AN ANALYSIS OF THE LEVALLOIS REDUCTION STRATEGY USING A DESIGN THEORY FRAMEWORK

By

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Abstract

The Levallois reduction strategy was selected from among a number of different lithic strategies available in the Middle Palaeolithic and was employed over a wide geographic area of the Old World for well over 200,000 years. This research attempts to examine the potential advantages of this reduction strategy that led to this long history of use. This requires the development of a model of Middle Palaeolithic lifeways from which can be identified those factors that would have influenced and constrained the design of Middle Palaeolithic stone technology and tool kits. From an understanding of these constraints on stone tool production and use, several hypotheses are developed which would explain the advantages that Levallois reduction would present and under what conditions we would expect it to be employed. These hypotheses are then tested through the analysis of both the morphology of the products of different reduction strategies and of tool blank selection patterns at four Middle Palaeolithic sites in SW and SE France. This analysis indicates that Levallois reduction would present notable advantages under conditions of restricted access to raw material, which may be due to circumstances of increased group mobility or distance from raw material sources. Some functional advantages may also rest in the morphology of certain Levallois products and in the products of similar reduction approaches. It is also apparent that classic Levallois reduction cannot be defined in isolation from other single-surface core strategies, and that much of the advantage of classic Levallois reduction is inherent in all such strategies.

Dedication

To Tracey

who gets me through it all

and to Alberto, an excellent clown and a very good friend

The deeper we dig into the earth's crust, the lower are the specimens of human remains which occur; and hitherto not a single 'find' has come to revive the faded glories of 'Adam the goodliest man of men since born.' We on the other hand hold, from the evidence of our senses, that early man was a savage very little superior to the brute; that during man's millions of years upon earth there has been a gradual advance towards perfection, at times irregular and even retrograde, but in the main progressive; and that a comparison of man in the 19th century with the caveman affords us the means of measuring past progress and of calculating the future of humanity. This is the answer to those who contend with much truth that the moderns are by no means superior to the ancients of Europe: they look at the results of only 3000 years instead of 30,000 or 300,000.

Sir Richard F. Burton
Love, War and Fancy – 1885

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However, that any errors in this thesis, in either content or logic, are all my own.

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Chapter 1: Introduction

The main research question of this dissertation is: what are the advantages of the Levallois reduction technique which resulted in its prehistoric use over a wide geographic area for over 200,000 years? In order to understand this it will be necessary to isolate those factors that influenced and constrained the design of Middle Palaeolithic stone technology and tool kits. Given the circumstances, task requirements and practical constraints in which the Levallois reduction technique was employed, what implicit advantages did the technique present to Palaeolithic knappers?

The stone tool production strategies selected or adopted by a group must produce a tool kit that is capable of satisfying the task requirements faced by the group and that conforms to the material culture constraints dictated by the group's circumstances. This means that, given the differences in raw materials, necessary skill levels, and variations in end-products, different reduction strategies are likely to be applicable in a range of different adaptive scenarios. I expect that the Levallois technique, like all reduction strategies, must present different specific advantages (and potential disadvantages) under different circumstances.

The traditional interpretation of the Levallois reduction technique is that the purpose of the technique was to produce a limited number of flakes that present certain high-utility characteristics, and that these characteristics are the result of predetermining each flake's morphology through careful preparation of the core prior to the flake's removal. This is one potential reason for the use of the technique, but since its initial suggestion (around the turn of the 19th century) this interpretation has been accepted without really being tested against any available data.

More recent research has been focused on technological analyses of the Levallois reduction process and this has become reasonably well understood (e.g., Boeda 1979, 1986, 1988; Van Peer 1992) However, these approaches still tend to maintain the traditional view of *why* it was used, with some notable exceptions (e.g., Bar Yosef 1995; Baumler 1995; Dibble 1995, 1989; Reynolds 1990; Wengler 1995; Rolland 1986).

The advantages of the Levallois technique, to those Palaeolithic groups who employed it, are not currently obvious. The real advantages may be, as the traditional interpretation suggests, in the morphological characteristics of a limited number of flake products, or it may be in morphological characteristics held by all end-products, or it may be that, like other reduction strategies, the advantages concern other issues such as: raw material size, form, and quality; raw material economization; versatility of the strategy; diversity of products; or the ease with which the strategy can be employed in different locations.

In this thesis I develop a design theory framework based on the archaeological context of Levallois occurrences in the French Middle Palaeolithic. This requires the identification of potential factors that could have influenced the nature of lithic reduction in the Middle Palaeolithic, including an understanding of the nature and availability of lithic raw materials, available technologies, some idea of the form and lifespan of the intended end-products of the reduction practices (i.e., tools), and some concept of Middle Palaeolithic tool needs based on subsistence patterns (e.g., food resources and acquisition, settlement patterns, seasonality of behaviours, climatic influence). By identifying the circumstances in which the technique was employed (and perhaps those contemporaneous circumstances in which it was not) I expect to better understand the advantages of the technique.

Presumably, the morphology of a flake tool is a product of both the constraints of its intended function and the nature of the reduction strategy used to produce it. The types, range of functions, and context of use for which the Levallois products were intended must have been a constraint on aspects of their morphology. Previous studies have provided us with a reasonably good understanding of the different types and relative frequencies of tasks to which Mousterian tools were applied (Anderson-Gerfaud 1990; Beyries 1988, 1987, 1984; Keeley 1980, 1977; and Shea 1988), and so use-wear examinations to determine specific task applications will not be part of this research. It will be more important to try to understand which flakes, of all the products resulting from the reduction process, were either used as tools or had the potential to be tools and which were simply the waste products of the production process.

Parameters of Research

Broad Temporal Limits

While the Major Palaeolithic periods are defined mainly on technological change, in Western Europe, at least, Levallois reduction has no apparent affiliation with any specific time periods. It occurs in what have been chronologically defined as Lower Palaeolithic and Middle Palaeolithic contexts, and possibly even Upper Palaeolithic assemblages. The Levallois technique also has no clear association with specific stone tool industries. It occurs in all the Mousterian industries to some degree and in Lower and Middle Palaeolithic industries in regions outside of Europe as well. In general, the appearance of the Levallois strategy seems to crosscut most culture-temporal units. Because of this widespread distribution it becomes necessary then to limit the field of data. In this study a simple approach might have been to limit the data employed, and subsequent discussions based on them, to the Middle Palaeolithic as it is defined for Western Europe. However, this is not so simple. There is no real consensus on what the temporal limits of this period should be and some suggest that it should not be defined based on temporal boundaries at all (e.g. Tuffreau 1982: 137). Traditionally, the Middle Palaeolithic has been defined by European researchers in relation to glacial chrono-stratigraphic markers, and the Middle Palaeolithic refers to the first part of the last glaciation (Würm or Weishselian) which, depending on the dating, began around 75 to 80 kya (e.g., Conrad 1990: 247; Dennell 1983: 199; Laville 1982: 131; Tuffreau 1982; Bordes 1977: 1). Others put the Lower/Middle Palaeolithic boundary earlier than this to within the last interglacial or around 200 kya (e.g., Chase 1985: 3; Renfrew and Bahn 1997: 157) or even earlier (e.g., Lautridou et al. 1986: 390; Roebroeks et al. 1988: 18; Tuffreau 1995: 416; White and Ashton 2003:598) which could put the date of the boundary between 200 and 300 kya. The major problem lies in both the tentative nature of our present abilities to assign absolute ages to glacial sequences and the difficulty in correlating different regional sequences.

While the Middle Palaeolithic is (more or less) an arbitrarily defined culture-temporal unit, in western Europe (and France especially) most of the archaeological materials dated to within this period belong to one of several stone tool industries collectively referred to as the Mousterian. Therefore, while the Middle Palaeolithic and the Mousterian are perhaps not synonymous, in practice when one's research in Western Europe is restricted to the former it tends to deal with the latter. Therefore, it seems prudent to use the limits of the Mousterian, as they are defined simply by the occurrences of Mousterian assemblages, as the limits of the research here.

Regional Limits

This research is spatially focused mainly on the Dordogne region of Southwest France where much of European Middle Palaeolithic research has been concentrated and large, well curated assemblages are numerous. However, some of the data will come from a site in the extreme southeast of France in the French Alps.

Climatic Limits

Levallois technology is generally (but not exclusively) associated with the Middle Palaeolithic period (c. 250,000 to 35,000 years bp.) in Europe. European prehistorians typically speak in geologic terms when discussing relative chronologies and refer to glacial epochs, löess cycles, and oxygen isotope stages when placing archeological units in time. The Middle Palaeolithic includes stages 6, 5, 4, and the initial half of 3 (c. 195,000 to 35,000 years bp.).

Some control over the chronologic relationship and climatic setting of assemblages included in the analysis was established by selecting assemblages dated to the same isotope stage -- early Oxygen Isotope Stage 3.

Middle Palaeolithic Subsistence

In order to attempt to understand the parameters of Middle Palaeolithic tool production and design of technology it is necessary to first try to reconstruct general Middle Palaeolithic subsistence patterns. This reconstruction will include several aspects of hunter-gatherer adaptations including settlement patterns (level of mobility, types of sites, seasonality of sites, etc.), type and acquisition of food resources, nature and acquisition of other resources (including lithic raw materials), level and nature of group interactions, and perhaps some idea of other aspects of technology that may have been present (e.g. use of other materials besides stone -- wood, bone, etc.). This reconstruction will also require a reasonable understanding of Middle Palaeolithic environments.

Changes in climate and flora and fauna through the course of the Middle Palaeolithic may be a significant factor in the formation of tool kits over time. This will be the framework from which intended tool kit and technology design constraints are inferred.

Because, in Middle Palaeolithic research, we are dealing with a different subspecies of Homo *sapiens*, issues of cognitive abilities inevitably arise. The fact that some very recent hunter-gatherer cultures produced material cultures no more sophisticated than those of the Middle Palaeolithic would suggest that the onus should be on those who favour a view of Neanderthals having a lower cognitive levels than morphological modern peoples, to prove this assertion. However, common practice dictates that the issue should be addressed to some degree in this research.

Data Collection

The testing of hypotheses was achieved through the analysis of samples of Mousterian assemblages. The primary study assemblages are from three different sites located in Southwest France: Pech de L'Azé IV, le Moustier and Combe Capelle Bas. By looking at assemblages from different sites with different characteristics (e.g., proximity to raw material sources, relative presence of Levallois artifacts, age of assemblage, climatic correlate of assemblage, etc.) better insight into some of the design variables was obtained.

A fourth study site will also be included as a specific control on geography. The site of Jiboui is located in the Vercors region of the French Alps in southeast France. Data on this site were not collected by the author and do not include information on all the variables, which were measured or examined in the three primary samples. Therefore, this site cannot be used in all aspects of the analysis.

Data Analysis and Interpretation

Initially the data from the four site samples are analyzed to compare the morphology of the used versus the unused flakes in order to determine the degree to which Middle Palaeolithic tools match the design expectations and hypotheses arising from my predictive model. The attributes associated with Middle Palaeolithic tools are then compared to the morphologies of the different products resulting from the different reduction technologies employed at the four sites (essentially Levallois and non-Levallois). The site-specific patterns of choice of reduction technology and blank selection criteria are then examined. This provides a means of identifying behaviours unique to specific conditions and should provide some insight into the circumstances under which the Levallois technique was employed.

