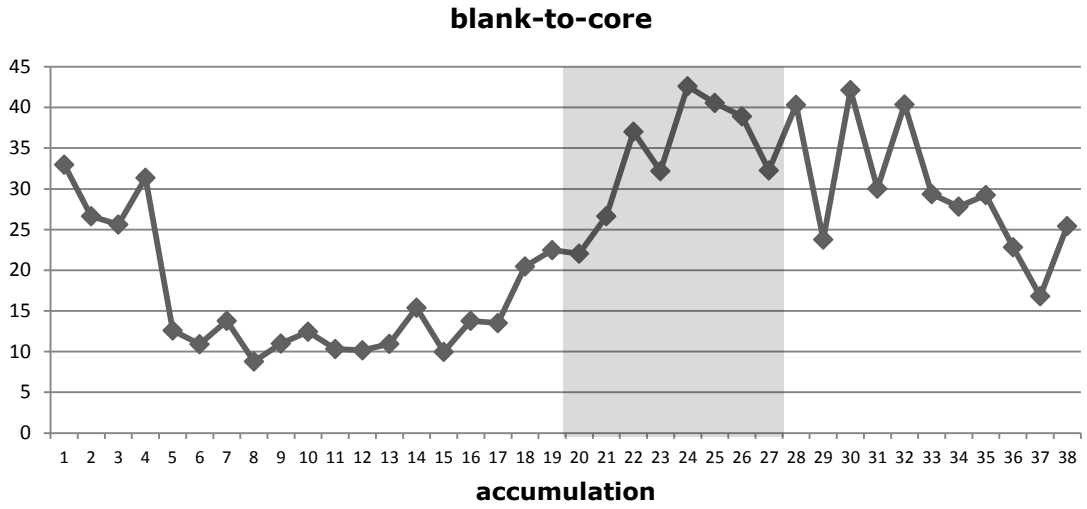

Figure 6 - 11: Blank-to-core per accumulation. The area in light-grey represents accumulations from MIS 4, and its boundaries are approximate.

Table 6 - 7: Summary data related to the quantity of cortical and non-cortical complete flakes. The boundaries of MIS 4 (light grey) are approximate.

accumulation	MIS	N of cortical complete flakes	N of non-cortical complete flakes
1		192	330
2		197	330
3		176	319
4		181	272
5		181	299
6		198	240
7		169	195
8		178	296
9		170	241
10	5	162	208
11		225	273
12		194	208
13		200	277
14		189	251
15		213	260
16		213	280
17		235	331
18		230	314
19		255	331

20		308	349
21		303	383
22		310	381
23	4	300	369
24		281	318
25		294	340
26		286	345
27		305	358
28		384	378
29		376	391
30		403	366
31		378	371
32		322	329
33	3	353	334
34		287	188
35		382	269
36		374	274
37		390	285
38		435	338

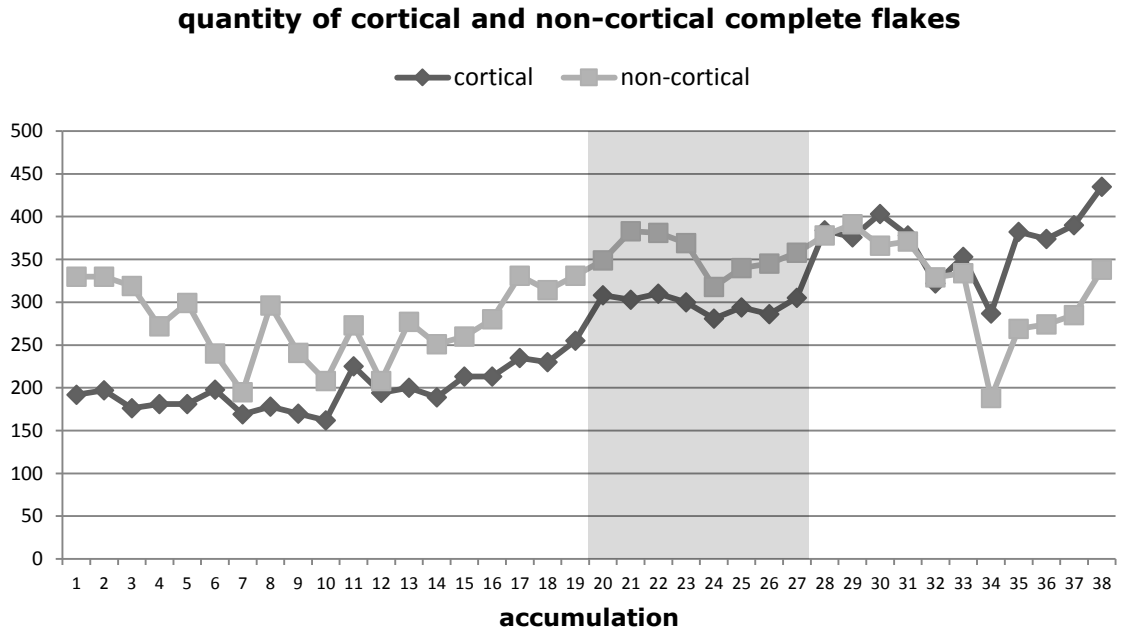

Figure 6 - 12: Quantities of non-cortical and cortical complete flakes per accumulation. The area in light-grey represents accumulations from MIS 4, and its boundaries are approximate.

Finally, the last set of data and calculations in this section are presented below for the purpose of investigating variability in movement practices within the climatic stages. Tables 6-8, 6-9, 6-10, and 6-11, and Figures 6-13 and 6-14, display the cortex ratio and transformation of this measure in the stone artifact record of each respective climatic stage, as this record accumulated through time. Tables 6-8, 6-9, and 6-10 present calculations of the approximate observed cortex amount, estimated cortex amount, and cortex ratio, respectively, per sequence made of sampled accumulations. These sequences are built up progressively each time by adding each subsequent accumulation to the (sequence of) accumulations that are stratigraphically below this respective accumulation. In other words, each sequence of accumulations (first column in the Tables below) represents the addition of one more sampled accumulation to the stone artifact record of the same climatic stage already accumulated at Pech IV by that time. At approximately the end of each climatic stage, this process of adding sampled accumulations to the record below is terminated, in order to begin with a new one from the beginning of the new stage.

Table 6 - 8: Summary data generated for calculating the approximate observed cortex amount per sequence of accumulations. The boundaries of MIS 4 (light grey) are approximate.

accumulation sequence	MIS	accumulation sequence volume (cm^3)	volume (cm^3) of the subset with cortex data	volume-to-surface conversion factor (F)	observed cortex amount (cm^2) on the subset with cortex data	approximate observed cortex amount (cm^2) of the accumulation sequence
1		5832.05	1755.67	2.22631	666.70	1484.28
1-2		11639.12	3393.04	2.27451	1457.25	3314.53
1-3	5	17232.70	5055.62	2.26492	2330.98	5279.48
1-4		22386.50	6612.50	2.25466	3151.86	7106.36
1-5		27855.77	8117.53	2.27507	3882.11	8832.06

1-6		33766.75	9550.23	2.32087	4797.85	11135.17
1-7		38575.77	10626.36	2.36204	5437.00	12842.40
1-8		44054.71	12269.56	2.34482	6289.78	14748.38
1-9		49420.76	13653.06	2.35751	7207.45	16991.61
1-10		54861.30	15006.80	2.37311	8067.79	19145.79
1-11		60943.96	16995.00	2.34282	9099.61	21318.78
1-12		67189.91	18892.30	2.32995	10093.26	23516.77
1-13		72988.89	20766.50	2.31169	11061.76	25571.32
1-14		79153.12	22542.00	2.31020	12024.73	27779.58
1-15		86004.97	24714.70	2.29639	13252.09	30431.95
1-16		92294.27	26523.65	2.29629	14222.40	32658.82
1-17		99538.03	29573.75	2.24589	15561.80	34950.09
1-18		106645.66	32556.45	2.20565	16741.54	36926.05
1-19		114770.41	35471.75	2.18758	18147.61	39699.43
20		7195.47	2995.80	1.79348	1560.05	2797.93
20-21		14964.94	6887.80	1.67750	3268.47	5482.86
20-22		22489.97	10405.30	1.67169	5018.38	8389.18
20-23	4	29401.87	13127.60	1.71183	6615.56	11324.69
20-24		36026.34	15528.80	1.75249	8019.71	14054.44
20-25		42863.20	18093.70	1.77707	9534.10	16942.77
20-26		51536.25	21753.40	1.77715	11244.88	19983.82
20-27		61599.93	26647.20	1.74831	13225.03	23121.49
28		6765.86	3169.40	1.65792	1731.36	2870.46
28-29		13137.15	6257.30	1.63962	3380.09	5542.06
28-30		19674.67	9395.30	1.63681	5067.40	8294.36
28-31		25946.09	12159.90	1.65740	6604.39	10946.13
28-32		32268.67	14585.70	1.69786	8013.95	13606.59
28-33	3	38854.18	17114.90	1.72733	9471.58	16360.55
28-34		45174.47	18713.80	1.79951	10367.05	18655.60
28-35		51633.05	20833.90	1.83135	11682.76	21395.23
28-36		58275.38	22942.30	1.86165	12866.67	23953.28
28-37		65931.61	25382.30	1.88962	14306.36	27033.63
28-38		73460.28	28688.80	1.87166	16142.41	30213.09

Table 6 - 9: Summary data generated for calculating the estimated cortex amount per sequence of accumulations. The boundaries of MIS 4 (light grey) are approximate.

accumulation sequence	MIS	N of cores	average length (L) (mm) of cortical complete flakes	provisional volume (V) (cm^3) of an average-sized nodule	estimated surface area (A) (cm^2) of an average-sized nodule	estimated cortex amount (cm^2)
1		27	38.24	55.92	70.70	1909.02
1-2		61	38.86	58.66	73.00	4452.81
1-3		95	39.41	61.20	75.09	7133.15
1-4		123	39.01	59.34	73.56	9048.08
1-5		196	38.94	59.03	73.31	14367.85
1-6		286	38.52	57.15	71.74	20517.61
1-7		354	38.28	56.08	70.84	25077.82
1-8		457	38.26	55.99	70.77	32340.65
1-9		540	38.23	55.85	70.65	38150.43
1-10	5	615	38.28	56.09	70.84	43569.67
1-11		705	38.42	56.71	71.37	50316.98
1-12		796	38.45	56.84	71.48	56894.63
1-13		879	38.57	57.36	71.92	63213.35
1-14		941	38.70	57.94	72.40	68129.07
1-15		1031	38.91	58.89	73.19	75457.52
1-16		1099	39.02	59.42	73.63	80918.85
1-17		1167	39.31	60.74	74.72	87194.21
1-18		1211	39.39	61.10	75.01	90836.56
1-19		1255	39.54	61.82	75.60	94874.55
20		43	41.10	69.43	81.68	3512.24
20-21		79	42.55	77.03	87.53	6915.06
20-22		106	43.14	80.29	89.99	9538.87
20-23	4	137	43.04	79.70	89.55	12268.03
20-24		160	42.97	79.34	89.28	14284.38
20-25		184	42.93	79.10	89.09	16393.41
20-26		209	42.91	78.98	89.01	18602.56
20-27		239	42.55	77.06	87.56	20926.15
28		25	36.51	48.68	64.46	1611.56
28-29		67	36.78	49.76	65.41	4382.61
28-30		91	36.79	49.80	65.45	5955.73
28-31		125	36.75	49.63	65.29	8161.84
28-32	3	150	37.02	50.71	66.25	9937.05
28-33		184	37.16	51.32	66.77	12285.80
28-34		221	37.00	50.65	66.19	14628.72
28-35		255	36.87	50.11	65.72	16758.17
28-36		298	36.81	49.89	65.53	19526.72

28-37	356	36.88	50.15	65.75	23408.41
28-38	395	37.00	50.64	66.19	26143.53

Table 6 - 10: The cortex ratio per sequence of accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation sequence	MIS	approximate observed cortex amount (cm^2)	estimated cortex amount (cm^2)	cortex ratio
1		1484.28	1909.02	0.78
1-2		3314.53	4452.81	0.74
1-3		5279.48	7133.15	0.74
1-4		7106.36	9048.08	0.79
1-5		8832.06	14367.85	0.61
1-6		11135.17	20517.61	0.54
1-7		12842.40	25077.82	0.51
1-8		14748.38	32340.65	0.46
1-9		16991.61	38150.43	0.45
1-10	5	19145.79	43569.67	0.44
1-11		21318.78	50316.98	0.42
1-12		23516.77	56894.63	0.41
1-13		25571.32	63213.35	0.40
1-14		27779.58	68129.07	0.41
1-15		30431.95	75457.52	0.40
1-16		32658.82	80918.85	0.40
1-17		34950.09	87194.21	0.40
1-18		36926.05	90836.56	0.41
1-19		39699.43	94874.55	0.42
20		2797.93	3512.24	0.80
20-21		5482.86	6915.06	0.79
20-22		8389.18	9538.87	0.88
20-23	4	11324.69	12268.03	0.92
20-24		14054.44	14284.38	0.98
20-25		16942.77	16393.41	1.03
20-26		19983.82	18602.56	1.07
20-27		23121.49	20926.15	1.10
28		2870.46	1611.56	1.78
28-29		5542.06	4382.61	1.26
28-30	3	8294.36	5955.73	1.39
28-31		10946.13	8161.84	1.34
28-32		13606.59	9937.05	1.37

28-33	16360.55	12285.80	1.33
28-34	18655.60	14628.72	1.28
28-35	21395.23	16758.17	1.28
28-36	23953.28	19526.72	1.23
28-37	27033.63	23408.41	1.15
28-38	30213.09	26143.53	1.16

Lastly, Table 6-11 below compares the cortex ratio of a single accumulation (the fifth column in this Table) with the cortex ratio of the respective sequence of accumulations that appears stratigraphically below (the third column in this Table), but in terms of the relative difference between these two cortex ratios (the last column in this Table). For example, cortex ratio of the accumulation 4 is 0.94, while this ratio of the already existing record (the sequence of accumulations 1-3) is 0.74. Thus, the cortex ratio of the accumulation 4 is higher than the cortex ratio of the sequence 1-3 by 27.28 %. These differences are examined in their relative form for the purpose of their proportional comparability. What this will allow is to tracing of variability and intensity of the transformation of the Pech IV stone artifact record (in this case, the cortex ratio in this record), as this record accumulated during the history of the use of this place.

Table 6 - 11: Transformation of cortex ratio in the record of Pech IV throughout its accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation sequence	MIS	cortex ratio	accumulation	cortex ratio	difference (%) in cortex ratio relative to the accumulation sequence below
1		0.78	**2**	0.72	-7.44
1-2		0.74	**3**	0.72	-2.79
1-3		0.74	**4**	0.94	27.28
1-4		0.79	**5**	0.33	-58.30
1-5		0.61	**6**	0.41	-33.86
1-6		0.54	**7**	0.39	-28.12
1-7		0.51	**8**	0.26	-48.64
1-8		0.46	**9**	0.39	-14.12
1-9		0.45	**10**	0.40	-10.46
1-10	5	0.44	**11**	0.32	-27.04
1-11		0.42	**12**	0.33	-21.43
1-12		0.41	**13**	0.32	-21.57
1-13		0.40	**14**	0.45	12.00
1-14		0.41	**15**	0.35	-13.38
1-15		0.40	**16**	0.41	1.93
1-16		0.40	**17**	0.39	-3.81
1-17		0.40	**18**	0.60	49.84
1-18		0.41	**19**	0.75	85.43
1-19		0.42	**-**	-	-
20		0.80	**21**	0.81	1.11
20-21		0.79	**22**	1.14	43.50
20-22		0.88	**23**	1.09	23.51
20-23	4	0.92	**24**	1.36	47.50
20-24		0.98	**25**	1.38	39.90
20-25		1.03	**26**	1.38	33.19
20-26		1.07	**27**	1.39	29.05
20-27		1.10	**-**	-	-
28		1.78	**29**	0.96	-46.19
28-29		1.26	**30**	1.75	38.43
28-30	3	1.39	**31**	1.20	-13.57
28-31		1.34	**32**	1.51	12.46
28-32		1.37	**33**	1.17	-14.70
28-33		1.33	**34**	0.98	-26.64

28-34	1.28	**35**	1.30	1.67
28-35	1.28	**36**	0.92	-27.63
28-36	1.23	**37**	0.79	-35.95
28-37	1.15	**38**	1.17	1.07
28-38	1.16	-	-	-

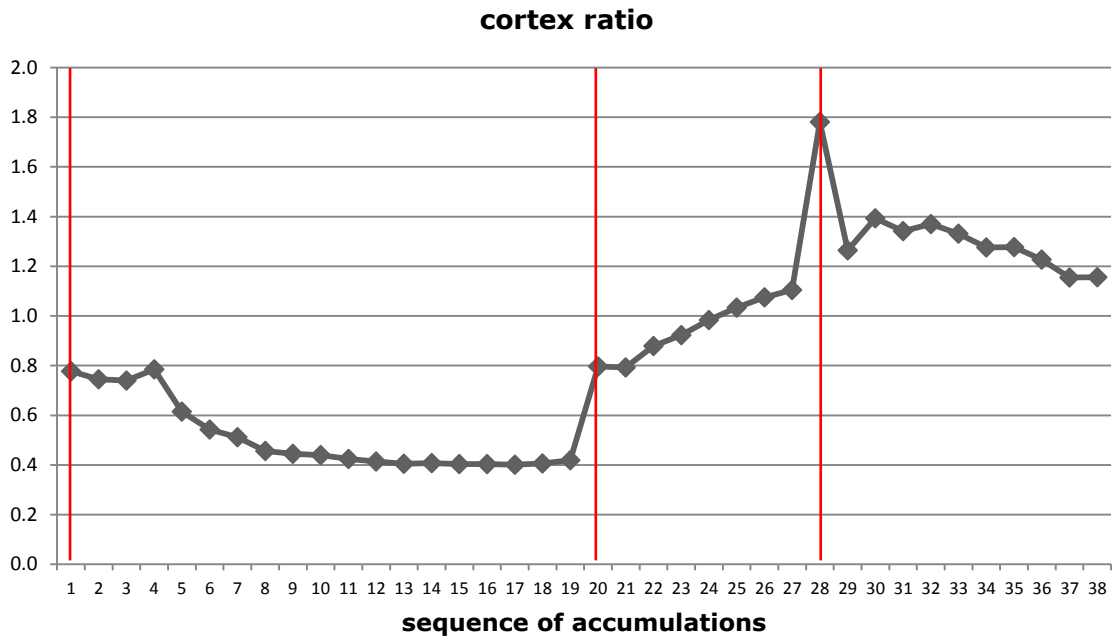

Figure 6 - 13: Cortex ratio per sequence of accumulations (third column in Table 6-11). Red vertical lines represent the beginning of a new sequencing process (placed approximately at the start of a new climatic stage). Numbers on the horizontal axis denote the extent of the sequence of accumulations, e.g., the cortex ratio at number '24' is the ratio of the sequence of accumulations 20-24.

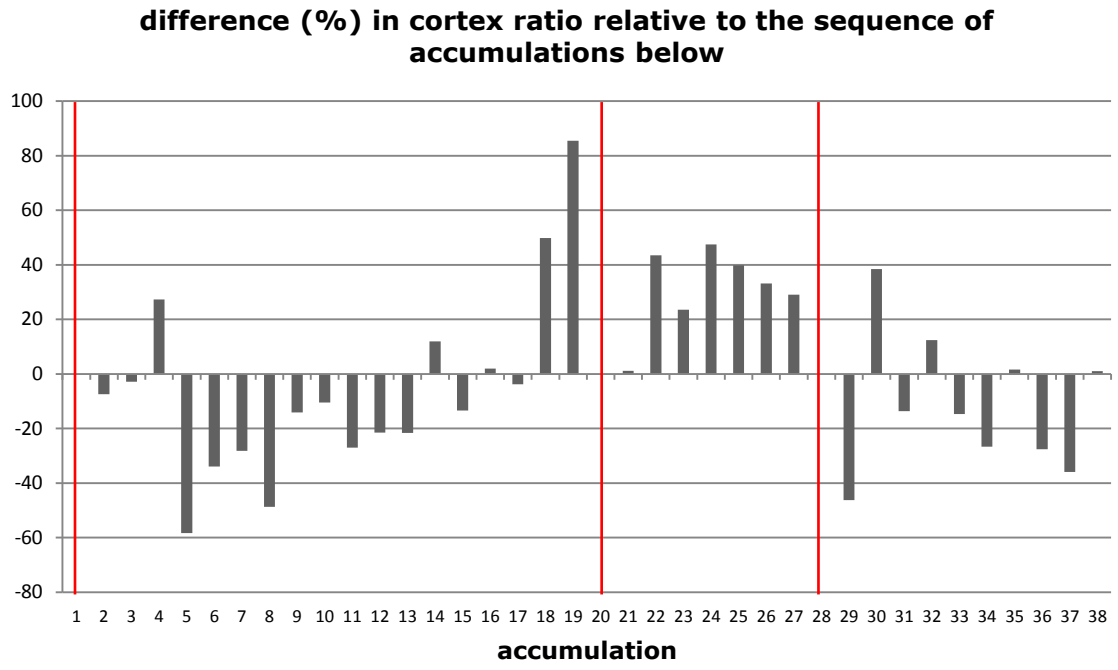

Figure 6 - 14: The relative change in the cortex ratio between each accumulation and the sequence of accumulations occurring below it (last column in Table 6-11). For example, the cortex ratio of the accumulation 8 is lower than the cortex ratio in the existing sequence below by 48.74%. Red vertical lines represent the beginning of a new sequencing process (placed approximately at the start of a new climatic stage).

Perhaps it is the best to start the general assessment of different movement practices during the history of use of Pech IV by comparing the stages that are the most similar in all variables examined so far, these being MIS 4 and MIS 3. These two stages are not significantly different in both the general cortex ratio (Figure 6-5) and general blank-to-core ratio (Figure 6-11) (Kruskal-Wallis, $\chi 2=1.336$, $p =.248$). These two stages are also similar in the general volume of their cores (Figure 6-7) (Kruskal-Wallis, $\chi^2=3.19$, $p=.074$). The only variable in which the sampled accumulations between these two stages differ is their volume, with the sampled accumulations in MIS 3 exhibiting a lower volume than those in MIS 4 (Figure 6-7).

When outlining the possible scenarios for the higher cortex ratios, as recorded in these two stages, it was mentioned that these ratios can be the result of bringing the elements with higher proportion of cortical surface to volume in and/or taking the elements with higher proportion of volume to cortical surface out of the record. Conceivably, there is no reason to limit the explanation of higher cortex ratio (or any cortex ratio) to only one of the two scenarios. In line with this, the higher cortex ratios of MIS 4 and MIS 3 here are taken to denote both the import of cortex and the export of volume, but with the variability along the continuum between these two ends, rather than categorically adhering only to one of those two scenarios. Conversely, low cortex ratios will be perceived here as denoting both the export of cortex and the import of volume, with gradational variability along this continuum.

In accordance with the interpretation of high cortex ratios as outlined above, due to high cortex ratios in these two stages (Figure 6-4) it is proposed here that the general similarity between the movement practices of MIS 3 and of MIS 4 can be seen in the higher intensity of cortex import relative to the import of volume. However, since in MIS 3 there is a general drop in volume relative to MIS 4, this suggests that the general difference between these practices is that the import of volume (in the form of nodules and/or cores) into the place was less intensive during MIS 3 than during MIS 4, *relative to* the respective import of cortex (cortical flakes) during these two stages. At the same time, this was most likely coupled with a higher export of volume in the form of non-cortical flakes during MIS 3, particularly during the later part of the MIS 3 stone artifact record (accumulations

34-38) when, for the first time in the history of the use of this place, the amount of cortical flakes exceeds the amount of non-cortical flakes (Figure 6-12). In the next section of this chapter, the differences in the core reduction intensity will be factored into this cortex-volume continuum.

What we can see from the relative differences in cortex ratio between single accumulations and the record below them (Figure 6-14), is that within MIS 3, the directionality of change along the continuum between cortex and volume switches for the most part of accumulation of the MIS 3 record. What this means is that there is a high variability in movement practices. When accumulation 29 is added to accumulation 28, the cortex ratio in that record is transformed: it drops from 1.78 to 1.26 (Table 6-10, Figure 6-13). However, with the deposition of artifacts that are sampled with accumulation 30, the cortex ratio of this record (now comprised of the sequence of accumulations 28-30) rises to 1.39. It is transformed again, but in the opposite direction along the cortex-volume continuum. Such a switch in the directionality of change in the relationship between cortex and volume continues until accumulation 33 becomes part of the MIS 3 record at this place. After that, the directionality of the change stays the same (with the differences in cortex ratio between accumulations 35 and 38 and the record below those accumulations, respectively, being less than 2%). This makes the variability in movement practices in the later part of the MIS 3 record lower than compared to such variability in the earlier part of this record.

More precisely, towards the very end of the use of this place, the cortex ratio in this record is continuously transformed in the same direction - towards its

decrease (Figure 6-13), even though, as discussed in the paragraph above, the quantity of cortical flakes exceeds the quantity of non-cortical flakes (Figure 6-12). The reason for this trend of decreasing cortex ratio at the end of the use of this place can most probably be sought in the increase in core size and in their number in the later part of the MIS 3 record, which can be observed in Figures 6-9 and 6-10, *relative to* the earlier part of the record of this stage. This higher import of cores (together with the export of non-cortical blanks) in turn also explains the overall decrease in blank-to-core ratio (Figure 6-11) towards the last accumulation of this stage.

How should this 'general' practice of greater import of cortex than volume along the cortex-volume continuum during the last stage of the use of this place be understood? Here, such practice is not interpreted as a time-averaged behavior during the time of accumulation of the record represented by the sequence of accumulations 28-38. This contrasts to the recently intensified vogue of interpreting the stone artifact record through the application of the concept of time-averaging (see Chapter 3) (e.g. Barton & Riel-Salvatore, 2014). The 'general' movement practice of any period or extent of record accumulation (either of the entire place, or a climatic stage, or a sampled accumulation) perhaps can here be interpreted as a re-transcribed 'identity' (Olivier, 2011) of that record at the final moment in the process of its deposition.

Due to a high cortex ratios (Figure 6-4) in MIS 4, the general movement practice in this stage also involved higher intensity of cortex import relative to the import of volume. Yet, compared to MIS 3, this import of volume seems to be greater

(Figure 6-7). This was most likely accompanied by less intense export of the volume in the form of non-cortical flakes, compared to such export during MIS 3 (Figure 6-12).

The directionality of the MIS 4 record transformation in terms of cortex ratio is clear: this ratio is rising throughout this stage (Figure 6-13). Differences in the cortex ratio between each accumulation and the already deposited MIS 4 record (Figure 6-14) yield two interesting observations. First, related to the pattern of rising cortex ratio, is that each subsequent accumulation represents an increase in cortex relative to volume, compared to the already existing record of this stage. If these transformations of the MIS 4 record are compared to the ones during MIS 3 (especially with the difference in cortex ratio between accumulations 29, 30, 31, 32, and 33, and the respective record into which these accumulations were deposited), during MIS 4 the variability in the nature of movement practices (that is, in the directionality of change along the cortex-volume continuum) was nonexistent. This observation means that the same practice of movement can be traced throughout the sampled accumulations of this stage.

The second observation, however, is that the average difference between each MIS 4 accumulations and the record of this stage into which they were incorporated at some point in the past is higher than such difference for MIS 3 accumulations. By adding absolute values of those percentages (for example, 35.95 instead of -35.95 for the accumulation 37) for accumulations of a single stage, and then dividing this sum by the number of those accumulations, this average for MIS 4 is about 31%, while for MIS 3 is about 22%. What this indicates is that the intensity

of the stone artifact record (of the cortex ratio) transformation at Pech IV was higher during MIS 4 times than after his stage.

To summarize, between MIS 4 and 3, there seems to be an opposite pattern between the variability of movement practices and the degree of their intensification. While during MIS 4 the nature of movement practice did not change, during the time of accumulation of that record this same movement practice was intensified: with each sampled accumulation there was an increase in cortex, that is, more and more cortex was brought in (relative to the import of volume). After this stage, there was more variability in the movement practice (observed especially in the earlier part of the MIS 3 record): with each sampled accumulation there was either an increase or a decrease in the exact amount of cortex import (relative to the import of volume).

Taken together, all measurements reported in this section of this chapter generally indicate different movement practices when compared to pre-MIS 4 times. Here, it will be proposed that the low cortex ratios during MIS 5 indicate a general practice of importing larger quantity of (non-cortical) cores (Figure 6-9) into the place than exporting cortex (cortical flakes) out of that record. At the same time this practice does not considerably inflate the overall volume of the record during this stage (Figure 6-10) because the cores of MIS 5 are of significantly smaller size (Figure 6-7) (Kruskal-Wallis between all three climatic stages, $\chi^2=261.142$, $p<.001$) (see also Dibble & McPherron, 2006). The larger quantity of cores also makes the blank-to-core ratio during MIS 5 significantly lower compared to the later two

stages (Figure 6-11) (Kruskal-Wallis between all three climatic stages, χ^2=18.441, p<.001).

Nevertheless, towards the end of this stage, the variability in movement practices increased (Figure 6-14). The average difference between accumulations of this stage and the record of this stage into which they were incorporated is about 26%, which places the average degree of intensification of movement practices during MIS 5 somewhat in between the two subsequent climatic stages. In Figures 6-13 and 6-14 one can observe that, after accumulation 4, the differences between each accumulation and the respective sequence of accumulations below are progressively decreasing, causing the cortex ratio in the record to stay relatively the same until the last accumulation of this stage. Even though the last two accumulations of this stage have considerably higher cortex ratios relative to the existing record below, due to the increased difference in (sample) size between that existing record and these accumulations (for example, 1033 artifacts of the accumulation 19 vs 17,728 artifacts of the sequence of accumulations 1-18), their higher cortex ratios are not making a noticeable effect on the record of MIS 5 by the time when these two accumulations became part of that record.

If we single out the lowest four accumulations (MIS 5c, Layer 8), all of their measurements together indicate that the nature of movement practices in these accumulations was generally somewhat between those occurring in later times (Figure 6-3). There is a certain variability in movement practices in this sequence of accumulations (see the accumulation 4 in Figure 6-14). However, together with the lowest average difference (12%) between the existing record of this stage and the

added accumulations, perhaps it can be proposed that the time of Layer 8 accumulation represents the time of the non-preferential and low-intensity movement of both cortex and volume in and out of the place.

If we go to a lower scale of discard events, from that of a climatic stage to the scale of a sampled accumulation, and examine the position of the lowest four accumulations relative to the entire sequence of this place as shown in Figure 6-3, an alternative interpretation can be made: the movement practices within each of these four sampled accumulations actually fluctuated much more than in later times. At the end of the formation history of these accumulations, the large oscillations in the movement practices between bringing the stone material in and taking it out would level the amounts of accumulated volume and cortex into a middle ground in the cortex-volume continuum. However, since these accumulations with the cortex ratio that is intermediate between the extremes of the entire Pech IV sequence appear in an arrangement above each other (instead of being dispersed across the sequence), a low movement intensity during the times represented by these four accumulations is arguably more likely. Moreover, the existence of multiple combustion features interpreted as hearths (Goldberg et al., 2012; Sandgathe et al., 2011) in Layer 8 (represent by the sequence of accumulations 1-4) that are potentially related to more stable occupation intensity in the use of this place relative to later times (Dibble, Berna, et al., 2009) conceivably can be taken to support lower stone movement intensity (rather than no movement at all) during the earliest time of the use of Pech IV.

6.3 Stone reduction and blank production

6.3.1 The method

The analytical method in investigating the process of stone reduction and blank production in this section, as well as in analyzing tool selection and management in the next section, is close to what Shott (2003, 2005; Shott & Nelson, 2008) referred to as a 'reduction thesis'. This concept is discussed in Chapter 4 as an approach towards the study of place and stone use intensity. 'Reduction' here refers to the reduction of stone starting with the removal of a blank from a cobble or other forms of source material. Stages or continua of further reduction of both the blank (reducing it either by detachment of smaller blanks or by retouching its workable edges) and the core constitute the life histories of these artifacts (see papers in Andrefsky, 2008). Such a framework has been used and developed by numerous researchers studying the record left in stone from various cultural and temporal contexts (e.g., Andrefsky, 2006, 2008; Clarkson & Lamb, 2006; Dibble, 1987, 1995; Frison, 1968; Hiscock & Clarkson, 2005; Holmes, 1894; Jelinek, 1976; Kuhn, 1992a, 1991; McPherron, 1994; Potts, 1991; Rolland & Dibble, 1990). In all of those studies, stone reduction has been used as a proxy for the behavioral phenomena related to the intensity of utilization of stone resources and those related with extending the use-life of stone artifacts. In this respect, the reduction thesis treats stone artifacts as representatives of the last stage of their reworking history, which was fragmented in time and space, and at least to some extent responsive to contextual economic and social constrains and opportunities (Bamforth, 1986; Binford, 1979; Elston, 1990; M. C. Nelson, 1991).

Definitions of categories and variables used

Below is a list and definitions of the categories of artifacts and the measured variables that are used in this section:

- Blank: complete or proximal unretouched or retouched artifact detached from a core.
- Complete flake: non-fragmented unretouched blanks.
- Complete flake length: measured from the point of percussion to the most distal end of the artifact.
- Complete flake width: measured at the midpoint and perpendicular to the length axis.
- Complete flake thickness: measured at the intersection of flake length and width.
- Platform depth (PD): measured from the point of percussion to the exterior edge of the platform.
- Exterior platform angle (EPA): measured at the intersection of the platform surface and the exterior surface of the blank.
- Core length: measured as the longest axis of the artifact.
- Cortex: measured using two ratio and five interval classes: 0%, 0-10%, 10-40%, 40-60%, 60-90%, 90-99%, 100%.

6.3.2 The results and their interpretation

The reduction of stone took place in the cave throughout its history of use. The direct evidence for this process comes from the presence of byproducts of knapping that were unlikely to be transported, such as shatter, and flakes smaller

than 25 mm in length. In order to measure the intensity of such reduction, probably the best way would be to measure the amount of volume or mass that was taken off the nodules, but this would require knowledge of the exact original nodule size. Similarly, comparing the sizes of cores, that is, their sizes at the point of their discard, would be helpful in cases where nodules used were uniform in their size. For these reasons, the most common proxy for reduction intensity has been the ratio between blanks (complete and proximal) and cores. However, the major problems with this measure relate to its three implicit assumptions. First, it assumes that both cores and blanks found in the same depositional context were part of the same reduction process or operations; second, it views the reduction events as started and executed at one single place within the landscape; and finally, it assumes that both cores and blanks were discarded at that place of reduction. In the previous section, cortex analysis showed that there was a considerable degree of variability in movement of stone artifacts in and out of the place of Pech IV, therefore making the ratio between blanks and cores an inappropriate measure for the differences in the intensity of stone reduction.

In this analysis, the differences in reduction intensity will be assessed on the basis of volumes of cores but relative to differences in the provisional original size (volume) of nodules (Table 6-12). The provisional volume of the average-sized nodule in an accumulation is derived using the average length of cortical (>10% of surface covered in cortex) complete flakes in the same accumulation. This is the same measure that was used in the previous section when calculating the estimated amount of cortex (Table 6-2). Here, the cores and the cortical complete flakes, as

two components used in estimating the difference in reduction intensity, are not assumed to be products of the same operations of reduction. The difference in the size of cortical complete flakes are taken to only be indicative of the differences in the average size of nodules that were selected and most likely to some extent reduced or fragmented (see Turq et al., 2013) away from the place of Pech IV in the landscape, before being brought into the cave. Therefore, the reduction intensity measured on cores that were discarded at Pech IV is regarded here as a degree of accumulative reduction of nodules over time and the landscape.

Table 6 - 12: Summary data generated for calculating the average core volume and the provisional volume of an average-sized nodule per accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation	MIS	N of cores used for average core volume [1]	average core volume (cm^3) [2]	average length (mm) of cortical complete flakes	log(10) average length (mm) of cortical complete flakes	provisional volume (cm^3) of an average-sized nodule [3]
1		23	14.51	38.24	1.58	55.92
2		30	13.13	39.42	1.60	61.26
3		34	11.95	40.61	1.61	66.97
4		26	12.13	37.81	1.58	54.05
5		62	8.70	38.64	1.59	57.69
6		72	8.98	36.49	1.56	48.59
7		49	7.41	36.77	1.57	49.71
8		75	10.12	38.12	1.58	55.39
9		68	8.08	37.97	1.58	54.72
10	5	52	9.35	38.78	1.59	58.31
11		79	9.13	39.48	1.60	61.54
12		74	10.87	38.75	1.59	58.17
13		60	8.81	39.76	1.60	62.85
14		48	9.47	40.32	1.61	65.54
15		76	12.87	41.44	1.62	71.16
16		52	10.63	40.59	1.61	66.88
17		60	13.17	43.22	1.64	80.73
18		34	17.48	40.59	1.61	66.85
19		40	21.58	41.67	1.62	72.36

20		41	16.23	41.10	1.61	69.43
21		35	24.79	43.95	1.64	84.91
22		25	23.58	44.23	1.65	86.50
23	4	29	16.28	42.73	1.63	78.01
24		22	18.77	42.71	1.63	77.91
25		23	18.71	42.69	1.63	77.81
26		25	25.58	42.75	1.63	78.13
27		27	39.34	39.91	1.60	63.55
28		23	20.13	36.51	1.56	48.68
29		40	13.62	37.05	1.57	50.87
30		24	21.46	36.81	1.57	49.87
31		31	18.62	36.62	1.56	49.11
32		23	14.55	38.27	1.58	56.03
33	3	32	20.05	37.90	1.58	54.46
34		29	22.41	35.79	1.55	45.84
35		30	20.43	36.02	1.56	46.72
36		42	18.83	36.39	1.56	48.20
37		56	24.07	37.42	1.57	52.40
38		35	26.92	38.00	1.58	54.86

[1] Those with recorded mass (which is used to calculate volume)
[2] Calculated as core mass divided by the density of quartz solids of 2.6 g/cm^3
[3] Calculated as ((average length of cortical complete flakes)/10)^3

Table 6 - 13: Summary data generated in transforming the average core volume and the provisional volume of an average-sized nodule, and converting the transformed values into standardized z scores, per accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation	MIS	log(10) average core volume	z-score of log average core volume	log(10) provisional volume of an average-sized nodule	z-score of log provisional volume of an average-sized nodule
1		1.16	-0.10	1.75	-0.41
2		1.12	-0.34	1.79	0.09
3		1.08	-0.57	1.83	0.57
4		1.08	-0.53	1.73	-0.59
5	5	0.94	-1.34	1.76	-0.24
6		0.95	-1.26	1.69	-1.17
7		0.87	-1.72	1.70	-1.04
8		1.01	-0.97	1.74	-0.46
9		0.91	-1.51	1.74	-0.52
10		0.97	-1.16	1.77	-0.18

11		0.96	-1.22	1.79	0.11
12		1.04	-0.80	1.76	-0.19
13		0.94	-1.31	1.80	0.23
14		0.98	-1.13	1.82	0.46
15		1.11	-0.39	1.85	0.90
16		1.03	-0.85	1.83	0.57
17		1.12	-0.34	1.91	1.59
18		1.24	0.35	1.83	0.56
19		1.33	0.86	1.86	0.99
20		1.21	0.17	1.84	0.77
21		1.39	1.19	1.93	1.86
22		1.37	1.07	1.94	1.96
23	4	1.21	0.18	1.89	1.40
24		1.27	0.52	1.89	1.39
25		1.27	0.51	1.89	1.39
26		1.41	1.27	1.89	1.41
27		1.59	2.30	1.80	0.29
28		1.30	0.69	1.69	-1.16
29		1.13	-0.25	1.71	-0.92
30		1.33	0.84	1.70	-1.03
31		1.27	0.50	1.69	-1.11
32		1.16	-0.10	1.75	-0.39
33	3	1.30	0.68	1.74	-0.55
34		1.35	0.95	1.66	-1.48
35		1.31	0.72	1.67	-1.38
36		1.27	0.53	1.68	-1.21
37		1.38	1.12	1.72	-0.76
38		1.43	1.39	1.74	-0.51
	average	1.18		1.78	
	sd	0.18		0.08	

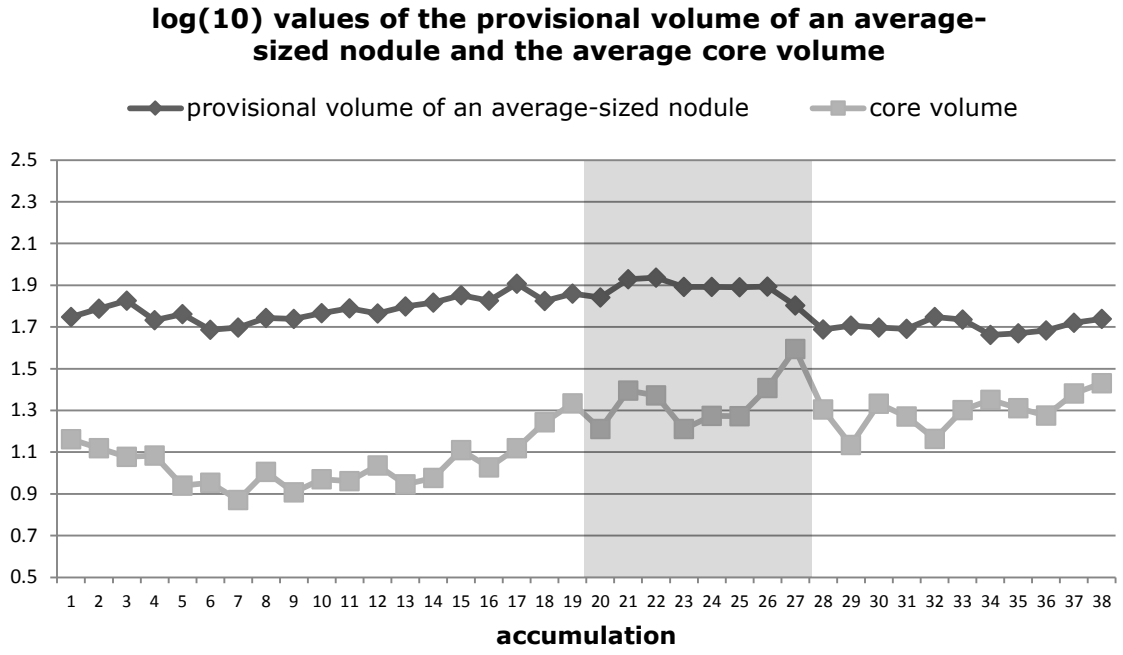

Figure 6 - 15: Transformed values of the provisional volume of an average-sized nodule and the average core volume, per accumulation. The area in light-grey represents accumulations from MIS 4, and its boundaries are approximate.