Contributions of this Research

The Levallois reduction technique has been the focus of significant attention for about a century for several reasons. One major reason is that following the very long initial use of stone tools throughout the Lower Palaeolithic, which mainly involved core tools such as choppers and handaxes, Levallois was one of the earliest stone tool technologies to focused on the patterned production and use of flake blanks for tools. It may, in fact, be the first core reduction technique to have involved preparation of the core prior to the production of the blanks. A second important aspect of Levallois is that, because of its apparent complexity, relative to other contemporaneous technologies, it is seen to hold potentially significant implications for, and insights into, Palaeolithic cognitive abilities (Bar-Yosef 1995).

Research that is specifically focused on the Levallois technique and its products has been shifting, over the last decade or two, towards a better understanding of the underlying technological structure of the process (e.g., Baumler 1995; Boëda 1995; Otte 1995; Sellet 1995; Van Peer 1992, 1995).

However, it is apparent that the majority of this research is rooted in the continued presumption that the *raison d'etre* of the technique is to produce large flake blanks of predetermined shape. While this may, in fact, turn out to be the case, by starting from a position of presumption of intention such research is preprogrammed to result in explanations and interpretations that will be necessarily limited in their potential scope. Potential alternative interpretations would be precluded from the outset. My research will investigate the Levallois technique from a technological point of view, but will specifically avoid the problem inherent in other approaches by not presuming any specific intention on the part of the prehistoric users of the technique. By analyzing the design of the technique through identification of all the visible factors influencing the stone tool technological organization of the people using it (and potentially by comparing this design structure to a similar one in which the technique is not evident), it is hoped that the potential advantage(s) of the technique may be better understood.

Chapter 2: Previous Research

Background Information and Previous Research on Levallois

Chronologically the boundary between the Lower and Middle Palaeolithic periods in Europe is now commonly set at around 200,000 BP. While a strict boundary in prehistory will almost always be somewhat arbitrary, there does appear to be general support in the archaeological record for this one. Although the hominid fossil record from Europe is sparse, early Neanderthal (Homo *sapiens neanderthalensis*) remains tend to date to around this time (although recent claims have arisen of substantially earlier Neanderthal remains in Northern and Eastern Europe – e.g., Golovanova et. al. 1999). There was also a notable change in the material record around this time. The Lower Palaeolithic was dominated by the use of core tools including large unifacial and bifacial choppers and bifacial handaxes. Around 200,000 years ago there was a switch to smaller tools made from flakes removed from cores. Core tools, specifically handaxes of various forms, were still produced but with less frequency. These Middle Palaeolithic assemblages included a variety of scrapers, notched tools, borers, and other tool types produced through little or no modification of a flake. The various Western European Middle Palaeolithic industries composed of these stone tools are collectively referred to as the Mousterian.

While many of the flakes from which these tools were made were produced through the random reduction of a core; around the early 1900s a specific systematic reduction technique was recognized among Mousterian assemblages. The technique was referred to as *Levallois* after a Paris suburb where it had been specifically noted. It involves the relatively limited initial preparation of a core such that two opposing convex surfaces are formed (fig. 2.1: A and B). From one of these surfaces small to medium size flakes are removed from around the periphery in a radial fashion (fig. 2.1: B). This results in an increased central convexity which is then reduced through the removal of one or two large flakes from the centre (fig. 2.1: C). This cycle is then repeated with the further removal of peripheral or *centripetal* flakes followed by the removal of another one or two central flakes.

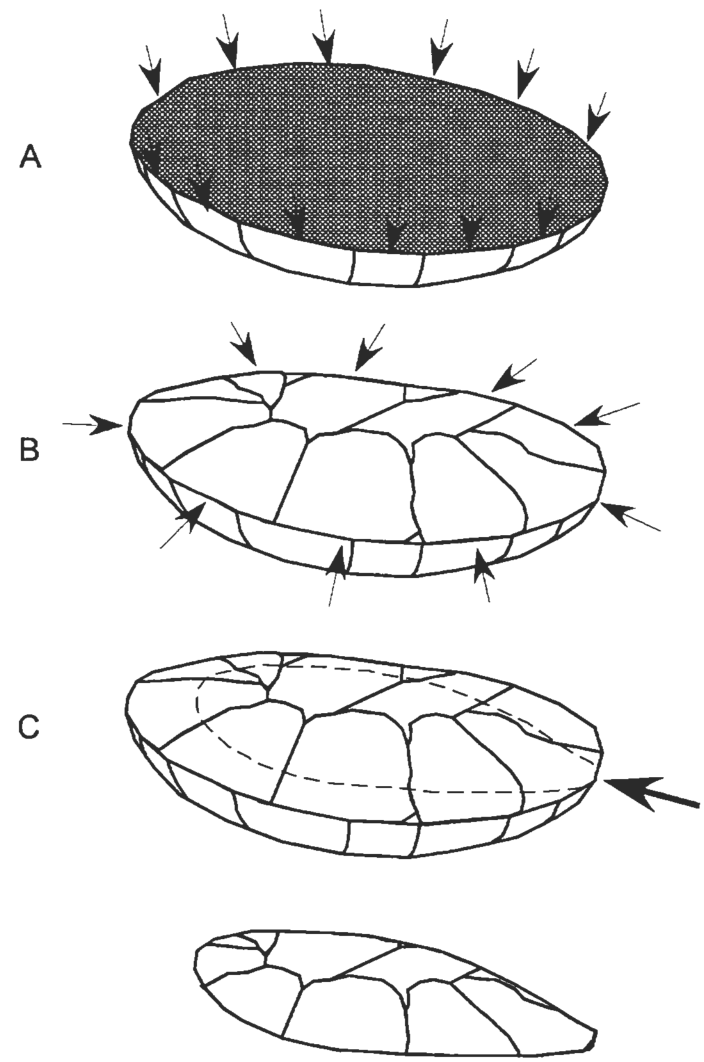


Figure 2.1 Classic Levallois technique.
Initial preparation of nodule to form peripheral striking platforms (A), followed by removal of flakes in a radial fashion from the core surface (B), producing a convex surface from which a Levallois flake can be removed (C).

From a general technological point of view the Levallois reduction technique is a relatively simple concept, which does not require any special reduction tools (such as wood or antler billets or punches) and was carried out with just a simple hammerstone. It also doesn't require any exceptional core preparation and, while it does require a skilled knapper to carry it out, it does not require the exceptional level of skill or training that systematic prismatic blade production typically does.

The traditional interpretation of the technique is that its primary purpose was to produce two or three large central flakes of predetermined shape from each core. The classic definition comes (translated from french and paraphrased) from Bordes (1961b, 14):

> *.... the Levallois flake (is) of predetermined form through the special preparation of the core prior to the removal of the flake.*

In this scenario, in each reduction cycle a single flake is removed from the central mass. *Classic* Levallois flakes are relatively large, generally sub-circular, have a sharp edge around the majority of the margin, exhibit a faceted striking platform, and the dorsal surface reflects the radial pattern of the preceding flake removals. It is these characteristics that are generally used to recognize apparent Levallois flakes in assemblages. Variations on Levallois end-products include Levallois *Points,* which are triangular in shape and have been interpreted by some as hafted projectile tips, and Levallois *blades*, two or more of which may be removed from the centre of the core in each reduction cycle.

Large, sub-circular Levallois flakes had been recognized in French Palaeolithic sites prior to the 1900s (e.g., de Mortillet 1883; see also: Baumler 1995: 18; Bordes 1961a: 805; Debénath and Dibble 1993: 23; Perpere 1981; Van Peer 1992: 1). It was early in the 20th century, however, when the nature of the reduction technique as a form of prepared core technology was described in the literature by Commont (Debénath and Dibble 1993: 23; Van Peer 1992: 1). Commont had referred to it as the "Mousterian" technique and it was not till 1926 that the term "Levalloisian" was used by Brueil (Debénath and Dibble 1993: 23, see also Rolland 1988: 163). Levallois cores were also recovered from British Palaeolithic sites and, due to their similarity to turtle's shells, were referred to as "tortoise cores".

A certain degree of "standardization" came to be recognized among flakes produced using the Levallois technique. This recognition, and later replicative experiments by Bordes, resulted in the traditional interpretation of the technique as a method for predetermining the form of a flake (Bordes 1953: 226, 1955: 113, 1961a: 805-6 - see also Van Peer 1992: 1-5 and Debénath and Dibble 1993: 23-29 for more thorough discussions of this issue).

In the course of the development of typologies and chronologies, through the first half of the 20th century, Levallois became almost inextricably intertwined with the definitions of western European Palaeolithic industries. In particular, Bordes' Mousterian industries were distinguished in part by the presence/absence or relative occurrence of Levallois flakes (Levallois Indices). In part because of this it became important to try to arrive at some consensus on what constituted a Levallois flake. Morphology rather than technology dominated Levallois discussions and research. One of the characteristics that some argued was a prerequisite for a flake to be Levallois was that it had to have a faceted platform. This reflected the opinion of some that significant platform preparation prior to flake removal was an unavoidable part of the process (Van Peer 1995:1-2). Others pointed out that this was also a characteristic of bifacial reduction flakes, which could be as common in Mousterian assemblages with handaxes and, therefore, this alone would fail to distinguish between them. Bordes originally included faceted platforms in his criteria for Levallois flakes, but later held that Levallois flakes could be produced with both faceted and plain platforms (1961a: 805).

It also came to be recognized that the Levallois technique had been used to produce a variety of products besides the "classic" sub-circular flakes first recognized in France. These products included "points" and "blades". Other than the issue of consistency of identification of Levallois "products" in assemblages, the idea of there being a range of intended products did not seem to elicit any concern about the traditional interpretation of the technique. Since Levallois had been seen, almost from its original recognition, only in terms of its presumed end-products, the addition of some variability to these was not initially a problem.

This was the nature of the situation through most of the middle of the 20th century; morphology was still the focus. Through the 1950s and 60s researchers dealing with Levallois were mainly concerned with the consistency among individual analysts in the identification of Levallois flakes as this had a direct influence in distinguishing Bordes' different Mousterian industries (Van Peer 1995: 1-5; Sellet 1995: 25-27). The potential problems inherent in the subjectivity involved in determining whether a flake was Levallois or not, simply by examining the gross morphology, had already been recognized (e.g. Bordes 1961b), but it was expected that this could be generally avoided or overcome with a modicum of training and experience (Bordes 1950: 30). Perpere (1986), in a simple experiment, demonstrated that this was not the case. Three prehistorians of significant Levallois experience were asked to divide up a small assemblage of flakes into Levallois, non-Levallois, and unknown. The individual results were significantly different, with only 69% of the assemblage being similarly categorized by all three individuals (Van Peer 1995: 2).