Both the average core volume, and the average length of cortical complete flakes of accumulations are different between the isotope stages, with those in MIS 4 being the greatest (for average core volume $p<.05$ in the Levene's nonparametric test of homogeneity in variance, therefore ANOVA was performed on log transformed values: $F=33.384$, $df=2,35$, $p<.001$; for average length of cortical complete flakes $p<.05$ in the Levene's nonparametric test of homogeneity in variance, therefore ANOVA was performed on log transformed values: $F=27.977$, $df=2,35$, $p<.001$). These differences, together with the comparison of the average core volume with the provisional size of an average-sized nodule suggest that nodules were reduced more intensively during the later part of MIS 5, in the sequence of accumulations 13-17 (Figure 6-15, 6-16). Relatively to the entire Pech

IV sequence, the reduction of nodules seemed to be less intensive during MIS 3. Cores of MIS 4 accumulations are bigger in size, but, based on the length of cortical complete flakes, so too were the nodules. In the sequence of accumulations 4-12, the opposite is the case, with both cores and nodules being of a smaller size. This suggests that there was no difference in the reduction intensity between this part of MIS 5 (accumulations 4-12) and MIS 4.

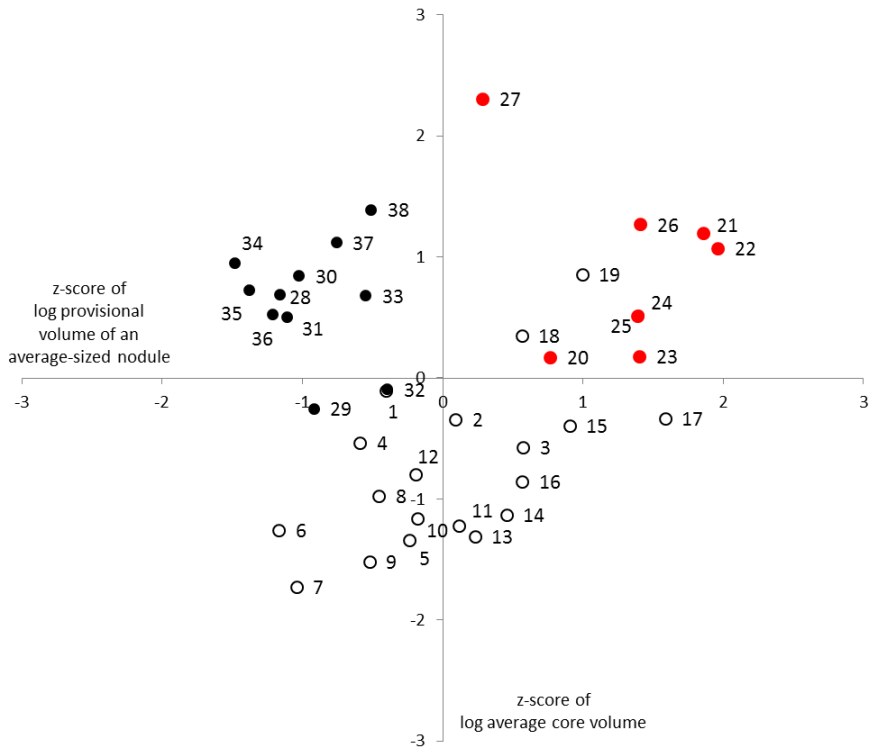

Figure 6 - 16: Z-scores of log provisional volume of an average-sized nodule and the average core volume. Points in red and black represent accumulations of MIS 4 and 3, respectively, while points in open circles are those of MIS 5 accumulations.

To start with the assessment of the extent and the nature of (the stage of) the reduction of cores that took place at Pech IV, an analysis of the relations between

the average length of cores and the average length of complete flakes with more than 60% of their surface covered in cortex is presented below. In general, if nodules started to be reduced in the cave, then complete flakes with such high coverage in cortex that were presumably taken off at the beginning of the nodule reduction, should be longer than what was left from those nodules at the end of the reduction process, i.e., the cores.

Table 6 - 14: Summary data related to the average core length and the average length of complete flakes with more than 60% cortex, per accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation	MIS	N of cores with measured length	average length of cores (mm)	N of complete flakes with cortex >60% and with measured length	average length (mm) of complete flakes with cortex >60%
1	5	27	45.47	49	37.18
2		33	46.22	50	39.90
3		34	45.70	47	38.46
4		28	45.14	61	36.54
5		73	40.73	56	37.63
6		89	39.43	66	37.45
7		59	38.43	53	36.08
8		103	38.69	66	39.66
9		82	38.68	65	38.83
10		75	37.66	57	39.20
11		89	40.06	67	38.70
12		87	39.29	66	37.65
13		77	38.20	68	40.70
14		61	39.86	62	37.50
15		86	43.70	83	40.81
16		63	41.33	64	38.59
17		68	44.30	59	43.33
18		44	42.51	64	41.08
19		40	52.31	86	40.93
20	4	43	46.99	88	42.01
21		35	52.87	91	42.67
22		27	54.55	104	43.43
23		31	46.98	105	41.26

24		22	52.20	96	41.61
25		23	52.02	111	42.04
26		25	55.34	90	42.30
27		30	57.78	77	39.42
28		24	51.56	136	36.20
29		42	45.05	119	36.33
30		24	51.59	127	36.75
31		34	48.73	128	36.17
32		24	45.94	117	38.25
33	3	34	46.41	102	38.53
34		32	44.18	90	36.26
35		32	45.42	111	35.94
36		43	45.21	103	36.66
37		58	47.00	103	38.32
38		39	52.05	126	37.07

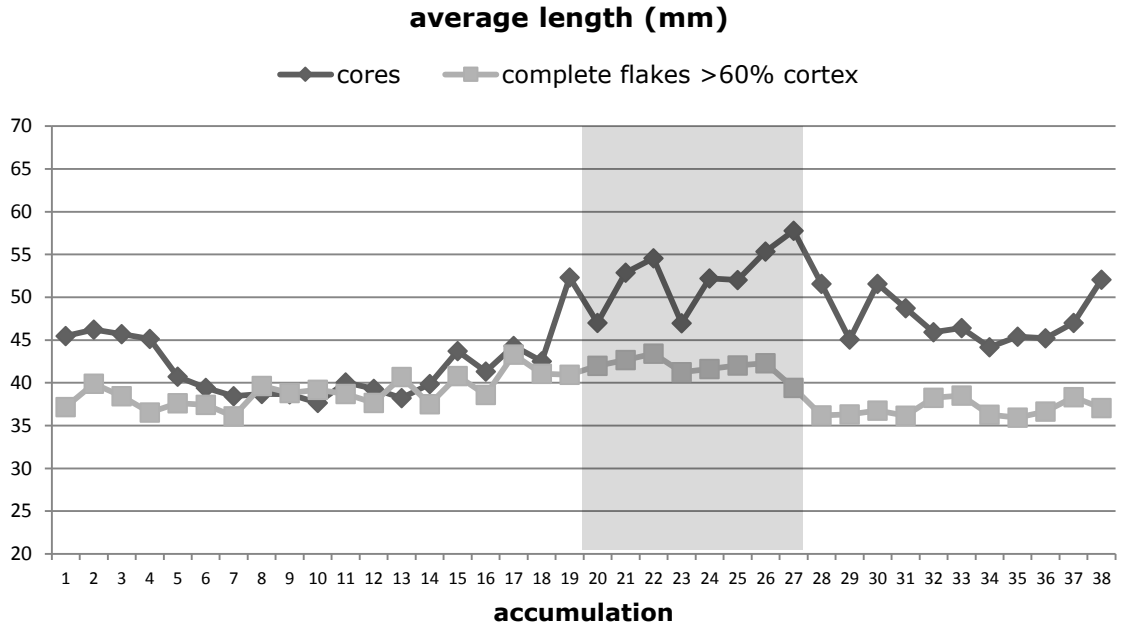

Figure 6 - 17: Average length dimensions for cores and complete flakes with more than 60% cortex, per accumulation. The area in light-grey represents accumulations from MIS 4, and its boundaries are approximate.

As can be observed in Table 6-14 and Figure 6-17, in the earlier accumulations of MIS 5, and in those of MIS 4 and MIS 3, complete flakes with high

coverage in cortex are not longer than the cores. This potentially means that in these three parts of the Pech IV sequence either the cores and these highly-cortical complete flakes were not part of the same reduction process, or that the longest such cortical flakes were exported from this place, or that nodules were brought to this cave and started to be reduced but that there was a production of small size blanks from the beginning. Production of blanks of smaller size from the start of nodule reduction would in turn imply that the production of such blanks was deliberate.

We can also look at the correlation between the ratio of blank to core and the average length of all complete flakes, the average core length, and the average percentage of cortex (the amount of cortex on artifacts was measured using two ratio and five interval classes: 0%, 0-10%, 10-40%, 40-60%, 60-90%, 90-99%, 100%, which are all then converted into ratio values corresponding the amount of cortex by these classes: 0 for 0%, 5 for 0-10%, 25 for 10-40%, 50 for 40-60%, 75 for 60-90%, 95 for 90-99%, and 100 for 100%). As more blanks are taken off the core, the latter three measures should decrease (see Roth & Dibble, 1998).

Table 6 - 15: Summary data related to the average length of complete flakes and the average percentage of cortex, per accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation	MIS	N of complete flakes with measured length	average length (mm) of complete flakes	N of artifacts with measured cortex amount	average % of cortex
1		409	37.80	643	17.46
2		427	38.40	669	17.74
3	5	413	38.18	665	18.56
4		400	37.23	600	20.49
5		391	37.44	582	20.86

6		406	35.23	530	26.61
7		320	36.01	485	24.97
8		407	36.71	652	21.17
9		417	36.11	549	23.78
10		474	35.59	486	25.33
11		443	37.77	657	23.89
12		360	37.97	545	25.43
13		442	38.91	578	21.37
14		437	38.62	525	23.95
15		399	40.26	537	25.09
16		436	39.23	535	22.67
17		455	40.60	652	22.17
18		448	39.58	625	22.18
19		472	39.33	687	23.44
20		519	38.77	864	23.79
21		531	42.72	738	23.45
22		583	42.06	734	24.44
23	4	562	40.47	698	24.69
24		528	40.17	630	25.47
25		517	39.93	657	25.26
26		478	39.01	654	24.98
27		478	37.91	712	23.79
28		593	36.04	901	27.61
29		597	36.77	911	26.91
30		597	36.50	900	26.98
31		613	35.90	886	26.71
32		556	36.79	774	27.15
33	3	573	36.54	806	26.30
34		489	34.18	549	30.99
35		554	34.84	739	30.85
36		572	34.39	721	29.49
37		531	36.08	776	30.15
38		628	36.43	854	29.48

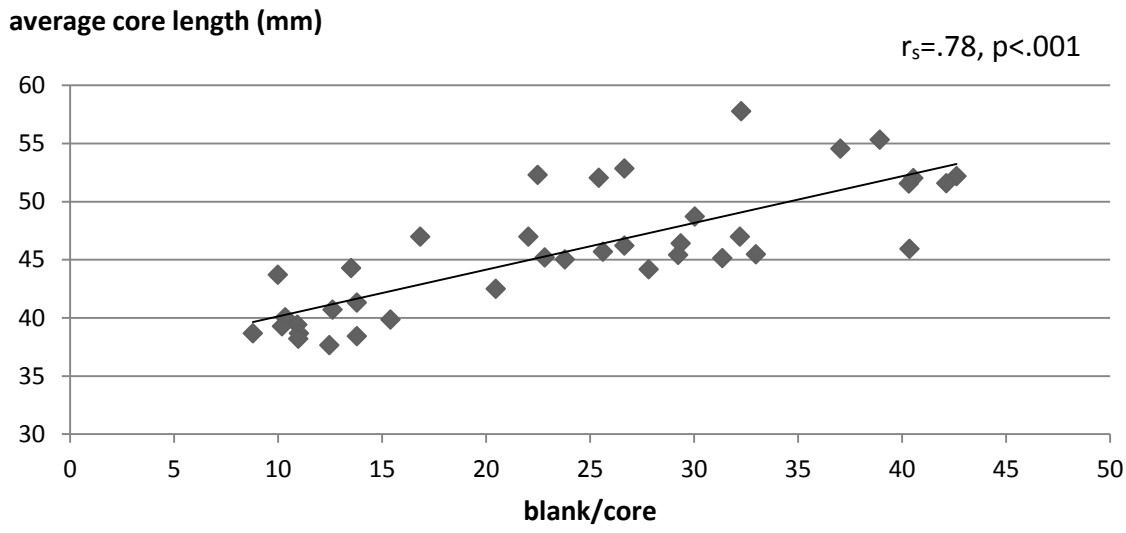

Figure 6 - 18: The relationship between blank/core and the average length of cores in the entire sequence. Individual points represent individual accumulations.

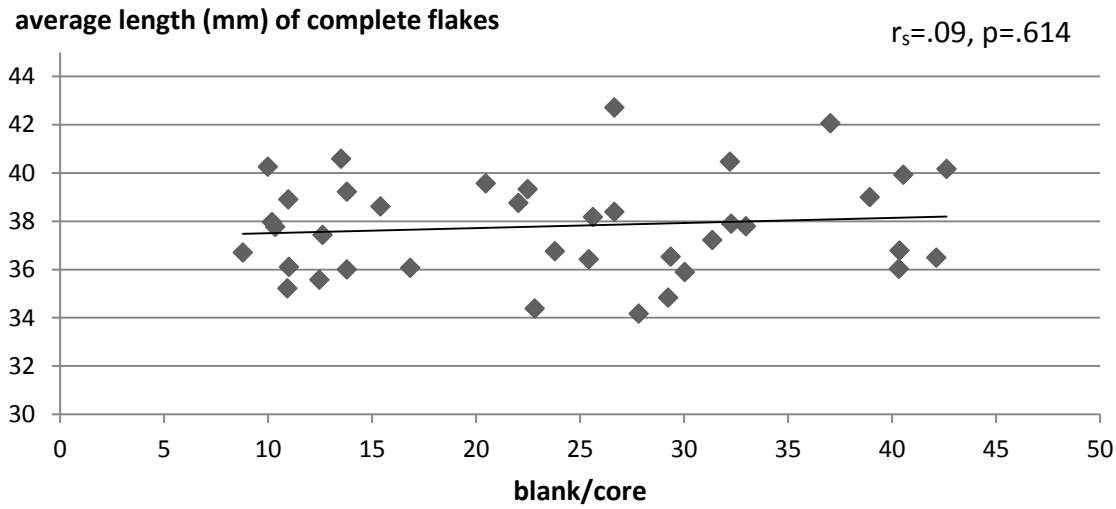

Figure 6 - 19: The relationship between blank/core and the average length of all complete flakes in the entire sequence. Individual points represent individual accumulations.

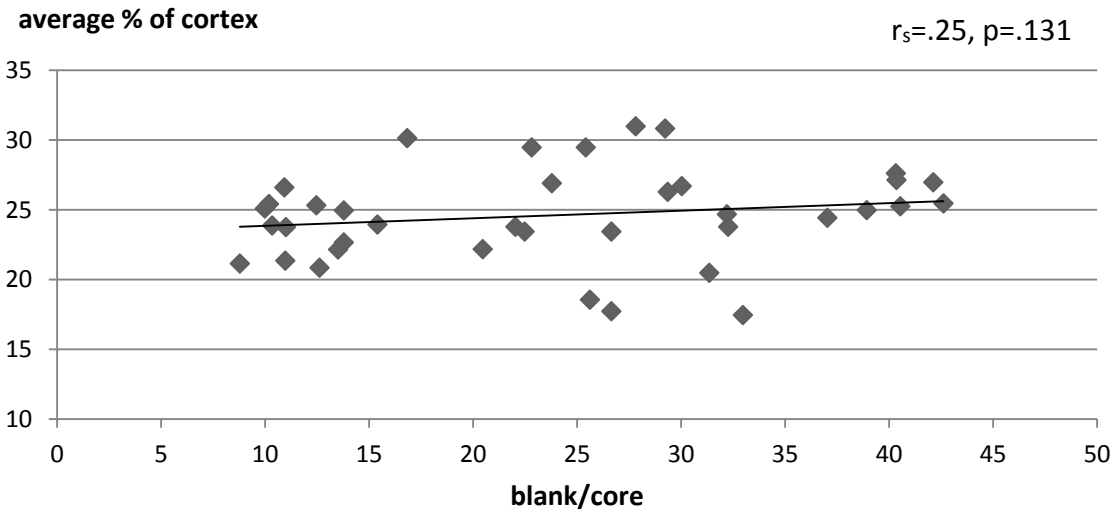

Figure 6 - 20: The relationship between blank/core and the average percentage of cortex in the entire sequence. Individual points represent individual accumulations.

In Figure 6-18, the increase in blank-to-core is actually correlated with the increase in the average core size, which contrasts with what would be expected if the complete nodule reduction took place at Pech IV throughout its history of use. Figures 6-19 and 6-20 reveal that the average length of complete flakes and the average percentage of cortex do not follow the amount of blanks relative to the amount of cores in accumulations. However, if we look at the relation between blank-to-core and the average percentage of cortex within individual isotope stages, during MIS 5 (Figure 6-21) the average percentage of cortex does decrease with higher quantity of blanks relative to the quantity of cores. This relationship is inversed during MIS 4 (Figure 6-22), meaning that the higher quantity of blanks is followed by the higher amount of cortex in the accumulations of this isotope stage.

This, together with the analysis of movement of stone artifacts from the previous section of this chapter, strongly suggests that during MIS 4 there was a

significant import of cortical blanks into the cave, and that cores and blanks from MIS 4 accumulations do not belong to the same stone reduction events. Significant negative or positive correlations between these two measures in the accumulations of MIS 5 and MIS 4, respectively, also suggests that within these two isotope stages the practices responsible for the accumulation of blanks, cores, and cortex in the cave varied less than during MIS 3 (Figure 6-23), where the structure of the record indicates greater variability in the nature of movement and accumulation of stone artifacts. This was already predicted in the previous section by tracing of the directionality of change in the cortex ratio transformation analysis (Figure 6-14). In that analysis, the formation of the MIS 3 record was marked more changes in the direction of cortex ratio values.

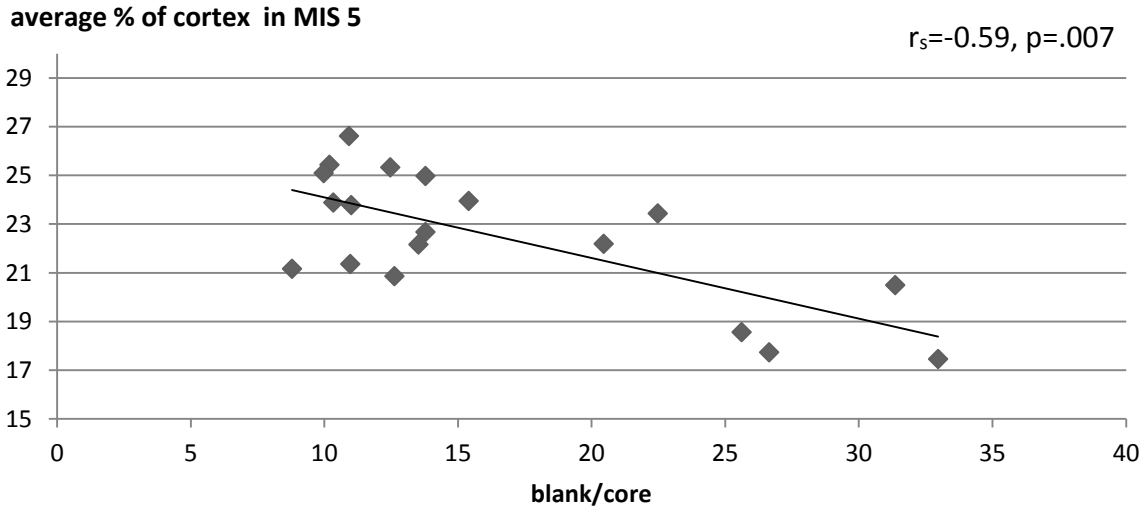

Figure 6 - 21: The relationship between blank/core and the average percentage of cortex in MIS 5. Individual points represent individual accumulations.

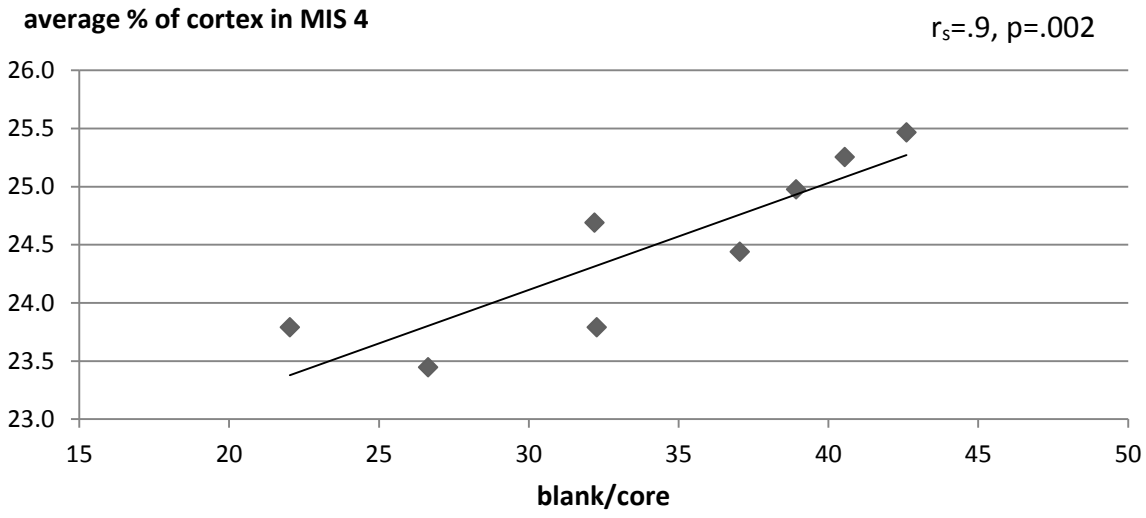

Figure 6 - 22: The relationship between blank/core and the average percentage of cortex in MIS 4. Individual points represent individual accumulations.

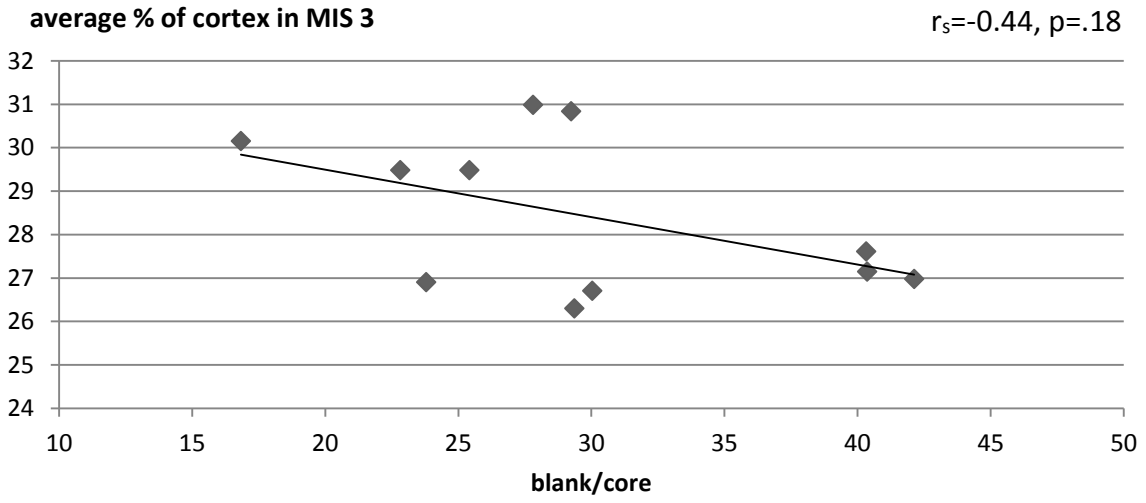

Figure 6 - 23: The relationship between blank/core and the average percentage of cortex in MIS 3. Individual points represent individual accumulations.

Lastly, with these insights into the differences in core reduction, movement of stone artifacts, and the structure of the record related to the variability in blank production if the record of Pech IV would be comprised only of products of complete

reduction of nodules taking place within the cave, it is necessary to examine the intensity of flaking. Intensity of flaking differs from intensity of core reduction in that the former is about the intensity of blank production, while the latter concerns the amount of volume taken off the nodules. For example, if the amount of reduced volume between two reduction events is the same, but the blanks produced during one of those events are bigger on average, then this reduction event can be interpreted as an event of lower flaking intensity. In this study, intensity of flaking in an accumulation will be assessed using the quantity of small non-cortical complete flakes relative to all non-cortical complete flakes. The category of small non-cortical complete flakes is here defined as those with a length less than the average length of non-cortical (less than 10% of their surface covered in cortex) complete flakes of the entire Pech IV sequence, which is 34.59 mm (or rounded to 35 mm). This analysis assumes that these smaller-size flakes were less likely to be affected by the movement of stone artifacts over the landscape, meaning that these flakes were produced and discarded in the cave.

Table 6 - 16: Summary data related to the quantity of small non-cortical flakes and their average length, per accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation	MIS	N of non-cortical complete flakes with measured length	average length (mm) of non-cortical complete flakes	log(10) average length (mm) of non-cortical complete flakes	N of small non-cortical complete flakes	average length (mm) of small non-cortical complete flakes	log(10) average length (mm) of small non-cortical complete flakes
1	5	255	37.69	1.58	145	29.95	1.48
2		250	38.06	1.58	148	30.25	1.48
3		246	37.75	1.58	137	30.45	1.48
4		215	38.06	1.58	116	29.83	1.47

5		239	36.94	1.57	134	29.50	1.47
6		199	35.63	1.55	127	30.36	1.48
7		162	35.82	1.55	110	30.96	1.49
8		242	36.10	1.56	155	30.53	1.48
9		192	36.02	1.56	119	30.26	1.48
10		181	36.63	1.56	108	30.22	1.48
11		234	36.74	1.57	151	30.10	1.48
12		181	37.89	1.58	101	30.38	1.48
13		238	39.23	1.59	125	30.16	1.48
14		214	39.63	1.60	104	30.37	1.48
15		215	39.51	1.60	118	30.78	1.49
16		241	39.06	1.59	124	30.29	1.48
17		255	39.15	1.59	144	30.44	1.48
18		242	40.06	1.60	124	30.34	1.48
19		249	37.87	1.58	143	30.24	1.48
20		279	36.82	1.57	176	30.13	1.48
21		283	41.70	1.62	109	30.73	1.49
22		299	40.77	1.61	115	30.77	1.49
23	4	296	38.78	1.59	137	30.65	1.49
24		255	39.06	1.59	118	30.38	1.48
25		265	37.53	1.57	128	29.95	1.48
26		257	36.30	1.56	149	30.27	1.48
27		247	36.52	1.56	162	29.99	1.48
28		281	35.62	1.55	214	30.01	1.48
29		297	36.54	1.56	184	29.82	1.47
30		269	36.17	1.56	182	30.12	1.48
31		288	35.20	1.55	216	29.88	1.48
32		253	36.41	1.56	175	30.00	1.48
33	3	274	35.24	1.55	188	29.41	1.47
34		149	34.24	1.53	110	29.61	1.47
35		211	33.82	1.53	148	29.51	1.47
36		191	33.67	1.53	137	29.42	1.47
37		202	34.53	1.54	146	29.47	1.47
38		257	34.65	1.54	163	29.53	1.47

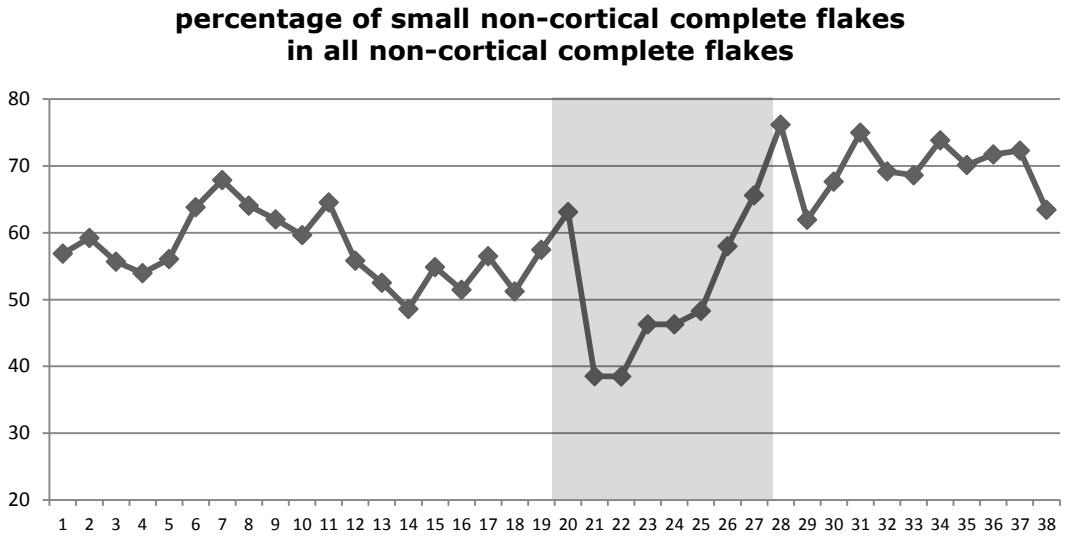

Figure 6 - 24: Percentages of small non-cortical (less than 10% of cortex) complete flakes within all non-cortical complete flakes, per accumulation. The area in light-grey represents accumulations from MIS 4, and its boundaries are approximate.

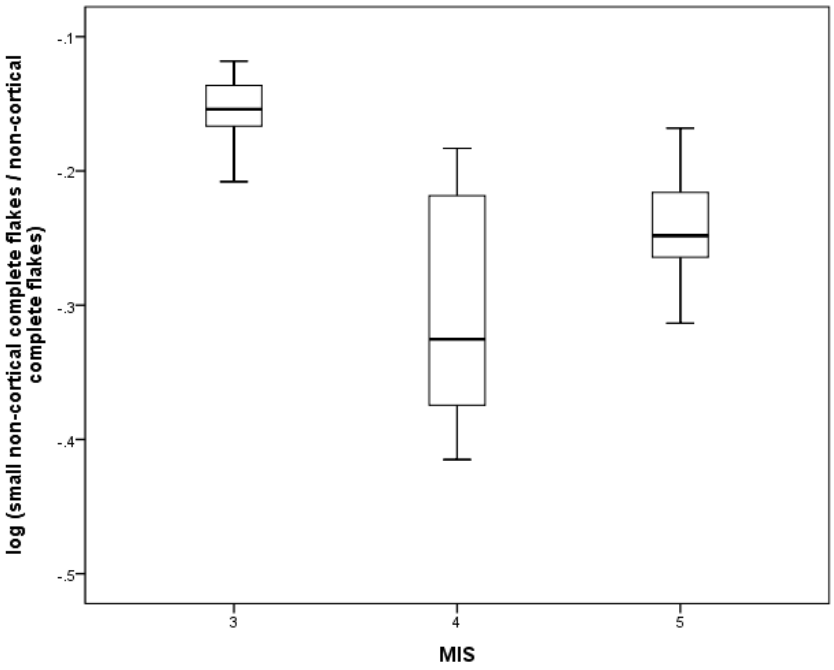

Figure 6 - 25: A boxplot indicating the distribution of log (small non-cortical complete flakes/non-cortical complete flakes) values in the three isotope stages.

The potential interpretations of the practices that would result in cores in MIS 3 accumulations being longer from highly cortical flakes (Table 6-14, Figure 6-17) are that either these two components of the record were not associated with the same reduction events, or that the longest highly cortical flakes were exported, or that there was a production of small flakes from the start of nodule reduction in the cave. The analyses above together indicate that during MIS 3 neither of these three interpretations are viable. When interpreting the results of cortex ratio in the previous section, it was suggested that there was less import of cortex than when compared to MIS 4, but higher export of volume in the form of non-cortical blanks. According to the high amount of small non-cortical complete flakes in this stage (Table 6-16, Figures 6-24 and 6-25) ($p<.05$ in the Levene's nonparametric test of homogeneity in variance, therefore ANOVA was performed on log transformed values ($F=20.622$, $df=2,35$, $p<.001$), it appears that this export entailed only bigger flakes. Therefore, it would seem that the practice of exporting bigger non-cortical flakes, rather than the production of small flakes, is what produced the high relative amount of small flakes in the MIS 3 record. The accumulations of MIS 3 indicate export of bigger non-cortical flakes, rather than production of small flakes, is also supported by the difference in the average length of all non-cortical flakes between the three stages (Table 6-16) ($p<.05$ in the Levene's nonparametric test of homogeneity in variance, therefore ANOVA was performed on log transformed values: $F=16.811$, $df=2,35$, $p<.001$), where non-cortical flakes of MIS 3 accumulations are the shortest. In Figure 6-29, it can be observed that the values of the average length of the longest scar on cores from accumulations of this stage in

general are not lower than such values from accumulations in other isotopes stages. All of this evidence implies that the longest flakes of this category are missing in the record of MIs 3.

It seems that such export was intensified in the upper part of MIS 3, in the sequence of accumulations 33-38, which can be seen in the higher quantity of cortical complete flakes relative to the quantity of non-cortical complete flakes in this sequence (Figure 6-12). An alternative explanation for this higher quantity of cortical complete flakes (>10% of cortex) in the upper part of MIS 3 is that the export of bigger flakes during the lower part of this stage (the sequence 28-32) might also have included cortical flakes. In this case, it would be expected that the average length of cortical flakes in the lower part of MIS 3 would be less than in the sequence 33-38. However, the average length of such flakes does not vary throughout MIS 3 (Table 6-12) (CV=2.1 %), indicating that the export of big flakes was largely restricted to non-cortical ones in both lower and upper accumulations of this stage.

In the upper part of MIS 3, together with intensified export of big non-cortical flakes, more cores or nodules were brought into the cave (Figure 6-9), leading to a decrease in the ratio between blanks and cores towards the end of this sequence (Figure 6-11). Highly cortical flakes of this stage are shorter than cores simply because there was a low reduction intensity of those nodules in the cave during those times (Tables 6-12 and 6-13, Figures 6-15 and 6-16). In any case, it is likely that this import of volume is behind the directionality in the change of cortex (Figure 6-14), where cortex ratio decreases towards the last accumulation. Also, the

variability in the processes of movement of stone objects makes the blank-to-core and the average percentage of cortex uncorrelated in this stage (Figure 6-23).

The above analyses follow the suggestion based on cortex ratio analysis in which there was an import of cortical flakes of somewhat larger size during MIS 4. In comparison with accumulations of the other two isotope stages, in MIS 4, cortical flakes are the longest, either counting complete flakes with more than 10% of their surface covered in cortex ($p<.05$ in the Levene's nonparametric test of homogeneity in variance, therefore ANOVA was performed on log transformed values: $F=33.384$, $df=2,35$, $p<.001$) or only those with more than 60% (Kruskal-Wallis $\chi^2=21.617$, $df=2$, $p<.001$; non-parametric Levene's test of homogeneity in variance, $p>.05$). This import of flakes is the reason why the higher ratio between the quantity of blanks and the quantity of cores is positively correlated with a higher amount of cortex (Figure 6-22). This evidence suggests that during MIS 4, more than during the other two stages (see the discussion about MIS 5 further below) and in relation to events of stone reduction, there is a disassociation between deposited cores and blanks.

In this stage, cores are longer (Table 6-14) (Kruskal-Wallis $\chi^2=22.142$, $df=2$, $p<.001$; non-parametric Levene's test of homogeneity in variance, $p>.05$), and of a bigger volume (Table 6-12) ($p<.05$ in the Levene's nonparametric test of homogeneity in variance, therefore ANOVA was performed on log transformed values: $F=27.977$, $df=2,35$, $p<.001$), and they are leftovers of reduction of bigger-sized nodules (which took place in the cave during this stage at least to some extent). Therefore, both the reduction intensity and the flaking intensity during this stage were not high in general (Figure 6-15, 6-24, 6-25). This is also evident in the

fact that cores are longer than highly-cortical flakes (Figure 6-17), and especially in the small relative quantity of small non-cortical flakes (Figures 6-24 and 6-25).

The import of cortical flakes of bigger size potentially could bias the analysis of core reduction intensity, since the provisional size of nodule is based on the size of cortical complete flakes (Tables 6-12 and 6-13). Nevertheless, this does not change the interpretation offered above, because if the provisional nodule size in accumulations of MIS 4 is less than in Figure 6-15, then the core reduction intensity was even lower. It can also be noticed that throughout this stage there seems to be a directional trend towards decrease in the number of cores (Figure 6-9) and in the intensity of their reduction (Figures 6-10 and 6-15). This is why blank-to-core generally increases (Figure 6-11). At the same time, however, there is an increase in flaking intensity towards MIS 3, as measured with the relative quantity of small non-cortical flakes (Figure 6-24).

During MIS 5, the general flaking intensity was higher than in MIS 4 (Figure 6-25) ($p<.05$ in the Levene's nonparametric test of homogeneity in variance, therefore ANOVA was performed on log transformed values: $F=6.54$, $df=1,25$, $p<.017$). Within this stage there was variability in this process, such that in the sequence of accumulations 5-11 this intensity was higher than in the sequence of accumulations 1-4 (just like with cortex ratio, the sequence 1-4, exhibits the medium intensity in flaking and in core reduction) and 12-19 (Figure 6-24). At the same time core reduction in the sequence 5-11 was not high (Figures 6-15 and 6-16). The only probable explanation for the relationship between high flaking intensity and a relatively smaller amount of volume taken off during core reduction

is the production of small flakes. Here, too, highly cortical flakes are not longer than cores (Figure 6-17), supporting the interpretation of the deliberate production of flakes of smaller size. Dibble and McPherron (2006) previously suggested the possibility of small flake production in layer 6A, which is the section of the Pech IV that would include the sequence of accumulations 8-16. The analysis here confirms such a practice, albeit as seen below, shifts the start of production of small flakes to accumulation 5 (the beginning of layer 6B), and restricts it to no further than accumulation 11 (somewhere within layer 6A).

Moreover, it seems that, during MIS 5, nodules were reduced more or less completely in the cave, which is why the average percentage of cortex decreases with the increase in blank-to-core (Figure 6-21). This would also suggest that the movement of cortex in or out of the cave during those times was not considerable, something that is already implied by the results of cortex analysis in the previous section. However, this does not preclude movement of volume. Cortex ratio for the sequence of accumulations 5-19 of MIS 5 (Figures 6-4 and 6-5) implies that if there was movement of volume out of the cave then the amount of this exported volume was not significantly high. This observation implies that the potential export of volume would be restricted to non-cortical flakes of smaller size. To investigate if there was export of non-cortical small flakes (of length between 25 and 35 mm), we can compare correlations between their relative amount, as an indicator of flaking intensity, and their average length. If there was no export of small flakes, then higher flaking intensity (of small non-cortical flakes) should correlate with progressively shorter flakes, as is the case in MIS 4 (Figure 6-28) (there is no such

correlation during MIS 3; r_s=.08, p=.811, which supports the interpretation of exporting non-cortical flakes during the latest stage of the use of Pech IV).

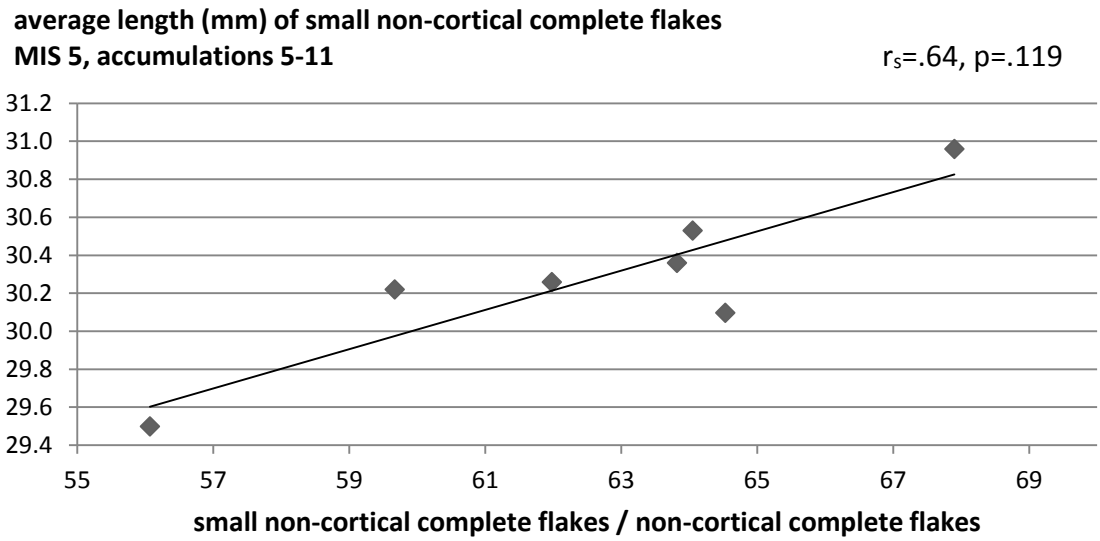

Figure 6 - 26: The relationship between small non-cortical complete flakes/non-cortical complete flakes and the average length of small non-cortical complete flakes in the sequence of accumulation 5-11. Individual points represent individual accumulations.

There is no correlation between the relative amount of small non-cortical flakes and their average length in the sequence 5-11 (Figure 6-26). In fact, Spearman's rho is close to indicating significant increase in size of such flakes with their amount. In any case, the lack of a correlation can be explained with some of the small non-cortical flakes as being missing (see the variability in the quantity of cortical and non-cortical complete flakes in the sequence 5-11 in Figure 6-12). Most likely the exported flakes were of a length that was closer to the upper limit (35 mm) of this 'small non-cortical' category, because in accumulations with smaller relative amount of small flakes (Figure 6-26) these flakes tend to be shortest on

average. Here, in these accumulations, these flakes were most likely leftovers after flakes with the length close to 35 mm were taken out of the cave.