Perpere's experiment reflected a general recognition through the 1960s, 1970s, and 1980s that the level of variability in the Palaeolithic record had outgrown the ability of classifications, based solely on morphology, to deal with it effectively (Boëda 1995: 41; Copeland 1983; Fish 1978; Rolland and Dibble 1990). This may have been best illustrated by the debate between Bordes and the Binfords about whether the different Mousterian industries represented different, but contemporary, cultural ("ethnic") entities or represented functionally specific assemblages (Binford and Binford 1966; Bordes and de Sonneville-Bordes 1970). At the same time interest grew in trying to understand the underlying technological variability and how it reflected human cognition and behavioural patterns (e.g., Boëda 1986, 1988; Chase 1985; Crew 1975; Dibble 1983, 1984; Geneste 1985; Henry 1989; Lieberman 1975; Roebroeks et al. 1988; Rolland 1981; Tixier et al. 1980; Van Peer 1988). Two potentially powerful tools brought to bear on this issue were functional analysis through tool edge use-damage (Anderson-Gerfaud 1990; Beyries 1988, 1985, 1984; Hayden 1979; Holdaway 1989; Keeley 1980; Semenov 1964; Shea 1989) and refitting studies (e.g., Volkman 1983; Marks and Volkman 1987; Van Peer 1992). Use-wear studies began to provide information about the behaviour of the users of the Levallois technique by examining the tasks to which the products of the process were applied. Some researchers addressed general subsistence questions (e.g., Beyries 1988, 1984, 1985). Others addressed more specific issues. One of these was the interpretation of the use of Levallois "points". These had been interpreted early on as being hafted to wooden shafts for use as throwing or thrusting spears (e.g., Leakey 1960). Use-wear analysis was employed to address this question (Holdaway 1989; Plisson and

Beyries 1998; Shea 1988; Solecki 1992) and most research presented on this has concluded that they had been used in such a fashion. If Levallois points were produced specifically as tips for projectiles it would be further proof that Mousterian people hunted and were not just scavenging meat. Beyond settling this question, it also indicates a significant focus on, and directing of time and energy towards hunting behaviour. Neanderthals were not just putting the minimum of effort into hunting tools (such as pointed sticks), but were putting together composite weapons which would include, at least, a wooden shaft, a stone tip and leather, sinew, or resin hafting materials.

Over the last decade or two, much of Levallois research has involved trying to arrive at a more comprehensive definition of Levallois: one that would encompass the range of variability apparent in both core and endproduct morphology. Based on the results of her experiment, which demonstrated the inaccuracy of a subjective approach, Perpere (1986) suggested that a solution to the problem would be to come up with a quantitative definition of Levallois flakes. Van Peer (1992) has used this as an example of the underlying barrier to achieving a better understanding of Levallois. Many (perhaps most) researchers perceive and define Levallois by its presumed intended end-products. The presumption of intention carries its own problems. However, defining a process like Levallois reduction based on its end-products will prevent a discreteness of definition because of both the range of variation in end-products and the issue of equifinality. It has been recognized that all Levallois products can be produced using non-Levallois techniques (Boëda 1995: 43-45). Flakes similar to the classic sub-circular Levallois flakes can be produced during bifacial reduction. Blades similar (or identical) to those produced from Levallois cores are produced through several other types of blade-core reduction. Core reconstructions from the Site of Boker Tachtit have shown that flakes recovered from one level that were initially identified as Levallois points were produced with a different reduction method (Marks and Volkman 1987).

Van Peer (1992 and 1995) provides a good summary of current problems. In general some researchers still see no problem with classic perceptions of Levallois and suggest that all that is required are more specific criteria for definitions of Levallois end-products (Van Peer 1992: 5-6). Others suggest that it is the underlying reduction process itself which we need to better understand and better define (Bar-Yosef 1995: xi; Baumler

1995; Boëda 1995; Dibble 1989: 424; Van Peer 1992, 1995). Some researchers in particular (e.g., Eric Boëda 1988, 1990, 1995) have been trying specifically to better understand Levallois as a technological process. These current attitudes and approaches were strongly reflected in the content of a 1993 conference held to specifically address the issue of defining and interpreting the Levallois technique (Dibble and Bar-Yosef 1995).

Describing and Defining the Levallois Technique

Levallois is a prepared core technique, carried out solely with hard hammer direct percussion, which involves two general phases (fig. 2.2). The first is the initial, rough preparation of a nodule of raw material in order to construct an acutely angled edge around the entire periphery to serve as a striking platform. This typically involves the removal of flakes around the margins of the nodule from one ("lower") face of the nodule. The periphery of this face then serves as a striking platform from which are initiated flake removals from the opposite face. In the classic Levallois technique, the second phase, the process of removing flakes from this opposite ("upper") face or 'surface of débitage', is carried out in a semi-systematic manner. At first, small to medium sized flakes are removed in a radial fashion (in the classic form) resulting in a convex or domed upper surface. The central mass of this domed surface is then removed in the form of one large flake. After this large flake has been removed a second series of peripheral or centripetal flakes can be removed, again resulting in an increased upper surface convexity. This cycle could have been carried out several times until the core was exhausted (Boëda 1995). The removal of the centripetal flakes appears to have been commonly carried out in such a fashion so as to predetermine the general shape of the large central flakes (e.g., Van Peer 1995). Using this technique, skilled knappers were able to produce large sub-circular flakes, triangular flakes, and long narrow 'blades'.

While, as mentioned above, the physical process of reducing a core using the Levallois technique does require a significant skill level (Rolland 1995: 333), it is not technically complicated. Actually defining the technique, however, has proven to be a problem. This is mainly due to the strong influence of a typological approach in Western European archaeology. It has been widely accepted among Palaeolithic researchers, over the last several decades at least, that the Levallois technique was used specifically to produce flakes of predetermined morphologies. The actual reduction technique has been eclipsed by a focus on its presumed intended end-products (Dibble 1995).

Much of the recent Levallois research carried out in Europe has involved the recognition and description of a number of different varieties or approaches to the use of the Levallois concept. Boëda (1988, 1993, 1995) has provided a useful morphological description of the Levallois concept. In his "volumetric conception" the Levallois core is viewed as "two asymmetrical, convex secant surfaces the intersection of which forms a plane". These two surfaces are hierarchized in that one (the 'upper' face or 'surface of debitage') is used solely as a source of flake blanks, while the other serves solely as a location for striking platforms for the removal of these blanks. Because these two surfaces are not symmetrical their roles cannot be reversed. Within Boëda's Levallois concept, he and other researchers (e.g., Lenoir and Turq 1995) have defined more specific types that have come into common usage. These differ based on whether the central removals from each prepared upper surface involved only one flake (*Preferential*) or several flakes (*Récurrent*), or whether, in the case of *Récurrent* types, the removals are unidirectional (all originate from the same end of the core), bidirectional (originate from two opposite ends of the core), or radial (Figure 2.2).

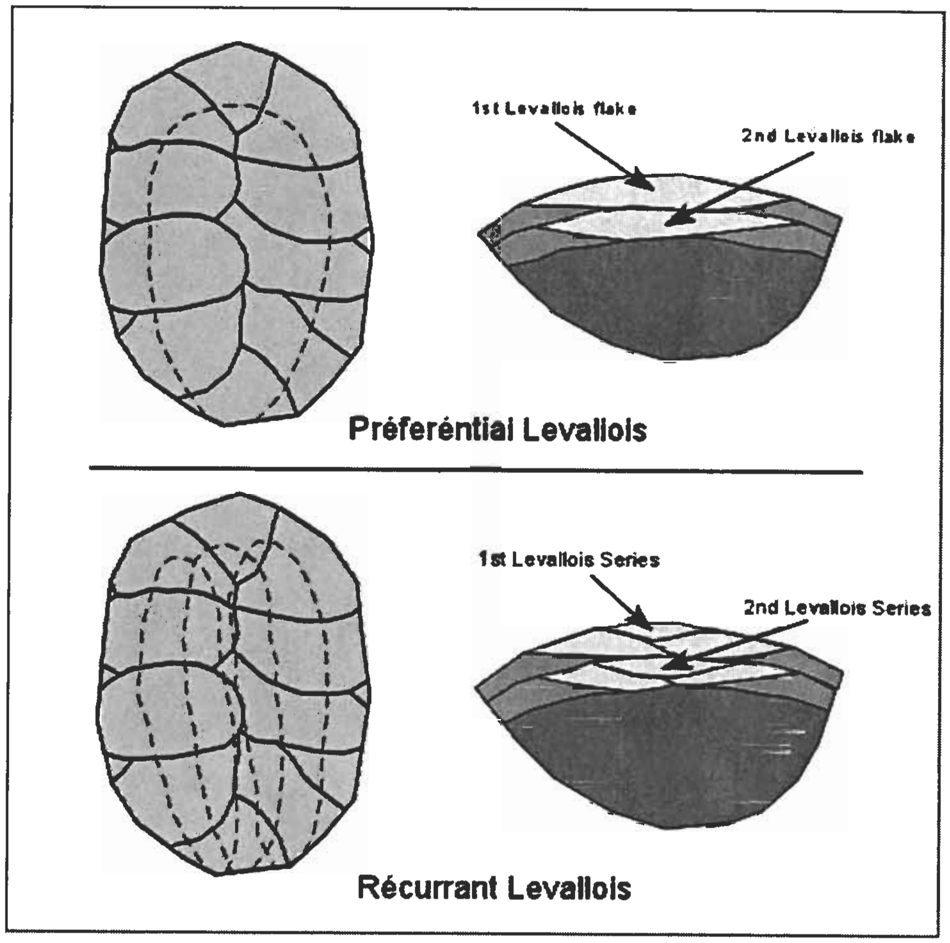


Figure 2.2 Prèferential and Récurrant Levallois approaches.

These variants of the Levallois concept can all be grouped into the larger category of *single-surface* core reduction. Within this category there are other approaches that are non-Levallois in the classical sense. *Centripetal* cores have a single surface of debitage, but from this only peripheral flakes are removed, with no subsequent central removal(s). Disc cores are the same as Centripetal cores except that their two surfaces can be symmetrical and so may not be hierarchized, either face can serve as the surface of debitage, and so these are essentially hardhammer biface cores (Figure 2.3).

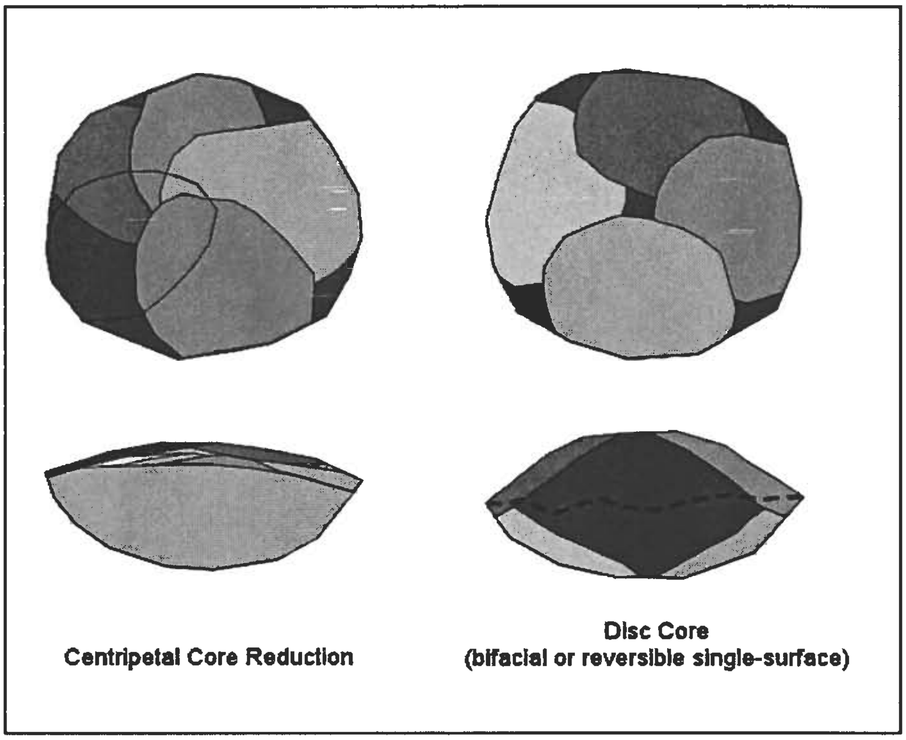


Figure 2.3 Centripetal and Disc core reduction approaches.