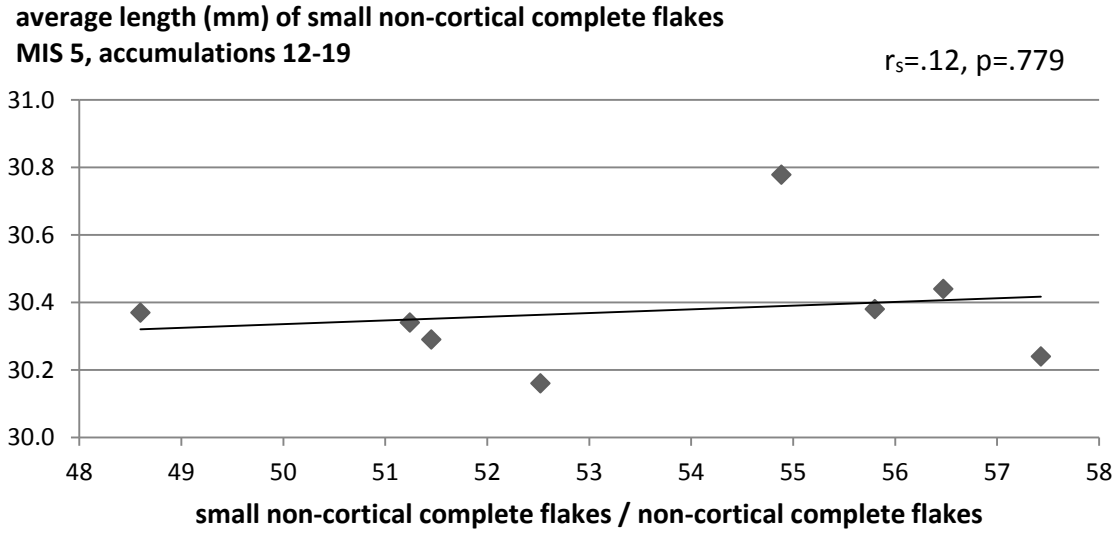

Figure 6 - 27: The relationship between small non-cortical complete flakes/non-cortical complete flakes and the average length of small non-cortical complete flakes in the sequence of accumulation 12-19. Individual points represent individual accumulations.

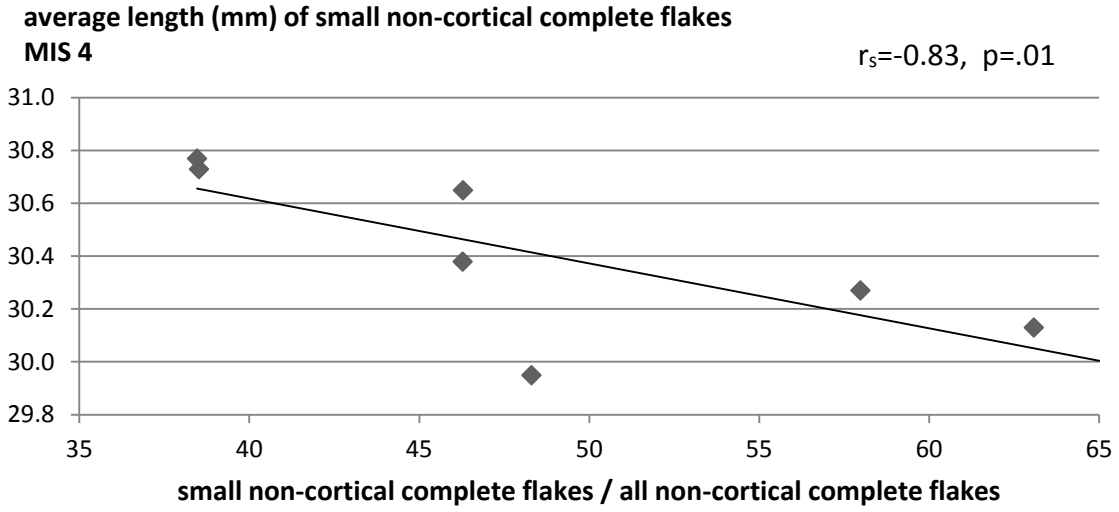

Figure 6 - 28: The relationship between small non-cortical complete flakes/non-cortical complete flakes and the average length of small non-cortical complete flakes in MIS 4. Individual points represent individual accumulations.

In the upper part of MIS 5, in the sequence 12-19, cores were reduced more (Figures 6-15 and 6-16). The decrease in their number could be related with somewhat increased blank-to-core (Figures 6-9 and 6-11), although the flaking intensity was lower than in the sequence 5-11 (Figure 6-24). This implies that flakes produced were of larger size than those in the sequence 5-11, that is, the production of small flakes stopped in the upper part of MIS 5. An increase in the average length of the longest scar on cores (Table 6-17, Figure 6-29) can be taken as support for this interpretation. The lack of correlation between the relative amount of small non-cortical flakes and their average size (Figure 6-27) is also suggestive of some export of non-cortical flakes.

Table 6 - 17: Summary data related to the average length of the longest scar on cores, per accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation	MIS	N of cores with measured length of their longest scar and with the scar >25mm	average length (mm) of the longest scar on cores
1	5	7	33.23
2		16	32.80
3		16	33.48
4		7	32.85
5		19	30.60
6		12	31.36
7		3	30.41
8		16	31.60
9		14	31.26
10		9	30.24
11		6	36.24
12		14	31.43
13		17	32.70
14		15	31.24
15		23	33.05
16		16	37.18

17		21	35.39
18		12	36.76
19		16	39.91
20		13	34.58
21		22	37.48
22		14	34.76
23	4	10	33.82
24		13	39.07
25		10	34.46
26		14	36.62
27		17	37.32
28		10	35.84
29		21	33.29
30		11	40.51
31		16	34.93
32		12	33.36
33	3	16	33.70
34		13	36.34
35		14	30.22
36		15	39.10
37		29	34.05
38		25	36.21

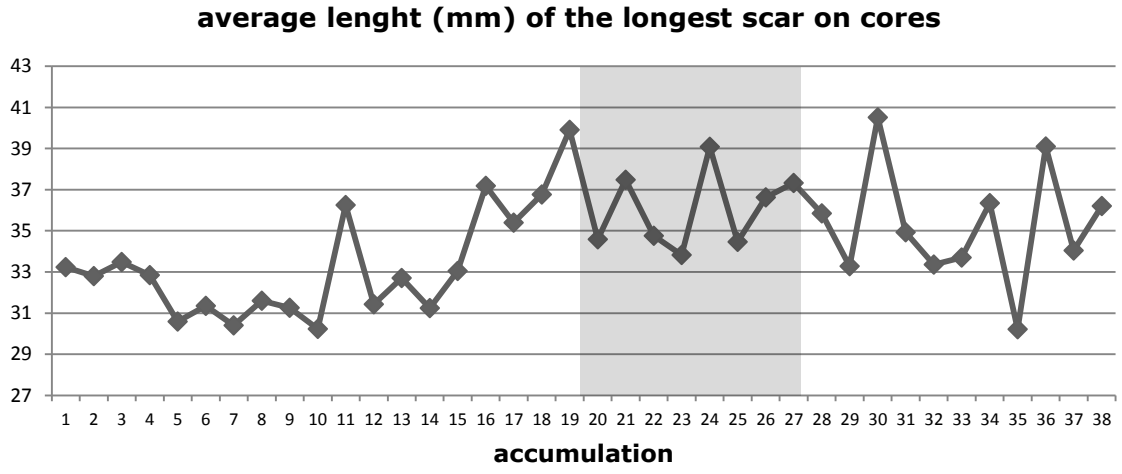

Figure 6 - 29: The average length of the longest scar on cores, per accumulation. The area in light-grey represents accumulations from MIS 4, and its boundaries are approximate.

When analyzing blank production and flaking intensity as dimensions of the nature of stone provision, it is necessary to examine the economic character of the products of stone reduction events. One of the most straightforward ways to express the economic dimension of blanks is in terms of the extracted amount of their usable edge per mass of raw material (Bar-Yosef & Kuhn, 1999; Kuhn, 1994; Tactikos, 2003; Van Peer, 1992). Recent mechanical lithic experiments have shown that the ratio of usable flake edge to mass is directly dependent on the interplay between two particular flake attributes: exterior platform angle (EPA) and platform depth (PD) (Dibble & Rezek, 2009; Lin et al., 2013). According to the experimental results, changes in the values of these two variables in the opposite direction (i.e., decreasing the value of one variable while increasing the value of the other) result in a number of changes in the morphology of a flake that alter measures of its overall economy. Increasing PD while decreasing EPA (or holding it constant) will result in flakes with less edge per mass, while increase in EPA for the same or smaller PD will result in a flake with more mass distributed along its surface than its thickness, providing a high edge-to-mass ratio. Manipulation of these two variables in the same way, i.e. either increasing or decreasing them both at the same time, will result in either bigger or smaller flakes without considerable differences in their economic properties.

Table 6 - 18: Summary data related to the average platform depth and exterior platform angle, per accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation	MIS	N of complete flakes with measured EPA and PD	average PD (mm) of complete flakes	average EPA of complete flakes	Log(10) average PD of complete flakes	Log(10) average EPA of complete flakes	z score of log average PD of complete flakes	z score of log average EPA of complete flakes
1		106	6.46	79.47	0.81	1.90	0.05	0.02
2		104	6.57	78.81	0.82	1.90	0.40	-0.38
3		94	6.49	77.02	0.81	1.89	0.15	-1.49
4		93	6.44	79.27	0.81	1.90	-0.01	-0.10
5		90	6.36	77.31	0.80	1.89	-0.28	-1.31
6		113	6.14	76.44	0.79	1.88	-1.00	-1.85
7		90	5.99	79.83	0.78	1.90	-1.50	0.24
8		148	5.84	77.09	0.77	1.89	-2.02	-1.44
9		108	5.94	77.69	0.77	1.89	-1.69	-1.07
10	5	120	6.26	77.98	0.80	1.89	-0.58	-0.89
11		138	6.39	79.94	0.81	1.90	-0.15	0.31
12		116	6.14	80.68	0.79	1.91	-1.00	0.75
13		153	6.45	79.10	0.81	1.90	0.01	-0.20
14		134	6.35	79.35	0.80	1.90	-0.29	-0.05
15		110	6.73	79.40	0.83	1.90	0.91	-0.02
16		123	6.26	81.53	0.80	1.91	-0.61	1.26
17		111	6.81	79.13	0.83	1.90	1.16	-0.19
18		114	7.03	78.18	0.85	1.89	1.80	-0.77
19		136	6.46	78.39	0.81	1.89	0.05	-0.64
20		128	5.99	78.84	0.78	1.90	-1.50	-0.36
21		166	6.20	81.52	0.79	1.91	-0.79	1.25
22		178	6.20	81.10	0.79	1.91	-0.79	1.00
23	4	159	6.21	80.12	0.79	1.90	-0.74	0.42
24		155	6.25	78.53	0.80	1.90	-0.62	-0.55
25		146	6.09	79.60	0.78	1.90	-1.16	0.10
26		138	6.68	77.68	0.82	1.89	0.75	-1.08
27		104	6.54	75.28	0.82	1.88	0.31	-2.59
28		235	6.70	76.77	0.83	1.89	0.82	-1.65
29		235	6.73	79.26	0.83	1.90	0.90	-0.10
30		243	6.84	79.71	0.84	1.90	1.24	0.17
31		259	6.41	80.44	0.81	1.91	-0.09	0.61
32	3	222	6.49	79.98	0.81	1.90	0.16	0.33
33		221	6.61	78.02	0.82	1.89	0.54	-0.86
34		114	6.46	77.03	0.81	1.89	0.05	-1.48
35		152	6.83	79.24	0.83	1.90	1.20	-0.12
36		149	6.59	76.83	0.82	1.89	0.46	-1.61

37	141	7.30	74.72	0.86	1.87	2.60	-2.95
38	187	6.81	76.55	0.83	1.88	1.16	-1.78
average				0.81	1.9		
s.d.				0.02	0.01		

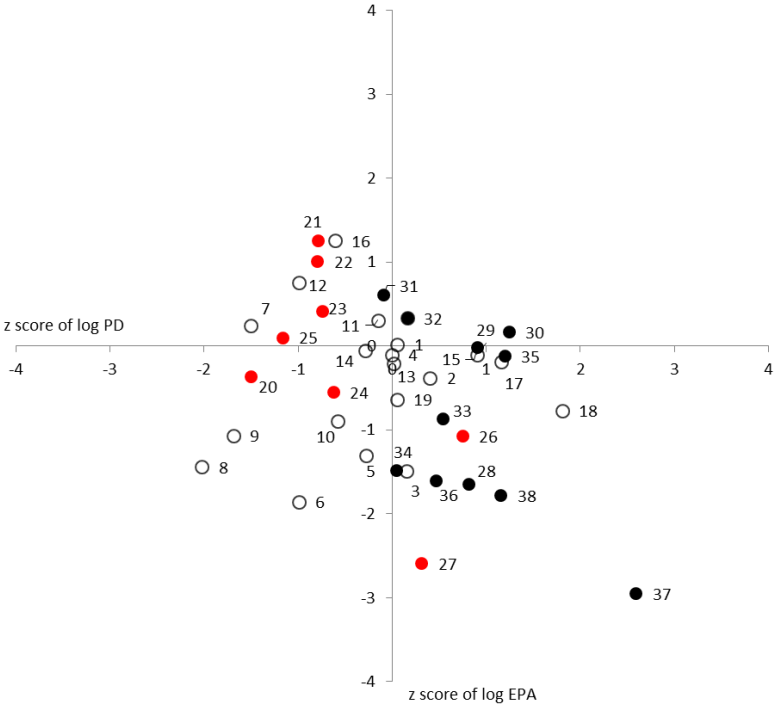

Figure 6 - 30: Z-scores of log average EPA and log average PD of complete flakes. Points in red and black represent accumulations of MIS 4 and 3, respectively, while points in open circles are those of MIS 5 accumulations.

There is no significant difference in the variance of the average EPA values (p>.05 in Levene's non-parametric test of equality in variance) and the average PD values (p>.05 in Levene's non-parametric test of equality in variance) between the three isotope stages. This is also evident in the lack of discrete clusters of accumulations belonging to a particular isotope stage in Figure 6-30. What can be observed in the same figure is that the sequence of accumulations 33-38 contains

less economical flakes. Compared to the group of complete flakes sampled with accumulations 21, 22, 23, and 25 of MIS 4, which are distributed in the most economic quadrant (upper left), the group of complete flakes from the sequence 33-38 have both lower EPAs ($t=-5.682$, $df=1846$, $p<.001$) and greater PDs (Mann Whitney $U=336166.5$, $p<.001$; the distributions of PD values are not normal). This follows the low ratio between the surface area (measured as $[length*width]^{1/2}$) and thickness in those accumulations (Table 6-19, Figures 6-31 and 6-32).

In terms of surface area per thickness, flakes in accumulations of MIS 3 are the least economical flakes (Figure 6-32) ($p<.05$ in the Levene's nonparametric test of homogeneity in variance, therefore ANOVA was performed on log transformed values: $F=52.73$, $df=2,35$, $p<.001$). This finding would also suggest that the bigger non-cortical flakes exported during MIS 3 most likely belonged to such a population of relatively thick flakes with surface area.

It is possible, however, that these exported flakes were, in fact, more economical (or the most economical) among those produced, and perhaps that this was the reason for their selection for transport. That is, the accumulations of this stage exhibit a non-economic character of produced flakes simply because flakes with more surface area per thickness were exported. If we look at variations in both EPA and PD values of complete flakes within accumulations of MIS 3 (Table 6-20), these appear to be somewhat greater than within accumulations of the other two stages. If what is missing is indeed longer flakes with more surface per thickness, and not just bigger flakes with the same economic properties as the smaller ones that are present, then this would mean that variation in EPA values before the

export was greater than now, while variation in PD values before the export was either greater or the same than after the export, because more economical *bigger* flakes mean higher EPA for the same PD. One way to investigate these possibilities is to compare variations in these two variables (EPA and PD) between blanks from accumulations of MIS 3 and blanks from the record that accumulated due to low intensity of stone artifact movement (or before export or import of blanks), such as the sequence of accumulations 1-4 (Layer 8). The range of coefficient of variation (CV) in EPA in accumulations of MIS 3 is 15.85 – 18.34 %, while the range of CV in PD values in the same accumulations is 38.08-59.35%. If we reference this to the ranges of CV in EPA and PD in accumulations 1-4, where the respective CV ranges are 13.96-15.52% and 36.09-43.74%, then increase in variation in both EPA and PD in accumulations of MIS 3 would mean that initially, before export of bigger flakes, these variations would necessarily be even greater relative to such variations in the sequence of accumulations 1-4 than after the export. Since the values and ranges of CV in EPA and PD in MIS 3 accumulations are already greater than in accumulations 1-4, then the adjustments needed for variations in EPA and PD in accumulations of MIS 3 to match those in accumulations 1-4 can be taken to indicate that exported bigger flakes during MIS 3 were not more economical than those that were left in the cave.

The most recent accumulations of MIS 4 (26 and 27) also exhibit the least economical flakes that can be found in the cave (Figure 6-30), while, as already mentioned above, complete flakes from the majority of the lower accumulation of this stage are the most economic. If we look at surface area per thickness (Figures 6-

31 and 6-32), accumulations of this stage generally contain complete flakes that have the highest such ratio, even higher than flakes from accumulations of MIS 5 ($p<.05$ in the Levene's nonparametric test of homogeneity in variance, therefore ANOVA was performed on log transformed values: $F=16.825$, $df=1,25$, $p<.001$).

In MIS 5, with their distribution in the lower left quadrant in Figure 6-30, accumulations 5-11 generally follow the interpretation about small flakes production during those times. The same figure indicates increase in the economic flake production in the upper part of MIS 5 (accumulations 12-19) compared to the sequence 5-11, and also in the size of flakes, which was already inferred in the previous analyses. If measured with surface per thickness, this increase in economic flake production in the sequence 12-19 is significant ($p<.05$ in the Levene's nonparametric test of homogeneity in variance, therefore ANOVA was performed on log transformed values: $F=7.508$, $df=1,13$, $p=.017$).

But what is more interesting in the sequence of accumulations 12-19 is that these accumulations somewhat differ between themselves in the economic properties of their flakes but not in flake size. Figure 6-30 shows that these accumulations are distributed along the economization axis (from the upper left corner to the lower right corner), with little or no variation along the size axis (from lower left corner to the upper right corner). While it is tempting to interpret the distribution of the average EPA and PD values in accumulations of the upper part of MIS 5 to exhibit concerns about economical properties of produced flakes during those times of the use of Pech IV, the question remains if differences in distribution of accumulations 12-19 along the economic axis in Figure 6-30 are significant.

Table 6 - 19: Summary data related to the average (length*width)$^{1/2}$ /thickness, per accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation	MIS	N of complete flakes with measured length, width and thickness	average (length*width)$^{1/2}$/thickness of complete flakes	log(10) average (length*width)$^{1/2}$/thickness of complete flakes
1		370	5.09	0.71
2		381	5.20	0.72
3		367	5.15	0.71
4		341	5.18	0.71
5		366	4.69	0.67
6		344	4.78	0.68
7		296	4.84	0.68
8		372	4.93	0.69
9		333	4.76	0.68
10	5	315	4.94	0.69
11		401	4.92	0.69
12		335	4.87	0.69
13		406	4.98	0.70
14		364	5.07	0.71
15		370	4.96	0.70
16		395	5.12	0.71
17		427	5.00	0.70
18		398	4.81	0.68
19		436	5.02	0.70
20		483	4.94	0.69
21		489	5.47	0.74
22		533	5.34	0.73
23	4	519	5.30	0.72
24		462	5.28	0.72
25		485	5.28	0.72
26		425	5.28	0.72
27		440	5.01	0.70
28		566	4.47	0.65
29		579	4.53	0.66
30		563	4.46	0.65
31		566	4.60	0.66
32	3	490	4.67	0.67
33		549	4.60	0.66
34		377	4.12	0.61
35		511	4.04	0.61
36		478	3.89	0.59

37	500	3.96	0.60
38	602	4.16	0.62

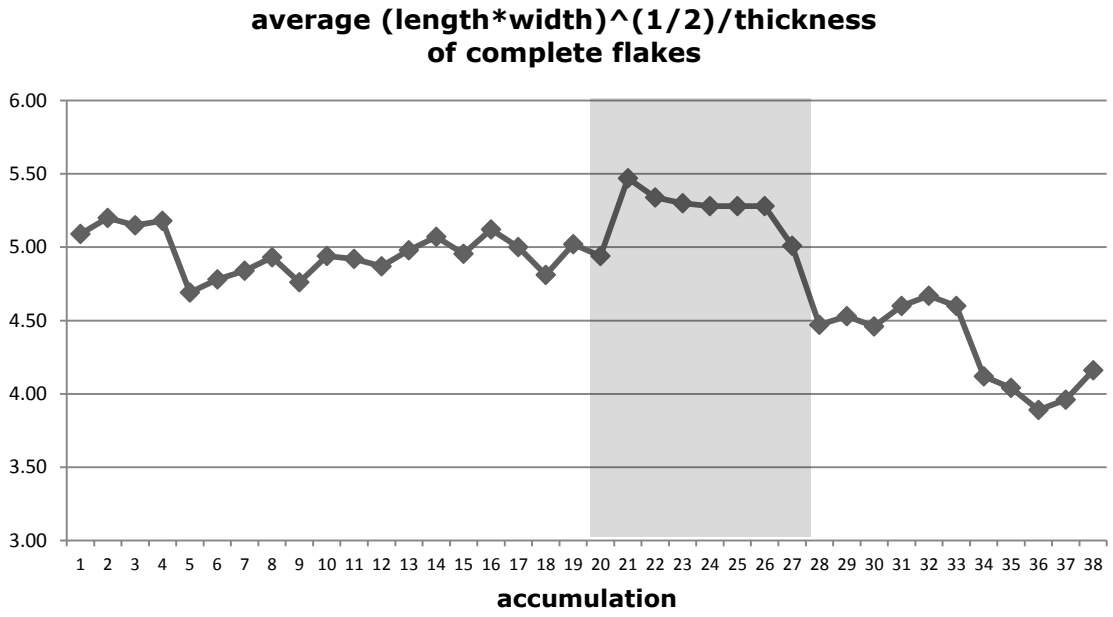

Figure 6 - 31: The average (length*width)^(1/2)/thickness, per accumulation. The area in light-grey represents accumulations from MIS 4, and its boundaries are approximate.

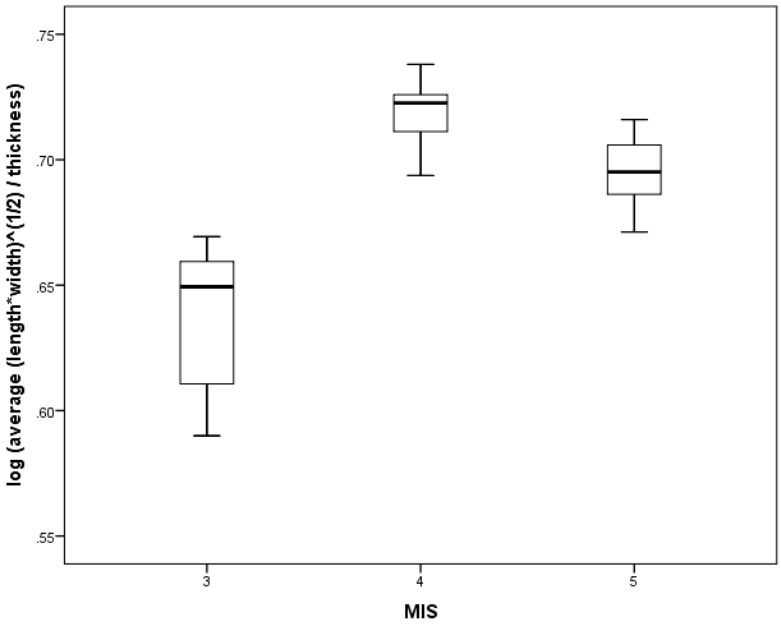

Figure 6 - 32: A boxplot indicating the distribution of log average ((length*width)$^{1/2}$/thickness) values in the three isotope stages.

Table 6 - 20: Summary data related to the coefficient of variation in the average platform depth and exterior platform angle, per accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation	MIS	CV (%) in PD of complete flakes	CV (%) in EPA of complete flakes
1		43.57	14.77
2		43.74	14.50
3		37.54	15.52
4		36.09	13.96
5		31.97	15.50
6		37.63	13.57
7		33.71	13.20
8	5	33.61	14.08
9		31.79	13.51
10		40.33	13.74
11		32.42	11.86
12		33.83	12.74
13		37.76	15.57
14		35.84	12.94
15		50.72	13.76

16		35.78	12.96
17		38.12	14.10
18		39.21	12.95
19		41.57	12.12
20		35.56	13.42
21		41.77	13.27
22		34.60	13.19
23	4	38.85	15.40
24		37.73	14.21
25		43.12	16.77
26		42.78	16.55
27		45.72	18.39
28		39.57	17.35
29		40.96	16.75
30		59.35	16.60
31		38.44	15.85
32		42.91	15.97
33	3	40.52	17.80
34		39.02	16.07
35		42.02	16.36
36		38.08	18.34
37		40.07	17.33
38		40.44	17.68

Table 6-21 and Figures 6-33, and 6-34 below are related to analyzing the transformation of the record of Pech IV in relation to production of flakes with more or less surface area per thickness. During MIS 3, there is a clear switch in such flake production practices, that is, the record is transformed into the opposite direction after accumulation 34 was deposited. Here, the average difference in surface area per thickness between accumulations of this stage and the record of this stage into which they were incorporated is 5.6%.

During most of MIS 4, variability in practices of more or less economic flake production is nonexistent. Every accumulation except the last one transforms the

record in the same direction: towards increase in surface area per thickness. The transformation of the MIS 4 record in the opposite direction comes when the last accumulation (27) is added to this record.

The practices of flake production during MIS 5 were more variable than during MIS 4 and MIS 3. Here, the record of flake surface area per thickness is transformed in the opposite direction much more often, especially during the latter part of MIS 5. During the formation of the MIS 5 record from the time of deposition of accumulation 5 until the deposition of accumulation 12, there was no variability in flake production practices. Flakes with less and less surface area per thickness were being produced, which is opposite to the use of place during MIS 4. What is common during both MIS 5 and MIS 4, however, is that the degree of intensification of their respective practices related to production of more or less economical flakes (2.3% and 2.8%, respectively) was less than the degree during MIS 3 (5.6%, as mentioned above).

Table 6 - 21: Transformation of the average (length*width)$^{1/2}$ /thickness in the record of Pech IV throughout its accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation sequence	MIS	average (length*width)$^{1/2}$/ thickness of complete flakes	**accumulation**	average (length*width)$^{1/2}$/ thickness of complete flakes	difference (%) in (length*width)$^{1/2}$/ thickness of complete flakes relative to the accumulation sequence below
1	5	5.09	**2**	5.20	2.16
1-2		5.15	**3**	5.15	0.00
1-3		5.15	**4**	5.18	0.58
1-4		5.16	**5**	4.69	-9.11

1-5		5.06	**6**	4.78	-5.53
1-6		5.02	**7**	4.84	-3.59
1-7		5.00	**8**	4.93	-1.40
1-8		4.99	**9**	4.76	-4.61
1-9		4.96	**10**	4.94	-0.40
1-10		4.96	**11**	4.92	-0.81
1-11		4.96	**12**	4.87	-1.81
1-12		4.95	**13**	4.98	0.61
1-13		4.95	**14**	5.07	2.42
1-14		4.96	**15**	4.96	-0.08
1-15		4.96	**16**	5.12	3.23
1-16		4.98	**17**	5.00	0.40
1-17		4.97	**18**	4.81	-3.22
1-18		4.96	**19**	5.02	1.21
1-19		4.97	**-**	-	-
20		4.94	**21**	5.47	10.73
20-21		5.20	**22**	5.34	2.69
20-22		5.25	**23**	5.30	0.95
20-23	4	5.27	**24**	5.28	0.19
20-24		5.27	**25**	5.28	0.19
20-25		5.27	**26**	5.28	0.19
20-26		5.27	**27**	5.01	-4.93
20-27		5.24	**-**	-	-
28		4.47	**29**	4.53	1.34
28-29		4.50	**30**	4.46	-0.89
28-30		4.48	**31**	4.60	2.68
28-31		4.51	**32**	4.67	3.55
28-32		4.54	**33**	4.60	1.32
28-33	3	4.55	**34**	4.12	-9.45
28-34		4.51	**35**	4.04	-10.42
28-35		4.45	**36**	3.89	-12.58
28-36		4.39	**37**	3.96	-9.79
28-37		4.35	**38**	4.16	-4.37
28-38		4.33	-	-	-

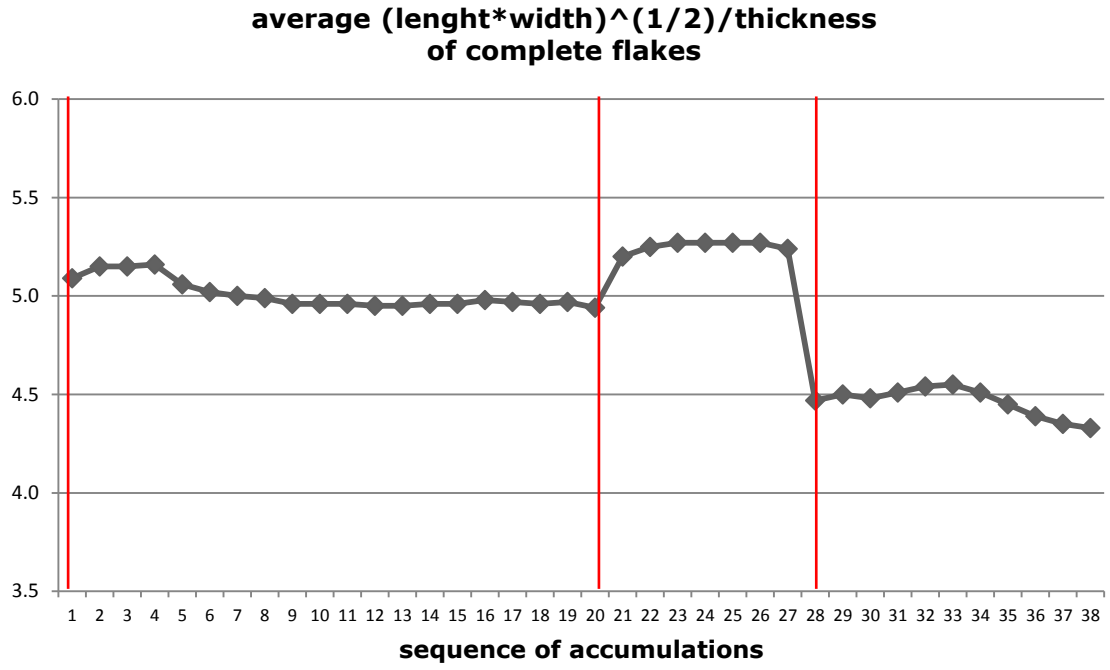

Figure 6 - 33: The average (length*width)^(1/2)/thickness, per sequence of accumulations (third column in Table 6-21). Red vertical lines represent the beginning of a new sequencing process (placed approximately at the start of a new climatic stage). Numbers on the horizontal axis denote the extent of the sequence of accumulations, e.g., the cortex ratio at number '24' is the ratio of the sequence of accumulations 20-24.

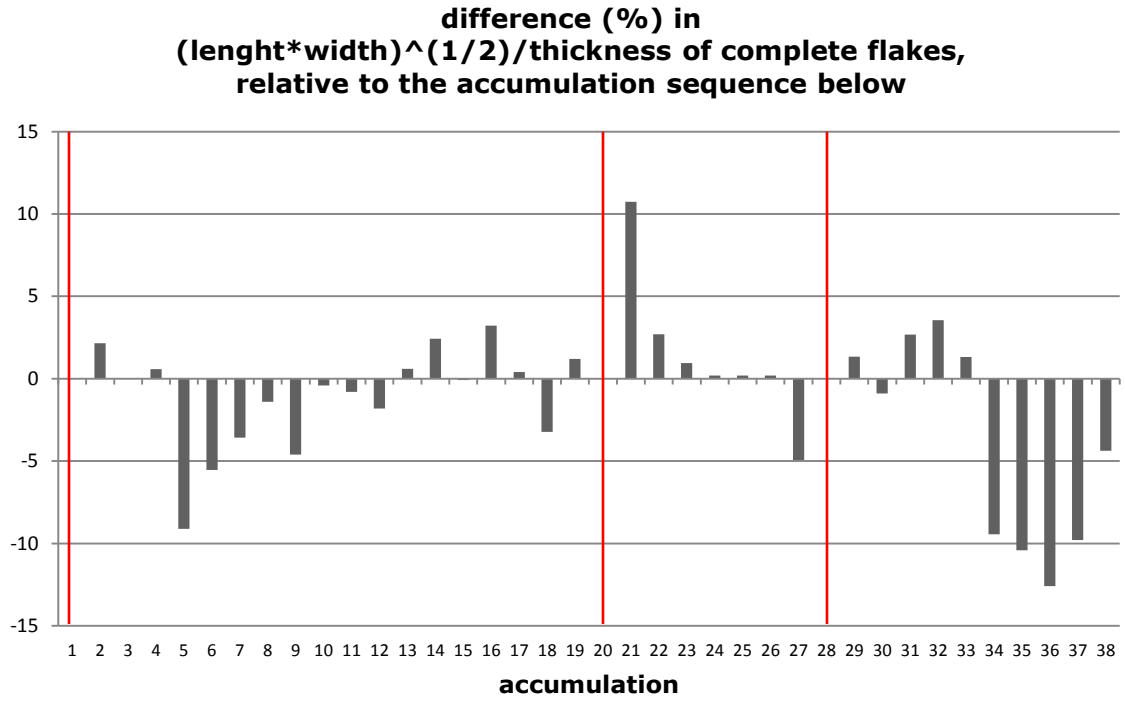

Figure 6 - 34: The relative change in the average (length*width)^(1/2)/thickness between each accumulation and the sequence of accumulations occurring below it (the last column in Table 6-21). Red vertical lines represent the beginning of a new sequencing process (placed approximately at the start of a new climatic stage).

6.4 Blank selection and management

Definitions of categories and variables used

Below is a list and definitions of the categories of artifacts and the measured variables that are used in this section:

- Retouched blank: complete or proximal retouched artifact detached from a core.

- Complete flake: non-fragmented non-retouched blanks.

- Complete flake length: measured from the point of percussion to the most distal end of the artifact.

- Complete flake width: measured at the midpoint and perpendicular to the length axis.

- Complete flake thickness: measured at the intersection of flake length and width.

- Cortex: measured using two ratio and five interval classes: 0%, 0-10%, 10-40%, 40-60%, 60-90%, 90-99%, 100%.

The intensity of blank selection is measured here as the ratio between retouched blanks (complete and proximal) and flakes (complete and proximal).

Table 6 - 22: Summary data related to the ratio between retouched blanks and flakes, per accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation	MIS	N of retouched blanks	N of flakes	retouched blanks / flakes
1	5	105	785	0.13
2		94	812	0.12
3		89	782	0.11
4		67	811	0.08
5		95	826	0.12
6		71	912	0.08
7		42	895	0.05
8		56	849	0.07
9		53	860	0.06
10		39	896	0.04
11		50	880	0.06
12		62	865	0.07
13		54	856	0.06
14		61	894	0.07
15		83	815	0.10
16		72	865	0.08
17		122	797	0.15
18		119	781	0.15
19		118	871	0.14
20	4	118	829	0.14
21		154	805	0.19
22		131	869	0.15
23		127	871	0.15

24		92	888	0.10
25		110	863	0.13
26		167	806	0.21
27		186	782	0.24
28		117	891	0.13
29		127	872	0.15
30		116	895	0.13
31		94	927	0.10
32		92	917	0.10
33	3	72	926	0.08
34		47	982	0.05
35		72	922	0.08
36		71	910	0.08
37		98	878	0.11
38		92	899	0.10

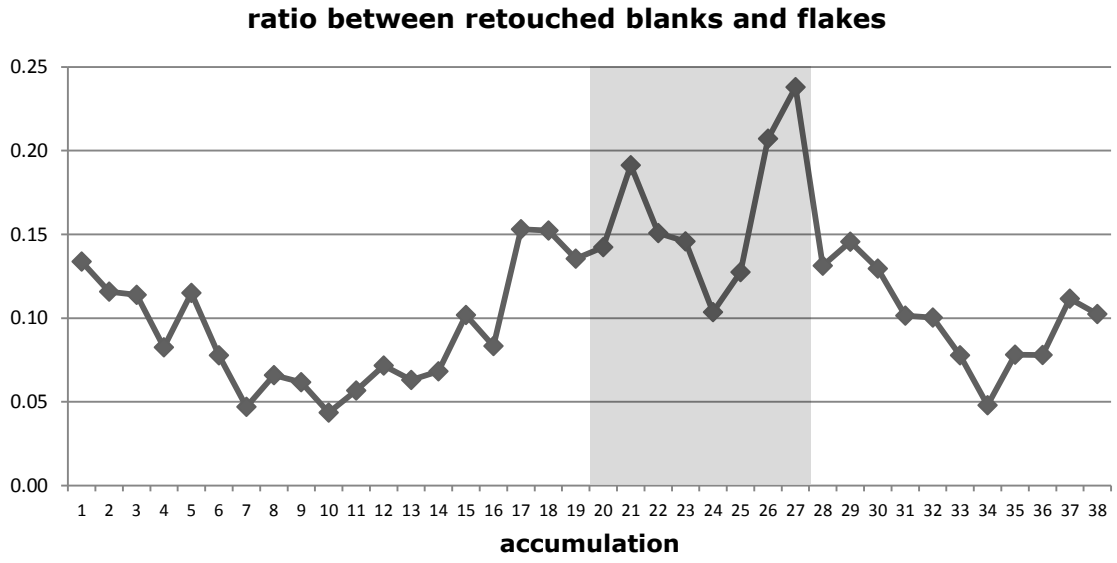

Figure 6 - 35: The ratio between retouched blanks and flakes, per accumulation. The area in light-grey represents accumulations from MIS 4, and its boundaries are approximate.

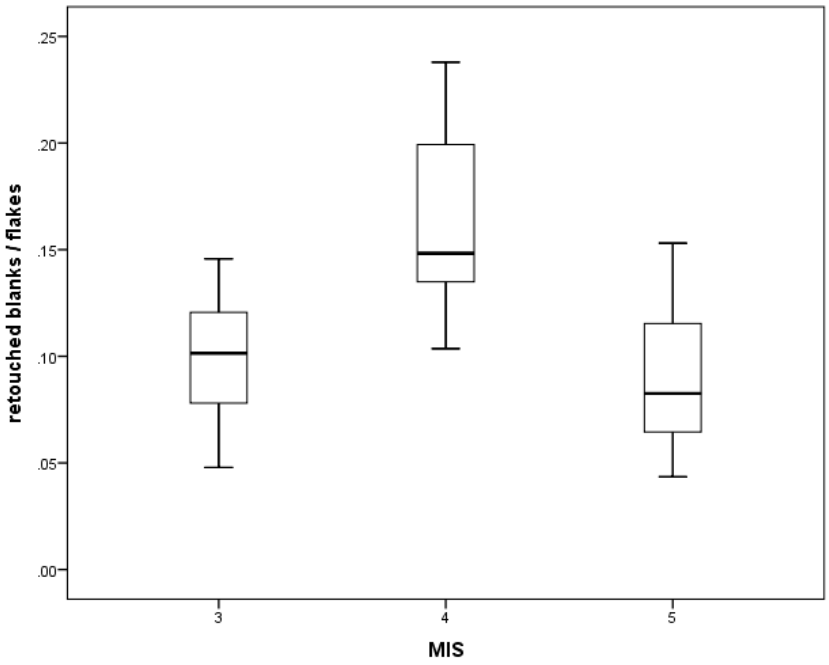

Figure 6 - 36: A boxplot indicating the distribution of retouched blanks-to-flake values in the three isotope stages.

As is clear from Table 6-22 and Figures 6-35 and 6-36, accumulations of MIS 4 exhibit greater relative amount of retouched blanks (Kruskal-Wallis χ^2=11.844, df=2, p=.003; non-parametric Levene's test of homogeneity in variance, p>.05), with the peak in this amount occurring in the last two accumulations (26 and 27). There is no general difference in the relative amount of retouched blanks between MIS 5 and MIS 3 (Kruskal-Wallis χ^2=0.504, df=1, p=.478; non-parametric Levene's test of homogeneity in variance, p>.05). The variation in this ratio within each of the isotope stages can be observed in Figure 6-35. Within MIS 5, the relative amount of retouched blanks decreases from accumulation 5, and then increases from accumulation 12. Within MIS 4 there is a decrease in the relative amount of retouched blanks in the lower part of this sequence, similarly to the lower part of

MIS 3. This variability within individual isotope stages will be explored more with the analysis of the record transformation in Figures 3-40 and 3-41.

Based on the comparison between the average length of complete retouched blanks comprised of categories of 'scrapers' and 'Mousterian points' (Bordes' types 6-31) and the average length of complete flakes (Table 6-23 and Figure 6-37), it is clear that blanks were selected based on their size throughout the sequence of Pech IV (with accumulation 7 not following this pattern).

Table 6 - 23: Summary data related to the average length of complete flakes and the average length of 'scrapers' and 'Mousterian points', per accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation	MIS	N of complete flakes with measured length	average length (mm) of complete flakes	N of 'scrapers' and 'Mousterian points' with measured length	average length (mm) of 'scrapers' and 'Mousterian points'
1		80	37.80	51	50.45
2		76	38.40	53	50.16
3		70	38.18	50	50.73
4		53	37.23	27	51.99
5		71	37.44	26	46.25
6		45	35.23	10	44.19
7		22	36.01	3	32.08
8		32	36.71	3	47.92
9		34	36.11	4	52.75
10	5	23	35.59	3	37.00
11		29	37.77	8	48.05
12		41	37.97	10	51.67
13		34	38.91	9	55.12
14		36	38.62	9	58.56
15		62	40.26	18	52.36
16		43	39.23	20	45.23
17		92	40.60	46	57.48
18		103	39.58	63	56.11
19		92	39.33	67	58.31
20	4	94	38.77	71	55.41

21		125	42.72	102	60.94
22		106	42.06	82	64.94
23		101	40.47	75	61.05
24		74	40.17	50	64.86
25		84	39.93	69	60.03
26		125	39.01	97	57.92
27		144	37.91	117	53.69
28		95	36.04	41	43.81
29		100	36.77	40	45.71
30		92	36.50	24	51.16
31		62	35.90	22	45.29
32		63	36.79	27	41.84
33	3	49	36.54	24	44.96
34		30	34.18	8	41.34
35		43	34.84	10	55.39
36		54	34.39	7	51.62
37		75	36.08	11	43.64
38		74	36.43	8	51.36

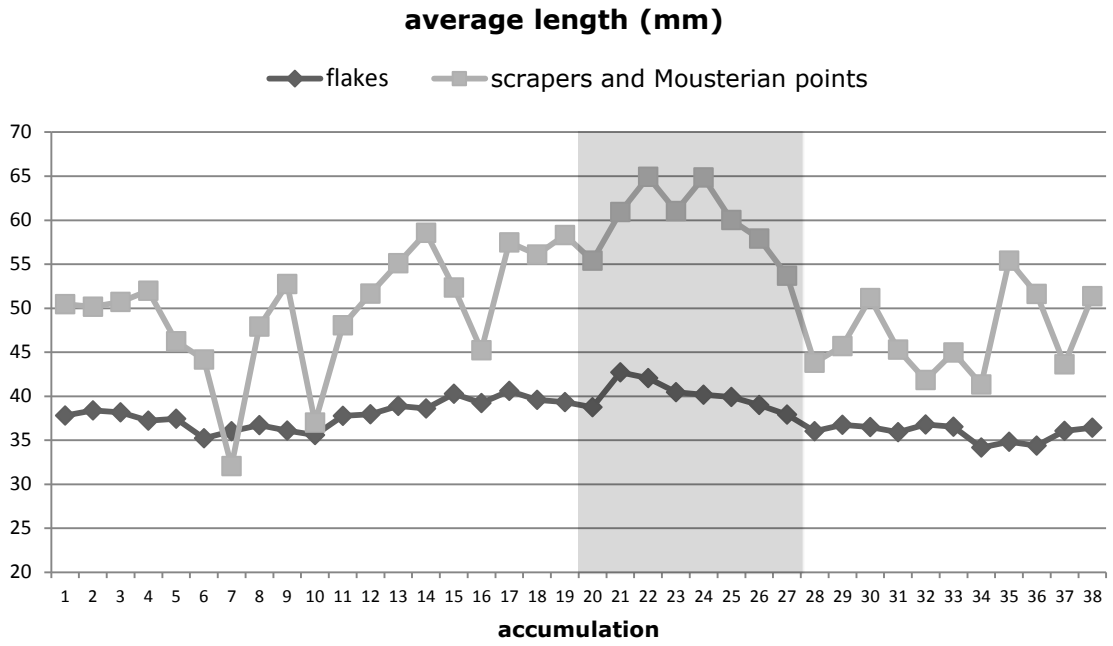

Figure 6 - 37: The average length of complete flakes and 'scrapers' and 'Mousterian points', per accumulation. The area in light-grey represents accumulations from MIS 4, and its boundaries are approximate.