Another variant on the single-surface approach is a method that produces notably distinct products called *Eclats Débordants* (Figure 2.4). The distinctive attribute of these products is the inclusion of a significant portion of core edge along one margin of the flake. This is accomplished by striking the intended flake platform on the core edge at an oblique angle (rather than parallel) to the radius of the core surface. On such flakes there tends to be one or two regular, sharp edges (the number depending on the configuration of the core surface) opposite the margin exhibiting a portion of the core edge. Often times, when the flake has two of these sharp edges and they form a point, the resulting flake shape is what Bordes classified as 'pseudo-Levallois points' (e.g., flake B in figure 2.4 and Plates 10 and 11 in the appendices).

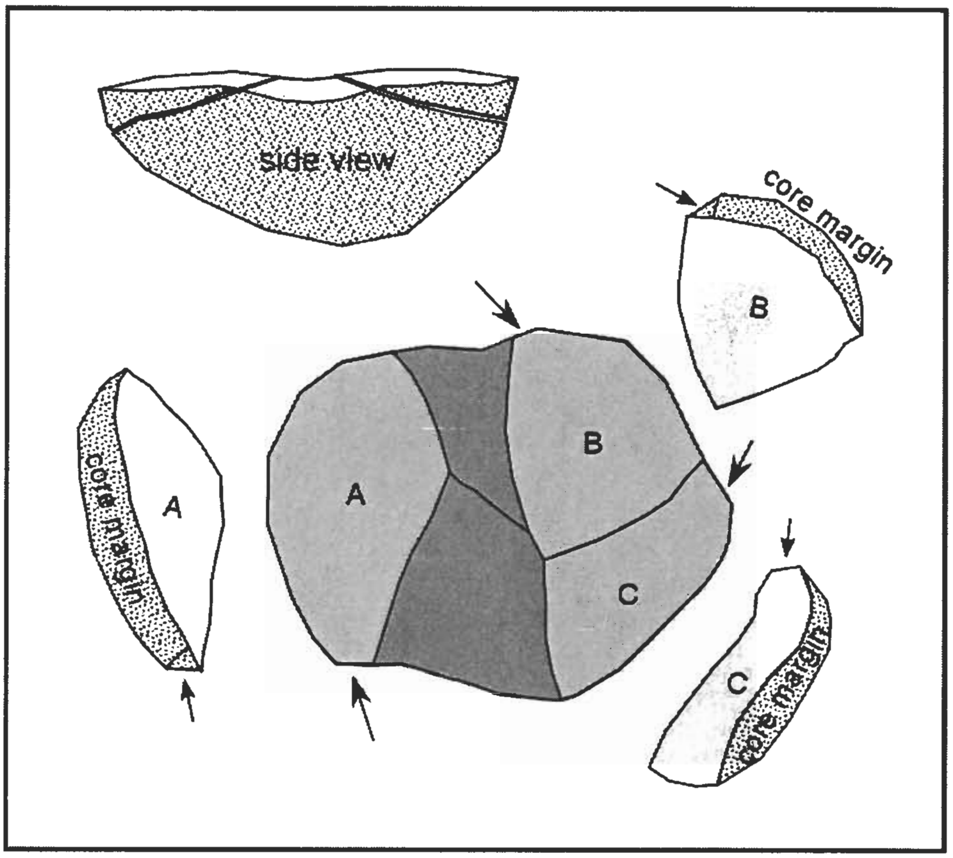


Figure 2.4 Method of production of Eclats Débordants. The darker shaded flake scars represent centrally-directed removals. The 3 éclats débordants (A, B, C) were removed with oblique impacts to the core edge.

Currently there is significant confusion among researchers and in the literature on Levallois and its definition, and different views and definitions seem to correspond mainly to differences in nationality and language. This is partly due to the slowness with which much of the most current research (most of it among the French and Belgians) has been accessed by British and North American researchers. Among Anglophones, especially the British, the terms 'Tortoise core' and 'Disc core', referring to Levallois variants, are still in common usage, while most Francophone researchers have been using terms like '*préferential*', *linèal*, *récurrent*, and '*céntripete*' for over 10 years.

General Spatial Distribution

The presence of the Levallois Technique has been recognized in the archaeological record in Africa, Western Eurasia, and parts of Asia-proper including southern Siberia (Derevianko and Markin 1995), Mongolia (Derevianko and Petrin 1995), and on the Indian sub-continent (Rolland 1995, 333). Convincingly Levallois-like cores have also been identified in the Japanese Middle Palaeolithic (Sato *et al.* 1995).

Origins and General Chronology

Determining the time span of the use of the Levallois technique is hampered by two general problems. The first is the inconsistency in the definition of Levallois and the recognition of its products in assemblages. This problem can arise in both the question of first appearances of Levallois and in determining the later duration of the use of the technique. Typically the Levallois technique is seen as evolving out of previous technologies and evolving into subsequent ones. The initial and final forms of the technique, tending to be dissimilar to the classic form(s) observed throughout the majority of the technique's use-span, lead to some disagreement about the actual points at which the technique emerged and finally disappeared (Rolland 1995; Vermeersch 1995). The second problem is in the accuracy and reliability of the dating of the earlier site assemblages. The Levallois technique seems to generally appear around, or prior to, the middle of the Riss (ca. 470-195 kya)(White and Ashton 2003; Rolland 1995; Vermeersch 1995). Tuffreau (1995: 417) puts the earliest evidence for it unequivocally in isotope stage 14 (ca. 550-500 kya) in northern France. White and Ashton (2003:598), however, put its emergence at 300,000 to 250,000 years ago (OIS 8). Rarely, however, are reliable absolute dates available for sites of these ages. Typically the ages of assemblages representing early occurrences of Levallois can only be expressed in Pleistocene chronostratigraphic terms; sometimes by association with a specific oxygen isotopic stage, but sometimes only by placement within a glacial period (e.g. "initial to later Riss times" - Rolland 1995: 349).

The Emergence of Levallois

Several researchers have suggested that the Levallois technique evolved directly from Acheulian handaxe technology (Rolland 1995: 346 and Tuffreau 1995, 1982: 142). While handaxes were still a component of Middle Palaeolithic assemblages in Europe, in Africa their use was paralleled in some regions by the use of other core reduction techniques such as the Tachenghit, Victoria West I and II, and "horses hoof" cores (Rolland 1995). Some saw these core reduction techniques as likely precursors to fully developed Levallois and, due to their ages, it seemed likely that the Levallois technique initially emerged in Africa. Coupled with the lack of potential pre and "proto-Levallois" candidates (besides handaxes) in Europe, this led some researchers to suggest that Levallois had entered Europe in its fully developed (classic) form from elsewhere, with Africa as the ultimate place of origin. This monothetic view of Levallois origins saw Levallois entering Europe either through the Middle East or directly from North Africa. The latter route was seen to be supported to some degree by the general similarities in handaxe types between the Iberian Peninsula and the Maghreb (Rolland 1995: 335-51).

Others see the technique developing independently in Europe (e.g. Tuffreau 1995; White and Ashton 2003). Bordes (1961a: 806) states outright that the technique was developed in Europe in the Middle Acheulian.

Rolland (1995) proposes a polycentric origin for Levallois with Africa and Europe, at least, having independent appearances. His proposed evolutionary sequence for the development of Levallois (Rolland 1995: 341-42, figure 24.1) includes pre-Levallois core technologies (e.g. Clactonian and Tachenghit), Proto-Levallois stages I and Stage II, and Levallois stages I to IV. Rolland sees the appearance of Proto-Levallois in the presence of faceted platforms and partial dorsal preparation. This transition is associated in South Africa with stage III of the Vaal River sequence and in North Africa with the Middle Acheulian. These cores are, however, thicker than fully Levallois cores and tend to be oblong or more like handaxes in plan-view. Early Levallois (Levallois stages I and II) are represented by the appearance of flatter Levallois cores approximating "classic" Levallois. Levallois stages III and IV are marked by the appearance of greater variability in Levallois products (i.e. blades and points). The actual dating of these stages is difficult, due in part to a lack of reliable dates, but also to regional variation in the occurrences of these technologies. Rolland does see Proto-Levallois materials in the Lake Baringo area dated to over 230 kya. In North Africa the Middle Acheulian roughly corresponds to the Antafian stage (associated with the Mediterranean Sicilian cycle) placed between oxygen isotope stages 16 and 12 (600 kya to 470 kya) (Rolland 1995: 341-45).

In Europe fully developed Levallois seems to appear quite early and with few obvious transitional forms between it and Acheulian handaxes, as is seen to be the case in Africa. While White and Ashton (2003) propose the existence of 'proto-Levallois' technology at the site of Purfleet in England dated to OIS 9/8, "genuine" Levallois cores and flakes have been identified at the site of Cagney la Garenne in the Somme valley, which has been assigned chronostratigraphically to isotope stage 12 (ca. 470 to 440 kya)(Tuffreau 1995, 1982). The early appearance of obvious Levallois products and the scarcity of potential transitional technologies led Rolland to suggest that the Levallois technique appeared here independently of its development elsewhere. The presence of fully developed Levallois at other sites such as Champvoisy and Argoeuves, placed in early oxygen isotope stage 8 (300 to 280 kya), indicates that the technique was established in Europe well prior to the Middle Palaeolithic (Rolland 1995: 345-46 and Tuffreau 1982).

The Disappearance of Levallois

In Europe, regardless of the actual nature of the temporal relationship of the various Mousterian industries (re. Mellars 1969; Laville 1972), the classic Levallois had apparently already become quite scarce in the terminal Mousterian Industries. However, some researchers have seen similarities to Levallois in other reduction methods observed in Late Middle/Early Upper Palaeolithic assemblages (e.g. Kozlowski 1990 and Otte 1990). Typically these other methods are oriented towards producing blades or blade-like flakes using faceted platform preparation and hard hammer, as opposed to the soft hammer or indirect percussion, methods typically associated with Upper Palaeolithic blade production (Newcomer 1975). Examples of such assemblages, exhibiting Upper Palaeolithic type tools produced with Middle Palaeolithic technology, include those of the Bohunician industry of Eastern Europe, dated to around 40,000 BP (Kozlowski 1990;

Svoboda and Skrdla 1995). The recognition of similarities between these two processes highlights two issues. The first is the problem of trying to define the Levallois technique (or any other process) based on its end-products rather than the nature of its technological process. The second implication of this recognition is that perhaps the underlying advantages of both the Levallois technique and certain blade production techniques are the same, or at least similar, in how they address reduction requirements and constraints and that their distinct products are a secondary characteristic.

In Africa the Levallois technique seems to disappear in most areas by around 40 kya. However, there are regions where it appears to continue, or perhaps reappear, in much later periods. Levallois is present ("reappears"?) in the Nile Valley around 21 kya (Vermeersch 1995: 309). Leakey *et al.* (1972: 332-33) identify the presence of Levallois cores at Olduvai Gorge in deposits well dated to 17 kya. In Tunisia Levallois flakes have been found associated with typical Upper Palaeolithic tools. While this assemblage remains undated, an estimate of c. 25 kya has been proposed (Vermeersch 1995: 308)

Distribution in Western Europe

As outlined above, Levallois materials have been recovered from stratigraphic positions placed quite early in European chronostratigraphic sequences. It seems apparent that the technique was established in Europe (whether it emerged there or not) by isotope stage 8 (ca. 300 kya) and continued on into and through the Middle Palaeolithic. The classic Levallois ended with the Mousterian industries (ca. 40 to 35 kya), but the method continued on to some degree into the Upper Palaeolithic in the form of blade-production or some transformed form. However, at no time does the Levallois method appear to have had a widespread employment by all contemporaneous groups/cultures in Europe or Africa. In fact, even if some form of long term chronological relationships emerge (such as that suggested by Mellars [1969]), the Levallois strategy appears to have had a sporadic history of use. In the European Middle Palaeolithic, Levallois is associated to some degree with all the Mousterian lithic industries. In some Mousterian industries the technique is more common while in others the presence of the technique is very limited. In the Typical Mousterian and the Denticulate Mousterian, Levallois materials are common in some components, but poorly represented at others. In the la Ferrassie tradition Levallois materials start out being common but slowly become scarcer through time. In the Quina (which likely follows the Ferrassie chronologically) Levallois becomes scarcer yet. In the Mousterian of Acheulian Tradition (MAT) the technique is less strongly represented, but is usually still present to some degree. Table 2.1 Presents some average Levallois indices for the Mousterian industries based on data from 13 sites in SW France (Combe Grenal, Pech de l'Azé I and II, Abri Chadourne, Roc en Pail, Hauteroche, Petit-Puymoyen, P. Baillard, Caminade, Ferrassie, Bouheben, Roc de Marsal [Rolland 1988], and Pech de l'Azé IV [Dibble and McPherron 2003]). While the data are limited the table does give some indication of the relative importance of Levallois reduction in each industry.

Table 2.1 Average Levallois Indices for the Mousterian Industries of 13 French sites (data from Rolland 1988 and Dibble and McPherron 2003). (CG=Combe Grenal, P=Pech, RdM=Roc de Marsal, BH=Bouheben, AC=Abri Chadourne, H=Hauteroche, ReP=Roc en Pail, C=Caminade, Fer=la Ferrassie, PP=Petit-Puymoyen, PB=P. Baillard).

Typical Mousterian		Denticulate Mousterian		Ferrassie Mousterian		MAT		Quina Mousterian	
Level	**IL**	**Level**	**IL**	**Level**	**IL**	**Level**	**IL**	**Level**	**IL**
CG–7	30	CG-8	13	CG–27	17	CG – 1	7	CG–17	3
CG-9	20	CG–11	20	CG–32	21	P-I – 7	6	CG–18	5
CG–10	25	CG–12	12	CG–33	22	P-I – 6	8	CG–19	1
CG–28	23	CG–13	3	CG–34	21	P-I –	9	CG–21	2
CG–29	27	CG–14	2	CG–35	32	P-I – B	11	CG–22	2
CG–30	25	CG–15	4	AC– C	19	P-I – 5	10	CG–23	4
CG–31	29	CG–16	18	AC - D	26	P-I– 5A	13	CG–24	3
CG–36	24	CG–38	20	ReP - 1	19	P-I – 4F	8	CG–25	4
CG–37	13	CG–41	13	ReP - 4	14	P-I - 3	6	CG–26	9
CG-39	13	P-II–4F	10	C – M1s	32	P-IV-F4	8	AC - B	12
CG–42	17	P-II–4B	9	C – M2b	56	P-IV-F3	4	ReP - 5	3
CG–46	15	AC - A	7	C – M2s	41	P-IV-F2	5	H - 1	8
CG–50a	7	H - 3	4	C – M3b	41	P-IV-F1	5	PP – lw	12
CG–50	11	RdM-3	20	C – M3s	23			PP - up	1
CG–52	14	RdM-2	22	Fer – C	51			PB – 1	8
CG–54	12			Fer – D1	40			PB - 2	2
CG-55	8			Fer – D2	21			C – M3s	4
P-II – 3	29							RdM-11	2
P-II–4C	10							RdM-10	1
C–M1b	25							RdM-9b	3
BH– 1	5							RdM-9a	2
BH–1a	19								
RdM-7	15								
RdM-6	14								
RdM-5	11								
RdM-4	22								
P-IV-Z	13								
P-IV-Y	15								
P-IV-X	13								
P-IV-J3c	15								

Typical Mousterian		Denticulate Mousterian		Ferrassie Mousterian		MAT		Quina Mousterian	
P-IV-J3b	21								
P-IV-J3a	22								
P-IV-J3	24								
P-IV-J2	12								
P-IV-J1	22								
P-IV-I2	18								
P-IV-I1	13								
P-IV-H	6								
Total	657		177		496		100		91
MEAN	**17.3**		**11.8**		**29.2**		**7.7**		**4.3**

Within some Bordesian types of traditions, in some components Levallois has a strong presence, while at other sites it will be all but non-existent. What this actually means in terms of human behaviour and choices is not clear. These industries are defined based on their relative contents of certain 'tool types' and technology, the meaning of which is still under debate. If these different industries (assuming they are real, distinct entities) represent different adaptations to specific conditions (individual site-related, regional, or climatic), as is being suggested here for choice of reduction technology, then this will require additional compilation of all the pertinent data (a massive undertaking by itself). Generally, the use of Levallois reduction cross-cuts the Bordian Industries (whatever they might represent), although its use is almost always significantly lower in the Quina and MAT industries. Occurrences of the MAT industry in the Aquitaine region are quite late in the Middle Palaeolithic and seem to represent a relatively short period of time (perhaps 10 ky in duration), and so might be more open to potential interpretations that take cultural tradition into consideration (Rolland 2000).

If Levallois reduction was related to distinct cultural traditions, or perhaps distinct adaptations, then we might expect some geographical patterning. There have been some previous attempts at detecting this (e.g., Jaubert and Farizy 1995; Rolland 1988), but these, like any such attempts, are severely limited by the resolution and quality of the available data. In France, the distribution of the use of Levallois technology appears, at a coarse level of resolution, to be generally homogeneous. However, throughout the Middle Palaeolithic a number of different reduction technologies were used in France including amorphous core reduction and other variants of single-surface core reduction (besides Levallois), including centripetal/disc core, sausage-slice reduction, and bidirectional approaches to the removal of flakes from the core surface. It is possible that there is some underlying patterning to the temporal and spatial distribution of Levallois (and other reduction techniques) throughout this period. To "map out" Levallois use through time and space would require a Levallois Index value for a large proportion of all the available Middle Palaeolithic site components and accurate dating and environmental reconstruction for each. Unfortunately, at this time data for these purposes are not generally available in quantified form to any reasonable degree. For the vast majority of known sites of this time period there is almost no data published. For those sites where significant work has been carried out, dates are not typically available for each component and often their associated Levallois Indices have not been made available by the researchers. To compile all the currently available evidence would represent a large PhD dissertation alone.

Nevertheless, there have been some anecdotal statements about reduction technology patterning by researchers in France. For example, Jaubert (1995: 228) indicates that, while the Levallois reduction approach may be common in regions like the Perigord and the northern European Plain, it is not common in Brittany, Quercy, Tarn, the Pyrenees, Catalonia, the Iberian Peninsula, Central Europe, or the Balkans (see also Rolland 1986: 123). Quantified distributional data to support these ideas would be welcome.

Within France itself, I have compiled much of the readily available data on Levallois distribution. This is far from exhaustive, but such data is actually quite rare for most sites. For the majority of sites included here, Levallois presence has been reported only in descriptive form (e.g., high, low, absent) and actual Levallois Indices are not available in the literature. It is presented here in figure 2.2. The addition of more data (with better resolution) may result in detectable patterns, but as these data stand, none are apparent. It should be noted that there are many known Middle Palaeolithic sites in those regions of France where none are indicated in the map below. The lack of plotted sites over much of the map is simply due to a lack of access to data.

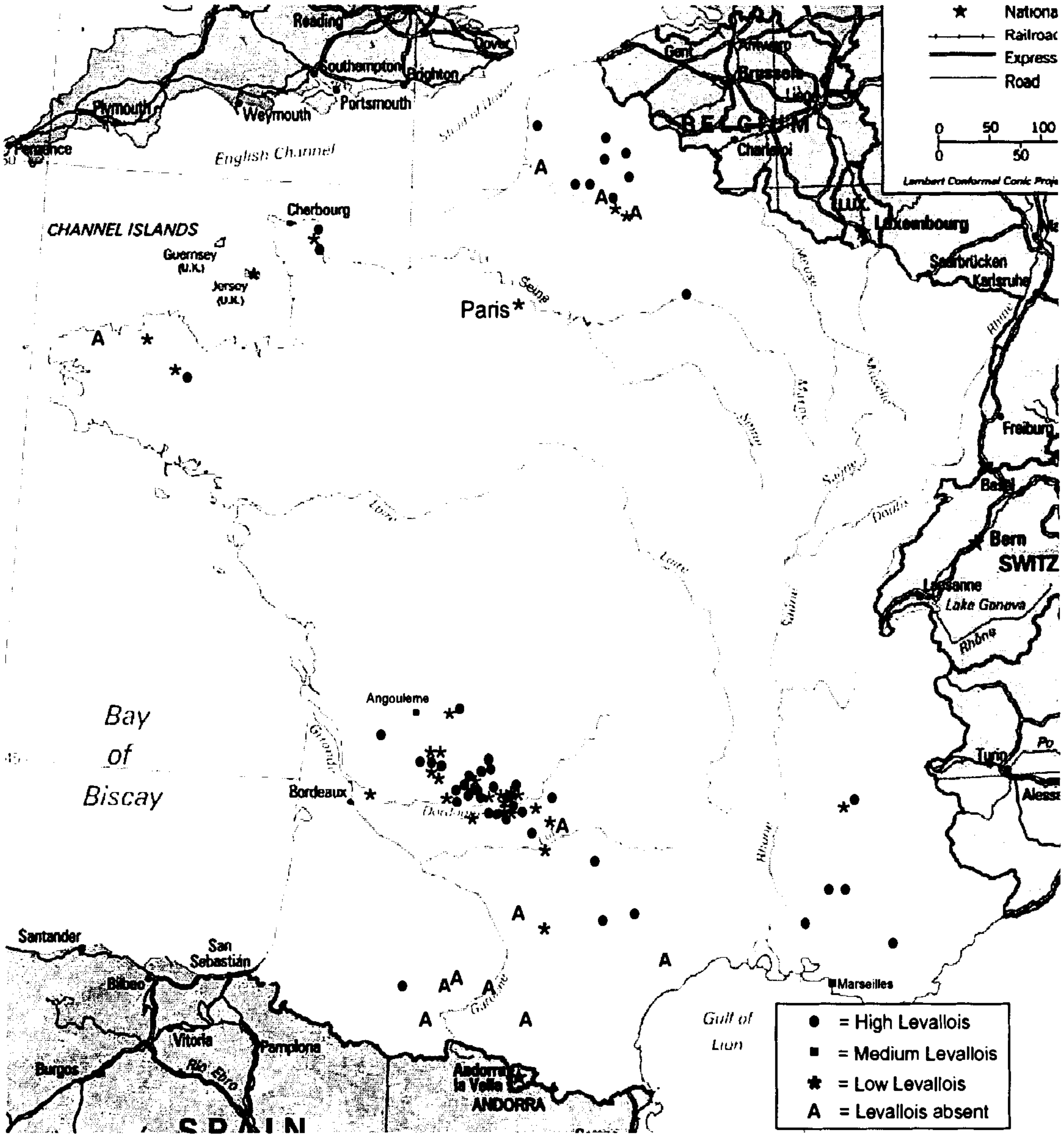


Figure 2.5 Distribution map of 77 Middle Palaeolithic sites in France indicating degree of Levallois technology present in their assemblages.

Table 2.2 List of sites used in figure 2.5.