Nevertheless, blank size may have been just one of the factors behind blank selection. To explore the nature of the process of selection more comprehensively, and to evaluate if there was a relationship between selection and the overall blank size (mass) and economy ([length*width]$^{1/2}$/thickness), as well as the amount of cortical surface, binary logistic regression analysis is performed treating all these variables as exploratory or predictive (Tables 6-24 and 6-25). This analysis assesses the synchronous effects of these four variables (length, (length*width)$^{1/2}$/thickness, mass, and the percentage of cortex) on the amount of complete retouched blanks (relative to the amount of complete flakes) in every accumulation. The category of retouched blanks in this analysis includes 'scrapers' and 'denticulates' (Bordes' types 9-31 and 43).

Table 6 - 24: Summary statistic of binary logistic regression between the response variable of the amount of 'scrapers' and 'denticulates' (vs the amount of complete flakes) and the explanatory variables of length, (length*width)$^{1/2}$/thickness, mass, and the amount of cortical surface, per accumulation. Explanatory variables with significant relationship to the amount of 'scrapers' and 'denticulates' are marked in grey.

Accumulation (N of 'scrapers' and 'denticulates', N or complete flakes)	Variables in the equation	**B**	Wald statistic	df	**p**	Exp(B)	95% CI for Exp(B) lower	95% CI for Exp(B) upper
1 (47, 229)	Length	**.061**	11.368	1	**.001**	1.063	1.026	1.102
	(Length*Width)$^{1/2}$ /Thickness	**-.055**	.255	1	**.614**	.947	.766	1.171
	Mass	**-.022**	1.859	1	**.173**	.979	.949	1.010
	% of Cortex	**-.016**	4.219	1	**.040**	.984	.969	.999
	Constant	**-3.564**	23.563	1	**.000**	.028	-	-
2 (48, 231)	Length	**.038**	4.375	1	**.036**	1.039	1.002	1.077
	(Length*Width)$^{1/2}$ /Thickness	**-.111**	1.221	1	**.269**	.895	.734	1.090
	Mass	**.029**	1.737	1	**.187**	1.030	.986	1.075
	% of Cortex	**-.016**	4.761	1	**.029**	.984	.971	.998
	Constant	**-3.011**	17.297	1	**.000**	.049	-	-

3 (50, 214)	Length	**.038**	3.546	1	**.060**	1.039	.998	1.081
	(Length*Width)$^{1/2}$ /Thickness	**.064**	.324	1	**.569**	1.066	.855	1.330
	Mass	**.016**	.540	1	**.463**	1.016	.974	1.059
	% of Cortex	**-.021**	6.769	1	**.009**	.979	.964	.995
	Constant	**-3.464**	20.492	1	**.000**	.031	-	-
4 (32, 236)	Length	**.078**	10.457	1	**.001**	1.081	1.031	1.134
	(Length*Width)$^{1/2}$ /Thickness	**-.106**	.767	1	**.381**	.899	.709	1.141
	Mass	**-.009**	.264	1	**.607**	.991	.957	1.026
	% of Cortex	**-.019**	4.130	1	**.042**	.981	.963	.999
	Constant	**-4.659**	21.483	1	**.000**	.009	-	-
5 (36, 282)	Length	**.008**	.111	1	**.739**	1.008	.961	1.058
	(Length*Width)$^{1/2}$ /Thickness	**.111**	.787	1	**.375**	1.117	.875	1.427
	Mass	**.052**	3.324	1	**.068**	1.053	.996	1.114
	% of Cortex	**-.003**	.251	1	**.616**	.997	.985	1.009
	Constant	**-3.535**	19.602	1	**.000**	.029	-	-
6 (13, 246)	Length	**.052**	1.824	1	**.177**	1.053	.977	1.135
	(Length*Width)$^{1/2}$ /Thickness	**-.013**	.003	1	**.955**	.987	.634	1.537
	Mass	**-.015**	.157	1	**.692**	.985	.915	1.061
	% of Cortex	**.001**	.004	1	**.948**	1.001	.983	1.019
	Constant	**-4.860**	12.550	1	**.000**	.008	-	-
7 (4, 236)	Length	**-.148**	1.055	1	**.304**	.862	.650	1.144
	(Length*Width)$^{1/2}$ /Thickness	**-.264**	.167	1	**.683**	.768	.217	2.721
	Mass	**.144**	1.433	1	**.231**	1.155	.912	1.464
	% of Cortex	**.019**	1.648	1	**.199**	1.019	.990	1.049
	Constant	**-.529**	.024	1	**.878**	.589	-	-
8 (9, 279)	Length	**.025**	.249	1	**.618**	1.026	.929	1.132
	(Length*Width)$^{1/2}$ /Thickness	**-.075**	.086	1	**.770**	.928	.562	1.531
	Mass	**.001**	.000	1	**.985**	1.001	.939	1.066
	% of Cortex	**-.002**	.017	1	**.896**	.998	.976	1.022
	Constant	**-4.131**	6.101	1	**.014**	.016	-	-
9 (7, 234)	Length	**.074**	1.622	1	**.203**	1.077	.961	1.208
	(Length*Width)$^{1/2}$ /Thickness	**.121**	.205	1	**.651**	1.129	.669	1.904
	Mass	**-.012**	.028	1	**.867**	.989	.864	1.131
	% of Cortex	**-.009**	.447	1	**.504**	.991	.963	1.018
	Constant	**-6.977**	14.645	1	**.000**	.001	-	-
10 (5, 243)	Length	**.054**	.970	1	**.325**	1.056	.948	1.175
	(Length*Width)$^{1/2}$ /Thickness	**-.081**	.061	1	**.805**	.922	.484	1.757
	Mass	**-.008**	.022	1	**.882**	.992	.897	1.098
	% of Cortex	**.003**	.065	1	**.799**	1.003	.977	1.030

	Constant	**-5.890**	8.746	1	**.003**	.003	-	-
11 (12, 288)	Length	**.014**	.176	1	**.675**	1.014	.949	1.083
	(Length*Width)$^{1/2}$ /Thickness	**.007**	.001	1	**.972**	1.007	.687	1.477
	Mass	**.009**	.087	1	**.767**	1.009	.949	1.074
	% of Cortex	**-.002**	.038	1	**.846**	.998	.979	1.018
	Constant	**-3.916**	10.938	1	**.001**	.020	-	-
12 (14, 259)	Length	**.042**	1.170	1	**.279**	1.043	.967	1.125
	(Length*Width)$^{1/2}$ /Thickness	**-.435**	2.501	1	**.114**	.647	.378	1.110
	Mass	**.029**	1.363	1	**.243**	1.029	.981	1.080
	% of Cortex	**-.004**	.135	1	**.713**	.996	.977	1.016
	Constant	**-3.518**	8.088	1	**.004**	.030	-	-
13 (13, 294)	Length	**.049**	2.364	1	**.124**	1.051	.987	1.119
	(Length*Width)$^{1/2}$ /Thickness	**-.398**	2.659	1	**.103**	.672	.416	1.084
	Mass	**.021**	.815	1	**.367**	1.021	.976	1.068
	% of Cortex	**-.029**	3.811	1	**.051**	.971	.944	1.000
	Constant	**-3.585**	11.455	1	**.001**	.028	-	-
14 (11, 262)	Length	**.028**	.634	1	**.426**	1.028	.961	1.100
	(Length*Width)$^{1/2}$ /Thickness	**.133**	.393	1	**.531**	1.142	.755	1.727
	Mass	**.043**	2.766	1	**.096**	1.044	.992	1.098
	% of Cortex	**-.008**	.302	1	**.583**	.992	.965	1.020
	Constant	**-5.911**	16.782	1	**.000**	.003	-	-
15 (25, 293)	Length	**.081**	10.474	1	**.001**	1.085	1.033	1.139
	(Length*Width)$^{1/2}$ /Thickness	**-.386**	5.375	1	**.020**	.680	.491	.942
	Mass	**-.056**	3.788	1	**.052**	.945	.893	1.000
	% of Cortex	**-.015**	3.102	1	**.078**	.985	.969	1.002
	Constant	**-3.228**	13.776	1	**.000**	.040	-	-
16 (19, 267)	Length	**.011**	.196	1	**.658**	1.011	.962	1.064
	(Length*Width)$^{1/2}$ /Thickness	**-.161**	.876	1	**.349**	.852	.609	1.192
	Mass	**.008**	.109	1	**.741**	1.008	.963	1.054
	% of Cortex	**-.009**	1.022	1	**.312**	.991	.975	1.008
	Constant	**-2.315**	5.527	1	**.019**	.099	-	-
17 (49, 368)	Length	**.081**	17.907	1	**.000**	1.084	1.044	1.125
	(Length*Width)$^{1/2}$ /Thickness	**-.312**	6.326	1	**.012**	.732	.574	.933
	Mass	**-.003**	.049	1	**.824**	.997	.970	1.024
	% of Cortex	**-.015**	4.828	1	**.028**	.985	.972	.998
	Constant	**-4.254**	37.943	1	**.000**	.014	-	-
18 (72, 325)	Length	**.051**	11.640	1	**.001**	1.052	1.022	1.083
	(Length*Width)$^{1/2}$ /Thickness	**-.068**	.523	1	**.470**	.934	.778	1.123
	Mass	**.006**	.322	1	**.571**	1.006	.985	1.028

	% of Cortex	**-.002**	.103	1	**.748**	.998	.989	1.008
	Constant	**-3.761**	40.671	1	**.000**	.023	-	-
19 (67, 307)	Length	**.089**	29.405	1	**.000**	1.093	1.059	1.129
	(Length*Width)$^{1/2}$ /Thickness	**-.294**	8.158	1	**.004**	.746	.610	.912
	Mass	**-.013**	1.350	1	**.245**	.988	.967	1.009
	% of Cortex	**-.035**	19.491	1	**.000**	.965	.950	.981
	Constant	**-3.668**	31.539	1	**.000**	.026	-	-
20 (69, 306)	Length	**.066**	15.212	1	**.000**	1.068	1.033	1.104
	(Length*Width)$^{1/2}$ /Thickness	**-.059**	.323	1	**.570**	.943	.769	1.156
	Mass	**-.004**	.102	1	**.749**	.996	.973	1.020
	% of Cortex	**-.016**	7.748	1	**.005**	.984	.973	.995
	Constant	**-4.058**	42.421	1	**.000**	.017	-	-
21 (101, 365)	Length	**.060**	22.046	1	**.000**	1.061	1.035	1.088
	(Length*Width)$^{1/2}$ /Thickness	**-.033**	.206	1	**.650**	.968	.840	1.115
	Mass	**.007**	.416	1	**.519**	1.007	.986	1.029
	% of Cortex	**-.023**	14.989	1	**.000**	.977	.966	.989
	Constant	**-4.022**	49.246	1	**.000**	.018	-	-
22 (80, 390)	Length	**.087**	39.856	1	**.000**	1.091	1.062	1.120
	(Length*Width)$^{1/2}$ /Thickness	**-.088**	1.242	1	**.265**	.916	.785	1.069
	Mass	**-.005**	.274	1	**.601**	.995	.976	1.014
	% of Cortex	**-.030**	18.131	1	**.000**	.970	.957	.984
	Constant	**-5.207**	55.041	1	**.000**	.005	-	-
23 (79, 343)	Length	**.066**	24.129	1	**.000**	1.068	1.040	1.096
	(Length*Width)$^{1/2}$ /Thickness	**-.010**	.016	1	**.900**	.990	.842	1.163
	Mass	**.014**	1.729	1	**.189**	1.015	.993	1.037
	% of Cortex	**-.022**	13.419	1	**.000**	.978	.967	.990
	Constant	**-4.628**	51.167	1	**.000**	.010	-	-
24 (46, 330)	Length	**.083**	25.312	1	**.000**	1.086	1.052	1.122
	(Length*Width)$^{1/2}$ /Thickness	**.132**	1.632	1	**.201**	1.141	.932	1.398
	Mass	**.016**	1.614	1	**.204**	1.016	.991	1.041
	% of Cortex	**-.024**	8.888	1	**.003**	.976	.960	.992
	Constant	**-6.966**	49.961	1	**.000**	.001	-	-
25 (71, 310)	Length	**.056**	18.044	1	**.000**	1.057	1.030	1.084
	(Length*Width)$^{1/2}$ /Thickness	**.041**	.209	1	**.648**	1.041	.875	1.240
	Mass	**.007**	.407	1	**.524**	1.007	.985	1.029
	% of Cortex	**-.019**	11.452	1	**.001**	.981	.971	.992
	Constant	**-4.249**	39.338	1	**.000**	.014	-	-
26 (99, 280)	Length	**.078**	32.085	1	**.000**	1.081	1.052	1.111
	(Length*Width)$^{1/2}$ /Thickness	**-.002**	.001	1	**.975**	.998	.858	1.160

	Mass	**.001**	.016	1	**.901**	1.001	.987	1.015
	% of Cortex	**-.015**	9.954	1	**.002**	.985	.977	.994
	Constant	**-4.628**	48.100	1	**.000**	.010	-	-
27 (116, 279)	Length	**.039**	8.085	1	**.004**	1.040	1.012	1.069
	(Length*Width)$^{1/2}$ /Thickness	**-.220**	5.716	1	**.017**	.802	.670	.961
	Mass	**.012**	2.538	1	**.111**	1.012	.997	1.028
	% of Cortex	**-.017**	13.721	1	**.000**	.983	.974	.992
	Constant	**-1.737**	11.006	1	**.001**	.176	-	-
28 (58, 417)	Length	**.043**	5.575	1	**.018**	1.044	1.007	1.082
	(Length*Width)$^{1/2}$ /Thickness	**-.340**	7.190	1	**.007**	.712	.555	.913
	Mass	**-.001**	.005	1	**.942**	.999	.978	1.020
	% of Cortex	**-.011**	5.224	1	**.022**	.989	.979	.998
	Constant	**-2.152**	11.309	1	**.001**	.116	-	-
29 (62, 443)	Length	**.018**	1.124	1	**.289**	1.019	.984	1.054
	(Length*Width)$^{1/2}$ /Thickness	**-.073**	.430	1	**.512**	.930	.747	1.156
	Mass	**.020**	3.260	1	**.071**	1.020	.998	1.043
	% of Cortex	**-.014**	6.837	1	**.009**	.986	.976	.997
	Constant	**-2.445**	15.874	1	**.000**	.087	-	-
30 (58, 442)	Length	**.053**	9.012	1	**.003**	1.055	1.019	1.092
	(Length*Width)$^{1/2}$ /Thickness	**-.195**	2.654	1	**.103**	.823	.650	1.040
	Mass	**-.012**	.839	1	**.360**	.988	.962	1.014
	% of Cortex	**-.016**	8.338	1	**.004**	.984	.973	.995
	Constant	**-2.876**	21.832	1	**.000**	.056	-	-
31 (44, 409)	Length	**.029**	1.570	1	**.210**	1.030	.984	1.078
	(Length*Width)$^{1/2}$ /Thickness	**-.232**	2.820	1	**.093**	.793	.604	1.040
	Mass	**-.006**	.153	1	**.695**	.994	.965	1.024
	% of Cortex	**-.024**	11.064	1	**.001**	.976	.962	.990
	Constant	**-1.848**	6.441	1	**.011**	.158	-	-
32 (37, 349)	Length	**.017**	.407	1	**.523**	1.017	.966	1.070
	(Length*Width)$^{1/2}$ /Thickness	**-.104**	.603	1	**.437**	.902	.694	1.171
	Mass	**.006**	.078	1	**.780**	1.006	.967	1.046
	% of Cortex	**-.019**	7.236	1	**.007**	.981	.968	.995
	Constant	**-2.131**	8.235	1	**.004**	.119	-	-
33 (30, 360)	Length	**.078**	10.104	1	**.001**	1.081	1.030	1.135
	(Length*Width)$^{1/2}$ /Thickness	**-.189**	1.712	1	**.191**	.828	.623	1.099
	Mass	**-.034**	2.467	1	**.116**	.967	.927	1.008
	% of Cortex	**-.007**	.944	1	**.331**	.993	.980	1.007
	Constant	**-4.395**	28.328	1	**.000**	.012	-	-
34	Length	**.075**	3.714	1	**.054**	1.078	.999	1.164

(12, 256)	(Length*Width)$^{1/2}$ /Thickness	**-.135**	.294	1	**.588**	.873	.536	1.424
	Mass	**-.018**	.265	1	**.607**	.982	.918	1.051
	% of Cortex	**.005**	.361	1	**.548**	1.005	.988	1.024
	Constant	**-5.655**	19.873	1	**.000**	.004	-	-
35 (21, 335)	Length	**.083**	7.261	1	**.007**	1.087	1.023	1.154
	(Length*Width)$^{1/2}$ /Thickness	**-.083**	.178	1	**.673**	.920	.625	1.355
	Mass	**.002**	.013	1	**.910**	1.002	.975	1.028
	% of Cortex	**-.002**	.082	1	**.775**	.998	.983	1.013
	Constant	**-6.016**	27.073	1	**.000**	.002	-	-
36 (23, 323)	Length	**.065**	4.945	1	**.026**	1.067	1.008	1.130
	(Length*Width)$^{1/2}$ /Thickness	**-.171**	.640	1	**.424**	.842	.554	1.282
	Mass	**-.005**	.073	1	**.787**	.995	.963	1.029
	% of Cortex	**-.007**	.774	1	**.379**	.993	.977	1.009
	Constant	**-4.482**	20.444	1	**.000**	.011	-	-
37 (29, 361)	Length	**.059**	4.835	1	**.028**	1.061	1.006	1.118
	(Length*Width)$^{1/2}$ /Thickness	**-.242**	1.567	1	**.211**	.785	.537	1.147
	Mass	**-.035**	2.037	1	**.153**	.966	.921	1.013
	% of Cortex	**-.012**	2.985	1	**.084**	.988	.974	1.002
	Constant	**-3.213**	14.838	1	**.000**	.040	-	-
38 (27, 425)	Length	**.075**	8.526	1	**.004**	1.078	1.025	1.134
	(Length*Width)$^{1/2}$ /Thickness	**-.478**	5.959	1	**.015**	.620	.422	.910
	Mass	**-.020**	1.223	1	**.269**	.980	.946	1.015
	% of Cortex	**-.017**	4.130	1	**.042**	.983	.967	.999
	Constant	**-3.571**	13.572	1	**.000**	.028	-	-

In the lowermost accumulations (1-4), blank length and the amount of cortex are the two variables related with the relative amount of complete retouched blanks ('scrapers' and 'denticulates'), as seen in the *p* column in Table 6-24. However, beta (*B*) values of regressions of these two predictor variables indicate that the relationship between the relative amount of complete retouched blanks and length is positive, while the relationship between this amount and the amount of cortex in negative. What these results suggest is that during accumulations 1-4, the selection

of blanks was related to those blanks that were longer and with less cortex. Nevertheless, it is possible that the relation between the relative amounts of complete retouched blanks and reduced cortex is just a result of selection for larger blanks which happened to be covered with a relatively smaller amount of cortex. In any case, the relative amounts of complete retouched blanks in these accumulations are not related to mass or to the ratio between surface area and thickness. This indicates that the process of selection of blanks during this period of cave occupation included little or no consideration of blank overall size or their economic properties.

For most of MIS 5, the selection of blanks is not related to any of the regressed predictive variables. As the low quantity of complete retouched blanks in most of these accumulations indicates (Table 6-22, Figure 6-35), the intensity of blank selection was generally. This intensity, however, changes in the last three accumulations of this stage (17, 18, and 19) where the selection of blanks was related with greater length, less cortex, and, what is most interesting, greater thickness relative to the surface area (Table 6-24).

The relationship between the relative amount of complete retouched blanks with greater length and greater thickness could actually be a result of more intensive lateral retouch among retouched blanks. Intensive lateral retouch would affect the width of those blanks, which is used for calculating their surface area (decreasing, therefore, the ratio between their surface and their thickness). If we look at the analysis of economic flake production based on EPA and PD values, then these three accumulations exhibit less economic flake production (they plot in the

lower right quadrant in Figure 6-30). This suggests that retouched blanks in these accumulations were selected from the population of already relatively thick blanks. Perhaps this can be taken to confirm that selection of blanks was here not oriented towards thicker blanks, but that greater relative thickness among retouched blanks is a result of retouch (which would result in them being even thicker relative to their surface than flakes that are left non-retouched). In addition, if we look at the ratio between the amount of 'scrapers' exhibiting higher degree of retouch (double, convergent, transverse, *déjéte* and *limace*) and the total amount of complete retouched blanks ('scrapers' and 'denticulates') (Table 6-25, Figure 6-38), the intensity of retouch, that is, tool management, is relatively higher in accumulations 17, 18, and 19.

The results of binary logistic regression for accumulations of MIS 4 imply that during these times the process of blank selection was related again with blanks that were longer and had less cortex, except in the last accumulation of this stage: 27. As seen in the subsequent accumulation 28 (MIS 3), blank selection practices were similar to those in the last accumulations of MIS 5. They involved blanks that were longer, had less cortex, and were relatively thicker.

There are two insights from this observation. One, because these two accumulations (27 and 28) also show less economic flake production (Figure 6-30), and at the same time a relatively higher intensity of retouch (Figure 6-38), it is most likely that, just like in the last three accumulations of MIS 5, the relationship between thicker blanks and retouch is not associated with selection but rather the production of thicker blanks (Figure 6-35). And two, relating to the accumulations

of MIS 4 in general, because selection during this stage was evidently oriented towards longer blanks that had smaller relative amount of cortex, and since cortex ratio analysis indicated that during this stage there was an import of cortex into the cave, this import during MIS 4 most likely involved cortical *unretouched* blanks, which, once imported, largely remained unretouched.

Generally, MIS 4 is the stage when the intensity of tool management in the form of retouch was the highest (Table 6-25, Figures 6-38 and 6-39) ($p<.05$ in the Levene's nonparametric test of homogeneity in variance, therefore ANOVA was performed on log transformed values [without accumulations 7-12, and 38, due to lack of 'scrapers' with higher degree of retouch]: $F=15,485$, $df=2,28$, $p<.001$). By observing the distribution of MIS 4 accumulations in the EPA-PD graph (Figure 6-30), it can be noted that there is no relationship between this high intensity of tool management and a particular economic property of produced flakes during this stage. For example, accumulations 21, 22, 23, and 25 are among the accumulations with the most economical flakes, while accumulations 26 and 27 are among accumulations with the least economical flakes. The significance of this observation is in interpreting blank production and blank selection as two processes of stone provisioning that are independent of each other, and which do not have to be correlated even within a single isotope stage. The correlation between different processes of stone provisioning will be explored and discussed more in the next chapter.

During MIS 3, blank selection was again oriented towards longer blanks. In the lower part of this stage (accumulations 28-32) it seems that blank selection was

also related with a lower amount of cortex, while there is no relation between the process of selection and the amount of cortex in the upper accumulations. Most likely such differences between the lower and the upper accumulations is a result of more intensive export of non-cortical flakes in the upper part of MIS 3, as discussed in the previous section of this chapter. In other words, the population of flakes (that were left in the cave) from which to select towards the end of MIS 3 was increasingly cortical, resulting in no significant difference in the amount of cortex between retouched blanks and flakes. Finally, during this stage, even though this is the time of less economic flake production (Figure 6-30), there is no relationship between blank selection and greater thickness, which contrasts with the end of MIS 5 and to the end of MIS 4. This difference is attributable to the low intensity of retouch or tool management during this stage in the cave (Figures 6-38 and 6-39), which creates the ratio between surface area and thickness for retouched blanks not significantly different than for flakes.

Table 6 - 25: Summary data related to the ratio between the number of 'scrapers' with higher degree of retouch and the number of all 'scrapers' and 'denticulates', per accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation	MIS	N of 'scrapers' with higher degree of retouch [1]	N of 'scrapers' and 'denticulates'	N of 'scrapers' with higher degree of retouch [1] / N of 'scrapers' and 'denticulates'
1		23	49	0.47
2		16	56	0.29
3		17	53	0.32
4	5	10	33	0.30
5		5	42	0.12
6		4	22	0.18
7		0	12	0.00

8		0	13	0.00
9		0	15	0.00
10		0	14	0.00
11		0	16	0.00
12		0	22	0.00
13		2	17	0.12
14		1	21	0.05
15		2	30	0.07
16		4	28	0.14
17		10	50	0.20
18		22	64	0.34
19		33	59	0.56
20		22	65	0.34
21		39	87	0.45
22		28	75	0.37
23	4	35	66	0.53
24		20	45	0.44
25		30	64	0.47
26		56	81	0.69
27		59	99	0.60
28		14	54	0.26
29		18	62	0.29
30		5	61	0.08
31		3	61	0.05
32		3	51	0.06
33	3	7	38	0.18
34		1	23	0.04
35		1	40	0.03
36		1	35	0.03
37		2	39	0.05
38		0	39	0.00

[1] Double, convergent, transverse, *déjéte*, and *limace* 'scrapers'.

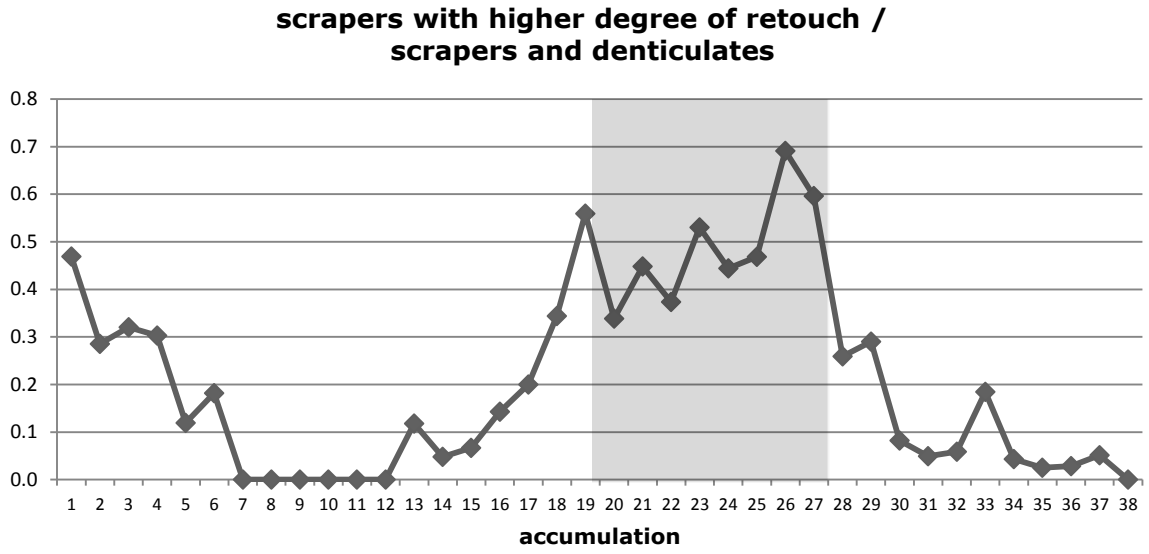

Figure 6 - 38: The ratio between the number of scrapers' with higher degree of retouch (double, convergent, transverse, *déjéte*, and *limace*) and the number of all 'scrapers' and 'denticulates', per accumulation. The area in light-grey represents accumulations from MIS 4, and its boundaries are approximate.

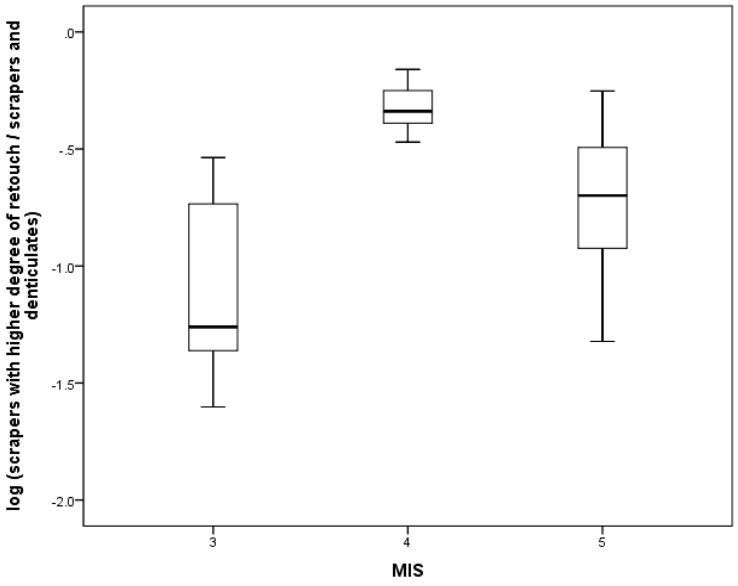

Figure 6 - 39: A boxplot indicating the distribution of log ('scrapers' with higher degree of retouch / 'scrapers' and 'denticulates') values in the three isotope stages.

Table 6-26 and Figures 6-40, and 6-41 present the transformation of the record of Pech IV in relation to the ratio between retouched blanks and flakes, that is, to the process of blank selection. For the majority of their formation, the record of MIS 5 and the record of MIS 3 were transformed in the same direction: towards a decrease in the relative amount of retouched blanks. The intensity of blank selection decreased until right before the end where there is a slight increase in the relative amount of retouched blanks (Figure 6-41). Based on this history of directionality of record transformation, we cannot say that variability in selection practices was low throughout the occupations during these two stages. Blank selection practices also varied during MIS 4.

The degree of intensification of selection practices seems to follow a linear pattern throughout the history of cave occupation. This can be observed with the average difference in the relative amount of retouched blanks between each of the accumulations and the record below them (Figure 6-41). The highest average (absolute) difference in this process occurred during MIS 5 (33%), then MIS 4 (29%), and lastly, during MIS 3 (22%). Again, this is about intensification in particular selection practices, -- not the intensification of selection. Some of these practices led to a high degree of selection, while others to a low degree of selection. From these insights into variability in selection practices and their intensification, it can be argued that during MIS 3 the process of blank selection was generally more uniform than during the previous two stages.

Table 6 - 26: Transformation of the ratio between retouched blanks and flakes in the record of Pech IV throughout its accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation sequence	MIS	retouched blanks / flakes	**accumulation**	retouched blanks / flakes	difference (%) in retouched blanks / flakes, relative to the accumulation sequence below
1		0.13	**2**	0.12	-13.45
1-2		0.12	**3**	0.11	-8.67
1-3		0.12	**4**	0.08	-31.76
1-4		0.11	**5**	0.12	3.35
1-5		0.11	**6**	0.08	-30.52
1-6		0.11	**7**	0.05	-55.61
1-7		0.10	**8**	0.07	-31.78
1-8		0.09	**9**	0.06	-33.57
1-9		0.09	**10**	0.04	-51.21
1-10	5	0.08	**11**	0.06	-32.65
1-11		0.08	**12**	0.07	-12.33
1-12		0.08	**13**	0.06	-22.02
1-13		0.08	**14**	0.07	-14.19
1-14		0.08	**15**	0.10	29.45
1-15		0.08	**16**	0.08	3.85
1-16		0.08	**17**	0.15	90.51
1-17		0.08	**18**	0.15	80.59
1-18		0.09	**19**	0.14	54.17
1-19		0.09	**-**	-	-
20		0.14	**21**	0.19	34.40
20-21		0.17	**22**	0.15	-9.44
20-22		0.16	**23**	0.15	-9.44
20-23	4	0.16	**24**	0.10	-34.05
20-24		0.15	**25**	0.13	-12.66
20-25		0.14	**26**	0.21	45.07
20-26		0.15	**27**	0.24	56.92
20-27		0.16	**-**	-	0.00
28		0.13	**29**	0.15	10.91
28-29		0.14	**30**	0.13	-6.35
28-30		0.14	**31**	0.10	-25.13
28-31	3	0.13	**32**	0.10	-20.78
28-32		0.12	**33**	0.08	-35.89
28-33		0.11	**34**	0.05	-57.96
28-34		0.10	**35**	0.08	-24.73

28-35	0.10	**36**	0.08	-22.38
28-36	0.10	**37**	0.11	13.86
28-37	0.10	**38**	0.10	3.01
28-38	0.10	-	-	-

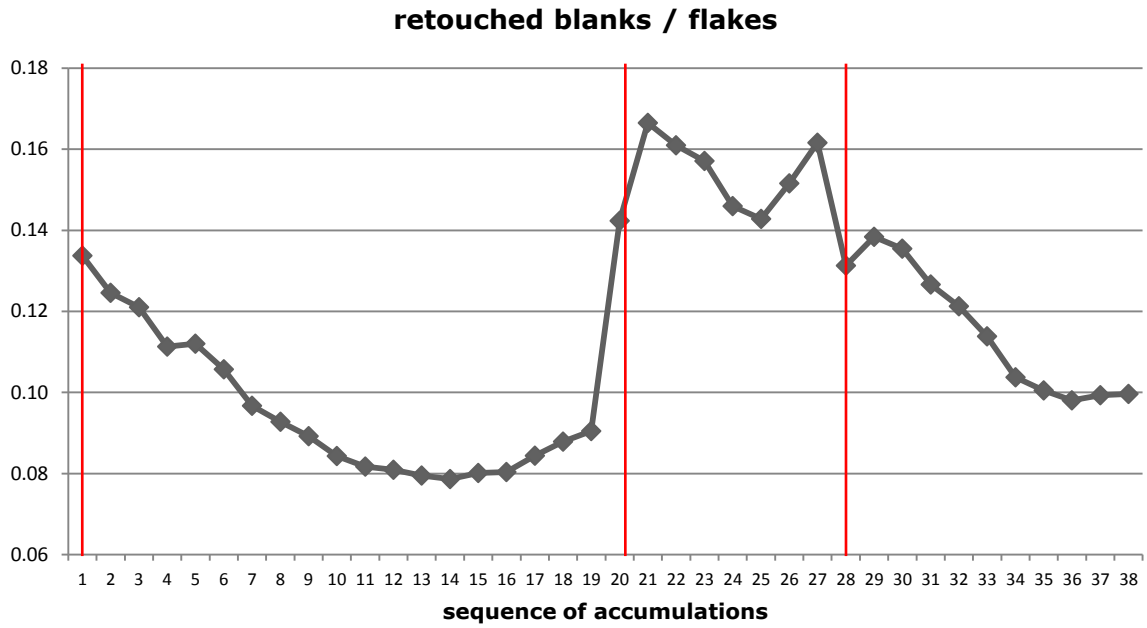

Figure 6 - 40: The ratio between retouched blanks and flakes, per sequence of accumulations (third column in Table 6-26). Red vertical lines represent the beginning of a new sequencing process (placed approximately at the start of a new climatic stage). Numbers on the horizontal axis denote the extent of the sequence of accumulations, e.g., the cortex ratio at number '24' is the ratio of the sequence of accumulations 20-24.

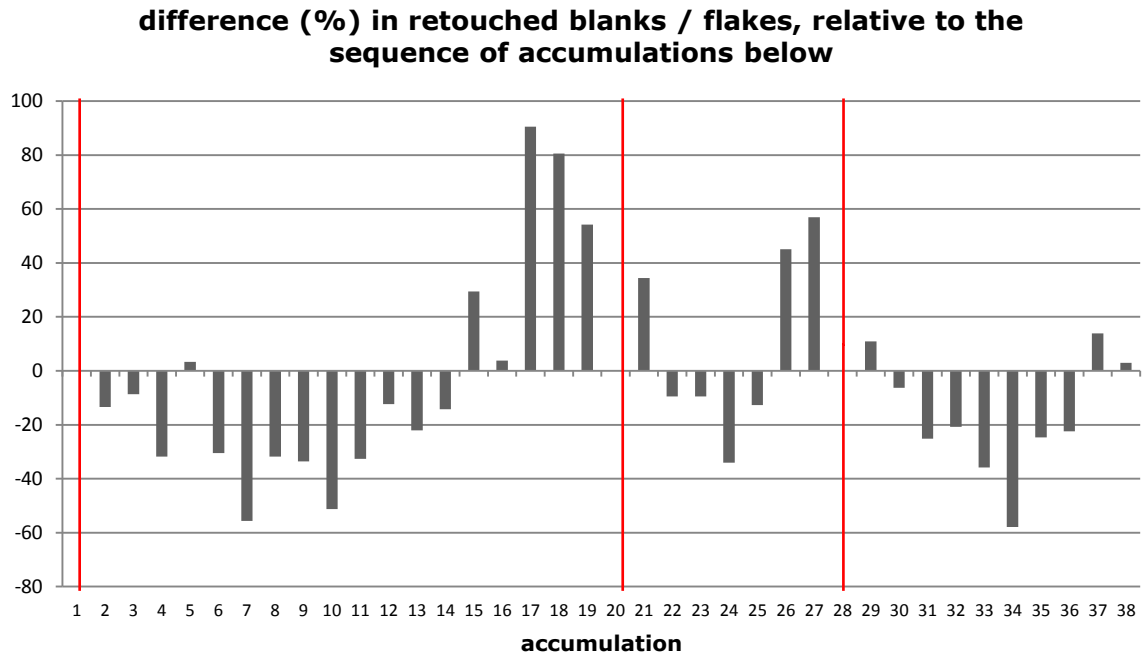

Figure 6 - 41: The relative change in the ratio between retouched blanks and flakes between each accumulation and the sequence of accumulations occurring below it (the last column in Table 6-26). Red vertical lines represent the beginning of a new sequencing process (placed approximately at the start of a new climatic stage).

Below is transformation of Pech IV record related to the process of tool management, as measured with the amount of 'scrapers' with higher degree of retouch relative to the amount of all 'scrapers' and 'denticulates' (Table 6-27; Figures 6-42 and 6-43). Compared to the process of selection (Figure 6-40), the record of MIS 5 and the record of MIS 3 during their formation were also transformed mostly in the same direction: towards the decrease in the relative amount of tools with higher degree of retouch (Figure 6-42). However, now the record of MIS 4 is transformed throughout this stage mostly in one direction, indicating the increase in tool management throughout its formation with the peak at the end of this stage. Variability in the practices of tool management was low during all three stages.

According to the average difference in the relative amount of highly retouched tools between each accumulation and the sequence of accumulations occurring below it (Figure 6-43), intensification in the respective tool management practices (whatever these practices were like) at Pech IV was much higher during MIS 5 (69%) and MIS 3 (64%) than during MIS 4 (25%). All of these observations indicate that the process of tool management was the most uniform during MIS 4.

Table 6 - 27: Transformation of the ratio between the number of 'scrapers' with higher degree of retouch and the number of all 'scrapers' and 'denticulates' in the record of Pech IV throughout its accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation sequence	MIS	'scrapers' with higher degree of retouch / 'scrapers' and 'denticulates'	**accumulation**	'scrapers' with higher degree of retouch / 'scrapers' and 'denticulates'	difference (%) in ('scrapers' with higher degree of retouch / 'scrapers' and 'denticulates') relative to the accumulation sequence below
			-	-	-
1		0.47	**2**	0.29	-39.13
1-2		0.37	**3**	0.32	-13.64
1-3		0.35	**4**	0.30	-14.50
1-4		0.35	**5**	0.12	-65.55
1-5		0.30	**6**	0.18	-40.33
1-6		0.29	**7**	0.00	-100.00
1-7		0.28	**8**	0.00	-100.00
1-8		0.27	**9**	0.00	-100.00
1-9	5	0.25	**10**	0.00	-100.00
1-10		0.24	**11**	0.00	-100.00
1-11		0.23	**12**	0.00	-100.00
1-12		0.22	**13**	0.12	-45.57
1-13		0.21	**14**	0.05	-77.49
1-14		0.20	**15**	0.07	-67.09
1-15		0.19	**16**	0.14	-25.89
1-16		0.19	**17**	0.20	5.48
1-17		0.19	**18**	0.34	80.29

1-18		0.21	**19**	0.56	168.57
1-19		0.24	**-**	-	-
20		0.34	**21**	0.45	32.45
20-21		0.40	**22**	0.37	-6.97
20-22		0.39	**23**	0.53	35.26
20-23	4	0.42	**24**	0.44	5.02
20-24		0.43	**25**	0.47	10.03
20-25		0.43	**26**	0.69	59.73
20-26		0.48	**27**	0.60	25.15
20-27		0.50	**-**	-	-
28		0.26	**29**	0.29	11.98
28-29		0.28	**30**	0.08	-70.29
28-30		0.21	**31**	0.05	-76.47
28-31		0.17	**32**	0.06	-65.00
28-32		0.15	**33**	0.18	23.81
28-33	3	0.15	**34**	0.04	-71.57
28-34		0.15	**35**	0.03	-82.84
28-35		0.13	**36**	0.03	-78.57
28-36		0.12	**37**	0.05	-58.88
28-37		0.12	**38**	0.00	-100.00
28-38		0.11	-	-	-

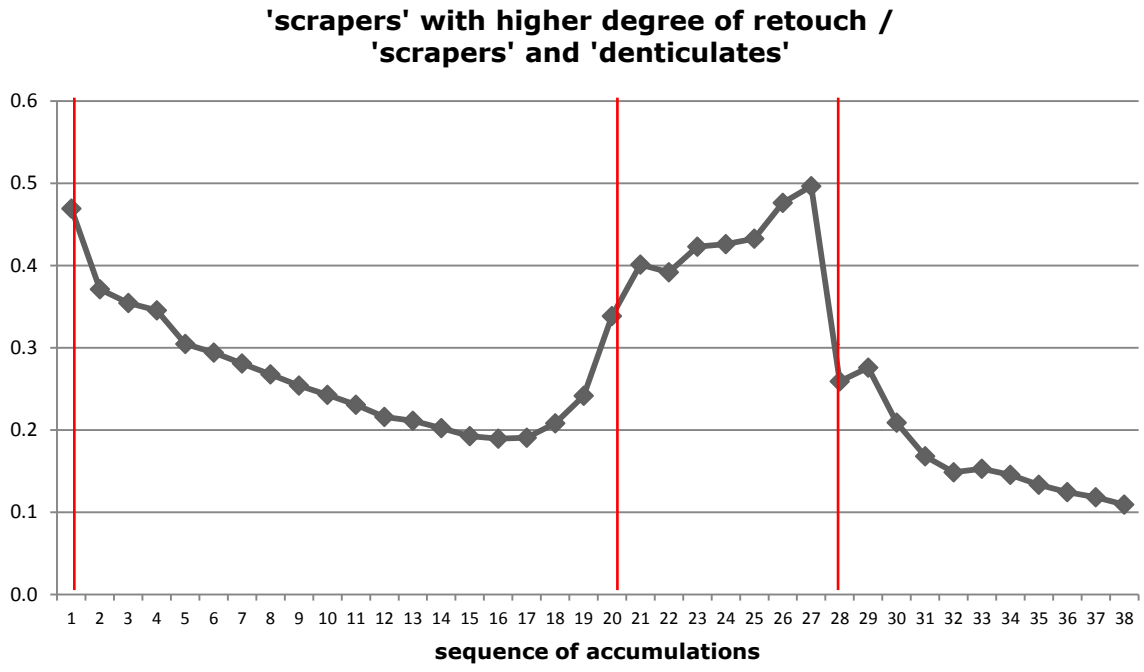

Figure 6 - 42: The ratio between the number of 'scrapers' with higher degree of retouch and the number of all 'scrapers' and 'denticulates', per sequence of accumulations (third column in Table 6-27). Red vertical lines represent the beginning of a new sequencing process (placed approximately at the start of a new climatic stage). Numbers on the horizontal axis denote the extent of the sequence of accumulations, e.g., the cortex ratio at number '24' is the ratio of the sequence of accumulations 20-24.