Site	Lithic Industry	Levallois Presence
Abri Chadourne	Ferrassie, Quina, Denticulate	High, medium , low
Abri des Festons	?	Low
Argoeuves	Acheulian?	High
Bapaume	Epi-Acheulian?	High
Bau de l'Aubesier	?	High
Baume Bonne	Charentian	Low to high
Baume des Peyrards	Charentian	High
Beaumetz-les-Loges	Mousterian type?	High
Berigoule	?	High

Site	Lithic Industry	Levallois Presence
Biache St. Vaast	Ferrassie?	High
Bois-de-Rocher	MTA	Low
Bouheben	Typical	Medium
Cagney-Cimetière	Acheulian	Low
Cagney-la-Garenne	Acheulian	Low
Cagney-l'Epinette	Acheulian	Absent
Camiac	?	Low
Caminade	Typical, Ferrassie, Quina	High & low
Cantalouette	Southern Acheulian	High
Combe Grenal 4 to 11	Denticulate	High
Combe Grenal 12 to 26	MTA	Low
Combe Grenal 27 to 36	Typical & Ferrassie	High
Combe Grenal 37 to 54	Typical & Ferrassie	medium
Combe Grenal 55 to 60	MTA	Low
La Cotte de St. Brelade	?	Low
Champvoisy	Ferrassie	High
Combe Capelle Bas	Typical	Low
Coudoulous I	?	Low
Coupe-Gorge (couche z)	Mousterian type?	Absent
Coursac (Font de Meaux)	?	High
Espagnac	?	Absent
Etaples/Bagarre	?	High
Fontbouillenc	?	High
Frechet Cave	Typical?	Absent
Chez Pinaud (Jonzac)	Quina & ?	High
Goaréva	Denticulate	Low
Gouberville	Denticulate	High
Grotte Vaufrey (XV)	Typical	High
Hauteroche	Quina & Denticulate	Low
Jiboui	Mousterian type?	High
La Borde	?	Low
La Chaise (facies A)	?	High
La Chaise (facies B)	?	Medium
La Chaise (facies C)	?	Low
La Ferrassie	Ferrassie	High
La Micoque	Early Mousterian?	Low
Le Dau	MTA	low
Le Mas Viel	Quina	Medium
Le Moustier (level G)	MTA	High
Le Portal (F2)	?	Absent
Le Rescoundudou	?	High
Le Rigabe	Typical	High
Le Terrasse 1	?	Absent
Les Canalettes 2	Denticulate?	High
Les Fieux Cave	?	Low
Mareuil	Acheulian	Absent
Marouatte	?	Low
Mauran	Denticulate	Absent
Montieres	?	High
Le Mont-Dol	Ferrassie	High
Orgnac	Typical	Medium to high
Padirac	MTA?	High
Pech de l'Azé I	MTA	Low
Pech de l'Azé II	Typical & Denticulate	Low
Pech de l'Azé IV 3	MTA	Low
Pech de l'Azé IV 4,5,6	Typical	Low, medium, high
Pech de l'Azé IV 8	Typical	Medium

Site	Lithic Industry	Levallois Presence
Petit Nareye	MTA	Low
Puycelsi	?	Absent
Regourdou	?	Low to medium?
Roc de Marsal	Denticulate, Typical, Quina	High & low
Rue de Boves	Acheulian	Medium?
Sandougne – upper level	MTA	Low
St. Acheul	Acheulian	Absent
Saint-Germain-des-Vaux	Denticulate	High
Saint-Vaast la Hougue	Typical	Low
Tréissény	MTAa	Absent
Vimy	?	High

Based on the limited data in figure 2.5 the use of Levallois reduction apparently did not follow any broad geographical patterning. If this lack of patterning is accurate then it would indicate that it was not strongly tied to broad, regional patterning in raw material types and availability, or in climate or ethnic groups. It must be noted, however, that access to good raw materials is not an issue in most regions of France. The major exceptions would be the Massif Centrale, the Garonne delta in the Bordeaux region (Carsac 1983:102), and possibly the extreme NW Brittany-Normandy area (for all of which little site-specific data is readily available, as reflected in the lack of plotted sites in these regions in figure 2.5).

The reported lack of Levallois among the sites situated in the foothills of the Pyrenees in figure 2.5 (data from Jaubert and Farizy 1995) might be an indication of raw material constraints influencing the selection of reduction strategy (these assemblages do include higher frequencies of non-flint materials, such as quartz, than in the Dordogne region, although sources of good quality flint are not uncommon in this region). However, the dominant reduction strategies among these assemblages are still based on single-surface core reduction (Jaubert and Farizy 1995), which suggests that raw material type alone would not preclude the application of classic Levallois reduction.

As mentioned above, however, more quantified data on occupation sites and components, more data on sources of raw material, and greater resolution in dates could help to identify any intra-regional patterning that might exist. Given the lack of geographic patterning, the most likely determinant of the use of Levallois reduction would be tied to site-specific circumstances, such as: place of this site within a seasonal cycle, local raw material quality and availability, and type of tasks carried out at the site.

Also, better resolution in dating could illuminate any diachronic patterning that might represent some association between changes in climate (and associated adaptation) and choice of reduction strategies. Mellar's (e.g., 1969, 1986) research over the last 4 decades has strongly indicated some chronological patterning in the occurrences of the Mousterian industries. If this holds true in the face of further refinement in absolute dates then we are seeing some strong chronological patterning in Levallois usage over the course of the Middle Palaeolithic. This might be a reflection of adaptations to the increasingly harsh climatic conditions associated with the onset of the last glacial cycle.

Levallois and Climate

The appearance of the method is not obviously associated with broad climatic conditions either. The sites of Pech de L'Azé and Le Moustier are examples of the apparent unpredictability of the appearance of Levallois. At Pech de L'Azé, in the Würm I deposits of this site, phase I (cold and damp to cold and dry) and phase III (cold and dry) are Typical Mousterian with strong Levallois representation while Würm phase II (warm) has Typical Mousterian without significant Levallois. However, at the site of Le Moustier, Würm phase II (warm) is occupied by Typical Mousterian with strong Levallois representation. In the late 1960s Mellars (1969) presented evidence, compelling at that time, for a simple sequential relationship between the three Mousterian industries Quina, Ferrassie, and MAT with the MAT as the final manifestation of the Mousterian, which was replaced, by Upper Palaeolithic industries, specifically the Perigordian I/ Chatelperronian. If this sequence was accurate it might suggest some sort of evolutionary process in the use of Levallois with a period of more intensive use earlier in the Middle Palaeolithic, but followed by a gradual decline towards disuse in the late Middle Palaeolithic and early Upper Palaeolithic. However, potentially serious flaws in Mellars scheme were subsequently presented (e.g. Laville 1972). The publication of new thermoluminescence dates for the site of Le Moustier may allow Mellars' original sequence to be re-argued (Mellars 1986), but any further discussion of a chronological patterning for Levallois use awaits this.

Some analysis of the relationship between the occurrence of Levallois and Middle and Late Pleistocene climatic sequences will be carried out here in an attempt to determine whether climate has a potential influence in Levallois use or not. Seasonality is a different issue and will play a part in addressing parameters such as availability of resources, including raw material, and in mobility patterns.

Late Pleistocene Chronostratigraphy and Environments

The reconstruction of Pleistocene environments in Europe involves data from many different sources, including glacial and löessic sequences in terraces of (especially) northern France, pollen analysis, and the comparison of these sequences to the complete climatic sequences represented by oxygen isotope analysis of deep sea cores. Unfortunately a major problem with this process has been the lack of absolute dates that would allow greater confidence in the correlation various sequences and the placement of specific environmental data, from short stratigraphic sequences, within the larger climatic sequences. Analysis of the pollen from Grand Pile peat bog has provided significant insight into the environments of the last interglacial and glacial periods in Western Europe.

The earliest appearance of Mousterian industries is typically associated with the Riss-Würm interglacial and early Würm glacial (terminology of southern France) or Eemien and Weichselien glacial periods (terminology of northern Europe). This coincides with the beginning of the Late Pleistocene and is associated with the start of oxygen isotope stage 5 (5e), roughly around 128 kya (Dennell 1983; Gamble 1986; Laville 1972, 1982; Villa 1991). Some have placed Mousterian assemblages earlier in isotope stage 6, which began around 195 kya (e.g., Tuffreau 1995: 416). The Riss-Würm interglacial lasted for about 10 ky (Gamble 1987, 82-83). The rest of stage 5 coincides with the beginning of the Würm period and was marked by several severe fluctuations. Stages 5d and 5b (Melissey I and II in northern and central European sequences) were very cold and dry. Stages 5c and 5a (St. Germain I and II) were warm and moist with stage 5 ending at approximately 75 kya. Stage 4 was a period of increasingly harsh glacial conditions between 60 and 75 kya with no significant periods of amelioration. Stage 3 was of longer duration and was also a period of harsh conditions, but did include several periods of short, but significant improvements in temperature and precipitation. The Upper Palaeolithic begins late in stage 3.

Traditional French chronology of the Late Pleistocene divides the Würm into four periods, Würm I to IV. Würm III and IV include the Upper Palaeolithic while Würm I and Würm II (including the shorter Würm I to II and II to III interstadials) are associated with the Middle Palaeolithic and Mousterian. These have been further divided into climatic phases representing shorter-term fluctuations in temperature and precipitation (Bordes 1968, 1961a; Laville 1972: 325). Figure 2.6 summarizes this sequence, and indicates where the components employed in this study fit.

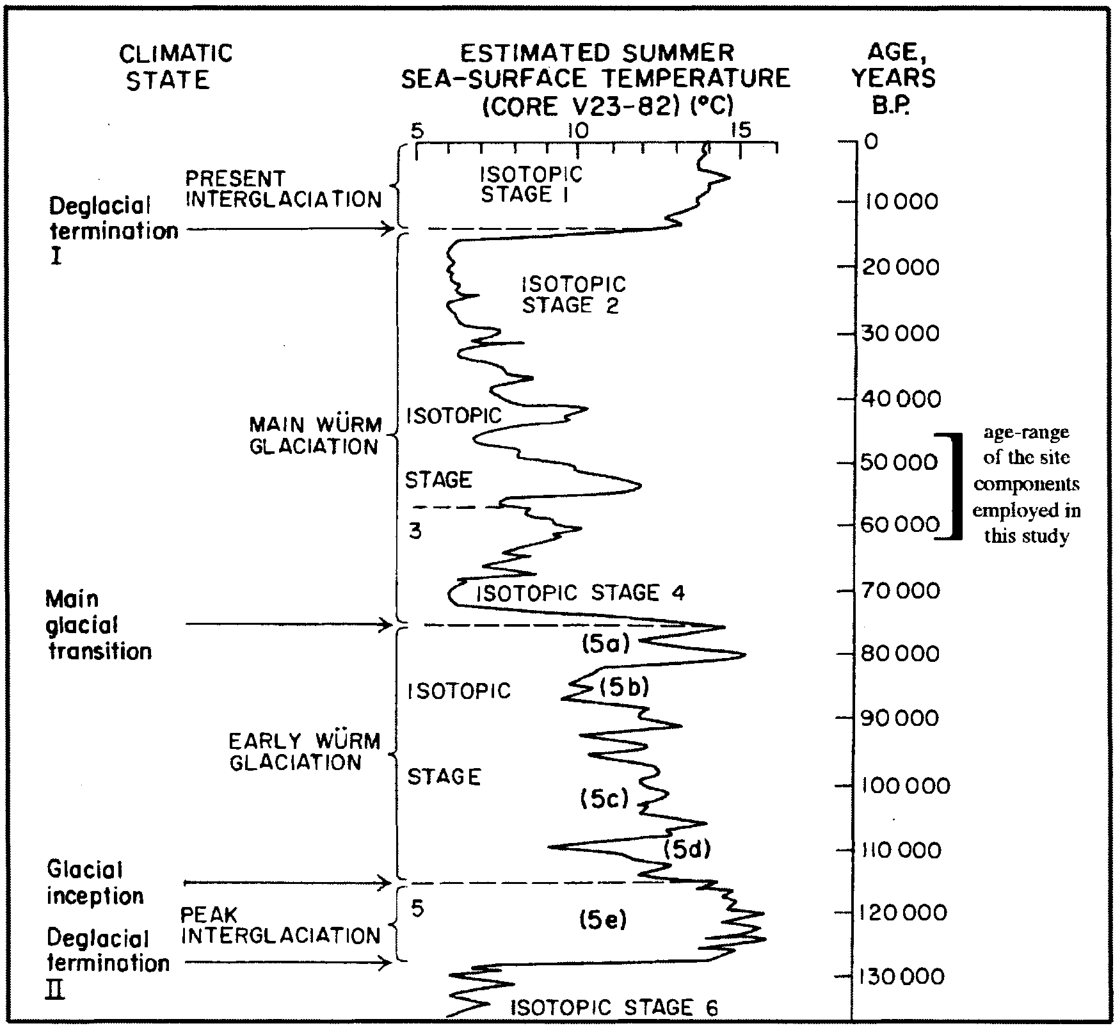


Figure 2.6 Oxygen Isotope Stages from the last glacial cycle with the age range of the four sample sites shown. The break between OIS 3 and 2 is currently placed around 24 ky, marking the start of the last glacial maximum (used by permission of Bradley 1995).