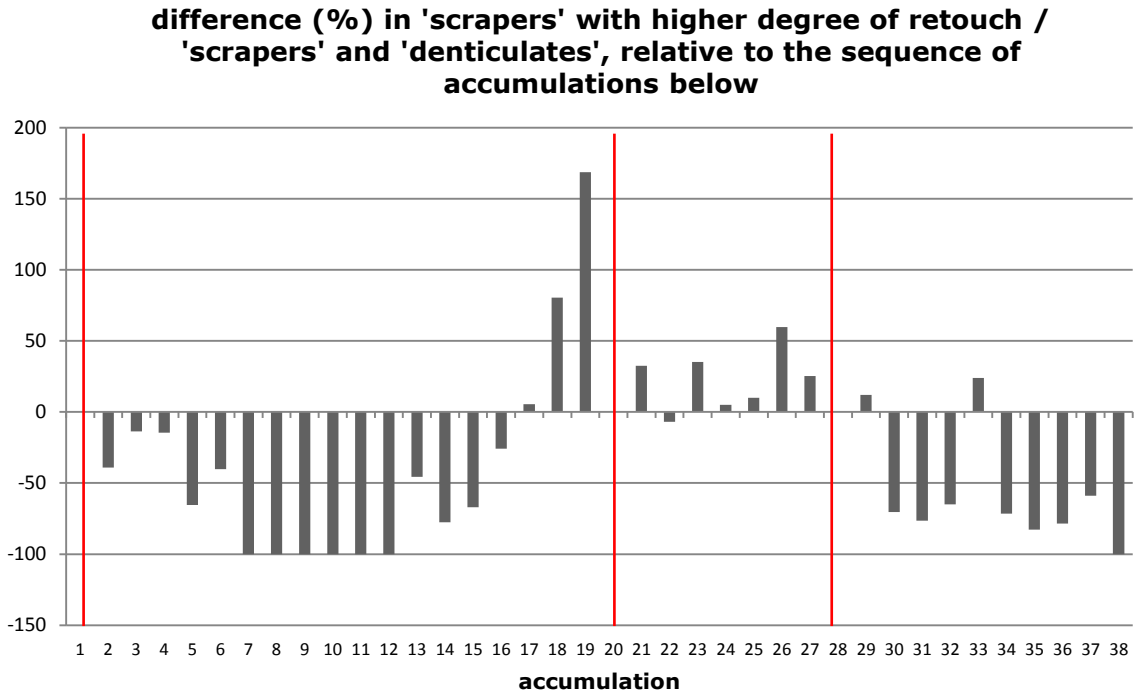

Figure 6 - 43: The relative change in the ratio between the number of 'scrapers' with higher degree of retouch and the number of all 'scrapers' and 'denticulates' between each accumulation and the sequence of accumulations occurring below it (the last column in Table 6-27). Red vertical lines represent the beginning of a new sequencing process (placed approximately at the start of a new climatic stage).

Chapter 7: Discussion

7.1 The use of Pech IV

The analysis of different processes of stone provisioning clearly suggests that there was variability in the use of Pech IV throughout its history. The structure of the stone artifact record in this cave is characterized more by variability than reoccurring patterns in stone provisioning. This indicates that the processes of movement of stone, its reduction and flaking intensity, blank production, and tool selection and management were intertwined together in a dynamic and non-uniform way during the use of this place and the landscape.

To explore the dynamics and scale of operation of each of these processes during the history of the use of Pech IV, and to determine whether if there is a relation between these scales of operation, a series of semivariograms (Chiles & Delfiner, 1999) is produced and shown in Figures 7-1, 7-2, 7-3, 7-4, 7-5, and 7-6 for these five processes. Each of the semivariogram models the spatial dependence for one process by analyzing correlation between the values for the respective process and the distance along the Pech IV sequence. In other words, they model a degree of dissimilarity between observations (accumulations) as a function of the distance between them.

Distance is here measured in the number of accumulations apart, and not, for example, in a specific vertical increment along the sequence. For example, the semivariogram in Figure 7-1 models the dependence or spatial autocorrelation in cortex ratio along the entire sequence by examining the difference in the value of

this ratio between pairs of two accumulations at thirty-seven different lag distances. On the horizontal axis of this semivariogram, the distance of 1 stands for the pairing of every accumulation with its subsequent accumulation, making, therefore, thirty-seven observations. Each of these thirty-seven observations is a squared difference between the two values of the cortex ratio in the respective pair of accumulations. The value at this distance on the vertical axis of the graph -- the semivariance -- is the half of the average of these thirty-seven observations, that is, half of these thirty-seven squared differences (or variances). At the distance of 2, the difference in cortex ratio is examined between the pairs of accumulations that are two accumulations apart. This makes thirty-six observations or pairs that are the same lag distance from each other. The greatest distance is 37 accumulations apart, which makes possible only one observation; between accumulation 1 and accumulation 38.

Since the distance used in the modeling of semivariograms is measured in the number of accumulations apart vertically from each other (along the Pech IV sequence), spatial autocorrelation here actually means autocorrelation through time: an increase or decrease in the value of interest across the formation of the Pech IV record. The semivariance at a distance of 0 should be zero, because that would represent a comparison of each of the accumulations to itself. The semivariance increases as accumulations are compared to increasingly distant accumulations, but only until a certain distance, -- the range. The range is the greatest distance over which the observed value at an accumulation is related to such value at another accumulation. The range is the distance where autocorrelation ends, and beyond this distance the accumulations (or their observed values) are no

longer spatially autocorrelated but independent of each other. The semivariance value at the range is known as 'sill'. In the application of semivariograms as shown here, the differences in the range and sill values for the five observed processes – movement of stone, its reduction and flaking intensity, blank production, and tool selection and management – are used to gain insights into the differences in the scale of operation between these processes.

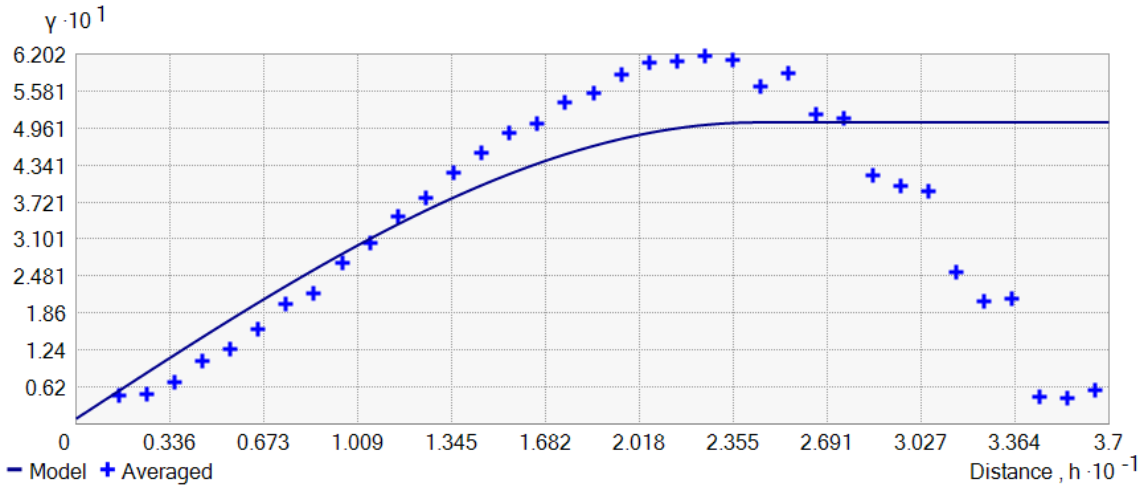

Figure 7 - 1: A semivariogram presenting spatial dependence of the process of stone movement, measured with cortex ratio. Log values of cortex ratio are used. The modeling was performed using spherical function. Range=24, sill=0.506

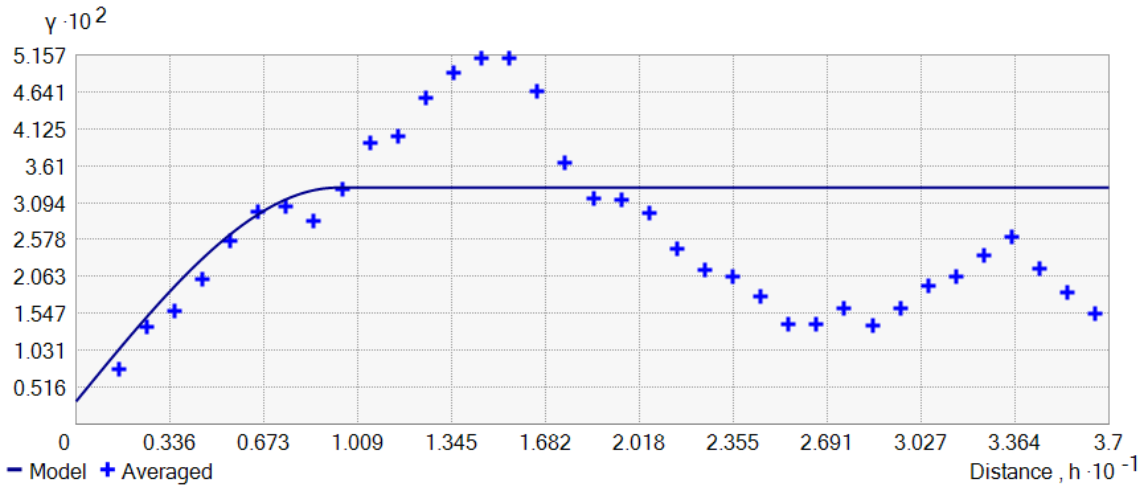

Figure 7 - 2: A semivariogram presenting spatial dependence of the process of flaking intensity, measured as small non-cortical flakes/non-cortical flakes. Log values of (small non-cortical flakes/non-cortical flakes) are used. The modeling was performed using spherical function. Range=9.4, sill=0.033

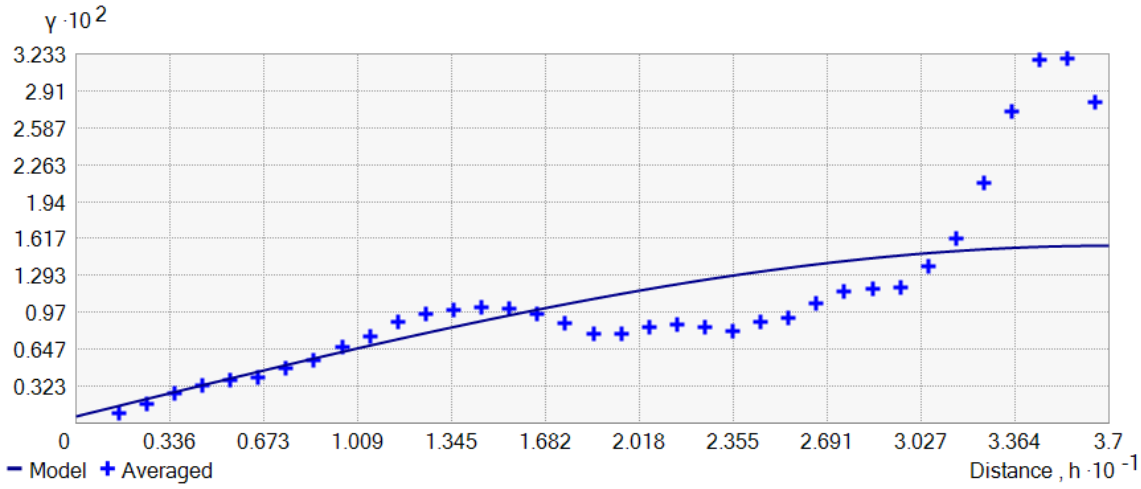

Figure 7 - 3: A semivariogram presenting spatial dependence of the process of economic flake production, measured as $(\text{lengh*width})^{1/2}$ /thickness. Log values of ($(\text{lengh*width})^{1/2}$ /thickness) are used. The modeling was performed using spherical function. Range=37, sill=0.016

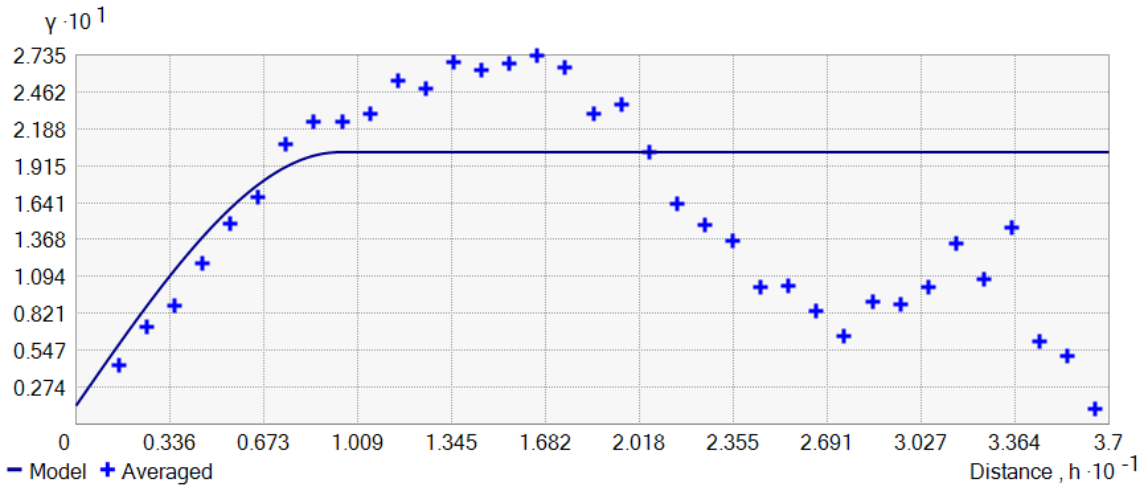

Figure 7 - 4: A semivariogram presenting spatial dependence of the process of selection, measured as retouched blanks/flakes. Log values of (retouched blanks/flakes) are used. The modeling was performed using spherical function. Range=9.4, sill=0.202

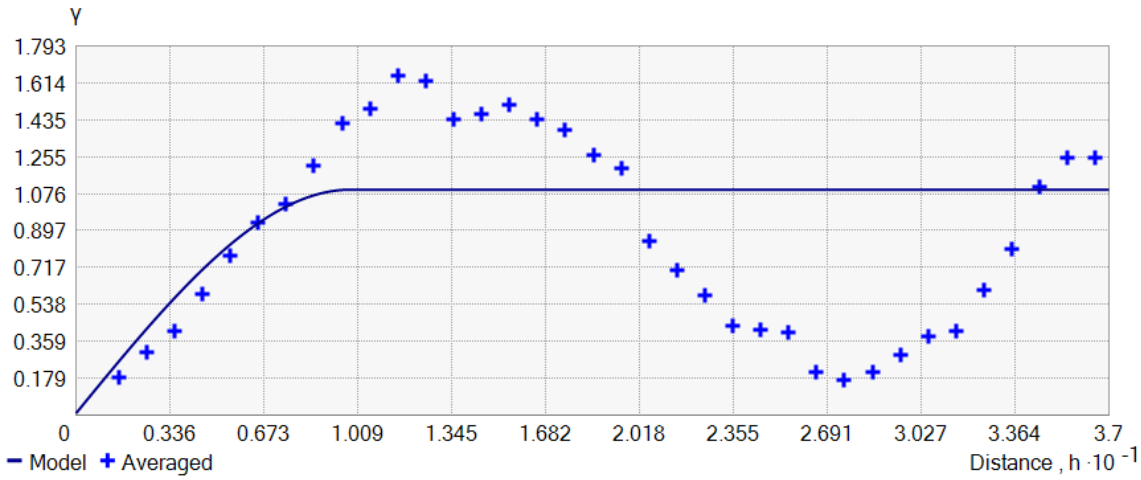

Figure 7 - 5: A semivariogram presenting spatial dependence of the process of stone use-life extension, measured as scrapers with higher degree of retouch/scrapers and denticulates. Since the values in some accumulations are zero, a normal score transformation with Gaussian kernel approximation of the values of ('scrapers' with higher degree of retouch/'scrapers' and 'denticulates') is used. The modeling was performed using spherical function. Range=9.8, sill=1.096

What is evident from the above semivariograms is that different processes were operating on different scales, either or both time and events, during the use of Pech IV. The range of the cortex ratio (Figure 7-1) is about 24, which means that change in this ratio is correlated from every accumulation across all the distances less than 24 accumulations apart. This is the greatest distance at which an accumulation from this sequence is correlated to another accumulation in terms of their cortex ratio values. The model levels out at the sill of 0.506, which is the semivariance that is approximately equal to the variance of the entire sequence. The processes of tool selection and management (Figure 7-4and 7-5) have the same range, -- about 9 accumulations apart --, which means that changes in both of these processes can be observable at the same scale of observation.

However, these two processes differ considerably in the degree of change, or the semivariance for that same scale of observation. While this semivariance for blank or tool selection is 0.202, for stone use-life extension or tool management is 1.096. The intensity of flaking is also spatially autocorrelated over the range of 9 accumulations apart, with the sill of 0.033. Lastly, change in the economic properties of flakes is correlated over the greatest lag distance: 37 accumulations apart, with the sill of 0.016. Dissimilarity in this value between accumulations is a function of the distance over the entire Pech IV sequence.

Either or both the difference in the scale of observation (the range) and the difference in the degree of change (the sill) between the processes suggest that they operated on a different scale of time and/or the scale of events, therefore, not following each other. The implication of this is that the record was formed due to

dynamic and various interactions among the various behavioral processes, rather than due to particular and re-occuring coalescence or packages of behavioral practices during the history of the use of this place and the landscape. A synthesis of the variability of this record requires a dissection of the interaction between different behavioral processes, and tracing their own temporalities. This will be discussed more in the next section of this chapter, which is about the implications of this analysis for Neanderthal landscape use in this part of southwest France and for the Mousterian as a type of industry. This section will continue assessing the variability in the use of this cave.

As already mentioned in previous Chapters, the degree of variability in the use of this cave will be inferred by comparing the intensity between the process of stone movement in and out of this place with the intensity of process that was executed in the cave, which is blank production or flaking, as measured with the relative amount of small non-cortical flakes (Tables 7-1 and 7-2, Figure 7-6). In addition, a comparison of the intensity of stone movement with the intensity of stone use-life extension (or management), as measured with the relative amount of highly retouched 'scrapers', will be used for inferences about the degree of variability in stone use (Tables 7-1 and 7-2, Figure 7-7).

Table 7 - 1: Summary data related to the ratio between small non-cortical complete flakes and all non-cortical complete flakes, the ratio between retouched blanks and flakes, and the ratio between the number of 'scrapers' with higher degree of retouch and the number of all 'scrapers' and 'denticulates', and their log values, per accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation	MIS	N of small non-cortical complete flakes / N of non-cortical complete flakes	cortex ratio	N of 'scrapers' with higher degree of retouch / N of 'scrapers' and 'denticulates'	Log(10) (small non-cortical complete flakes / non-cortical complete flakes)	Log(10) cortex ratio
1		0.57	0.78	0.47	-0.25	-0.11
2		0.59	0.72	0.29	-0.23	-0.14
3		0.56	0.72	0.32	-0.25	-0.14
4		0.54	0.94	0.30	-0.27	-0.03
5		0.56	0.33	0.12	-0.25	-0.48
6		0.64	0.41	0.18	-0.20	-0.39
7		0.68	0.39	0.00	-0.17	-0.41
8		0.64	0.26	0.00	-0.19	-0.58
9		0.62	0.39	0.00	-0.21	-0.41
10	5	0.60	0.40	0.00	-0.22	-0.40
11		0.65	0.32	0.00	-0.19	-0.49
12		0.56	0.33	0.00	-0.25	-0.48
13		0.53	0.32	0.12	-0.28	-0.49
14		0.49	0.45	0.05	-0.31	-0.34
15		0.55	0.35	0.07	-0.26	-0.45
16		0.51	0.41	0.14	-0.29	-0.39
17		0.56	0.39	0.20	-0.25	-0.41
18		0.51	0.60	0.34	-0.29	-0.22
19		0.57	0.75	0.56	-0.24	-0.12
20		0.63	0.80	0.34	-0.20	-0.10
21		0.39	0.81	0.45	-0.41	-0.09
22		0.38	1.14	0.37	-0.41	0.06
23	4	0.46	1.09	0.53	-0.33	0.04
24		0.46	1.36	0.44	-0.33	0.13
25		0.48	1.38	0.47	-0.32	0.14
26		0.58	1.38	0.69	-0.24	0.14
27		0.66	1.39	0.60	-0.18	0.14
28		0.76	1.78	0.26	-0.12	0.25
29		0.62	0.96	0.29	-0.21	-0.02
30	3	0.68	1.75	0.08	-0.17	0.24
31		0.75	1.20	0.05	-0.12	0.08
32		0.69	1.51	0.06	-0.16	0.18

33		0.69	1.17	0.18	-0.16	0.07
34		0.74	0.98	0.04	-0.13	-0.01
35		0.70	1.30	0.03	-0.15	0.11
36		0.72	0.92	0.03	-0.14	-0.03
37		0.72	0.79	0.05	-0.14	-0.10
38		0.63	1.17	0.00	-0.20	0.07
	average		0.85	0.21	-0.23	-1.14
	s.d.		0.44	0.2	0.07	0.25

Table 7 - 2: Summary data related to the z scores of log values of the ratio between small non-cortical complete flakes and all non-cortical complete flakes, z scores of log values of cortex ratio, z-scores of cortex ratio, and z scores of the ratio between the number of 'scrapers' with higher degree of retouch and the number of all 'scrapers' and 'denticulates', per accumulation. The boundaries of MIS 4 (light grey) are approximate.

accumulation	MIS	z score of log (small non-cortical complete flakes / non-cortical complete flakes)	z score of log cortex ratio	z score of cortex ratio	z score of 'scrapers' with higher degree of retouch / 'scrapers' and 'denticulates'
1		-0.21	0.12	-0.16	1.30
2		0.03	-0.01	-0.30	0.38
3		-0.33	0.00	-0.29	0.55
4		-0.52	0.46	0.21	0.47
5		-0.29	-1.38	-1.19	-0.45
6		0.48	-1.00	-1.01	-0.14
7		0.85	-1.08	-1.05	-1.05
8		0.50	-1.76	-1.33	-1.05
9		0.30	-1.07	-1.04	-1.05
10	5	0.08	-1.04	-1.03	-1.05
11		0.54	-1.42	-1.20	-1.05
12		-0.32	-1.35	-1.18	-1.05
13		-0.68	-1.40	-1.20	-0.46
14		-1.14	-0.82	-0.90	-0.81
15		-0.42	-1.25	-1.13	-0.72
16		-0.80	-0.98	-1.00	-0.34
17		-0.25	-1.08	-1.05	-0.05
18		-0.83	-0.33	-0.57	0.67
19		-0.15	0.07	-0.22	1.75
20	4	0.41	0.17	-0.12	0.64
21		-2.53	0.18	-0.10	1.19

22		-2.53	0.78	0.65	0.82
23		-1.43	0.70	0.54	1.60
24		-1.43	1.10	1.16	1.17
25		-1.18	1.12	1.20	1.29
26		-0.09	1.12	1.20	2.41
27		0.64	1.13	1.22	1.93
28		1.53	1.56	2.12	0.25
29		0.30	0.49	0.25	0.40
30		0.83	1.53	2.05	-0.64
31		1.44	0.88	0.80	-0.80
32		0.96	1.27	1.50	-0.76
33	3	0.91	0.83	0.72	-0.13
34		1.35	0.52	0.29	-0.83
35		1.04	1.01	1.01	-0.93
36		1.17	0.42	0.17	-0.91
37		1.22	0.14	-0.15	-0.79
38		0.44	0.83	0.72	-1.05

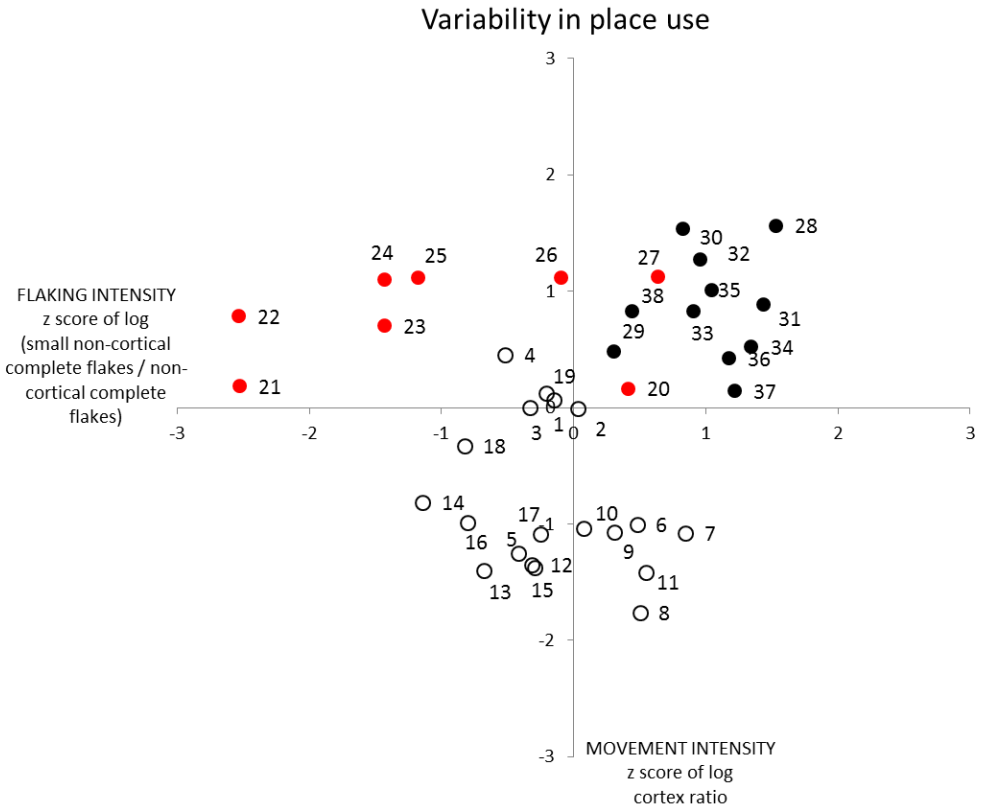

Figure 7 - 6: Variability in place use, using z-scores of log values of the ratio between the number of small non-cortical complete flakes and the number of all non-cortical complete flakes, and z-scores of log values of the cortex ratio. Points in red and black represent accumulations of MIS 4 and 3, respectively, while points in open circles are those of MIS 5 accumulations.

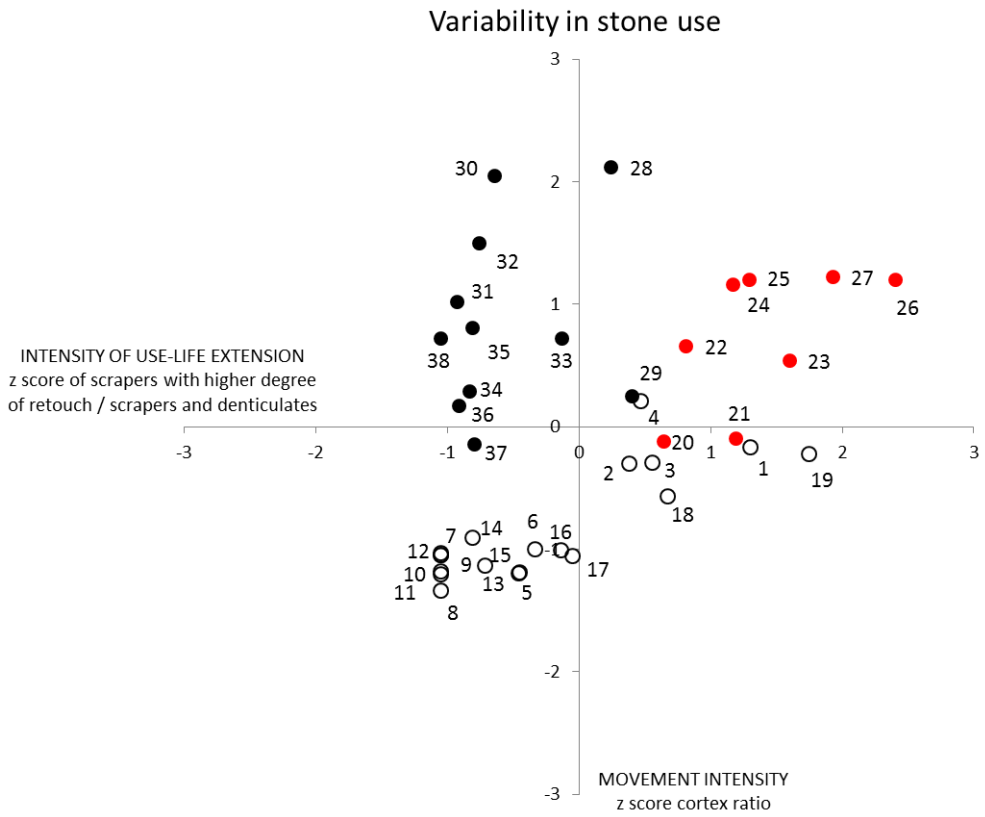

Figure 7 - 7: Variability in stone use, using z-scores of the ratio between the number of scrapers with higher degree of retouch and the number of scrapers and denticulates, and z-scores of the cortex ratio. Points in red and black represent accumulations of MIS 4 and 3, respectively, while points in open circles are those of MIS 5 accumulations.

7.1.1 MIS 5: sequence 1-4

During the earliest occupation of the cave, when the sequence of accumulations 1-4 was being formed, and according to cortex ratio analysis, the movement of stone material in and out of this place was of low intensity. Low intensity of stone movement in this sequence has already been reported by Dibble et al. (2009) based on their study of stone raw material provenience and their cortex ratio calculations. Together with stacked combustion features in this sequence, this suggests that occupation intensity during those times did not vary

considerably and that the nature of the use of this cave was relatively stable (see Dibble et al., 2009). This interpretation is also confirmed by the graph in Figure 7-6, which presents variability in place use. Here, the accumulations of this sequence are distributed close to the midpoint of the two axes. The intensity of flaking (Figure 6-24) and the intensity of tool selection and management (Figures 6-35 and 6-38) in these accumulations are somewhere between the highest and the lowest intensity of these two processes in the Pech IV sequence (just as is the case with cortex ratio). The same is true of the degree of economic flake production (Figure 6-30), where the measure of surface area relative to thickness (Figure 6-31) indicates somewhat more economic flake production during the formation of this earliest record in Pech IV.

The distribution of these four accumulations in Figure 7-7 indicates that stone use during those times of Pech IV occupation was restricted to this place. In other words, the use of stone during that period of MIS 5 was of rather limited extent or scale within the landscape. The graph shows that the low stone movement intensity (the range of the cortex ratio is from 0.72 to 0.94 as presented in Table 7-1) in this lowermost sequence is accompanied with relatively higher intensity of tool use-life extension. All of this suggests that the sequence 1-4 (Layer 8) formed due to the use of stone in this place, and that, throughout the occupation of this cave in this period of MIS 5, this use, together with the use of place, was of a low variability.

7.1.2 MIS 5: sequence 5-11

As seen in Figure 7-6, most of the accumulations of the sequence 5-11 are distributed in the lower-right quadrant, which stands for high intensity of flake production and high intensity of stone movement (low cortex ratio). Following the interpretation of low cortex ratio for this sequence of accumulations, the high movement of stone is here related with import of volume (cores). The non-existing or non-significant export of cortex from the cave is corroborated with the inverse correlation between a decrease in the average percentage of cortex and an increase in blank-to-core ratio in this sequence (Figure 6-21). In any case, import of volume and high intensity of flake production are suggestive of lower variability in the use of this place. Low variability in the use of this place in this sequence is also implied by lower variability in stone movement practices (transformation of values of cortex ratio in Figure 6-14) and lower variability in selection practices (Figure 6-41) during the formation of this record.

The sequence 5-11 of MIS 5 marks a time in the use of the cave when the intensity of selection and management in the cave was generally low (for the most part of this sequence there are no 'scrapers' with a higher degree of retouch) (Figures 6-35, 6-38, and 7-7). Together with high flaking intensity, this would indicate that this record accumulated due to various occupations of the cave during which times the processes of stone reduction and those of the management of stone tools were not correlated by the same needs, limitations or opportunities. Here, flake production is related with the production of small flakes (Figure 6-30), as indicated by association between high flaking intensity (Figure 6-24) and the

relatively smaller amount of volume taken off during core reduction (Figures 6-15 and 6-16) (see also Dibble & McPherron, 2006). The lack of correlation between the relative amount of small non-cortical flakes and their average length (Figure 6-26) suggests that some small non-cortical flakes were selected from the population of flakes produced, or of those already present in the cave, and taken out of this place and most likely managed elsewhere. This, in turn, implies that stone use was in general not restricted to this place but deployed over the landscape**.** Thus, in contrast to the place use, all of this indicates that during the formation of this sequence the variability in the use of stone was high.

7.1.3 MIS 5: sequence 12-19

Most of the accumulations from the later part of MIS 5 exhibit high movement intensity, except at the very end (accumulations 18 and 19), where cortex ratio comes close to 1. At the same time, flaking intensity decreased (Figure 6-24). The import of volume, a change in this import in the last accumulations, and low flaking intensity altogether suggest that variability in the use of this place at the end of MIS 5 was high (Figure 7-6). This finding is also implied by the higher variability in the values of cortex ratio transformation (Figure 6-14), and by higher variability in selection practices (Figure 6-41) during this last phase of the formation of MIS 5 record.

Since nodules were reduced more intensively (Figure 6-15), lower flaking intensity in this upper sequence of MIS 5 was related to the end of small flake production. The export of non-cortical flakes continued to be practiced, as suggested

by the lack of correlation between the relative amount of small non-cortical flakes and their average size (Figure 6-27), although the intensity of this export relative to such intensity in the sequence 5-11 in not clear. In general, during sequence 12-19, the intensity of selection and management was low (Figure 7-7) but increasing (Figures 6-35 and 6-38). Lastly, for most of the sequence 5-19, selection of blanks was not based on any one particular flake attribute (Table 6-24). All of this, together with a relatively high variability in the economic properties of produced flakes (Figures 6-30 and 6-34), indicates that variability in the use of stone remained high until the end of MIS 5.

7.1.4 MIS 4

Accumulations of this stage largely exhibit low flaking intensity (Figure 6-24) and high intensity of stone movement in the form of cortical blanks (Figures 6-4 and 6-22). These factors in themselves do not indicate that the use of the place was of high variability, especially if one considers the lack of variability in the transformation of cortex ratio values during the formation of the MIS 4 record (where this record was transformed in the same direction, Figure 6-14). The interpretation of high import of flakes followed by low flaking intensity as reflecting low variability in the use of this place during MIS 4 can potentially be supported by the distribution of the two last accumulations of MIS 5 (18 and 19), which are near to accumulations 1-4 in Figure 7-6, together with the accumulation 20, early in MIS 4. As discussed above, the sequence of accumulations 1-4 can be interpreted as reflecting a stable use of this place, meaning low variability. In terms of place use, it

is possible that more uniform use of this place re-emerged at the end of MIS 5, and continued for most of MIS 4, even though the nature of this use was different from the use during sequence 1-4. The use of this cave seems to have changed at the end of MIS 4 with higher flaking intensity in accumulation 27 (Figures 6-41 and 7-6), exhibiting more variable place use, which continues into MIS 3.

The relative amount of retouched blanks in the accumulations of MIS 4 is greater (Figures 6-35 and 7-7), and the intensity of their management is higher (Figure 6-38). However, the analysis of selection practices (Table 6-24) indicates that the process of use-life extension did not involve imported cortical blanks, which largely remained unretouched at the place. The most recent accumulations of MIS 4 (26 and 27) exhibit the least economical flakes that are found in the cave (Figure 6-30), while complete flakes from the majority of the lower accumulation of this stage are the most economical in the entire Pech IV sequence (Figures 6-31 and 6-34). Such a record indicates that the variability of stone use during MIS 4 was high. Exceptions are seen in the lowermost accumulations, 20 and 21 (Figure 7-7), where, just like in the record of accumulations 18 and 19 at the end of MIS 5 (and in the record of accumulations 1-4), variability in stone use seems to be more stable.

7.1.5 MIS 3

During this stage, stone movement intensity was high (Figures 6-4 and 7-6). As discussed in the previous chapter, this movement entailed the export of non-cortical flakes of larger size, which was intensified in the upper part of this stage (Figure 6-12), thereby producing the high relative amount of small non-cortical

flakes in this stage (Figures 6-24 and 7-6). This means that flaking intensity during this stage was most likely somewhat lower than suggested by the placement of MIS 3 accumulations on the graph in Figure 7-6. This record suggests that reduction of nodules also was less intensive (Figure 6-16). Regardless of somewhat lower flaking intensity, high movement intensity, the variability in movement practices (Figure 6-14) (in the upper part of this stage, there was more import of volume in the form of cores, Figure 6-9) and the absence of correlation between blank-to-core and the amount of cortex (Figure 6-23) indicate that there was variation in practices that led to accumulation of blanks, cores and cortex in the cave during the latest part of its use. All these features point to higher variability in the use of this place during MIS 3.

For most of the MIS 3 record, flakes are less economical (Figures 6-30 and 6-31). Based on the values and ranges of coefficient of variation in EPA and PD which are greater than those during relatively stable use of the place in the period of formation of sequence 1-4, exported flakes were not more economical than those left in the cave. Selection practices were mostly correlated with the greater length of blanks (Table 6-24), and variability in those practices was only present at the beginning and the end of the formation of the MIS 3 record (Figure 6-41). In this stage, high movement intensity is accompanied by low intensity of extension of stone tool use-life at this place (Figures 6-38 and 7-7), and low variability in such tool management practices (Figure 6-43). All of this indicates low variability in the use of stone during this stage.

The record at the very beginning of this stage, accumulations 28 and 29, is an exception. These two accumulations do exhibit somewhat higher intensity of tool management, suggesting that variability in the use of stone during the formation of these accumulations was higher (Figure 7-7). In this process, the record of these two accumulations is more closely related with the accumulations of MIS 4 than with the rest of the MIS 3 record. In addition, the uppermost accumulation of MIS 4 -- accumulation 27-- also exhibits higher variability in the use of place (Figure 7-6), just like the record of MIS 3. In terms of variability in both place and stone use, accumulations 27, 28, and 29 are related more to each other than to the record of their respective isotope stages.

7.2 Degree of variability in the use of Pech IV and in the use of stone

The degree of variability in both place and stone use at Pech IV is summarized below (Figures 7-8 and 7-9). These graphs show models developed for this variability as can be inferred based on the analysis of the stone artifact record from this cave presented in this dissertation.

In the middle of the graphs in Figure 7-8 are the lowermost accumulations of MIS 5 (accumulations 1-4) and the uppermost accumulations of this stage (accumulations 18 and 19) together with accumulation 20. Relative to the entire Pech IV record, these accumulations exhibit medium flaking intensity and cortex ratio values close to 1, which means low intensity of the movement of stone. Such a record is here interpreted as reflecting low variability in the use of this place. Low variability in place use is also interpreted for the record in the upper left quadrant

in the graphs in this figure, as well as for the record in the lower right quadrant. In these two sectors are located most of the accumulations of MIS 4 and accumulations 5-11 of MIS 5, respectively. The former accumulations exhibit low flaking intensity and high intensity of stone movement, which involved import of cortical blanks, suggesting that during those times of the use of this cave stone objects were provisioned largely through import. The sequence of accumulations 5-11 exhibits high flaking intensity and high movement of stone, although, unlike in MIS 4, this high movement resulted in cortex ratio values lower than 1. Such values of cortex ratio are here associated with import of volume (with some export of non-cortical blanks). During the times of accumulation of this sequence stone objects were provisioned in the place by stone reduction and blank production.

Thus, the sequence of accumulations 1-11 and the uppermost accumulations of MIS 5 (accumulations 18 and 19) together with the record of MIS 4 (except the uppermost accumulation 27) lie along an axis of low variability in place use, even though these different times of the use of this cave differed in terms of stone provisioning practices. Variability increases along the other axis, going from the low intensity of stone movement (cortex ratio close to 1) towards higher intensity of such movement (with cortex ratio values considerably higher or lower than 1). At the ends of this axis are the sequence of accumulations 12-17 of MIS 5, which exhibits low flaking intensity, import of volume, and some export of blanks, and the uppermost accumulation of MIS 4 (the accumulation 27), which exhibits high flaking intensity and import of cortex. These practices, which include import of stone into the place of Pech IV but its relatively low levels of reduction (accumulations 12-17),

and import of stone tools coupled with high level of production of stone objects at the place (accumulation 27), indicate high variability in the use of this place. The record of MIS 3 arguably can be interpreted as being accumulated due to medium variability in the use of Pech IV.