Most of the Würm, as the last glacial period, tended to be significantly colder than current conditions. The general pattern throughout the Würm period was one of increasing cold and decreasing precipitation leading up to the glacial maximum in the middle of the Upper Palaeolithic. While the period was marked by short-term fluctuations, the environment in general was dominated by cold steppes and boreal forest. Climatic fluctuations were paralleled by the appearance and disappearance of different flora and fauna. During the colder periods with lower precipitation a steppic environment emerged with open vegetation dominated by grasses and sages and large grazing animals including reindeer, horse, mammoth, woolly rhinoceros, aurochs and bison. Predators included cave bears, lions, hyenas, wolves, and foxes. Smaller steppe adapted animals included arctic hares and various bird species. During slightly warmer periods, and especially when precipitation increased, forests dominated by coniferous species, but with some mixed forest species like oak and birch, would spread. In these periods the faunal make-up of southwestern Europe changed somewhat with forest adapted species, especially deer and wild pigs, becoming more dominant. Some larger species such as horse, bison, and aurochs appear to have remained throughout both warmer and colder fluctuations in the Würm. The stratigraphy of the site of Combe Grenal appears to span most of the Mousterian period. The faunal remains of the layers associated with the slightly warmer and wetter Würm I are dominated by red deer, a more forest adapted species. In the layers associated with Würm II, a colder and dryer period, red deer remains are much less common and reindeer and horse tend to dominate (Champion et al. 1984: 63).

Chapter 3: Methods

Theoretical Framework

The general methodology used in this study is to apply a design theory framework to the question of Middle Palaeolithic stone tool production.

Design theory is an analytical tool that approaches the understanding of the nature of an item, artifact, technique, *etc.* by viewing its form as the result of a problem solving process defined by specific parameters and limited by specific constraints (Bleed 1986; Hayden et. al. 1996; Horsfall 1987; Pye 1964). This is a reverse approach to that applied in industrial design from which it is borrowed. In industry, manufacturers approach the design of tools or techniques needed to perform specific tasks by first analyzing their intended function and identifying all the constraints that will affect the performance of that tool or technique. Besides just the actual task that must be performed, such constraints might include: availability of potential raw materials (in terms of cost), the physical properties of potential raw materials, the necessary portability of the tool or technique, the desired ease of use (the level of skill or training that would be required), and how long a tool needs to last (cost of replacement).

Diagrammatic conception of the general design process

Task requiring tool or technique (*function*)	>>>>	Constraints and possible components (*design parameters*)	>>>>	Range of potentially effective solutions (*form of tool or technique)*

Design theory, as it is applied in archaeology, is similar to systems theory in that it involves analyzing the relationships of various interacting variables. Design theory, however, is applied to processes that have a trajectory. That is they have a beginning and end which can be essentially isolated in time and space. While there are likely to be multiple and varied constraints on any specific design process, the outcome will typically be directed at satisfying a very limited number of goals; perhaps even a single one. Unlike industrial design, in applying design theory in archaeology we begin with the end-product, the artifact type or artifact production technique or strategy, and work backwards to identify the constraints and other details of the design process, and ultimately, the use for which the tool was designed. In the case of an artifact type, this analysis would first require determining at least the general function of tools.

Design theory has seen little explicit application to archaeological questions (with some notable exceptions, e.g., Hayden et. al. 1996 and Horsfall 1987). However, in very general terms, it is an analytical approach that has been commonly used in attempting to explain artifact function, or past behaviour in general, but typically only in a casual, intuitive, implicit, or unstructured manner and without a formalized framework of analysis. In the interpretation of artifacts, structures, or features of unknown function, archaeologists will, consciously or not, typically try to take into account any known or perceived constraints that may have played a role in how the item in question may have functioned. Identification of such constraints might employ analogy of various levels, from general personal experience to specific ethnographic data. In the case of relatively simple items, such as flaked stone tools, archaeologists who commonly work with such items tend to have a reasonably good understanding of such things as the mechanical properties (sharpness, brittleness) and flaking behaviour of raw materials and will automatically recognize and take into account such potential constraints on the function of a tool.

However, such informal approaches generally fail to attempt to identify all the potential constraints that may have played a role. Furthermore, the researcher may not have immediate access to the necessary information to allow them to apply the appropriate weighting, in terms of potential influence, to each potential constraint and to understand the nature of interactions between different constraints. For example, a researcher may not know of all the potential sources of raw material in a region and the relative qualities of each, and thus might not be able to accurately weigh the costs (time and effort) associated with acquiring each type of raw material against the level of effectiveness they might provide. The effective application of design theory requires a *systematic* attempt to recognize and reconstruct all the potential constraints.

Design theory is another example of Middle Range Theory; it serves as a useful method for discovering or better understanding the past contexts which were specifically responsible for the nature of aspects of the archaeological record (the form of an artifact or the technique used to produce it) as they are encountered by archaeologists.

For some aspects of material culture this approach will be severely limited. For more examples of complex material culture where symbolism and stylistic elements may be dominant aspects of the design, the relationship between the form of the item, its perceived function, and its design elements may be quite ambiguous. Carved figurines, like those in Upper Palaeolithic Europe, are a good example of this issue. First of all, there is still a lack of consensus among archaeologists on what the function of these items were, if there even was a single function throughout the time period in which they were produced. Secondly, in such examples where symbolism is obviously a primary attribute, there is no reason to expect a direct, logical relationship between form and function. This means that one cannot assume that the design of these items was influenced to any significant degree by constraints of the same pragmatic nature as those that tend to dictate the design of less complex items, such as retouched flakes.

Another, notably ambiguous constraint that can have a strong influence in the design of material culture is cultural tradition or cultural "style". The manner in which people carry out tasks and the form of their material culture is very often dictated by the fact that this is the way these things have been done in their culture for some time. In such contexts people's actions and decisions are influenced by social constraints and learning traditions. However, this is a pattern that might be visible only at relatively high archaeological resolution. Over relatively short periods of time, social norms may take precedence over true efficacy, creating a lag in adaptive response. A traditional method or tool may continue to be used even though the contexts for its use have changed and it no longer represents the most optimal design. If changes in circumstances (e.g., the nature of a task, time available to carry it out, available raw materials, etc.) occur at a gradual pace then designs may also change gradually to adapt to changing constraints. Changes may also be dramatic however, in which case the design of methods, tools, etc. must adapt rapidly to the new circumstances.

With respect to the relatively simple flaked stone tools of the Middle Palaeolithic, few would argue that style and symbolism played much, if any, role in their design. Both the lack of complexity of these items and the sparseness of evidence for widespread symbolic behaviour during this and earlier periods support this conclusion. Furthermore, when dealing with Palaeolithic contexts, the degree of temporal resolution is particularly coarse. Any role that cultural tradition, as well as individual behaviour, might have played probably would be lost in the broader patterns of material culture change over the tens of thousands of years involved. Over such spans of time, the optimal design of material culture, especially in the predominantly harsh Middle and Late Pleistocene climatic conditions (as we are dealing with here), must have been paramount to any other considerations in design of tool form, tool production, and any other behavioural choices. Task constraints would have been much more narrowly constituted allowing little latitude for non-optimal solutions. As expressed by Horsfall (1987: 334), the major difference between traditional (perhaps especially during the Palaeolithic) and modern design is the degree of consciousness of the designer in the process and the rate of change. The application of design theory in a specific archaeological context still presumes that the underlying decision making that is in question was practical and adaptive. That is to say that the driving rationale of the decision-making process is to increase the "goodness of fit" (Alexander 1964:33) of the tool or technique to the target task within the circumstantial constraints.

Design theory involves the analysis of the relationships of the different components that interact in the process of designing or developing something (e.g., a tool, structure, or technique) to satisfy a need. The recognition of potentially significant parameters in this process comes in large part from ethnographic data. From specific ethnographic contexts (many of which may be in modern, even industrialized, settings) we have obtained a general understanding of the range of considerations that must come into play if a tool or method is to be a good fit to a specific problem or need. For example, in the process of developing a manual tool for harvesting grain we can obtain a fairly accurate understanding of the potential effectiveness of different possible raw materials (e.g., wood, bone, flint, bronze, iron, or steel), the sources of these materials and the costs (such as time, energy, or social networks) involved in obtaining them, the potential range of tool sizes and forms that could be manufactured with the different materials, the potential returns for different tool designs (in terms of quantity of grain collected per time spent in the field), and the costs in maintenance for different designs. Thus, if we were given a more specific context we could reconstruct with some accuracy the range of choices available to a farming culture. However, after we have identified the particular constraints that might have played a role in the design of whatever object it is we are investigating, it is an analysis of the interplay between these various considerations that is used to arrive at an interpretation. Thus design theory is not simply the application of analogy, and its potential accuracy in particular cases is not limited by the availability of suitable ethnographic cases that are applicable due to their presumed similarity to the time period, region, and general lifeway of the past culture under study.

Design Theory and Middle Palaeolithic Stone Tools

As the application of design theory in archaeology involves the reverse of the analytical process employed in industry, the optimal starting point for understanding the context of the design and use of specific Middle Palaeolithic artifacts would be to determine their function.

Within archaeology, there are only a limited number of research tools (aside from design inferences) available that can be used to try to determine the specific applications of prehistoric artifacts. This is particularly the case for pre-Holocene periods, and even more so for pre-modern human contexts (for which modern analogs may be questionable). In some cases ethnographic analogy can provide direct insight into tool function: the ubiquitous endscraper is a good example of this. In some cases depositional context may provide indirect understanding of artifact uses, but such evidence requires strong, clear patterning which is typically lacking in very old sites. Usewear analysis and, to some extent, residue analysis are currently the most promising techniques for determining stone tool function, and might eventually be regularly applied to artifacts manufactured from other materials as well. Further refinement in these methods might allow a significant degree of confidence in their results. Minimally, we can say that flint was used because of the sharp, durable edges that could be created with it, which only makes design sense in terms of cutting, shaving, and scraping materials like meat, hides, wood and bone. In fact, it is the sharp edges of flint tools that exhibit usewear and this usewear corresponds to these materials.