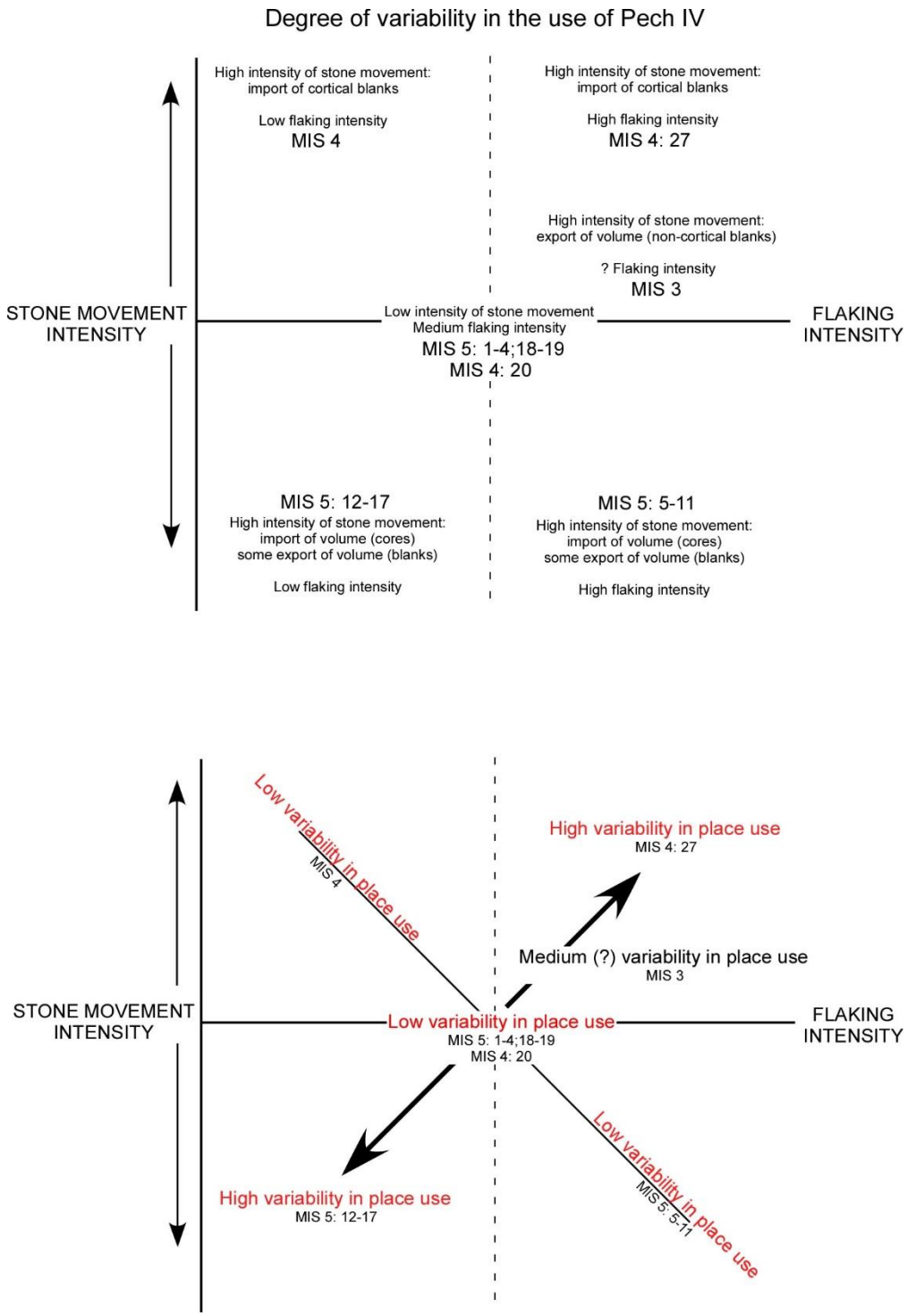

Figure 7 - 8: Model of the degree of variability in the use of Pech IV, seen as an interaction between the process of flaking intensity and the process of stone movement. The movement of stone was calculated with cortex ratio, where values of this ratio that are either greater or lower than 1 indicate higher intensity of stone movement.

With respect to stone use in the landscape (Figure 7-9), the accumulations found at the center of the graphs showing variability in place use (Figure 7-8) are the same ones demonstrating variability in stone use . Those are accumulations 1-4, 18, and 19 of MIS 5, as well as accumulations 20 and 21 of MIS 4, and 29 of MIS 3. With low intensity of stone movement, the record of these accumulations exhibits somewhat higher intensity of stone use-life extension, indicating relatively low variability in stone use. This grouping, along with most of the MIS 3 record (accumulations 30-38: high intensity of stone movement and low intensity of stone use-life extension), lies along the axis of low variability in the use of stone.

In a manner similar to high variability in place use, high variability in stone use lies along the opposite axis. It goes towards higher intensity of movement, where import of cortex is related with high intensity of stone use-life extension, as in accumulations 22-27 of MIS 4 together with the lowermost accumulation of MIS 3 (accumulation 28), or import of volume is associated with low intensity of tool use-life extension, as in accumulations 5-17 during MIS 5. Together with zooarchaeological study of Pech IV fauna record, these inferences about the degree of variability in stone use will provide insights into the exact nature of practices and actions related to the use of stone.

It should be emphasized that the use of stone, as interpreted here, refers to the use of stone across the landscape, with Pech IV being a part and a window into the distribution of the record over that landscape. As mentioned in the previous section, and discussed in more detail in Chapter 3, the stone artifact record recovered at a particular place offers insights into the treatment, use and

operationalization of stone over the landscape, and in this respect, this record is a record of the landscape more than the record of a 'site' (see Dunnell, 1992; Foley, 1981; Gould, 1980). Therefore, the stone artifact record of Pech IV is approached not as a site record that would be in antinomy with the record beyond this site (usually termed an 'off-site' record) but rather as part of the record of the landscape itself (see the discussion about the notion 'site' in Chapter 3). The practices and events as part of the processes of the movement of stone and its management were not confined to the topographical boundaries of this cave, but were performed over landscape and over time.

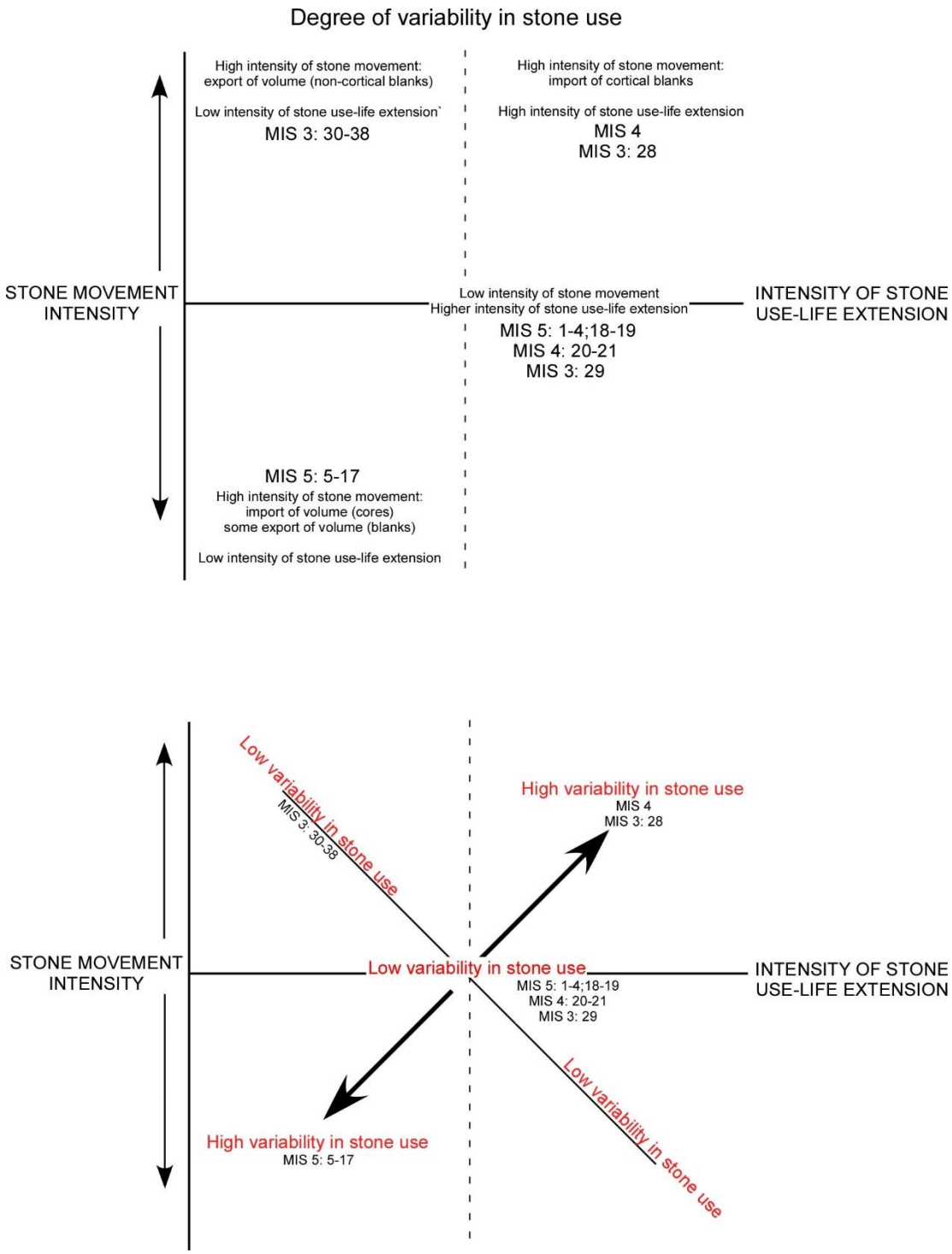

Figure 7 - 9: Model of the degree of variability in the use of stone in the landscape (including the place of Pech IV), seen as an interaction between the process of stone tool use-life extension and the process of stone movement. The movement of stone was calculated with cortex ratio, where values of this ratio that are either greater or lower than 1 indicate higher intensity of stone movement.

7.3 Variability in Neanderthal landscape use in southwest France

The variability of the Middle Paleolithic record in southwest France recently and increasingly has been associated with variations in the paleoenvironment (Delagnes & Rendu, 2011; Pettitt, 2003; Rolland, 2001). These associations largely rely on (and argue for) the proposed temporal patterning of technological and typological qualities in that record (Discamps et al., 2011; Faivre et al., 2014; Jaubert et al., 2011; Mellars, 1965, 1996; Morin et al., 2014; Rolland, 1988). Accordingly, the record of MIS 5 with higher frequencies of Levallois were succeeded by the Quina of MIS 4, after which came stone artifacts that exhibited features of the MTA production system and the discoid-denticulate system of MIS 3 (but see Guérin et al., 2012; Guibert et al., 2008b; Richter, Dibble, et al., 2013; Richter, Hublin, et al., 2013; Vieillevigne et al., 2008). In these studies, it has been advocated that different qualities of a patterned record reflect different adaptive strategies of mobility and resource procurement within the changing landscape during the Late Pleistocene. Chapter 2 of this dissertation presents these studies and their models in more detail. Their major premises are outlined below again due to their relevance for this discussion.

Using the results of stone provenience studies by Féblot-Augustins (1993), Geneste (1985), and Turq (1985, 1989, 1990), who argued that the stone artifacts which were moved over greater distances are predominantly of the Levallois system of production, while those produced using the Quina system by and large were made in stone that was available more closely to the places where these artifacts have been found, Pettitt (2003) proposed that the transition from Levallois to Quina

represented a switch in Neanderthal mobility from higher into relatively lower and with restricted range. Another major argument used is that, because of their greater economical properties, Levallois items would be more convenient for transport over greater distances than bulkier Quina items. In addition, they would offer greater flexibility in use and management compared to Quina items and to the short and morphologically highly unstandardized blanks produced with a discoidal technological system. According to Pettit (2003), due to limited mobility triggered by relatively hostile environments of MIS 4 and MIS 3, a more suitable strategy in those times was an *ad hoc* stone tool production and greater curation of a single tool, as represented by Quina items and MTA bifaces, respectively.

The opposite model for Neanderthal landscape use was proposed by Delagnes and Rendu (2011). By considering Levallois to be a technological system that is oriented towards production of a single predetermined outcome, and due to lower retouch intensity (which these authors interpret as an 'expedient' edge modification) on Levallois items, such items when produced are here considered to be of limited recycling, use, hence, of short use-life. The assumed presence of predetermination in the Levallois technological system, as well as some examples of Levallois reduction sequences and refitting from northwest France, according to Delagnes and Rendu (2011), indicate that the Levallois production sequence was long, elaborate, and being executed entirely at one place, near a stone raw material resource. For these authors, all of this would be diagnostic of the low transportability of Levallois products, used at the sites and landscapes within a strategy of non-selective hunting of year-long available prey.

In contrast, Delagnes and Rendu (2011) stressed that Quina items were produced with a low investment in core preparation, and their volume would allow them a high maintenance potential and a long use-life. These assumed features imply that such items offered greater flexibility in use and reliability in stone provision as needed in the landscape. This, together with associated reindeer fauna in the record with Quina items, suggests that Quina technological system reflects a high mobility strategy as part of a specialized exploitation of migratory reindeer populations (see also Costamagno et al., 2006; Discamps et al., 2011; Grayson & Delpech, 2003; Niven et al., 2012; Rendu et al., 2012) and specialized use of places across the landscape as task-specific sites. Similar interpretation of the record containing Quina items was also offered by Rolland (2001).

According to Delagnes and Rendu (2011), items produced with a discoidal technological system reflect the same character of landscape use (with the predominant taxa of bison and horse replacing reindeer), only that the shorter use-lives of such items (relative to Quina tools) are here compensated for by their higher versatility and the use of a wider range of stone raw material in their production. Delagnes and Rendu (2011), and Soressi (2004), argue that MTA technological system represents a somewhat higher mobility strategy because of the preferential use of a 'non-local' flint (Geneste, 1985; Soressi & Hays, 2003) and the proposed long use-life and recycling potential associated with bifacially shaped tools.

As seen above, Pettitt (2003) and Delagnes and Rendu (2011) used various and sometimes contrasting premises related to the variability in the stone artifact record in their modeling of Neanderthal mobility and landscape use. If these

arguments are interpreted in terms of higher or lower variability in place use and higher or lower variability in stone use, then these two proposed models represent contrasting interpretations.

Pettitt (2003) emphasized the principle of *débitage* technology during MIS 5 (and related to Levallois) (Boëda, Geneste, & Meignen, 1990), where the stone reduction was performed by one of a number of different *chaînes opératoires* producing blanks of various shapes and sizes. These were highly transportable and they offered great flexibility in use. These assumptions would imply that MIS 5 was a period of high variability in stone use. The same principle of *débitage* in stone tool production was used during MIS 4 for the production of thick blanks (in Quina system). However, since these were mostly produced in local raw material and offered low flexibility and portability, the stone record of this stage predominantly would reflect low variability in stone use. In Pettitt's (2003) model, low variability in stone use would also be a feature of Neanderthal behavior during MIS 3, reflected in more extensive use and curation of a single tool, where through the principle of *façonnage* (Boëda et al., 1990) stone would be reduced towards an envisaged final form: a biface.

Delagnes and Rendu (2011) emphasized predetermination, low retouch intensity, limited recycling potential and shorter use-lives of Levallois items. This would be suggestive of low variability in stone use during MIS 5, according to their model. During MIS 4 and MIS 3, high maintenance, longer use-lives, and greater flexibility of Quina items and greater versatility of items produced by a discoidal-denticulate production system would indicate high variability of stone use in those

times related to these latter two technological systems. The same would be true for the duality within the MTA system, where bifaces, being either single purpose tools or used as tools and cores, are considered to be highly portable items (Kuhn, 1994), while other elements in the MTA are interpreted as results of core reduction sequences performed more or less entirely at sites (Soressi, 2004).

The model and interpretation of variability in stone use (Figure 7-9) developed in this dissertation on the basis of the Pech IV stone record does not follow either of the two models above in their entirety. As described in the previous section, at Pech IV, the record of MIS 5 seems to exhibit low variability in stone use in the sequence of accumulations 1-4 and in the segment of the Pech IV sequence that most likely accumulated during the transition from MIS 5 into MIS 4 (accumulations 18-21). The largest part of the MIS 5 record, the sequence of accumulations 5-17 exhibits high variability in stone use, and this finding follows the implied degree of variability in stone use during this stage according to Pettitt's (2003) model. Most of the MIS 4 record (accumulations 22-27) also exhibits high variability in stone use, which follows the implied degree of variability in this use in Delagnes and Rendu's (2011) model. However, the MIS 3 record largely exhibits low variability in stone use, in accordance with the implied degree of stone use variability in Pettit's (2003) interpretation.

Regarding settlement dynamics, Delagnes and Rendu (2011) went further than Pettitt (2003) in interpreting mobility strategies. In their model, the differences in mobility patterns between those reflected in the Levallois (and laminar) system and those reflected in Quina and discoid-denticulate systems are explained using

the much contested and largely outdated forager-collector landscape use dichotomy proposed by Binford (1980; see also Parry & Kelly, 1987). According to Delagnes and Rendu (2011), the premises surrounding the stone artifact record of a Levallois system as outlined above, together with associated fauna that is suggestive of non-selective or non-seasonal hunting strategies prior to MIS 4, can be related to a forager-like mobility strategy. This would imply that places of occupation across the landscape were used not for any one particular practice, meaning that the variability in the use of these places was high. According to this same interpretation, during MIS 4 and MIS 3, the premises of the Quina and the discoidal technological systems would indicate a collector-like settlement pattern. According to Delagnes and Rendu (2011), this would be corroborated with the associated faunal record, which are suggestive of seasonal and mono-specific hunting strategies and, based on frequencies of different anatomical portions of preyed upon taxa, of the task-specific use of various places across the landscape. This would in turn imply low variability in the use of each of these places.

High variability in place use in the MIS 5 record of Pech IV is inferred only for a segment of its upper part, in the sequence of accumulations 12-17 (Figure 7-8). The rest of this record seems to be accumulated during a use of this place that was relatively stable. Without question, for more reliable and comprehensive study of variability in place use, this analysis of the stone record in the future needs to be merged with zooarchaeological analysis of the Pech IV fauna record. At the moment, the faunal analysis is in progress. Dibble et al. (2009), however, reported preliminary insights into prey exploitation practices during the accumulations of

Layer 8 (accumulations 1-4). Here, red deer predominates, but there is also a small sample of roe deer and boar present. Remains of all of these species show traces of disarticulation, skinning and meat removal. There is also a degree of differential representation in anatomical parts and of seasonality in prey acquisition. The sample of red deer suggests that appendicular segments were transported in relatively complete state.

Perhaps the major difference between this lowermost layer and the rest of the Pech IV deposits is that numerous and well-preserved combustion features -- interpreted as hearths -- were found throughout this layer. Dibble et al (2009) reported on their restricted size, low temperature ranges, and their thin and patchy occurrence, all of which, according to these authors, indicates that these features are remains of short-lived combustion events. In addition to the fauna record described above, there was preservation of delicate ashes as seen in micromorphological samples, and a low incidence of retouched tools (low intensity of selection). Together, this evidence suggests that the sequence of accumulations 1-4 was most likely formed during several seasonal and relatively ephemeral occupations (Dibble, Berna, et al., 2009), without much evidence for variability in these episodes of the use of this cave. The interpretation of this lowermost part of MIS 5 record reflecting low variability in place use as proposed in this dissertation (Figure 7-8) is consistent with that reported by Dibble et al. (2009).

Unlike in the case of MIS 5 record, there is more agreement between the modelled low variability of place use in the Pech IV MIS 4 record with the degree of variability in the use of places by Neanderthals during those times as implied by

Delagnes and Rendu's (2011) model. However, the uppermost accumulation on this stage (accumulation 27) departs from this interpretation, in exhibiting high variability in place use. The record of MIS 3 also exhibits somewhat higher variability in place use relative to most of the MIS 4 record at this place, which, due to its classification as an MTA system (McPherron et al., 2005; McPherron & Dibble, 1999; Turq et al., 2011), may be in line with Delagnes and Rendu's (2011) placement of this system somewhere between low and high mobility patterns. The analysis of the Pech IV fauna, once completed, will make possible to complement these insights.

What is clear from the above discussion of the Pech IV record is that the overall variability in place use and the overall variability in stone use from MIS 5 until MIS 3 are much greater than implied by models of Delagnes and Rendu (2011) and Pettitt (2003). The Pech IV record shows that landscape use by Neanderthals from MIS 5 until MIS 3 was much more dynamic and that its variability can hardly be captured by these two overly simplistic models, especially if entrusted to elegant but facile and reductive constructions such as the forager-collector dichotomy, as in the case of Delagnes and Rendu (2011). A synthesis of variability does not mean reduction of that variability, nor impelling the phenomena into predetermined categories.

The treatment of the MTA in their model has to be mentioned again. Unlike the Levallois, Quina, and discoidal systems, the MTA system does not fit into the imposed forager-collector framework, which is why the authors place it somewhere in between. However, the very case of one of the systems not following the imposed

interpretative framework for resource procurement strategies should perhaps be seen as indicative of the unsuitability of such a framework, rather than treated as an outlier that can conveniently be interpreted as somewhere along the forager-collector continuum. The use of forager-collector framework has been reassessed recently to a considerable extent (Brantingham, 2006; Carr & Bradbury, 2011, pp. 311–312; Holdaway & Douglass, 2011; M. C. Nelson, 1991, pp. 62–66; Perreault & Brantingham, 2011). However, since the examination of the Pech IV record here does not follow Delagnes and Rendu's (2011) example of adopting this framework for interpreting Neanderthal mobility and landscape use in southwest France, it is out of the scope of this discussion to delve into the criticism of its use.

In this study, exploring variability in Neanderthal landscape use is based on modeled degree of variability in the use of place (Figure 7-8) and the modeled degree of variability in the use of stone (Figure 7-9). Interpretations based on the interaction between degrees of these two kinds of variability are presented in Figure 7-10.

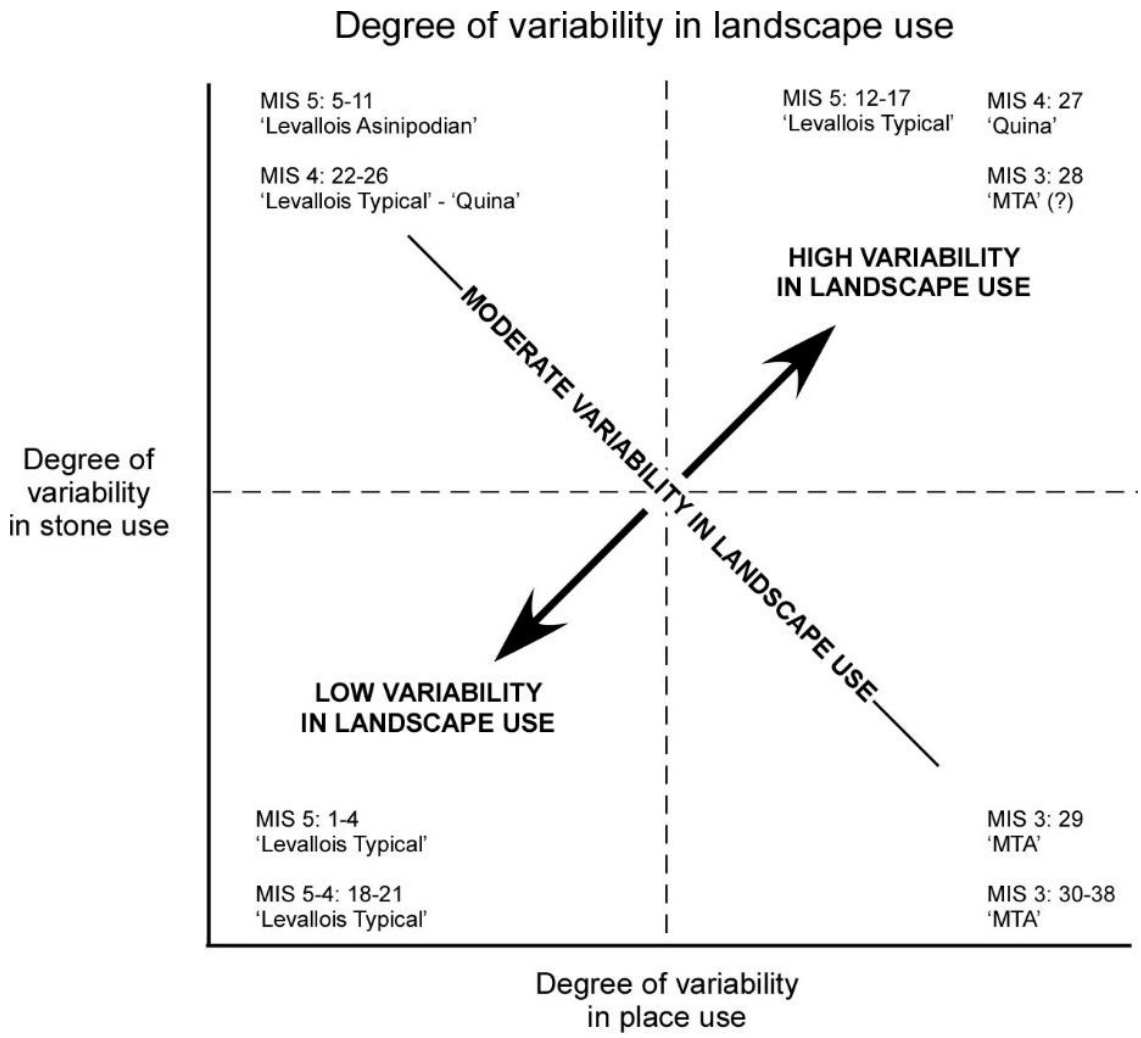

Figure 7 - 10: Model of the degree of variability Neanderthal landscape use in southwest France, seen as the interaction between the degree of variability of place use and the degree of variability in stone use, based on the stone artifact record of Pech de l'Azé IV.

Low variability in both place and stone use inferred for the MIS 5 sequence of accumulations 1-4 (Figures 7-8 and 7-9) is here interpreted as reflecting low variability in the use of landscape during those times (Figure 7-10), meaning there was a limited number of different practices related to resource exploitation. At Pech IV, there was a low intensity of stone movement, and the use of this place during those times was relatively stable (Dibble, Berna, et al., 2009). The processes of tool

selection and management were of medium intensity (or somewhat higher for the latter process). The record-transformation graphs (Figures 6-14, 6-34, 6-41, and 6-43) show that during the accumulation of this record (Layer 8) the nature of its transformation in regard to stone movement, production of blanks with higher economic properties, blank selection, and tool management, respectively, included very little change in directionality and in the average degree of transformation. In cortex ratio, this average degree is 12.5%, for surface area to thickness 0.9%, for retouched blanks to flakes 17.9%, and for relative amount of highly retouched tools is 22.4% (Table 7-3). The record of this sequence can be classified as Levallois Typical Mousterian (Bordes, 1975; Dibble, Berna, et al., 2009; McPherron & Dibble, 1999; Turq et al., 2011).

Table 7 - 3: The average changes (%) in cortex ratio, $(\text{length}*\text{width})^{1/2}$/thickness, retouched blanks/flakes, and 'scraper's with higher degree of retouch/'scrapers' and 'denticulates', during the accumulation of the stone artifact record at Pech de l'Azé IV. The values are computed based on absolute values of relative change in these four measures presented in Figures 6-14, 6-34, 6-41, and 6-43.

accumulations	cortex ratio	$(\text{length}*\text{width})^{1/2}$ / thickness	retouched blanks / flakes	'scrapers' with higher degree of retouch / 'scrapers' and 'denticulates'
1-4	12.5	0.9	17.9	22.4
5-11	31.5	3.6	34.1	86.55
12-17	12.4	1.4	28.7	53.6
18-21 [1]	-	-	-	-
22-26	47.4	0.8	22.1	23.4
27	-	-	-	-
28	-	-	-	-
29	-	-	-	-
30-38	19.1	6.1	23.3	69.7

[1] In Figures 6-14, 6-34, 6-41, and 6-43, the change with the accumulation 21 is calculated relatively to the accumulation 20, while in accumulations 18 and 19 relative to the beginning of MIS 5 record at this cave (accumulation 1), which is the reason of not calculating the average changes in the four measures in this sequence.

The MIS 5 sequence of accumulations 5-11 exhibits low variability in place use, but high variability in the use of stone (Figures 7-8 and 7-9). During those times, the intensity of stone movement was high, and included nodules (cores) and blanks, which in the case of Pech IV were taken out of this place, indicating that stone use extended over the landscape. Intensity of selection and intensity of stone use-life extension were generally low, while the intensity of flake production was high and related to the production of small flakes (see Dibble & McPherron, 2006). This difference between intensity of flake production and intensity of tool management can be interpreted as reflecting operational contexts that required stone to be provisioned more by production of flakes than by production of fresh edges on already existing tools. During the accumulation of this record, there was no change in directionality of transformation of this record in regard to examined processes, as can be observed in the record-transformation graphs (Figures 6-14, 6-34, 6-41, and 6-43), but the degree (or intensification) of transformation is among the highest in all those respective processes within the entire Pech IV sequence (Figure 7-3). In comparison to sequence 1-4, all of these aspects of the record of sequence 5-11 are here interpreted to reflect somewhat higher variability in the use of landscape (Figure 7-10). The record of this sequence has been classified as Levallois Asinipodian (Bordes, 1975; Dibble, Berna, et al., 2009; McPherron & Dibble, 1999; Turq et al., 2011). A comprehensive zooarchaeological analysis of fauna from these deposits, as well as from deposits of this age from other places in the area, will be instrumental in inferring the context of why during these times the

variability in the use of stone increased while the variability in the use of the cave remained low as during the times of accumulation of sequence 1-4.

In the MIS 5 sequence of accumulations 12-17, high intensity of stone movement was coupled with low flaking intensity, the end of small flake production, and low intensity of stone use-life extension. It seems that the selection process was also not based on any particular flake attribute (Table 6-24). At the same time, the record-transformation analysis shows that during the accumulation of this record there was a certain variability in stone movement and selection practices (Figures 6-14 and 6-41), and in economic properties of produced flakes (Figure 6-34). In addition, with regard to selection and tool management practices, the degree of record transformation is among the highest within the Pech IV sequence (Table 7-3). High variability in the use of stone is here followed with high variability in the use of this place (Figures 7-8 and 7-9). This suggests that these were the times of a variety of different practices related to the use of resources across the landscape. Or, in terms of the overall behavior of landscape use, this record is here interpreted as exhibiting high variability in such behavior (Figure 7-10). Typologically, this record has been regarded as Levallois Typical Mousterian (Bordes, 1975; Dibble, Berna, et al., 2009; McPherron & Dibble, 1999; Turq et al., 2011).

In contrast, sequence of accumulations 18-21 exhibits low variability in the use of resources across the landscape, just like sequence 1-4. However, even though both sequences 18-21 and 1-4 exhibit low variability in landscape use, the exact behavior of landscape use was potentially different. In other words, the number of practices related to resource exploitation in sequence 1-4 was also limited, but this

may have included completely different practices as compared to those during the times of sequence 18-21. Analysis of fauna from sequence 18-21 will help in inferring if this was truly the case. Based on correlations between Pech IV layers, reconstructions of paleoenvironments, and chronometric dates (Goldberg et al., 2012; Richter, Dibble, et al., 2013; Sandgathe et al., 2011; Turq et al., 2011), the sequence of sampled accumulations 18-21 marks the transition between MIS 5 and MIS 4, and it can be also classified as Levallois Typical Mousterian (Bordes, 1975; Dibble, Berna, et al., 2009; McPherron & Dibble, 1999; Turq et al., 2011).

In the sequence of accumulations 22-26, the MIS 4 record exhibits low variability in place use, but high variability in the use of stone (Figures 7-8 and 7-9), suggesting that, just like sequence 5-11 of MIS 5, during that time the behavior of landscape use was less constant if compared to sequence 1-4 and sequence 18-21, but somewhat less variable compared to sequence 12-17 (Figure 7-10). The sample of comprehensive zooarchaeological analyses that could here be used to examine correlation between the proposed variability in landscape use and practices related with prey acquisition during MIS 4 in the region is limited. Costamagno et al (2006) reported on their analysis of MIS 4 fauna from Marillac des-Pradelles, where anatomical profiles and degree of exploitation of reindeer imply that their carcasses were in transit at this place. This record indicates that the process of exploitation of reindeer carcasses was segmented over space, and most likely included several places across the landscape. The movement of parts of reindeer carcasses was documented also in layer 22 at Jonzac (Jaubert et al., 2008; Niven et al., 2012). In addition, on the basis of over-representation of long bones of this taxon in the fauna

record of the cave of Roc de Marsal, Soulier (2007) reported on segmentation of reindeer carcass exploitation over the landscape. These limited faunal studies are indicative of a certain degree of variability in landscape use during MIS 4.

As presented above, a certain degree of this variability is also reflected in the record of the MIS 5 sequence 5-11. But in contrast to this sequence, high intensity of stone movement during MIS 4 involved import of cortical blanks into Pech IV, at which place the flaking intensity was low. Low variability in the use of this place during this time is a continuation of a degree of this variability from sequence 18-21 (see above). Intensity of selection and tool management was high, and relatively stable throughout the accumulation of this record (degrees of record transformation are not among the highest along the Pech IV sequence, Table 7-3), but there is variability in the economic properties of flakes within this sequence (22-26). The lower part contains the most economical flakes of the entire Pech IV sequence, while accumulation 26 (and the subsequent 27) has the least economical flakes. This sequence can be classified as Levallois Typical Mousterian overlaid by Quina elements (Bordes, 1975; Dibble, Berna, et al., 2009; McPherron & Dibble, 1999; Turq et al., 2011).

Accumulation 27 exhibits high variability in landscape use (Figure 7-10), with high variability in the use of both place and stone (Figure 7-8 and 7-9). High stone movement intensity at this place entailed import of cortical blanks rather than import of volume and some export of non-cortical blanks, as seems to be the case in the sequence of accumulations 12-17 of MIS 5. Relative to the rest of the MIS 4 record (sequence 22-26), accumulation 27 exhibits higher flaking intensity, and, as

mentioned above, production of flakes with low economic properties. All of this suggests that towards the end of MIS 4, the behavior of landscape use again involved a variety of different practices related to exploitation of resources, and potentially different ones than during the times of the accumulation of sequence 12-17 of MIS 5. Accumulation 27 is classified as Quina Mousterian (Bordes, 1975; Dibble, Berna, et al., 2009; McPherron & Dibble, 1999; Turq et al., 2011).

Stone movement intensity continued to be high after accumulation 27, but now it involved export of non-cortical blanks, especially towards the end of the entire sequence. As presented in more detail in the previous section of this chapter, this record indicates that there was variation in practices behind the accumulation of stone artifacts during MIS 3. Variability in place use was somewhat higher, while variability in stone use was mostly low during this stage (Figures 7-8 and 7-9). Flakes produced were of relatively low economic properties, and the intensity of stone use-life extension was low, but throughout its accumulation this record was transformed to a high degree (in regard to these two processes) (Table 7-3). There is also some degree of variability in the practices of selection (Table 6-24). All of this is interpreted as reflecting a degree of variability in practices related to exploitation of resources. Following the same rationale as for other segments of the Pech IV stone artifact record (sequences 5-11 and 22-26) , the MIS 3 record of this place is interpreted as exhibiting moderate variability in landscape use (Figure 7-10). This record has been classified as MTA (Bordes, 1975; Dibble, Berna, et al., 2009; McPherron & Dibble, 1999; Turq et al., 2011).

7.4 Re-examining the question of the Mousterian of southwest France

There are several important points that can be made based on the interpretation of variability of landscape use from the discussion above. Although one-to-one relationships between particular variability in landscape use and MIS is absent (except perhaps in the case of MIS 3 record), most of the MIS 4 and MIS 3 record at Pech IV indicates that during the times after MIS 5 the degree of variability in landscape use was higher, where the record with Quina elements exhibits the highest variability in this behavior. Some parts of the MIS 5 record at this place exhibit low variability in landscape uses, while others exhibit high variability in this use. Also, the sequence the record comprised of MIS 5 and MIS 4 deposits indicates a *cyclical pattern* in the degree of variability in this behavior. This record started to accumulate due to low variability in landscape use (sequence 1-4), then there was a period of higher (or overall moderate) variability in such behavior (sequence 5-11), becoming even higher (sequence 12-17), after which such behavior decreased in its variability (sequence 18-21) at the transition between MIS 5 and MIS 4 to go high again until the end of MIS 4 record. Landscape use first involved a limited number of different practices of resource exploitation, then the number of such practices increased, to decrease at the end of the MIS 5 record and to start rising again during MIS 4. Overall, the record of Pech IV indicates that during MIS 5 the landscape use varied more than in subsequent stages. There were times during this stage when the number of different resource exploitation practices was more limited and there were times during this stage when this number was higher.

In some instances, a particular degree of variability does not end with the particular isotope stage, as in the case of low variability in landscape use in the uppermost record of MIS 5 and the lowermost record of MIS 4 (from accumulation 18 until accumulation 21). But what is more interesting is that with MIS 3 the cyclical pattern in the degree of variability in landscape use ceased. Instead of going back to more constant use of both place and stone as was the case after MIS 5 sequence 12-17, the record of MIS 3 with MTA elements continues to exhibit high variability in place use like accumulation 27 with Quina elements, albeit with a decrease in variability in the use of stone. The true meaning of this disruption of the cyclical pattern in the degree of variability in landscape use and its implications at the last stage of Neandertal occupation of southwest France requires comprehensive analysis of fauna and stone artifact record from other places in this region.

There is a certain amount of patterning in association between the degree of variability in landscape use and particular Mousterian technological system(s). Low variability in landscape use left the record with higher incidences of Levallois elements, while moderate or high variability in landscape use produced the record that is technologically less uniform: it has or it can have elements of Levallois, Quina and MTA systems.

While Levallois-rich deposits (those that can be classified as 'Levallois Typical' or 'Levallois Asinipodian') in the record of Pech IV, are associated with all degrees of variability in landscape use, the record exhibiting elements of MTA system is associated with moderate variability, and the record classified as Quina is

associated with high variability in this behavior. Related to this, there is some patterning in the degrees of variability in place and stone use among technological systems. The record with elements of Levallois exhibits more constant place use and either low or high variability in stone use, or high variability in both place and stone use. The combinations of degrees of variability in place and stone use in Quina and MTA record are more restricted. Quina exhibits high (or higher) variability in place use coupled with high variability in stone use. On the other hand, MTA record exhibits higher uniformity in the ways of using stone, but higher variability in the use of place.

Second important observation is that the analysis and interpretation point to a lack of association between practices of movement of stone (e.g., import of nodules, import of blanks, or export of blanks) and the degree of variability in the use of landscape. Different practices of stone movement can be related to either high or low variability in place use (Figure 7-8), high or low variability in stone use (Figure 7-9), and, finally, high or low variability in the use of landscape. These observations imply that modeling landscape use and settlement dynamics based solely on the process of stone movement is ineffective approach in archaeology, especially if such modeling is based on nominal typological and/or technological categories (like 'Levallois', 'Quina scraper', 'discoid', and 'MTA biface') that have unclear and presumed interpretations for mobility of hominin or human groups. It is argued here that the analysis of the stone artifact record should not be constrained by partitioning the record according to the presence or absence, or differences in the frequencies, of such categories. Such categories are part of the overall variability

of the record and they should not be dismissed. However, their potential analytical use needs to come at the end of behavioral inferences, like presented above, rather than at the beginning of the inferential process.

Based on this reassessment, the potential general chronological patterning of sets of techno-typological features in the Middle Paleolithic record of southwest France (Delagnes & Meignen, 2006; Delagnes & Rendu, 2011; Faivre et al., 2014; Jaubert et al., 2011; Mellars, 1965, 1996; Morin et al., 2014; but see Guérin et al., 2012, 2015; Guibert et al., 2008b; Richter, Dibble, et al., 2013; Richter, Hublin, et al., 2013; Vieillevigne et al., 2008) does not need to entail the temporal patterning of particular Neanderthal behavior (besides the one related to the production of tools), but it can reflect the trajectories of the stone artifact record for which arguably more simpler explanation can be offered. Ascher in his *Time's Arrow and the Archaeology of a Contemporary Community* (1968) used two contemporary contexts to document the process of record transformation and development. One from a Seri Indian settlement served as a basis in Schiffer's formation theory (1972, 1985). The second context of a wrecker's yard in New York, however, received less attention, but it offered an insight how the process of the record transformation can result in temporal patterning. Tracing the degree of wear and the removal of original parts in a sample of cars spanning couple of decades, the study showed that older cars had more of their original parts than newer cars. Newer objects get *selected* and *reused* more. Extension of this process over some time will necessarily result in a period with a limited number of techno-typological features in the record, which will last until another such process involving a different set of features takes

hold. If such selection is absent, then sporadic finds of particular forms are usually interpreted as anomalies in the record, like is the case, for example, with erratic occurrences of MTA-like bifaces in some contexts dated to MIS 5 (Guérin et al., 2015; see Ruebens, 2013).

While the invoked example of process of record transformation in a wrecker's yard in New York City is by no means here treated as an ultimate explanation of potential temporal patterning of stone artifact record spanning almost over hundred millennia, examples of studies such as Ascher's (1968) provide insights into how processes such as selection and recycling can produce a degree of patterning in the archaeological record. In his more thorough discussion of record transformation (from the perspective of European Iron Age), Olivier (2011) raises a similar point that new objects emerged not as a result of their predetermined form by their makers, but as a result of 'negotiation' between already existing capital and historicized contextual restrictions, opportunities, and tensions. According to him, in order to properly evaluate the importance of forms (or types), we need to study the aspects of negotiation that particular forms could achieve in the context in which they are found. A way to explore the negotiating potential (to use Olivier's terms) of stone artifacts is through experimentation (e.g., Dibble & Rezek, 2009; Lin et al., 2013).

To put this into the perspective of stone artifact record in southwest France, it has been proposed, for example, that forms of the Quina system exhibiting lower economical properties were potentially used to negotiate the future need for stone, through maximizing the number of resharpening episodes in the environment with

arguably less predictable raw material resources (Bourguignon et al., 2006; Bourguignon, 1997; Faivre, 2008; Hiscock et al., 2009; Rolland & Dibble, 1990; Rolland, 2001; Turq, 1992). What is important in this example is that the behavioral process behind the seemingly less economic flake production, as in Quina, is the one related to negotiation with different factors and concerns than, for example, those concerns associated with more economic flake production of the Levallois system, but within the context of economy and not tradition of stone tool manufacturing.

But even here, to consider all artifacts in the form of, for example, a Quina scraper to had been operationalized in the same way as described above (in anticipation of future needs) would presume that they all had one stable time- and context-transgressing identity. This presumption would negate their use-life (see Olsen, 2010). Such negation is of even a greater scale if one single strategy of negotiating with the environment is attached to the entire assemblages as collectives of individual artifacts on the basis of their shared typo-technological attributes. The recent models for interpreting Mousterian variability, such as those proposed by Pettitt (2003) and Delagnes and Rendu (2011), relate assemblage classes of the 'Levallois system', the 'Quina system', the 'Discoid-denticulate system', and the 'MTA system' with a specific strategy of Neanderthal landscape use in southwest France. In this respect, their interpretations of Mousterian variability, are, in essence, neither different from each other nor different from interpretations offered decades ago by Bordes and Binford. In all of these interpretations there is a presumed reciprocity between techno-typological features of stone artifacts and a Neanderthal stone tool making tradition, an immediate function of stone tools, or an

adaptation to the environment. With the insights from the stone artifact record of Pech IV presented here, this dissertation argues for a non-universal correlation between a particular set of techno-typological attributes of stone artifacts left by Neanderthals in southwest France and a particular subsistence, mobility, and resource procurement strategy, that is, a particular behavioral adaptation to the environment. At Pech IV, deposits with Quina elements and some deposits with Levallois elements both exhibit high variability in landscape use, implying that they both formed due to a high number of different practices of resource procurement.

Chapter 8: Conclusions

Due to the abundance of recovered stone artifacts and fauna remains, the region of southwest France continues to have a pivotal role in modeling Neandertal behavior. A related component is the interpretation of variability in the Middle Paleolithic stone artifact record. Although at a somewhat slower pace, this interpretation has been advancing towards explaining Neandertal behavior that is of evolutionary significance: their use and adaptation to their environment and distribution of resources (e.g., Delagnes & Rendu, 2011; Morin et al., 2014; Pettitt, 2003). Some interpretative models even propose a new classification system, comprised of various phases or lithic techno-complexes, as a replacement for Bordian systematics (e.g., Morin et al., 2014). Even though these developments add to the known extent of Mousterian techno-typological variability and improve our understanding of some of its formational processes, the degree to which such approaches represent a true departure from the framework for interpreting the archaeological record as inherent in both Bordes' and Binford's interpretations, is open for discussion.

As argued in this dissertation, the problem of relating Mousterian variability with the variability in Neanderthal behavior is more complex than it seems, because this problem is more associated with the very definition of our basic units of analysis -- assemblages -- and with the concept of the stone archaeological record that emerged almost two centuries ago, than with tinkering with frequencies and

occurrences of largely nominal typological or technological categories (e.g. 'Levallois', 'discoidal', 'Quina scraper', 'MTA biface').

The research presented in this dissertation investigated temporalities in stone provisioning in the record of Pech de l'Azé IV by analyzing processes of stone movement, flake production, tool selection, and tool management. The results of this analysis were used to infer the degree of variability in the use of this place and the degree of variability in the use of stone. A specific sampling procedure was employed as a response to the concept of the archaeological record as discussed and adopted in this dissertation.

There are several important findings from this research. First, this research shows that processes of stone provisioning operated on different scale of time and events, insofar as such scales can be represented by a number of accumulations (samples). What such differences in the temporalities of processes indicate is that the stone artifact record at this place was structured and accumulated due to dynamic and various interactions between different behavioral processes, rather than due to re-occuring coalescence of particular behavioral practices during the history of the use of this place and the landscape.

A second finding in modeling the interaction of some of these processes is that there aree certain patterns in the association between different degrees of variability in landscape use with the three isotope stages and with the record of particular techno-typological attributes. While some parts of the MIS 5 record at this place exhibit low variability in landscape uses and other parts of this record exhibit

high variability in this behavior, most of the MIS 4 and MIS 3 record at Pech IV indicates that during post-MIS 5 times the degree of variability in landscape use was higher. Also, the sequence of the record comprised of MIS 5 and MIS 4 deposits indicates a cyclical pattern in the degree of variability in this behavior, which was disrupted in MIS 3. In terms of techno-typological attributes, low variability in landscape use left the record with higher incidences of Levallois elements, while moderate or high variability in landscape use produced the record that is technologically less uniform and which has elements of Levallois, Quina and MTA systems.

The lowermost accumulations of the MIS 5 record ('Levallois Typical') indicate that the use of this cave was relatively stable, confirming interpretations of this record by Dibble et al. (2009). These were the times of low variability in the use of stone, which all points to low variability in landscape use.

In the middle part of the MIS 5 sequence ('Levallois Asinipodian') the record is indicative of low variability in the use of place, but of high variability in the use of stone. This pattern is interpreted as indicating moderate variability in landscape use. Variability in the use of stone remained high until the end of the accumulation of the MIS 5 record ('Levallois Typical'), but now the use of place became more variable too. This high variability in landscape use during the times of the upper part of MIS 5 record decreased at the transition towards the harsher climate of MIS 4 ('Levallois Typical'), to increase again sometime during this stage (MIS 4) (transition between 'Levallois Typical' and 'Quina') with higher variability in the use of stone.

It seems that sometime at the end of MIS 4 or at MIS 4/ MIS 3, variability in landscape use increased even more ('Quina'), but then became moderate again for most of MIS 3 ('MTA'), when variability in place use was somewhat higher, while variability in stone use was somewhat lower.

All of this suggests that the proposed interpretations of Neandertal landscape use (Delagnes & Rendu, 2011; Pettitt, 2003) are overly reductive in terms of modeling the variability in this behavior, and that known Mousterian techno-complexes cannot be interpreted as resulting from one particular Neandertal landscape use strategy.

In addition to its implications for variability in Neandertal landscape use and correlation with Mousterian techno-complexes, the research presented here also has implications for the concept of stone artifact record formation and its sampling. One of the major strengths of stone artifacts in investigating past behavior is that, unlike fauna, stones do not adapt. The physical processes behind stone fragmentation and formation of flakes are invariable across different environmental settings. At the same time, however, stone artifacts are not rocks, meaning that their emplacement in deposits is due to factors other than just those of natural geological origin. As Dunnell (1992, p. 29) notes, concentrations of artifacts certainly do occur, "… but objects found in spatial proximity, however, may have, and frequently do have, entirely unrelated histories that preclude a simple equation between spatial proximity and systemic relevance". Using DeLanda's (2006) terms, the formation of the archaeological record is a result of both territorialization and de-

territorialization or de-assembled entities. The dimensions of time and space in the formation of the archaeological record involve various processes entwined with the use-lives of individual objects and with transformations of that same record over a landscape scale due to social agencies. Re-use, discard and accumulation of stone objects are as much as important for the formation of the stone artifact record as their manufacture. They are even more important for inferring past behaviors that go beyond the mere production of stone tools and which are of higher evolutionary significance for human or hominin adaptation to their environments. To a large degree this perception is not new (see Bailey, 1981; Binford, 1981; Foley, 1981; Gould, 1980; Schiffer, 1972). However, the research in this dissertation is an attempt to go beyond a mere critique of current approaches and to explore (one of the) possible venues.

A sample may be useful for more than one archaeological inquiry, but more likely different kinds of analyses and questions will require different sampling procedures. With this in mind, and with the understanding that it is impossible to survey or excavate the entire archaeological record, there are two related questions that follow exigently: how much sampling, and of what exactly, would be sufficient? The first question is about the number of samples and their size, while the second is largely about the place of the extraction of a sample. For example, constrained with limited research funds, we may find ourselves deliberating whether excavating about ten percent of the cave area would give us a representative sample of the structure of the archaeological record in that cave context, or if surveying a particular area would enable us to record the dynamics of movement of stone

objects that is characteristic for the whole landscape. In *Kaleidoscope or Tarnished Mirror?,* Freeman (1994) noted the substantial unevenness of the structure of the stone artifact record at Cueva Morín in Cantabria. Here, the same level showed significantly different proportions of retouched forms from two adjacent excavation areas to the extent that the two samples would be classified into two different Mousterian technocomplexes, provoking Freeman to question the validity and usefulness of these units of analysis. This case of Cueva Morín is not invoked here to question horizontal homogeneity in the structure of the stone artifact record in all depositional contexts in general, and perhaps the answer for the above questions is more often than not dependent on the specific research. But what is being argued here is that any single sample can hardly serve as an analytical unit that would be appropriate for many different research inquiries simultaneously.

Furthermore, with the concept of the archaeological record adopted here, this dissertation calls for liberation from the suppressive autocracy of categories that have unclear ontological and epistemological status, like 'components', 'assemblages' and 'sites'. "The possibility of a remade archaeological ontology raises a whole host of epistemic issues foremost among which must be the significance we are to attach to the empirical character (structural properties) of the archaeological record" (Murray, 1997, p. 454).

Following these lines, the 'assemblageless' approach to the archaeological record in this dissertation prefers to view this record as a unique phenomenon: an *aggregate* of temporalities of various behavioral and natural processes.

Instead of characterizing it with deficiencies like disturbance, mixture, and especially incompleteness, this perspective underscores and appreciates its exclusiveness. This dissertation aimed to approach the stone artifact record not as an impoverished material imprint or 'tarnished mirror' reflecting the past, but as, to borrow from Freeman, a kaleidoscope, where, just as various designs appear with every rotation bringing different assortments of colored particles into the space of reflecting mirrors, past processes, patterns, and variances will emerge with shifts and flexibility in its sampling. Such venues for stone artifact archaeology have been long overdue, and in front of us all are exciting times in exploring and exposing the particularities of the archaeological record across its spatial and temporal dimensions.

Bibliography

Adams, W. Y., & Adams, E. W. (1991). *Archaeological Typology and Practical Reality: A Dialectical Approcach to Artifact Classification and Sorting*. Cambridge: Cambridge University Press.

Airvaux, J., & Soressi, M. (2005). Nouvelles observations sur le Moustérien final du site paléolithique de Chez-Pinaud à Jonzac. *Préhistoire Du Sud-Ouest*, *12*, 163–174.

Andrefsky, W. (1991). Inferring trends in prehistoric settlement behavior from lithic production technology in the Southern Plains. *North American Archaeology*, *12*, 129–144.

Andrefsky, W. (1994). Raw-material availability and the organization of technology. *American Antiquity*, *59*, 21–34.

Andrefsky, W. (2006). Experimental and archaeological verification of an index of retouch for hafted bifaces. *American Antiquity*, *71*, 743–759.

Andrefsky, W. (Ed.). (2008). *Lithic Technology: Measures of Production, Use, and Curation*. Cambridge: Cambridge University Press.

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

Anklin, M., Barnola, J. M., Beer, J., Blunier, T., Chappellaz, J., Clausen, H. B., … Oeschger, H. (1993). Climate instability during the last interglacial period recorded in the GRIP ice core. *Nature*, *364*, 203–207.

Appadurai, A. (Ed.). (1986). *The Social Life of Things*. Cambridge: Cambridge University Press.

Armand, D. (1998). La faune de la grotte Bourgeois-Delaunay commune de la Chaise de Vouthon (Charente). Résultats préliminaires. *Paléo*, *10*, 77–86.

Ascher, R. (1961). Analogy in archaeological interpretation. *Southwestern Journal of Anthropology*, *17*, 317–325.

Ascher, R. (1968). Time's arrow and the archaeology of contemporary comunity. In K. C. Chang (Ed.), *Settlement Archaeology* (pp. 43–52). Palo Alto: National Press Books.

Bailey, G. N. (1981). Concepts, time-scales and explanations in economic prehistory. In A. Sheridan & G. N. Bailey (Eds.), *Economic Archaeology* (pp. 97–117). Oxford: British Archaeological Reports International Series 96.

Bailey, G. N. (1983). Concepts of Time in Quaternary Prehistory. *Annual Review of Anthropology*, *12*, 165–192.

Bailey, G. N. (2007). Time perspectives, palimpsests and the archaeology of time. *Journal of Anthropological Archaeology*, *26*, 198–223.

Bailey, G. N. (2008). Time Perspectivism: origins and consequences. In S. J. Holdaway & L. Wandsnider (Eds.), *Time in Archaeology. Time Perspectivism Revisited* (pp. 13–30). Salt Lake City: University of Utah Press.

Bamforth, D. B. (1986). Technological efficiency and tool curation. *American Antiquity*, *51*, 38–50.

Bamforth, D. B. (1991). Technological organization and hunter-gatherer land use: A California example. *American Antiquity*, *56*, 216–234.

Bamforth, D. B., & Bleed, P. (1997). Technology, flaked stone technology, and risk. In M. C. Barton & G. A. Clark (Eds.), *Rediscovering Darwin: Evolutionary Theory in Archaeological Explanation* (pp. 109–139). Arlington: American Anthropological Association.

Banes, L., & Dorigny, A. (2005). le gisement des Ramandils (Port-la-Nouvelle, Aude). Approche paléoenvironnementale. In A. Tuffreau (Ed.), *Peuplements humains et variations environnementales au Quaternaire* (pp. 95–104). BAR International Series 1352.

Barton, M. C., & Riel-Salvatore, J. (2014). The formation of lithic assemblages. *Journal of Archaeological Science*, *46*, 334–352.

Bar-Yosef, O., & Kuhn, S. L. (1999). The big deal about blades: laminar technologies and human evolution. *American Anthropologist*, *101*, 322–338.

Behrensmeyer, A. K. (1982). Time resolution in fluvial vertebrate assemblages. *Paleobiology*, *8*, 211–227.

Behrensmeyer, A. K., & Schindel, D. (1983). Resolving time in paleobiology. *Paleobiology*, *9*, 1–8.

Berry, L. G., & Mason, B. (1959). *Mineralogy; Concepts, Descriptions, Determinations*. San Franciso: W. H. Freeman and Co.

Bettinger, R. L. (1991). *Hunter-Gatherers: Archaeological and Evolutionary Theory*. New York: Plenum Press.

Binford, L. R. (1964). A consideration of archaeological research design. *American Antiquity*, *29*, 425–441.

Binford, L. R. (1973). Interassemblage variability: the Mousterian and the "functional" argument. In C. Renfrew (Ed.), *The Explanation of Cultural Change* (pp. 227–254). London: Duckworth.

Binford, L. R. (1978). Dimensional analysis and site structure: learning from an Eskimo hunting stand. *American Antiquity*, *43*, 330–361.

Binford, L. R. (1979). Organization and formation processes: looking at curated technologies. *Journal of Anthropological Research*, *35*, 225–273.

Binford, L. R. (1980). Willow smoke and dogs ' tails: hunter-gatherer settlement systems and archaeological site formation. *American Antiquity*, *45*, 4–20.

Binford, L. R. (1981). Behavioral archaeology and the "Pompeii Premise." *Journal of Anthropological Research*, *37*, 195–208.

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

Binford, L. R. (1989). Isolating the transition to cultural adaptations: an organizational approach. In E. Trinkaus (Ed.), *The Emergence of Modern Humans: Biocultural Adaptations in the Later Pleistocene* (pp. 18–41). Cambridge: Cambridge University Press.

Bird, D. W., & O'Connell, J. F. (2006). Behavioral ecology and archaeology. *Journal of Archaeological Research*, *14*, 143–188.

Bleed, P. (1986). The optimal design of hunting weapons: Maintenability or reliability. *American Antiquity*, *51*, 737–747.

Bocherens, H., Drucker, D. G., Billiou, D., Patou-Mathis, M., & Vandermeersch, B. (2005). Isotopic evidence for diet and subsistence pattern of the Saint-Césaire I Neanderthal: review and use of a multi-source mixing model. *Journal of Human Evolution*, *49*, 71–87.

Boëda, E. (1993). Le débitage Discoïde et le débitage Levallois récurrent centripète. *Bulletin de La Société Préhistorique Française*, *90*, 392–404.

Boëda, E. (1994). *Le Concept Levallois: Variabilité des Méthodes*. Paris: Centre de la Recherche Scientifique (CNRS).

Boëda, E. (1995). Levallois: a volumetric construction, methods, and technique. In H. L. Dibble & O. Bar-Yosef (Eds.), *The Definition and Interpretation of Levallois Technology* (pp. 41–68). Madison: Prehistory Press.

Boëda, E., Fontugne, M., Valladas, H., & Ortega, I. (1996). Barbas III. Industries du Paléolithique moyen récent et du Paléolithique supérieur ancien. In E. Carbonell & M. Vaquero (Eds.), *The Last Neandertals, the First Anatomically Modern Humans: A Take About the Human Diversity. Cultural Shange and Human Evolution: The Crisis at 40 ka BP* (pp. 147–156). Tarragona: Universitat Rovira i Virgili Press.

Boëda, E., Geneste, J.-M., & Meignen, L. (1990). Identification de chaînes opératoires lithiques du Paléolithique Ancien et Moyen. *Paléo*, *2*, 43–80.

Bordes, F. (1950a). L'Évolution buissonnante des industries en Europe Occidentale. Considérations théoriques sur le Paléolithique ancien et moyen. *L'Anthropologie*, *54*, 393–420.

Bordes, F. (1950b). Principes d'une méthode d'étude des techniques et de la typologie du Paléolithique ancient et moyen. *L'Anthropologie*, *54*, 19–34.

Bordes, F. (1953). Essai de classification des industries moustériennes. *Bulletin de La Société Préhistorique Française*, *50*, 457–466.

Bordes, F. (1954). Les gisements du Pech de l'Azé (Dordogne) I; Le Mousterien de tradition Acheulien. *L'Anthropologie*, *58*, 401–432.

Bordes, F. (1955). Les gisements du Pech de l'Azé (Dordogne). *L'Anthropologie*, *59*, 1–38.

Bordes, F. (1961a). Mousterian cultures in France. *Science*, *134*, 803–810.

Bordes, F. (1961b). Typologie du Paléolothique ancien et moyen. In *Publications de L'Institut de Préhistoire de Bordeaux, Mémoire no.1*. Bordeaux: Delmas.

Bordes, F. (1966). Acheulian cultures in southwest France. In D. Sen & A. K. Ghosh (Eds.), *Studies in Prehistory - Robert Bruce Foote memorial volume* (pp. 49–63). Calcutta: Firma K. L. Mukhopadhyay.

Bordes, F. (1971). Observations sur l'Acheuléen des grottes en Dordogne. *Munibe*, *23*, 5–23.

Bordes, F. (1972). *A Tale of Two Caves*. New York: Harper & Row.

Bordes, F. (1975). Le gisement de Pech de l'Azé IV: note préliminaire. *Bulletin de La Société Préhistorique Française*, *72*, 293–308.

Bordes, F. (1978). Typological variability in the Mousterian layers at Pech de l'Azé I, II, and IV. *Journal of Anthropological Research*, *34*, 181-193.

Bordes, F. (1981). Vingt-cinq ans après: le complexe moustérien revisité. *Bulletin de La Société Préhistorique Française*, *78*, 77–87.

Bordes, F. (1984). *Leçons sur le Paléolithique. Tome II: Le Paléolithique en Europe*. Paris: CNRS.

Bordes, F., & Bourgon, M. (1950). Legisement du Pech de l'Azé Nord. Prise de date et observations préliminaires. *Bulletin de La Société Préhistorique Française*, *47*, 381–383.

Bordes, F., & Bourgon, M. (1951a). Le complexe moustérien: Moustérien, Levalloisien et Tayacien. *L'Anthropologie*, *55*, 1–23.

Bordes, F., & Bourgon, M. (1951b). Le gisement du Pech de l'Azé Nord. Campagnes 1950-1951. *Bulletin de La Société Préhistorique Française*, *48*, 520–538.

Bourguignon, L. (1997). *Le Moustérien de type Quina: Nouvelle Definition d'une Entité Technique*. Université Paris X-Nanterre.

Bourguignon, L., Delagnes, A., & Meignen, L. (2006). Systèmes de production lithique, gestion des outillages et territoires au Paléolithique moyen: où se trouve la complexité? In *Normes techniques et pratiques sociales: de la simplicité des outillages pré- et protohistoriques. XXVIe Rencontres Internationales d'Archéologie et d'Histoire d'Antibes* (pp. 75–86). Antibes: Editions APDCA.

Bousman, B. C. (1993). Hunter-gatherer adaptations: Economic risk and tool design. *Lithic Technology*, *18*, 59–86.

Bowman, S. G. E., Loosemore, R. P. W., Sieveking, G. D. G., & Bordes, F. (1982). Preliminary dates for Pech de l'Azé IV. *Revue Du Groupe Européen D'études Pour Les Techniques Physiques, Chimiques et Mathématique Appliquées À L'archéologie*, *6*, 362–369.

Brantingham, P. J. (2006). Measuring forager mobility. *Current Anthropology*, *47*, 435–459.

Braun, D. R. (2006). *The Ecology of Oldowan Technology: Prspectives for Koobi Fora and Kanjera South (Kenya)*. Rutgers University, New Brunswick.

Breuil, H. (1913). Les subdivisions du Paléolithique supérieur et leur signification. In *Congrès International d'Archéologie et d'Art Préhistorique* (pp. 165–238). Genève.

Breuil, H., & Koslowski, L. (1932). Etudes de stratigraphie paléolithique dans le nord de la France. *L'Anthropologie*, *42*, 27–47.

Briki-Hereich, D., Duran, J.-P., Saos, T., Gregoire, S., & Moigne, A.-M. (2005). Le gisement moustérien de al Rouquette à Puycelsi (Tam, France): une occupation de plein air de chasseurs de grands herbivores. In N. Molines, M.-H. Moncel, & J.-L. Monnier (Eds.), *Les premiers peuplements en Europe* (pp. 215–226). BAR International Series 1364.

Britton, K., Vaughan, G., Niven, L., Steele, T. E., McPherron, S. P., Soressi, M., … Richards, M. P. (2011). Strontium isotope evidence for migration in late Pleistocene Rangifer: implications for Neanderthal hunting strategies at the Middle Palaeolithic site of Jonzac, France. *Journal of Human Evolution*, *61*, 176–185.

Burke, A. (1993). Applied skeletochronology: the horse as a human prey during the pleniglacial in southwestern France. In G. L. Peterkin, H. M. Bricker, & P. Mellars (Eds.), *Hunting and Animal Exploitation in the Later Palolithic and Mesolithic of Euroasia* (pp. 145–150). Archaeological Papers of the American Anthropological Association No. 4.

Butzer, K. (1982). *Archaeology as Human Ecology: Method and Theory for a Contextual Approach*. Cambridge: Cambridge University Press.

Callow, P., & Webb, R. E. (1981). The application of mulitvariate statistical techniques to Middle Paleolithic assemblages from southwestern France. *Revue d'Archéometrie*, *5*, 129–138.

Capitan, L., & Peyrony, D. (1909). Deux squelettes humaines au milieu de foyers de l'époque Moustérienne. *Revue de l'Ecole d'Anthropologie*, *19*, 402–409.

Carr, P. J., & Bradbury, A. P. (2011). Special Issue: Reduction Sequence,. *PaleoAnthropology*, 9–10.

Chapman, J. (2000). *Fragmentation in Archaeology. People, Places, and Broken Objects in the Prehistory of South Eastern Europe*. London: Routledge.

Chapman, J., & Gaydarska, B. (2007). *Parts and Wholes. Fragmentation in Prehistoric Context*. Oxford: Oxbow Books.

Chase, P. G. (1986). Relationships between Mpusterian lithic and faunal assemblages at Combe Grenal. *Current Anthropology*, *27*, 69–71.

Chase, P. G. (1999). Bison inthe context of complex utilization of faunal resources: a preliminary report on the Mousterian zooarchaeology of la Quina (Charente, France). In J.-P. Brugal, F. David, J. G. Enloe, & J. Jaubert (Eds.), *Le Bison: Gibier et*

moyen de subsistance des hommes du Paléolithique aux Paléoindiens des Grandes Plaines (pp. 159–185). Antibes: Éditions APDCA.

Chase, P. G., & Dibble, H. L. (1987). Middle Paleolithic symbolism: a review of current evidence and interpretations. *Journal of Anthropological Archaeology*, *6*, 263–296.

Chiles, J. P., & Delfiner, P. (1999). *Geostatistics: Modelling Spatial Uncertainity*. New York: Wiley.

Chiotti, L., McPherron, S. P., Olszewski, D. I., Dibble, H. L., & Smith, J. R. (2007). Paleolithic Abydos : Reconstructing individual behaviors across the high desert landscape. In *The Archaeology and Art of Egypt: Essays in Honor of David B. O'Connor* (pp. 169–184). Cairo: Supreme Council of Antiquities Press.

Clarkson, C., & Lamb, L. (Eds.). (2006). *Lithics "Down Under": Australian Approaches to Lithic Reduction, Use, and Classification*. Oxford: BAR International Series 1408.

Claud, E. (2008). *Le statut fonctionnel des bifaces au Paléolithique moyen récent dans le Sud-Ouest de la France. Etude tracéologique intégrée des outillages des sites de La Graulet, La Conne de Bergerac, Combe Brune 2, Fonseigner et Chez-Pinaud/Jonzac.* PhD Dissertation. Université Bordeaux 1 Talence.

Close, A. E. (2000). Reconstructing movement in prehistory. *Journal of Archaeological Method and Theory*, *7*, 49–77.

Collins, M. B. (1975). Lithic technology as a means of processula inference. In E. D. Swanson (Ed.), *Lithic Technology: Making and Using Stone Tools* (pp. 15–34). Chicago: Aldine.

Commont, V. (1909). L'industrie moustérienne dans la region de Nord de la France. In *Congrés Préhistorique de France, V ème Session* (pp. 115–157). Beauvais.

Commont, V. (1913). *Les Hommes Contemporaines du Renne Dans la Valle de la Somme*. Amiens: Imprimerie Yvert et Tellier.

Cook, S. F. (1946). A reconsideration of shell mounds with repsect to population and nutrition. *American Antiquity*, *12*, 51–53.

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

Crawford, O. G. S. (1953). *Archaeology in the Field*. London: Phoenix House.

D'Errico, F., Zilhão, J., Julien, M., Baffier, D., & Pelegrin, J. (1998). Neanderthal acculturation in Western Europe?: A critical review of the evidence and its interpretation. *Current Anthropology*, *39*, S1–S44.

Daniel, G. E. (1950). *A Hundred Years of Archaeology*. London: Gerald Duckworth & Co.

Daujeard, C., Fernandes, P., Guadelli, J.-L., Moncel, M.-H., Santagata, C., & Raynal, J.-P. (2012). Neanderthal subsistence strategies in Southeastern France between the plains of the Rhone Valley and the mid-mountains of the Massif Central (MIS 7 to MIS 3). *Quaternary International*, *252*, 32–47.

Daujeard, C., & Moncel, M.-H. (2010). On Neanderthal subsistence strategies and land use: A regional focus on the Rhone Valley area in southeastern France. *Journal of Anthropological Archaeology*, *29*, 368–391.

David, F., & Fosse, P. (1999). Le bison comme moyen de subsistance au Paléolithique: gisements de plein air et sites en grotte. In J.-P. Brugal, F. David, J. G. Enloe, & J. Jaubert (Eds.), *Le Bison: Gibier et moyen de subsistance des hommes du Paléolithique aux Paléoindiens des Grandes Plaines* (pp. 121–141). Antibes: Editions APDCA.

David, N. (1972). On the life span of pottery, type frequencies, and archaeological inference. *American Antiquity*, *37*, 141–142.

Davidson, D., & Shackley, M. (Eds.). (1976). *Geoarchaeology: Earth Science and the Past*. Boulder, CO: Westview Press.

De Mortillet, G. (1872). Classification des diverses périodes de l'âge de la pierre. *Revue d'Anthropologie*, *1*, 432–442.

De Mortillet, G. (1883). *Le Préhistorique: Antiquité de l'Homme*. Paris: C. Reinwald.

De Mortillet, G., & de Mortillet, A. (1900). *Le Préhistorique Origine et Antiquité de l'Homme*. (S. Frères, Ed.). Paris: C. Reinwald.

Delagnes, A. (1993). Un mode se preduction inédit au Paléolithique moyen dans l'industrie du niveau 6e du Pucheuil (Seine-Maritime). *Paléo*, *5*, 111–120.

Delagnes, A., & Meignen, L. (2006). Diversity of lithic production systems. In E. Hovers & S. L. Kuhn (Eds.), *Transitions Before the Transition: Evolution and Stability in the Middle Paleolithic and Middle Stone Age* (pp. 85–107). New York: Springer.

Delagnes, A., & Rendu, W. (2011). Shifts in Neandertal mobility, technology and subsistence strategies in western France. *Journal of Archaeological Science*, *38*, 1771–1783.

Delagnes, A., Tournepiche, J.-F., Armand, D., Desclaux, E., Diot, M.-F., Ferrier, C., … Vandermeersch, B. (1999). Le gisement Pléistocène moyen et supérieur d'Artenac (Saint-Mary, Charente): premier bilan interdisciplinaire. *Bulletin de La Société Préhistorique Française*, *96*, 469–494.

DeLanda, M. (2006). *A New Philosophy of Society: Assemblage Theory and Social Complexity*. London: Continuum.

Deleuze, G., & Guattari, F. (1987). *A Thousand Plateaus*. Minneapolis: University of Minnesota Press.

Delpech, F. (1996). L'environment animal des Moustériens Quina du Périgord. *Paléo*, *8*, 31–46.

Delpech, F. (1999). La chasse au Bison dans le sud-ouest de la France au cours du Würm. In J.-P. Brugal, F. David, J. G. Enloe, & J. Jaubert (Eds.), *Le Bison: Gibier et moyen de subsistance des hommes du Paléolithique aux Paléoindiens des Grandes Plaines* (pp. 63–84). Antibes: Éditions APDCA.

Demars, P.-Y. (1982). *L'utilisation du silex au Paléolithique supérieur: choix, approvisionnement, circulation: L'exemple du Basin de Brive. Cahiers du Quaternaire No 5*. *Cahiers du Quaternaire* (Vol. 5). Paris: CNRS.

Dibble, H. L. (1984). Interpreting typological variation of Middle Paleolithic scrapers: function, style, or sequence of reduction. *Journal of Field Archaeology*, *11*, 431–436.

Dibble, H. L. (1987). The interpretation of Middle Paleolithic scraper morphology. *American Antiquity*, *52*, 109–117.

Dibble, H. L. (1988). The interpretation of Middle Paleolithic scraper reduction patterns. In L. R. Binford & J.-P. Rigaud (Eds.), *L'Homme de Neandertal Volume 4: La Technique* (pp. 49–58). Liège: Etudes et Recherches Archéologiques de l'Université de Liège.

Dibble, H. L. (1991). Local raw material exploitation and its effects on Lower and Middle Paleolithic assemblage variability. In A. Montet-White & S. Holen (Eds.), *Raw Material Economies among Prehistoric Hunter-Gatherers. University of Kansas Publications in Anthropology* (pp. 33–47). Lawrence: University of Kansas.

Dibble, H. L. (1995). Middle Paleolithic scraper reduction: background, clarification, and review of the evidence to date. *Journal of Archaeological Method and Theory*, *2*, 299–368.

Dibble, H. L., Aldeias, V., Alvarez-Fernández, E., Blackwell, B., Hallett-Desguez, E., Jacobs, Z., … El-Hajraoui, M. (2012). New excavations at the site of Contrebandiers Cave, Morocco. *PaleoAnthropology*, 145–201.

Dibble, H. L., Aldeias, V., Goldberg, P., McPherron, S. P., Sandgathe, D., & Steele, T. E. (2015). A critical look at evidence from La Chapelle-aux-Saints supporting and intentional Neandertal burial. *Journal of Archaeological Science*, *53*, 649–657.

Dibble, H. L., & Bar-Yosef, O. (Eds.). (1995). *The Definition and Interpretation of Levallois Technology*. Madison: Prehistory Press.

Dibble, H. L., Berna, F., Goldberg, P., McPherron, S. P., Mentzer, S. M., Niven, L., … Turq, A. (2009). A preliminary report on Pech de l'Azé IV, Layer 8 (Middle Paleolithic, France). *PaleoAnthropology*, *8*, 182–219.

Dibble, H. L., & Lenoir, M. (1995). Summary of the industrial sequence. In H. L. Dibble & M. Lenoir (Eds.), *The Middle Paleolithic Site of Combe-Capelle Bas (France)* (pp. 161–173). Philadelphia: University of Pennsylvania Museum.

Dibble, H. L., & McPherron, S. P. (2006). The Missing Mousterian. *Current Anthropology*, *47*, 777–803.

Dibble, H. L., & McPherron, S. P. (2007). Truncated-faceted pieces: haftin modifications, retouch or cores? In S. P. McPherron (Ed.), *Tools Versus Cores: Alternative Approaches in Stone Tool Analysis* (pp. 75–90). Newcastle: Cambridge Scholars Publishing.

Dibble, H. L., McPherron, S. P., Sandgathe, D., Goldberg, P., Turq, A., & Lenoir, M. (2009). Context, curation, and bias: an evaluation of the Middle Paleolithic collections of Combe-Grenal (France). *Journal of Archaeological Science*, *36*, 2540–2550.

Dibble, H. L., Raczek, T. P., & McPherron, S. P. (2005). Excavatore bias at the site of Pech de l'Azé IV, France. *Journal of Field Archaeology*, *30*, 317–328.

Dibble, H. L., & Rezek, Z. (2009). Introducing a new experimental design for controlled studies of flake formation: results for exterior platform angle, platform depth, angle of blow, velocity, and force. *Journal of Archaeological Science*, *36*, 1945–1954.

Dibble, H. L., & Rolland, N. (1992). On assemblage variability in the Middle Paleolithic of Western Europe; History, perspectives and a new synthesis. In H.

L. Dibble & P. Mellars (Eds.), *The Middle Paleolithic: Adaptation, Behavior and Variability* (pp. 1–28). Philadelphia: University of Pennsylvania Museum.

Dibble, H. L., Schurmans, U. A., Ioviţă, R., & McLaughlin, M. V. (2005). The measurement and interpretation of cortex in lithic assemblages. *American Antiquity*, *70*, 545–560.

Discamps, E., Jaubert, J., & Bachellerie, F. (2011). Human choices and environmental constraints: deciphering the variability of large game procurement from Mousterian to Aurignacia times (MIS 5-3) in southwestern France. *Quaternary Science Reviews*, *30*, 2755–2775.

Djindjian, F. (2012). Is the MP-EUP transition also an economic and social revolution? *Quaternary International*, *259*, 72–77.

Douglass, M. J. (2010). *The Archaeological Potential of Informal Lithic Technologies: A Case Study of Assemblage Variability in Western New South Wales, Australia*. PhD Dissertation. The University of Auckland.

Douglass, M. J., Holdaway, S. J., Fanning, P. C., & Shiner, J. I. (2008). An assessment and archaeological application of cortex measurement in lithic assemblages. *American Antiquity*, *73*, 513–526.

Dunnell, R. C. (1971). *Systematics in Prehistory* (1st ed.). New York: The Free Press.

Dunnell, R. C. (1986). Methodological issues in Americanist artifact classification. In M. B. Schiffer (Ed.), *Advances in Archaeological Method and Theory* (pp. 35–99). New York, NY: Academic Press.

Dunnell, R. C. (1992). The notion site. In J. Rossignol & L. Wandsnider (Eds.), *Space, Time, and Archaeological Landscapes* (pp. 21–42). New York: Plenum Press.

Elston, R. G. (1990). A cost-benefit model for lithic assemblage variability. In R. G. Elston (Ed.), *The Archaeology of James Creek Shelter* (pp. 153–163). Salt Lake City: University of Utah Press.

Eren, M. I., & Lycett, S. J. (2012). Why Levallois? A morphometric comparison of experimental "preferential" Levallois flakes versus debitage flakes. *Plos ONE*, *7*(1), e29273. http://doi.org/10.1371/journal.pone.0029273

Faivre, J.-P. (2008). *Organisation techno-économique des systèmes de production dans le Paléolithique moyen récent du nord-est Aquitain: Combe-Grenal et les Fieux*. PhD Dissertation. Université Bordeaux I.

Faivre, J.-P., Discamps, E., Gravina, B., Turq, A., Guadelli, J.-L., & Lenoir, M. (2014). The contribution of lithic production systems to the interpretation of

Mousterian industrial variability in south-western France: the examle of Combe-Grenal (Dordogne, France). *Quaternary International*, *350*, 227–240.

Farizy, C. (1990). Du Mustérien au Châtelperronien à Arcy-sur-Cure: un état de la question. In C. Farizy (Ed.), *Paléolithique moyen et Paléolithique supérieur ancien en Europe* (pp. 281–289). Nemours: Mémoires du Musée de Préhistoire d'Île-de-France 3.

Féblot-Augustin, J. (1993). Mobility strategies in the late Middle Paleolithic of Central Europe and Western Europe: elements of stability anbd variability. *Journal of Anthropological Archaeology*, *12*, 211–265.

Féblot-Augustin, J. (1999). Raw material transport patterns and settlement systems in the European Lower and Middle Paleolithic; continuity, change and variability. In W. Roebroeks & C. Gamble (Eds.), *The Middle Paleolithic Occupation of Europe* (pp. 193–214). Leiden: University of Leiden.

Foley, R. A. (1981). A model of regional archaeological structure. *Proceedings of the Prehistoric Society*, *47*, 1–17.

Freeman, L. G. (1994). Kaleidoscope or tarnished mirror? Thirty years of Mousterian investigations in Cantabria. In J. A. Lasheras (Ed.), *Homenaje al Dr. Joaquín González Echegaray* (pp. 37–54). Madrid: Museo y Centro de Investigación de Altamira.

Frison, G. (1968). A functional analysis of certain chipped stone tools. *American Antiquity*, *33*, 149–155.

Gargett, R. H., Bricker, H. M., Clark, G., Lindly, J., Farizy, C., Masset, C., … Weber, A. W. (1989). Grave shortcomings: the evidence for Neandertal burial [and Comments and Reply]. *Current Anthropology*, *30*, 157–190.

Gell, A. (1992). *The Anthropology of Time: Cultural Constructions of Temporal Maps and Images*. Oxford: Berg.

Geneste, J.-M. (1985). *Analyse Lithique d'Industries Moustériennes du Périgiord: Une Approche Technologique du Comportment des Groupes Humains au Paléolithique Moyen*. PhD Dissertation. Université de Bordeaux.

Geneste, J.-M. (1988). Les industries de al Grotte Vaufrey: technologie du débitage, économie et circualtion de la matière première lithique. In J.-P. Rigaud (Ed.), *La Grotte Vaufre: paléoenvironment, chronologie, activités humaines* (pp. 441–517). Paris: Mémoires de la SociétéPréhistorique Française 19.

Geneste, J.-M. (1989). Econmie des resources lithiques dans le Moustérien de sud-ouest de la France. In M. Otte (Ed.), *L'Homme de Néandertal, Vol 6: La*

Subsistence (pp. 75–97). Liège: Etudes et Recherches Archéologiques de l'Universitéde Liège.

Geneste, J.-M., & Plisson, H. (1996). Production et utilisation de l'outillage lithique dans le Moustérien du sud-ouest de la France: Les Tares, à Sourzac, Vallée de l'Isle, Dordogne. *Quaternaria Nova*, *VI*, 343–368.

Genty, D., Combourieu-Nebout, N., Peyron, O., Blamart, D., Wainer, K., Mansuri, F., … Brauer, A. (2010). Isotopic characterization of rapid climate events during OIS 3 and OIS 4 in Villars Cave stalagmites (SW France) and correlation with Atlantic and Mediterranean pollen records. *Quaternary Science Reviews*, *29*, 2799–2820.

Gibbard, P., & van Kolfshoten, T. (2004). The Pleistocene and Holocene series. In F. Gradstein, J. Ogg, & A. Smith (Eds.), *A Geologic Time Scale* (pp. 441–452). Cambridge: Cambridge University Press.

Gifford, E. W. (1916). Composition of California shellmounds. *University of California Publications in American Archaeology and Ethnology*, *12*, 1–29.

Goldberg, P., & Berna, F. (2010). Micromorphology and context. *Quaternary International*, *214*, 56–62.

Goldberg, P., Dibble, H. L., Berna, F., Sandgathe, D., McPherron, S. P., & Turq, A. (2012). New evidence on Neandertal use of fire: Examples from Roc de Marsal and Pech de l'Azé IV. *Quaternary International*, *247*, 325–340.

Gosden, C., & Marshall, Y. (1999). The cultural biography of objects. *World Archaeology*, *31*, 169–178.

Gould, R. A. (1980). *Living Archaeology*. Cambridge: Cambridge University Press.

Gradstein, F. M., Ogg, J. G., & Smith, A. G. (2004). *A Geologic Time Scale*. Cambridge: Cambridge University Press.

Grayson, D. K., & Delpech, F. (2003). Ungulates and the middle-to-upper Paleolithic transition at the Grotte XVI (Dordogne, France). *Journal of Archaeological Science*, *30*, 1633–1648.

Grün, R., Mellars, P., & Laville, H. (1991). ESR chronology of a 100,000-year archaeological sequence at Pech de l'Azé II, France. *Antiquity*, *65*, 544–551.

Grün, R., Yan, G., McCulloch, M., & Mortimer, G. (1999). Detailed mass spectrometric U-series analysis of two teeth from the archaeological site of Pech de l'Azé II: implications for uranium migration and dating. *Journal of Archaeological Science*, *26*, 1301–1310.

Guadelli, J.-L. (1987). *Contribution à l'étude des zoocénoses préhistoriques en Aquitaine (Würm ancien et interstade würmien)*. PhD Dissertation. Université Bordeaux 1.

Guérin, G., Discamps, E., Lahaye, C., Mercier, N., Guibert, P., Turq, A., … Soulier, M.-C. (2012). Multi-method (TL and OSL), multi-material (quartz and flint) dating of the Mousterian site of Roc de Marsal (Dordogne, France): correlating Neanderthal occupations with the climatic variability of MIS 5–3. *Journal of Archaeological Science*, *39*, 3071–3084.

Guérin, G., Frouin, M., Talamo, S., Aldeias, V., Bruxelles, L., Chiotti, L., … Turq, A. (2015). A multi-method luminescence dating of the Palaeolithic sequence of La Ferrassie based on new excavations adjacent to the La Ferrassie 1 and 2 skeletons. *Journal of Archaeological Science*, *58*, 147–166.

Guibert, P., Bechtel, F., Bourguignon, L., Brenet, M., Couchoud, I., Delagnes, A., … Villeneuve, G. (2008a). Les sociétés du Paléolithique dans un grand sud-ouest de la France. In J. Jaubert, J.-G. Bordes, & I. Ortega (Eds.), *Les sociétés du Paléolithique dans un grand sud-ouest de la France: Nouveaux gisements, nouveaux résultats, nouvelles méthodes* (pp. 19–40). Paris: Mémoire de la Société Préhistorique Française.

Guibert, P., Bechtel, F., Bourguignon, L., Brenet, M., Couchoud, I., Delagnes, A., … Villeneuve, G. (2008b). Un base de données pour la chronologie du Paléolithique moyen dans le Sud-Ouest de la France. In J. Jaubert, J.-G. Bordes, & I. Ortega (Eds.), *Les sociétés du Paléolithique dans un Grand Sud-Ouest de la France: nouveaux gisements, nouveau résultats, nouvelles méthodes* (pp. 19–40). Paris: Société Préhistorique Française.

Harris, E. C. (1989). *Principles to Archaeological Stratigraphy*. London: Academic Press.

Hayden, B. (1979). *Paleolithic reflections: Lithic technology and ethnographic excavation among the Australian Aborigines*. Canberra: Australian Institute of Aboriginal Studies.

Hayden, B., & Cannon, A. (1983). Where the garbage goes: Refuse disposal in the Maya highlands. *Journal of Anthropological Archaeology*, *2*, 117–163.

Hill, J. N., & Evans, R. K. (1972). A model for classification and typology. In D. J. Clark (Ed.), *Models in Archaeology* (pp. 231–273). London: Methuen.

Hiscock, P. (2002). Quantifying the size of artefact assemblages. *Journal of Archaeological Science*, *29*, 251–258.

Hiscock, P., & Clarkson, C. (2005). Experimental evaluation of Kuhn's geometric index of reduction and the flat-flake problem. *Journal of Archaeological Science*, *32*, 1015–1022.

Hiscock, P., Turq, A., Faivre, J.-P., & Bourguignon, L. (2009). Quina procurement and tool production. In B. Adams & B. S. Blades (Eds.), *Lithic Materials and Paleolithic Societies* (pp. 232–246). Oxford: Wiley-Blackwell.

Hodder, I. (1989). This is not an article about material culture as text. *Journal of Anthropological Archaeology*, *8*, 250–269.

Hodder, I. (2012). *Entangled*. Malden: Wiley-Blackwell.

Hodder, I., & McAnnany, P. (2009). Thinking about stratigraphic sequences in social terms. *Archaeological Dialogues*, *16*, 1–22.

Holdaway, S. J., & Douglass, M. J. (2011). A Twenty-First Century Archaeology of Stone Artifacts. *Journal of Archaeological Method and Theory*. DOI: 10.1007/s10816-011-9103-6

Holdaway, S. J., Douglass, M. J., & Fanning, P. C. (2012). Landscape scale and human mobility: Geoarchaeologcal evidence from Rutherfords Creek, New South Wales, Australia. In S. J. Kluiving & E. B. Guttmann-Bond (Eds.), *Landscape Archaeology Between Art and Science: From a Muliti- to an Interdisciplinary Approach* (Amsterdam, pp. 279–294). Amsterdam: Amsterdam University Press.

Holdaway, S. J., Douglass, M. J., & Fanning, P. C. (2013). A new ecological framework for understanding human-environment interaction in arid Australia. In D. Frankel & J. M. Webb (Eds.), *Archaeology in Environment and Technology: Intersections and Transformations* (pp. 51–68). London: Routledge.

Holdaway, S. J., & Wandsnider, L. (2006). Temporal scales and archaeological landscapes from the Eastern Desert of Australia and Intermontane North America. In G. Lock & B. Molyneaux (Eds.), *Confronting Scale in Archaeology: Issues of Theory and Practice* (pp. 183–202). New York: Kluwer Plenum Press.

Holdaway, S. J., & Wandsnider, L. (Eds.). (2008). *Time in Archaeology: Time Perspectivism Revisited*. Salt Lake City: The University of Utah Press.

Holmes, W. H. (1890). A quarry workshop of the flaked stone implement makers in the District of Columbia. *American Anthropologist*, *3*, 1–26.

Holmes, W. H. (1894). Natural history of flakes stone implements. In C. S. Wake (Ed.), *Memoirs of the International Congress of Anthropology* (pp. 120–139). Chicago: Schulte.

Hublin, J.-J., Spoor, F., Braun, M., Zonneveld, F., & Condemi, S. (1996). A late Neanderthal associated with Upper Palaeolithic artefacts. *Nature*, *381*, 224–226.

Ingold, T. (1993). The temporality of the landscape. *World Archaeology*, *25*, 152–174.

Isaac, G. L. (1972). Chronology and the tempo of cultural change during the Pleistocene. In W. W. Bishop & J. A. Miller (Eds.), *Calibration of Hominoid Evolution* (pp. 381–430). Edinburgh: Academic Press.

Isaac, G. L. (1981). Stone Age visiting cards: approaches to the study of early land use patterns. In I. Hodder, G. L. Isaac, & N. Hammond (Eds.), *Patterns of the Past: Studies in Honour of David Clarke* (pp. 131–155). Cambridge: Cambridge University Press.

Jaubert, J., Bordes, J.-G., & Gravina, B. (2011). A new look at the end of the Middle Palaeolithic sequence in southwestern France. In A. P. Derevianko & M. V. Shunkov (Eds.), *Characteristic Features of the Middle to Upper Paleolithic Transition in Eurasia* (pp. 102–115). Novosibirsk: Asian Paleolithic Association.

Jaubert, J., & Farizy, C. (1995). Levallois debitage: exclusivity, absence or coexistence with other operative schemes in the Garonne Basin, southwestern France. In H. L. Dibble & O. Bar-Yosef (Eds.), *The Definition and Interpretation of Levallois Technology* (pp. 227–248). Madison: Prehistory Press.

Jaubert, J., Hublin, J.-J., McPherron, S. P., & Soressi, M. (2010). Le gisement paléolithique de Chez Pinaud à Jonzac. In J. Buisson-Cattil & J. Primault (Eds.), *Préhistoire entre Vienne et Charente. Hommes et sociétés du Paléolithique* (pp. 117–121). Villefranche-de-Rouergue: Association des Publications Chauvinoises.

Jaubert, J., Hublin, J.-J., McPherron, S. P., Soressi, M., Bordes, J.-G., Claud, E., … Thiébaut, C. (2008). Paléolothique moyen récent et Paléolithique supérieur ancien à Jonzac (Charent-Maritime): Premiers résultats des campagnes 2004-2006. In J. Jaubert, J.-G. Bordes, & I. Ortega (Eds.), *Les sociétés du Paléolithique dans un Grand Sud-Ouest de la France: nouveaux gisements, nouveau résultats, nouvelles méthodes* (pp. 203–244). Bordeaux: Société Préhistorique Française.

Jelinek, A. (1976). Form, function, and style in lithic analysis. In C. E. Cleland (Ed.), *Cultural Change and Continuity: Essays in Honor of James Bennett Griffin* (pp. 19–33). New York: Academic Press.

Jeske, R. J. (1989). Economies in raw material use by prehistoric hunter-gatherers. In R. Torrence (Ed.), *Time, Energy, and Stone Tools* (pp. 34–45). Cambridge: Cambridge University Press.

Jones, R., & White, N. (1988). Point blank: stone tool manufacture at the Ngilipitji quarry, Arnhem Land, 1981. In B. Meehan & R. Jones (Eds.), *Archaeology with Ethnography: An Australian Perspective*. Canberra: Australian National University.

Kelly, R. L. (1983). Hunter-gatherer mobility strategies. *Journal of Anthropological Research*, *39*, 277–306.

Kelly, R. L. (1988). The three sides of a biface. *American Antiquity*, *53*, 717–734.

Klejn, L. S. (1982). *Archaeological Typology*. Oxford: BAR International Series 153.

Kohler, T. A., & Blinman, E. (1987). Solving mixture problems in archaeology: analysis of ceramic materials for dating and demographic reconstruction. *Journal of Anthropological Archaeology*, *6*, 1–28.

Kuhn, S. L. (1991). "Unpacking" reduction: Lithic raw material economy in the mousterian of west-central Italy. *Journal of Anthropological Archaeology*, *10*, 76–106.

Kuhn, S. L. (1992a). Blank form and reduction as determinants of Mousterian scraper morphology. *American Antiquity*, *57*, 115–128.

Kuhn, S. L. (1992b). On planing and curated technologies in the Middle Paleolithic. *Journal of Anthropological Research*, *48*, 185–214.

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

Kuhn, S. L. (1995). *Mousterian Lithic Technology: An Ecological perspective*. Princeton: Princeton University Press.

Lalueza, C., Péréz-Perez, A., & Turbón, D. (1996). Dietary inferences through buccal microwear analysis of Middle and Upper Pleistocene human fossils. *American Journal of Physical Anthropology*, *100*, 367–387.

Laquay, G. (1981). *Recherches sur les faunes du Würm I en Périgord*. PhD Dissertation. Université de Bordeaux I.

Larson, M. Lou, & Finley, J. B. (2004). Seeing the trees but missing the forest. In C. T. Hall & M. Lou Larson (Eds.), *Aggregate Analysis in Chipped Stone* (pp. 95–111). Salt Lake City: The University of Utah Press.

Lartet, E., & Christy, H. (1864). Cavernes du Périgord. Objects gravés et sculptés des tems Préhistoriques dans l'Europe occidentale. *Revue Archéologique*, *(1864)*, 1–37.

Lartet, E., & Christy, H. (1875). *Reliquiae Aquitanicae: Being Contributions to the Archaeology and Palaeontology of Périgord and the Adjoining Provinces of Southern France*. (T. R. Jones, Ed.). London: Williams and Norgate.

Latour, B. (2005). *Reassembling the social*. Oxford: Oxford University Press.

Laville, H., Rigaud, J.-P., & Sackett, J. (1980). *Rock Shelters of the Perigord: Geological Stratigraphy and Archaeological Succession*. New York: Academic Press.

Laville, H., Turon, J.-L., Texier, J.-P., Raynal, J.-P., Delpech, F., Paquereau, M.-M., … Debénath, A. (1983). Histoire paléoclimatique de l'Aquitaine et du Golfe de Gascogne au Pléistocène supérieur depuis le dernier interglaciaire. *Bulletin de l'Institut Géologique Du Bassin de l'Aquitaine, Bordeaux*, *34*, 219–241.

Lazuén, T., & Delagnes, A. (2014). Lithic tool management in the Early Middle Paleolithic: an integrated techno-functional approach applied to Le Pucheuil-type production (Le Pucheuil, northwestern France). *Journal of Archaeological Science*, *52*, 337–353.

Le Tensorer, J.-M. (1978). Le Moustérien type Quina et son Évolution dans le sud de la France. *Bulletin de La Société Préhistorique Française*, *75*, 141–19.

Lehman, S. J., Sachs, J. P., Crotwell, A. M., Keigwin, L. D., & Boyle, E. A. (2002). Relation of subtropical Atlantic temperature, high-latitude ice rafting, deep water formation, and European climate 130,000-60,000 years ago. *Science*, *21*, 1917–1924.

Lenoir, M. (1986). Un mode d'obtention de la retouche "Quina" dans le Moustérien de Combe-Grenal (Domme, Dordogne). *Bulletin de La Société Anthropologique Du Sud-Ouest*, *21*, 153–160.

Leroi-Gourhan, A. (1964). *Le Geste et la Parole*. Paris: Albin Michel.

Lin, S. C., Douglass, M. J., Holdaway, S. J., & Floyd, S. J. (2010). The application of 3D laser scanning technology to the assessment of ordinal and mechanical cortex quantification. *Journal of Archaeological Science*, *37*, 694–702.

Lin, S. C., Rezek, Z., Braun, D., & Dibble, H. L. (2013). On the utility and economization of unretouched flakes: the effects of exterior platform angle and platform depth. *American Antiquity*, *78*, 724–745.

Lisiecki, L. E., & Raymo, M. E. (2005). A Pliocene-Pleistocene stack of 57 globally distributed benthic 18O records. *Paleoceanography*, *20*, 1–17.

Locht, J.-L., & Swinnen, C. (1993). Le débitage discoïde du gisement de Beauvais (Oise): aspects de la chaîne opératoire au travers de quelques remontages. *Paléo*, *6*, 89–104.

Lubbock, J. (1865). *Pre-historic times, as illustrated by ancient remains, and the manners and customes of modern savages*. London: Williams and Norgate.

Lucas, G. (2005). *The Archaeology of Time*. London: Routledge.

Lucas, G. (2012). *Understanding the Archaeological Record*. Cambridge: Cambridge University Press.

Magne, M. P. (1985). Lithics and livelihood: Stone tool technologies of Central and Southern Interior B.C. In *Archaeology Survey of Canada, Mercury Series No. 33*. Ottawa.

McPherron, S. P. (1994). *A Reduction Model for Variability in Acheulian Biface Morphology*. PhD Dissertation. University of Pennsylvania.

McPherron, S. P., & Dibble, H. L. (1999). The lithic assemblages of Pech de l'Azé IV (Dordogne, France). *Préhistoire Européenne*, *15*, 9–43.

McPherron, S. P., Dibble, H. L., & Goldberg, P. (2005). Z. *Geoarchaeology*, *20*, 243–262.

McPherron, S. P., Soressi, M., & Dibble, H. L. (2001). Deux nouveaux programmes de recherche au Pech se l'Azé I et IV (Dordogne, Fraance). *Bulletin Préhistoire Du Sud-Ouest*, *8*, 11–30.

McPherron, S. P., Talamo, S., Goldberg, P., Niven, L., Sandgathe, D., Richards, M. P., … Dibble, H. L. (2012). Radiocarbon dates for the late Middle Palaeolithic at Pech de l'Azé IV, France. *Journal of Archaeological Science*, *39*, 3436–3442.

McTaggart, J. M. E. (1908). The unreality of time. *Mind*, *17*, 457–473.

Meignen, L. (1988). Un exemple de comportement technologique différentiel selon les matières premières: Marillac, couches 9 et 10. In M. Otte (Ed.), *L'Homme de Néandertal, Vol 4: La Technique* (pp. 71–79). Liège: Etudes et Recherches Archéologiques de l'Université de Liège.

Meignen, L., & Vandermeersch, B. (1987). Le gisement moustérien de Marillac, Charente, couches 9 et 10: caractéristiques des outillages, économie des matières premières. In *Préhistoire de Poitou-Charentes: Problèmes actuels* (pp. 135–144). Paris: Editions du C.T.H.S.

Mellars, P. (1965). Sequence and development of Mousterian traditions in south-west France. *Nature*, *205*, 626–627.

Mellars, P. (1967). *The Mousterian Succession in South-west France*. PhD Dissertation. University of Cambridge.

Mellars, P. (1969). The chronology of Mousterian industries in the Périgord region of south-west France. *Proceedings of the Prehistoric Society*, *35*, 134–171.

Mellars, P. (1986). A new chronology for the French Mousterian period. *Nature*, *322*, 410–411.

Mellars, P. (1988). The chronology of the south-west French Mousterian: a review of the current debate. In M. Otte (Ed.), *L'Homme de Néandertal, Vol 4: La Technique* (pp. 97–120). Liège: Etudes et Recherches Archéologiques de l'Universitéde Liège.

Mellars, P. (1992). Technological change in the Mousterian of southwest France. In H. L. Dibble & P. Mellars (Eds.), *The Middle Paleolithic: Adaptation, Behavior and Variability* (pp. 29–43). Philadelphia: University of Pennsylvania Museum.

Mellars, P. (1996). *The Neanderthal Legacy*. Princeton: Princeton University Press.

Mills, B. J. (1989). Integrating functional analysis of vessels and sherds through models of ceramic assemblage formation. *World Archaeology*, *21*, 133–147.

Moncel, M.-H., & Daujeard, C. (2012). The variability of the Middle Palaeolithic on the right bank of the Middle Rhône Valley (southeast France): Technical traditions or functional choices? *Quaternary International*, *247*, 103–124.

Monnier, G. (2006). The Lower/Middle Paleolithic periodization in Western Europe. *Current Anthropology*, *47*, 709–744.

Montelius, O. (1903). *Die älteren Kulturperioden im Orient und in Europa, I: Die Methode*. Stockholm: Selbstverlag.

Morin, E., Delagnes, A., Armand, D., Castel, J.-C., & Hodgkins, J. (2014). Centennial- to millennial-scale change in archaeofaunas and their implications for Mousterian lithic variability Article. *Journal of Anthropological Archaeology*, *36*, 158–180.

Mourre, V. (2003). Discoïde ou pas Discoïde? Réflexions sur la pertinence des critères techniques définissant le débitage Discoïde. In M. Peresani (Ed.), *Discoid Lithic Technology: Advances and Implications* (pp. 1–18). Oxford: BAR International Series 1120.

Mourre, V., & Colonge, D. (2007). Et si "Acheuléen méridional n"était pas là où on l'attendait?... *Congrès Du Centenaire de La Société Préhistorique Française, 26 Ème Session Du Congrès Préhistorique de France, Avignon, 2004*, *3*, 63–78.

Murray, P. (1980). Discard location: The ethnographic data. *Americna Antiquity*, *45*, 490–502.

Murray, T. (1997). Dynamic modeling and the new social theory of the mid- to long-term. In S. E. van der Leeuw & J. McGlade (Eds.), *Time, Process, and Structured Transformation in Archaeology* (pp. 449–463). London: Routledge.

Murray, T. (1999a). A return to the "Pompeii premise." In T. Murray (Ed.), *Time and Archaeology* (pp. 8–27). London: Routledge.

Murray, T. (Ed.). (1999b). *Time and Archaeology*. New York, NY: Routledge.

Murray, T. (2008). Paradigms and metaphysics, or, "Is This the End of Archaeology as We Know It?" In S. J. Holdaway & L. Wandsnider (Eds.), *Time in Archaeology. Time Perspectivism Revisited* (pp. 170–180). Salt Lake City: University of Utah Press.

Nelson, B. A., Kohler, T. A., & Kintigh, K. W. (1994). Demographic alternatives: Consequences for current models of southwestern prehistory. In G. J. Gummerman & M. Gell-Mann (Eds.), *Understanding Complexity in the Prehistoric Southwest* (pp. 113–146). Reading, MA: Addison-Wesley.

Nelson, C. G. (1909). Shellmounds of San Francisco bay region. *University of California Publications in American Archaeology and Ethnology*, *7*, 309–356.

Nelson, M. C. (1990). Sedentism, mobility and regional assemblage: problems posed in Southwestern Prehistory. In P. E. Minnis & C. Redman (Eds.), *Perspectives in Southwestern Prehistory* (pp. 150–156). Boulder: Westview Press.

Nelson, M. C. (1991). The study of technological organization. In M. B. Schiffer (Ed.), *Archaeological Method and Theory Vol 3* (Vol. 3, pp. 57–100). Tucson: University of Arizona Press.

Niven, L., Steele, T. E., Rendu, W., Mallye, J.-B., McPherron, S. P., Soressi, M., … Hublin, J.-J. (2012). Neandertal mobility and large-game hunting: the exploitation of reindeer during the Quina Mousterian at Chez-Pinaud Jonzac (Charente-Maritime, France). *Journal of Human Evolution*, *63*, 624–635.

Nordstokke, D. W., & Zumbo, B. D. (2010). A new nonparametric Levene test for equal variances. *Psicologica*, *31*, 401–430.

O'Brien, M. J., & Lyman, R. L. (2002). The epistemological nature of archaeological units. *Anthropological Theory*, *2*, 37–56.

Olivier, L. (1999). The Hochdorf "princely" grave and the question of the nature of archaeological funerary assemblages. In T. Murray (Ed.), *Time and Archaeology* (pp. 109–138). London: Routledge.

Olivier, L. (2011). *The Dark Abyss of Time; Archaeology and Memory*. Lanham: AltaMira Press.

Olsen, B. (2010). *In Defense of Things. Archaeology and Ontology of Objects*. Walnut Creek, CA: AltaMira Press.

Olszewski, D. I., Dibble, H. L., McPherron, S. P., Schurmans, U. A., Chiotti, L., & Smith, J. R. (2010). Nubian Complex strategies in the Egyptian high desert. *Journal of Human Evolution*, *59*, 188–201.

Paletta, C. (2005). *L'évolution des comportements de susistance des hommes du Moustérien au Solutréen dans la région Poitou-Charentes*. PhD Dissertation. Muséum national d'histoire naturelle.

Park, S.-J. (2007). *Systèmes de production lithique et circulation des matières premières au Paléolithique moyen récent et final: une approche techno-économique à partir de l'étude des industries lithiques de La Quina (Charente)*. PhD Dissertation. Université Paris X, Nanterre.

Park, S.-J., & Féblot-Augustin, J. (2010). Circulation des matières premières et modalités d'explotation territoriale au Paléolithique moyen récente dans le bassin de la Charente. In N. J. Conard & A. Delagnes (Eds.), *Settlement Dynamics of the Middle Paleolithic and Middle Stone Age* (pp. 397–426). Tübingen: Kerns Verlag.

Parry, W. J., & Kelly, R. L. (1987). Expedient core technology and sedentism. In J. K. Johnson & C. A. Morrow (Eds.), *The Organization of Core Technology* (pp. 285–308). Boulder: Westview Press.

Pasty, J.-F. (2000). Le gisement Paléolithique moyen de Meillers (Allier): un exemple de la variabilité du débitage discoïde. *Bulletin de La Société Préhistorique Française*, *97*, 165–190.

Patou-Mathis, M. (1993). Taphonomic and paleoethnographic study of the fauna associated with the Neandertal of Saint-Césaire. In F. Lévêque, A. M. Backer, & M. Gilbaud (Eds.), *Context of a Late Neandertal: Implications of Multidisciplinary Research for the Transition to Upper Paleolithic Adaptations at Saint-Césaire* (pp. 79–102). Madison: Prehistory Press

Patou-Mathis, M. (2000). Neanderthal subsistence behaviours in Europe. *International Journal of Osteoarchaeology*, *10*, 379–395.

Patrik, L. E. (1985). Is there an archaeological record? *Advances in Archaeological Method and Theory*, *8*, 27–62.

Pelegrin, J. (1984). Réflexions sur le comportment technique. In M. Otte (Ed.), *La signification culturelle des indistries lithiques. Actes du colloque de Liège du 3 au 7 octobre 1984* (pp. 72–88). BAR International Series 239.

Pelegrin, J. (1990). Prehistoric lithic technology: some aspects of research. *Archaeological Review from Cambridge*, *9*, 116–125.

Perreault, C., & Brantingham, P. J. (2011). Mobility-driven cultural transmission along the forager-collector continuum. *Journal of Anthropological Archaeology*, *30*, 62–68.

Petit, J. R., Jouzei, J., Raynaud, D., Barkov, N. I., Barnola, J. M.Basile, I., Bender, J., … Stievenard, M. (1999). Climate and atmospheric history of the past 420,000 years from Vostok core. *Nature*, *399*, 429–436.

Pettitt, P. B. (2003). The Mousterian in action: chronology, mobility, and Middle Paleolithic variability. In N. Moloney & M. J. Schott (Eds.), *Lithic Analysis at the Millennium* (pp. 29–43). London: Left Coast Press.

Peyrony, D. (1920). Le Moustérien - ses faciès. In *Comptes Rendus de l'Association Française pour l'Advancement des Sciences, XLIV ème Session* (pp. 496–497). Strassbourg.

Phillipps, R. S. (2012). *Documenting Socio-Economic Variability in the Egyptian Neolithic Through Stone Artefact Analysis*. PhD Dissertation. University of Auckland.

Potts, R. (1991). Why the Oldowan? Plio-Pleistocene toolmaking and the transport of resources. *Journal of Anthropological Research*, *47*, 153–176.

Powell, S. (1988). anasazi demographic patterns and organizational responses: Assumptions and interpretative difficulties. In G. J. Gummerman (Ed.), *The Anasazi in a Changing Environement* (pp. 168–191). Cambridge: Cambridge University Press.

Price, D. T., & Brown, J. A. (1985). *Prehistoric Hunter-Gatherers; The Emergence of Cultural Complexity*. New York: Academic Press.

Pyddoke, E. (1961). *Stratification for the Archaeologist*. London: Phoenix House.

Ramenofsky, A. F., & Steffen, A. (Eds.). (1998a). *Unit Isues in Archaeology: Measuring Time, Space and Material*. Salt Lake City: The University of Utah Press.

Ramenofsky, A. F., & Steffen, A. (1998b). Units as tools of measurement. In F. Ramenofsky, Ann & A. Steffen (Eds.), *Unit Isues in Archaeology: Measuring Time, Space and Material* (pp. 3–17). Salt Lake City: The University of Utah Press.

Reille, M., & de Beaulieu, J.-L. (1990). Pollen analysis of a long upper Pleistocene continental sequence in a Velay maar (Massif Central, France). *Palaeogeography, Palaeoclimatology, Palaeoecology*, *80*, 35–48.

Rendu, W. (2010). Hunting behavior and Neanderthal adaptability in the Late Pleistocene site of Pech-de-l'Azé I. *Journal of Archaeological Science*, *37*, 1798–1810.

Rendu, W., Beauval, C., Crevecoeur, I., Bayle, P., Balzeau, A., Bismuth, T., … Maureille, B. (2014). Evidence supporting an intentional Neandertal burial at La Chapelle-aux-Saints. *Proceedings of the National Academy of Sciences of the United States of America*, *111*, 81–6.

Rendu, W., Costamagno, S., Meignen, L., & Soulier, M.-C. (2012). Monospecific faunal spectra in Mousterian contexts: Implications for social behavior. *Quaternary International*, *247*, 50–58.

Richards, M. P., Taylor, G., Steele, T. E., McPherron, S. P., Soressi, M., Jaubert, J., … Hublin, J.-J. (2008). Isotopic dietary analysis of a Neanderthal and associated fauna from the site og Jonzac (Charent-Maritime), France. *Journal of Human Evolution*, *55*, 179–185.

Richter, D., Dibble, H. L., Goldberg, P., McPherron, S. P., Niven, L., Sandgathe, D., … Turq, A. (2010). New chronometric data for Pech de l'Azé IV and its place in the Middle Paleolithic of southwestern France. In *Paleoanthropology Society Annual Meetings*. St. Louis.

Richter, D., Dibble, H. L., Goldberg, P., McPherron, S. P., Niven, L., Sandgathe, D., … Turq, A. (2013). The late Middle Palaeolithic in southwest France: new TL dates for the sequence of Pech de l'Azé IV. *Quaternary International*, *294*, 160–167.

Richter, D., Hublin, J.-J., Jaubert, J., McPherron, S. P., Soressi, M., & Texier, J. P. (2013). Thermoluminescence dates for the Middle Palaeolithic site of Chez-Pinaud Jonzac (France). *Journal of Archaeological Science*, *40*, 1176–1185.

Robinson, R. (1962). *Definition*. Oxford: Clarendon Press.

Rolland, N. (1981). The interpretation of Middle Palaeolithic variability. *Man*, *16*, 15–42.

Rolland, N. (1988). Observations on some Middle Paleolithic time series in southern France. In H. L. Dibble & A. Montet-White (Eds.), *Upper Pleistocene Prehistory of Western Eurasia* (pp. 161–180). Philadelphia: University of Pennsylvania Museum.

Rolland, N. (2001). Determinants of Middle Paleolithic settlement organization: a review of evidence, based on the record from Western Europe. In N. J. Conard (Ed.), *Settlement Dynamics of the Middle Paleolithic and Middle Stone Age* (pp. 545–571). Tübingen: Kerns Verlag.

Rolland, N., & Dibble, H. L. (1990). A new synthesis of Middle Paleolithic variability. *American Antiquity*, *55*, 480–499.

Rossignol, J., & Wandsnider, L. (Eds.). (1992). *Space, Time, and Achaeologicsl Landscapes*. New York: Plenum Press.

Roth, B. J., & Dibble, H. L. (1998). Production and transport of blanks and tools at the French Middle Paleolithic site of Combe-Capelle Bas. *American Antiquity*, *63*, 47–62.

Ruebens, K. (2013). Regional behaviour among late Neanderthal groups in Western Europe. A comparative assessment of Late Middle Paleolithic bifacial tool variability. *Journal of Human Evolution*, *65*, 341–362.

Sackett, J. (1982). From de Mortillet to Bordes: a century of French Paleolithic research. In G. Daniel (Ed.), *Towards a History of Archaeology* (pp. 85–89). London: Thames & Hudson.

Salomon, J. N., & Astruc, J. G. (1992). Exemple en zone tempérée d'un Paléocryptokarst tropical exhumé (La Cuvette du Sarladais, Dordogne). In J. N. Salomon & R. Maire (Eds.), *Karst en Évolution Climatiques* (pp. 431–447). Talence: Presses Universitaires de Bordeaux.

Sánchez Goñi, M. F., Landais, A., Fletcher, W.-J., Naughton, F., Desprat, S., & Duprat, J. (2008). Contrasting impacts of Dansgaard-Oescher events over a western European latitudinal transect modulated by orbital parameters. *Quaternary Science Reviews*, *27*, 1136–1151.

Sandgathe, D., Dibble, H. L., Goldberg, P., McPherron, S. P., Turq, A., Niven, L., & Hodgkins, J. (2011). On the role of fire in Neandertal adaptations in Western Europe: Evidence from Pech de l'Azé IV and Roc de Marsal, France. *PaleoAnthropology*, 216–242.

Schiffer, M. B. (1972). Archaeological context and systemic context. *American Antiquity*, *37*, 156–165.

Schiffer, M. B. (1975a). Archaeology as behavioral science. *American Antiquity*, *77*, 836–848.

Schiffer, M. B. (1975b). The effects of occupation span on site content. In M. Schiffer & J. House (Eds.), *The Cache River Archaeological Project: An Experiment in Contract Archaeology* (pp. 265–269). Fayetteville: Arkansas Archaeological Survey Research Series 8.

Schiffer, M. B. (1976). *Behavioral Archaeology*. New York: Academic Press.

Schiffer, M. B. (1983). Toward the identification of formation processes. *American Antiquity*, *48*, 675–706.

Schiffer, M. B. (1985). Is there a "Pompeii Premise" in archaeology? *Journal of Anthropological Research*, *41*, 18–41.

Schiffer, M. B. (1987). *Formation Process of the Archaeological Record*. Albuquerque: University of New Mexico Press.

Schiffer, M. B. (1988). The structure of archaeological theory. *American Antiquity*, *53*, 461–485.

Schlanger, S. H. (1990). Artifact assemblage composition and site occupation duration. In P. E. Minnis & C. L. Redman (Eds.), *Perspectives on Southwestern Prehistory* (pp. 103–121). Boulder: Westview Press.

Schlanger, S. H. (1992). Recognizing persistent places in Anasazi settlement systems. In J. Rossignol & L. Wandsnider (Eds.), *Space, Time, and Archaeological Landscapes* (pp. 91–112). New York: Plenum Press.

Schwartz, H., & Blackwell, B. (1983). 230Th/234U age of Mousterian sites in France. *Science*, *301*, 236–237.

Seronie-Vivien, M., & Seronie-Vivien, M.-R. (1987). Les silex du Mésozoïque nord-aquitain: approche géologique de l'étude du silex pour servir à la recherche. *Bulletin de La Société Linnéenne de Bordeaux (Supplement)*, *15*.

Shanks, M., & Tilley, C. (1987). *Social Theory and Archaeology*. Oxford: Polity Press.

Shiner, J. I., Holdaway, S. J., Allen, H., & Fanning, P. C. (2007). Burkes Cave and flakes stone assemblage variability in Western New South Wales, Australia. *Australian Archaeology*, *64*, 35–45.

Shott, M. J. (1986). Technological organization and settlement mobility: An ethographic examination. *Journal of Anthropological Research*, *42*, 15–51.

Shott, M. J. (1989). On tool-class use lives and the formation of archaeological assemblages. *American Antiquity*, *54*, 9–30.

Shott, M. J. (1998). Status and role of formation theory in contemporary archaeological practice. *Journal of Archaeological Research*, *6*, 299–329.

Shott, M. J. (2003). Size as a factor in Middle Paleolithic assemblage variation in the Old World: a North American perspective. In N. Moloney & M. J. Shott (Eds.), *Lithic Analysis at the Millennium* (pp. 137–149). London: Left Coast Press.

Shott, M. J. (2005). The reduction thesis and its discontents: overview of the volume. In C. Clarkson & L. Lamb (Eds.), *Lithics "Down Under": Australian Perspectives on Lithic Reduction, Use and Classification. BAR International Series 1408* (pp. 109–125). Oxford: BAR International Series 1408.

Shott, M. J. (2008). Lower Paleolithic industries, time, and the meaning of assemblage variation. In S. J. Holdaway & L. Wandsnider (Eds.), *Time in Archaeology. Time Perspectivism Revisited* (pp. 46–60). Salt Lake City: The University of Utah Press.

Shott, M. J. (2010). Size dependence in assemblage measures: essentialism, materialism, and "SHE" analysis n archaeology. *American Antiquity*, *75*, 886–906.

Shott, M. J., & Nelson, M. C. (2008). Lithic reduction, its measurement, and implications: comments on the volume. In W. Andrefsky (Ed.), *Lithic Technology: Measures of Production, Use, and Curation* (pp. 23–45). Cambridge: Cambridge University Press.

Shott, M. J., & Sillitoe, P. (2005). Use life and curation in New Guinea experimental used flakes. *Journal of Archaeological Science*, *32*, 653–663.

Smith, E. A. (1979). Human adaptation and energetic efficiency. *Human Ecology*, *7*, 53–74.

Smith, E. A. (1983). Anthropological applications of Optimal Foraging Theory: A critical review. *Current Anthropology*, *24*, 625–651.

Soressi, M. (2002). *Le Moustérien de tradition acheuléenne du sud-ouest de la France. Discussion sur la signification du faciès à partir de l'étude comparée de quatre sites: Pech de l'Azé I, Le Moustier, La Rochette et la Grotte XVI*. PhD Dissertation. Université Bordeaux I.

Soressi, M. (2004). From the Mousterian of Acheulian Tradition type A to type B: a change in technical tradition, raw material, task, or settlement dynamics? In N.

J. Conard (Ed.), *Settlement Dynamics of the Middle Paleolithic and Middle Stone Age* (pp. 343–366). Tübingen: Kerns Verlag.

Soressi, M., Armand, D., D'Errico, F., Jones, H. L., Pubert, E., Rink, W. J., … Vivent, D. (2002). Pech de l'Azé I (Carsac, Dordogne): nouveaux travaux de recherche dur le Moustérien de tradition acheuléene. *Bulletin de La Société Préhistorique Française*, *99*, 5–11.

Soressi, M., & Hays, M. (2003). Manufacture, transport and use of Mousterian bifaces. A case study from the Perigord (France). In M. Soressi & H. L. Dibble (Eds.), *Multiple Approaches to the Study of Bifacial Technologies* (pp. 125–147). Philadelphia: University of Pennsylvania Museum.

Soressi, M., Jones, H. L., Rink, W. J., Maureille, B., & Tillier, A.-M. (2007). The Pech de l'Azé I Neandertal chile: ESR, uranium series, and AMS 14C dating of its MTA type B context. *Journal of Human Evolution*, *52*, 455–466.

Soulier, M.-C. (2007). *Etude archéozoologique du carré M16 de la couche II du gisement moustérien du Roc de Marsal (Dordogne)*. Master's Thesis. Université Toulouse II.

Stein, J. (1993). Scale in archaeology, geosciences, and geoarchaeology. In J. Stein & A. R. Linse (Eds.), *Effects of Scale on Archaeological and Geoscientific Perspectives* (pp. 1–10). Boulder: Geological Society of America Special Paper 283.

Stein, J. (2000). Stratigraphy and archaeological dating. In S. Nash (Ed.), *It's About Time. A History of Archaeological Dating in North America* (pp. 14–40). Salt Lake City: University of Utah Press.

Stein, J. K., & Farrand, W. R. (Eds.). (2001). *Sediments in Archaeological Context*. Salt Lake City: University of Utah Press.

Stern, N. (1993). The structure of the Lower Pleistocene archaeological record: a case study from the Koobi Fora Formation. *Current Anthropology*, *34*, 201–225.

Stern, N. (1994). The implications of time-averaging for reconstructing the land-use patterns of early tool-using hominids. *Journal of Human Evolution*, *27*, 89–105.

Stern, N. (2008). Time averaging and the structure of Late Pleistocene archaeological deposits in southwest Tasmania. In S. J. Holdaway & L. Wandsnider (Eds.), *Time in Archaeology. Time Perspectivism Revisited* (pp. 134–148). Salt Lake City: The University of Utah Press.

Sullivan, A. P., Mink, P. B., & Uphus, P. M. (2007). Archaeological Survey Design, Units of Observation, and the Characterization of Regional Variability. *American Antiquity*, *72*, 322–333.

Surovell, T. A. (2009). *Toward a behavioral ecology of lithic technology*. Tucson: The University of Arizona Press.

Tactikos, J. C. (2003). A re-evaluation of Paleolithic stone tool cutting edge production rates and their implications. In N. Moloney & M. J. Shott (Eds.), *Lithic Analysis at the Millennium* (pp. 151–162). London: Left Coast Press.

Taylor, K. C., Lamorey, G. W., Doyle, G. A., Alley, R. B., Grootes, P. M., Mayewski, P. A., … Barlow, L. K. (1993). The "flickering switch" of Late Pleistocene climate change. *Nature*, *361*, 432–436.

Thiébaut, C. (2005). *Le Moustérien à denticulés: variabilité ou diversité technoéconomique?* PhD Dissertation. Université de Provence, Aix-en-Provence.

Thiébaut, C., Mourre, V., Chalard, P., Colonge, D., Coudenneau, A., Deschamps, M., & Sacco-Sonador, A. (2012). Lithic technology of the final Mousterian on both sides of the Pyrenees. *Quaternary International*, *247*, 182–198.

Thomas, J. (1996). *Time, Culture, and Identity*. London: Routledge.

Thomsen, C. J. (1837). *Leitfaden zur nordischen Alterthumskunde. Herausgegeben von der Königlichen Gesellschaft für nordische Alterthumskunde*. Kopenhagen: Der Königlichen Gesellschaft für Nordische Alterthumskunde.

Tindale, N. (1965). Stone implement making among the Nakako, Ngadadjara, and Pitjandjara of the Great Western Desert. *Records of the South Australian Museum*, *15*, 131–164.

Torrence, R. (1983). Time-budgeting and hunter-gatherer technology. In G. N. Bailey (Ed.), *Hunter-Gatherer Economy in Prehistory: A European Perspective* (pp. 11–22). Cambridge: Cambridge University Press.

Torrence, R. (Ed.). (1989). *Time, Energy and Stone Tools*. New York: Cambridge University Press.

Torrence, R. (2001). Hunter-gatherer technology: Macro- and microscale approaches. In C. Panter-Brick, R. H. Layton, & P. Rowley-Conwy (Eds.), *Hunter-Gatherers: An Interdisciplinary Perspective* (pp. 73–99). Cambridge: Cambridge University Press.

Trigger, B. G. (2006). *A History of Archaeological Thought* (2nd ed.). Cambridge: Cambridge University Press.

Turq, A. (1985). Le Moustérien de type Quina du Roc de Marsal (Dordogne). *Bulletin de La Société Préhistorique Française*, *82*, 45–51.

Turq, A. (1989). Explotation des matières prèmieres lithiques et occupation du sol: l'exemple du Moustérien entre Dordogne et Lot. In H. Laville (Ed.), *Variations des paléomilieux et peuplement préhistorique* (pp. 179–204). Paris: CNRS et Centre régional de Publication de Bordeaux (Cahiers du Quaternaire 13).

Turq, A. (1990). Explotation des matières prèmieres lithiques dans le Moustérien entre Dordogne et Lot (sud-ouest de la France). In M.-R. Séronie-Vivien & M. Lenoir (Eds.), *Le silex de sa genèse à l'outil, Tome 2* (pp. 415–427). Paris: CNRS et Centre régional de Publication de Bordeaux (Cahiers du Quaternaire 17).

Turq, A. (1992). Raw material and technological studies of the Quina Mousterian in Périgord. In H. L. Dibble & P. Mellars (Eds.), *The Middle Paleolithic: Adaptation, Behavior and Variability* (pp. 75–85). Philadelphia: University of Pennsylvania Museum.

Turq, A., Antignac, G., & Roussel, P. (1999). Les silicifications coniaciennes du Sarladais et du Gourdonnais: inventaire et implications archéologiques. *Paléo*, *11*, 145–160.

Turq, A., Dibble, H. L., Faivre, J.-P., Goldberg, P., McPherron, S. P., & Sandgathe, D. (2008). Le Moustérien récent du Périgord Noir: quoi de neuf? *Mémoire de La Société Préhistorique Française*, *XLVII*, 83–93.

Turq, A., Dibble, H. L., Goldberg, P., McPherron, S. P., Sandgathe, D., Jones, H., … Steenhuyse, A. (2011). Les Fouilles Recentes du Pech de L'Azé IV (Dordogne). *Gallia Préhistoire*, *53*, 1–58.

Turq, A., Roebroeks, W., Bourguignon, L., & Faivre, J.-P. (2013). The fragmented character of Middle Paleolithic stone tool technology. *Journal of Human Evolution*, *6*, 641–655.

Van Peer, P. (1992). *The Levallois Reduction Strategy*. Madison: Prehistory Press.

Varien, M. D. (1996). *Sedentism and Mobility in Horticultural and Agricultural Societies: A Case Study From the Mesa Verde Region*. PhD Dissertation. Arizona State University, Tempe.

Varien, M. D., & Mills, B. J. (1997). Accumulations research: problems and prospects for estimating site occupation span. *Journal of Archaeological Method and Theory*, *4*, 141–191.

Varien, M. D., & Potter, J. M. (1997). Unpacking the discard equation: Simulating the accumulation of artifcats in the archaeological record. *Journal of Archaeological Method and Theory*, *4*, 141–191.

Vaufrey, R. (1933). Le Moustérien de tradition acheuléenne du Pech de l'Azé (Dordogne). *L'Anthropologie*, *37*, 425–427.

Vieillevigne, E., Bourguignon, L., Ortega, I., & Guibert, P. (2008). Analyse croisée des données chronologiques et des industries lithiques dans le grand sud-ouest de la France (OIS 10 à 3). *Paléo*, *20*, 145–166.

Wandsnider, L. (1996). Describing and comparing archaeological spatial structire. *Journal of Archaeological Method and Theory*, *3*, 319–384.

Wargo, M. C. (2009). *The Bordes-Binford Debate: Transatlantic Interpretative Traditions in Paleolithic Archaeology*. PhD Dissertation. The University of Texas at Arlington.

Whallon, R., & Brown, J. (1982). *Essays on Archaeological Typology*. (R. Whallon & J. A. Brown, Eds.). Evanston: Center for American Archaeology Press.

Winograd, I. J., Landwehr, J. M., Ludwig, K. R., Coplen, T. B., & Rigg, A. C. (1997). Duration and structure of the past four interglaciations. *Quaternary Research*, *48*, 141–154.

Winterhalder, B., & Smith, E. A. (1981). *Hunter-gatherer foraging strategies*. Chicago: University of Chicago Press.

Winterhalder, B., & Smith, E. A. (2000). Analyzig adaptive strategies: Human behavioral ecology at twenty-five. *Evolutionary Anthropology*, *9*, 51–72.

Wobst, M. (1978). The archaeo-ethnography of hunter-gatherers or the Tyranny of the Ethnographic Record in archaeology. *American Antiquity*, *43*, 303–309.

Wohlfarth, B., Veres, D., Ampel, L., Lacourse, T., Blaauw, M., Preusser, F., … Zander, A. (2008). Rapid ecosystem response to abrupt climate changes during the last glacial period in western Europe, 40-16 ka. *Geology*, *36*, 407–410.

Worsaae, J. J. (1849). *The Primeval Antiquities of Denmark*. London: John Henry Parker.

Zilhão, J. (2007). The emergence of ornaments and art: an archaeological perspective on the origins of "behavioral modernity." *Journal of Archaeological Research*, *15*, 1–54.

Index

P

R

S

T

V