However, the emphasis of the analysis here is not aimed at interpreting the specific use of Middle Palaeolithic stone tools, but is intended to understand the nature of the design of the reduction strategies that produced these tools. In the case of lithic reduction, if the end-products of the different reduction strategies were obviously distinct then the answer might be as simple as the need to produce different tool forms, presumably intended for different functions. However, for some of the different reduction strategies employed in the Middle Palaeolithic, the end-products are not notably distinct, and even for strategies that do produce distinct tool blanks (e.g., blades verses flakes), many of the different end-products were apparently employed for similar tasks. Thus, any inherent advantages of specific product forms are not necessarily critical to understanding reasons why different reduction strategies were used. The design of reduction techniques must have typically involved more considerations than simply creating end-products for specific tasks. The main goal of my analysis was to identify those other potential considerations and attempt to determine the nature of their roles as constraints.

Listed below are some examples of reduction strategies that, like Levallois, have been adopted at various times and places in the Middle Palaeolithic presumably to satisfy certain requirements in the context of specific constraints:

Random/Amorphous Core Reduction
Biface Production/Bifacial Reduction
Blade Production
Bipolar Reduction
"Sausage-Slice" Reduction
Single-Surface Core Reduction (Levallois and Disc Core)
Kombewa Core Reduction

According to current understanding, each of these strategies should have certain advantages and disadvantages and, whether by itself or in combination with others, either occurs (or does not occur) under certain circumstances as a result of these advantages and disadvantages.

Recent research has identified some of the advantages and disadvantages of these and other strategies and the conditions under which we might expect them to appear. This, coupled with all the appropriate ethnographic data, should allow us to identify the major constraints that would be faced in the production and application of stone tools (e.g., Sandgathe 2004; Hayden *et. al.* 1996; Kuhn 1994; Henry 1989; Bleed 1986; Kelly 1988; Kelly and Todd 1988; Parry and Kelly 1987; Shott 1986; Bamforth 1986). The major variables constraining or significantly influencing the choice and design of lithic strategies include things like intended function of the reduction products, degree of mobility, and quantities and qualities of available raw materials. These and other lithic reduction constraints are discussed in more detail in Chapter 5.

The application of different reduction strategies at different sites likely reflects differences in some or all of these potential variables. At one site the quality, form, and quantity of available raw materials might differ from another site and this might result in the choice to employ a different reduction strategy in the production of tool blanks. This may also dictate whether a group has to arrive at or leave a site with an appropriate supply of raw material or tools. Occupying a site during different seasons might result in similar changes in raw material availability (due to snowcover, water levels, or groundfrost, which might require different raw material economizing strategies) and might also involve carrying out different tasks at that site.

The available evidence indicates that much of the variability in the choice of different reduction strategies in the Middle Palaeolithic represents adaptation to short-term changes. This is demonstrated by the fact that many assemblages from individual levels at a site, and produced from a single raw material type, often have the products of several different reduction strategies combined. The site components used here are such examples. In the study components from Pech de l'Azé IV and Combe Capelle Bas, flint nodules were reduced, to varying degrees, through Levallois, Disc, and Amorphous core reduction. The frequent use of different reduction strategies in this manner may represent responses to relatively short-term changes in circumstance (e.g., seasonality or the place of the site within a cycle of mobility), but may also reflect the use of different strategies by different individuals within a group; for example, men verses women, young verses old, individuals of different abilities, or individuals carrying out different tasks.

Some of the variability might also represent longer-term, evolutionary processes, both biological and technological, but this might apply more to the Lower Palaeolithic since all the lithic reduction strategies employed in the Middle Palaeolithic had appeared in Europe by, or prior to, 250,000 years ago. Some of the patterning within the Middle Palaeolithic might reflect adaptations to longer-term climatic changes. The Mousterian of Acheulian Tradition consistently occurs at the top of Middle Palaeolithic site sequences (Mellars 1969 and 1986). Thus, Mousterian bifaces and formal endscrapers appear relatively late in the last glacial cycle (c. 50,000 years ago or later) and could reflect the stone tool components of adaptations specific to very cold, dry, steppic environments.

Constraints in the French Middle Palaeolithic

In order to arrive at an understanding of the specific nature of the general constraints, outlined above, it is necessary to first develop a model of French Middle Palaeolithic lifeways. This is done in Chapter 4, where each of the constraints listed above is examined, in the context of Southwest France in early Oxygen Isotope Stage 3, to the extent that available evidence and theory allows. The intent here is to establish as reasonable a picture as possible of the nature of these constraints as faced by people in this region in this time period.

Based on this reconstruction of Middle Palaeolithic adaptations and the resulting framework of factors identified as influencing the design of tool production (Chapter 5), several hypotheses were formulated which could explain the conditions in which the Levallois technique appears with its potential advantages. These are presented in Chapter 6. Based on these hypotheses, testable variables are then identified.

The data on specific variables were collected by myself (Chapter 7) through the analysis of samples of assemblages from components of three different Mousterian sites. These are the three primary sources of data used here. One of these components has a significant Levallois component, one has a moderate Levallois component, and the third has a negligible one. These three primary sites, Pech de L'Azé IV, le Moustier, and Combe Capelle are all located in reasonably close proximity to each other (by modern perceptions). Pech de L'Azé IV is in the Dordogne River valley just south of the city of Sarlat; Combe Capelle Bas is about 30 km west and slightly south in the valley of the

Couze river, a tributary of the Dordogne; and Le Moustier is just over 20 km directly northwest of Pech de L'Azé IV in the valley of the Vezere River, another tributary of the Dordogne. These sites are among the largest and most thoroughly investigated Middle Palaeolithic sites in Western Europe and at least portions of their associated lithic collections have been excavated in recent years using modern, rigorous standards and methods. Data from a fourth site, Jiboui, in the Northern French Alps were also included here because it represents a completely different geographical situation and has a comparatively high Levallois Index. The lithic data for Jiboui come from analyses carried out by other researchers which did not include all the same variables that were recorded for the primary sites. Therefore, the Jiboui data are not included in every aspect of this analysis. More detailed information on each of the sites, the study components, and the sampling methods are provided in Chapter 7.

The three primary sites were selected, in part, because of their close proximity, and the sample components were selected because of their comparable ages. This provided a control on some possible constraints, such as local climate and the general type and abundance of most floral and faunal resources. The fourth site was included because it is comparable in age, has a very strong Levallois component, but has a significantly different geographic situation. It is situated in a high alpine setting and, therefore, provides a data set for comparison to the three primary sample components that allowed an examination of the potential influences that geography, season, and activity might present. In particular, the high alpine setting means colder temperatures (especially at night), greater difficulty in moving around the landscape, reduced access to certain resources (e.g., wood, most edible plant species, many games species), and limits on season of occupation. The location of Jiboui almost certainly precludes it having been occupied during the colder seasons.

The data from these four samples are analyzed with the intention of trying to reach a good understanding of the morphological characteristics influencing the selection of tool blanks (Chapter 8). Chapter 9 examines how the characteristics of flakes selected for use compare to the characteristics specific to Levallois and non-Levallois reduction products. Also, an assemblage of experimentally produced softhammer ('billet') flakes was analyzed in order to compare the characteristics of these flakes to those selected for tools in the four sites, and these data will be include in Chapter 9 as well. Chapter 10 then deals with how the conditions specific to each of the four sample sites might affect choices of lithic reduction and tool production strategies at those locations.

The questions at issue in the actual assemblage analyses include:

First - Addressing Blank Selection:

1/ What were the general morphological criteria used to select flake blanks for use as tools?
2/ How did these vary between the three site samples?

In order to achieve some understanding of what the sought-after characteristics of Levallois products were it is necessary to examine all the products, with specific attention paid to those products which show indications of being used as tools. Prior to any discussion of the actual analyses to be undertaken, the basic assumption, that there were desired characteristics, must be discussed. Any analysis relies on the accuracy of the assumption that for any tasks for which flake tools were manufactured there would be at least some general morphological characteristics necessary for the tool to work at all, and that there would be some characteristics that would be desired to a greater or lesser degree than other characteristics because they improve or detract from the potential utility of the flake. In the case of relatively simple flake tools these might be such things as greater size, sharper edges, lesser ventral-curvature, or greater regularity of edge morphologies. In practical terms the assumption is that, of all the flakes produced in the reduction of a core, some will be of greater inherent value because they have the desired characteristics to a greater degree than others.

All Middle Palaeolithic stone tool assemblages include those flakes whose margins had been modified to some extent through retouching. It seems likely that some of these were modified prior to use in order to produce a tool more suitable for the task at hand (e.g., the task requires a more obtuse edge), and that some were initially used unmodified and were then retouched in order to resharpen an edge that had dulled from use. Unfortunately, these are not always readily distinguishable and so it is not possible (in many cases) to determine what the desired edge characteristics were at the start of a task. The ability to separate these two classes of tools would allow a better understanding of the potentially desirable edge characteristics within the range presented by a series of flake blanks removed from a core.

However, an important component of the analysis in this study was the identification of usewear. All flakes in the three primary site samples were examined under low-power microscopy for any obvious use-damage. A significant portion of all, otherwise unmodified, flakes in the samples had evidence of use, indicating that such unmodified flakes were the most common tool type used. Flakes used in unmodified form likely represent two different, and potentially overlapping, behaviours. In some cases the natural, unretouched edge of a flake will be the optimal choice. However, in some situations resharpening of the flake might have been a potential option, but did not occur because either the task was completed before the original flake edge dulled or because it was easier to replace the flake with another even though retouching the first edge might have been a viable option. We can presume, however, that in every case where a flake was used in an unmodified state it was because the flake exhibited certain, sought-after characteristics.

Second - Blank Selection and the Morphology of Products of Different Reduction Strategies:

1/ What are the actual morphological characteristics of the products?

2/ How do the central Levallois flakes compare to the Peripheral ones?

3/ What are the morphological characteristics of the non-Levallois products?

4/ How do these characteristics compare to those of the flake blanks selected for use as tools?

5/ How do these characteristics relate to the reduction process?

Note: throughout this study, unless specifically mentioned, I use the term 'Levallois' to include both the classical definition (see Chapter 2) and centripetal core reduction. "Non-Levallois' refers to any other reduction techniques, including, amorphous core, biface production, bipolar reduction, Sausage-Slice reduction. 'Levallois flakes' include both Central Levallois and Peripheral flakes. 'Peripheral Levallois flake' refers to those flakes removed from around the perimeter of the surface of debitage of a single-surface core. 'Central Levallois flake' refers to the relatively large flakes that were removed from the centre of the core surface.

One exception to this is that *Éclats Débordants*, which are single-surface core products (a variation on Disc core reduction), are treated as a separate category. This because they are quite distinctive from other single-surface core products and because they are an important component of at least one of the sample assemblages included in the study.

Third - Site-Specific Patterns:

1/ How did choices of reduction strategies differ between the three sites?
2/ What conditions specific to each site might account for these differences?

3/ Why were different reduction strategies employed at the same site at different times? Were there changes over time in the nature of circumstances at each site that resulted in changes in the constraints influencing the selection of reduction strategies?

The results of these different stages of the analysis are discussed and weighed together in Chapter 11. The hope was that recognizable patterns would emerge in relationships between the blank selection data, the reduction technology data, and the specific site characteristics that can all be logically tied to identifiable constraints. This would potentially indicate (at least some of) the motives behind the choice of one reduction strategy over another in the Middle Palaeolithic. Conclusions regarding this are presented in Chapter 12.

Chapter 4: Middle Palaeolithic Subsistence Model

Because of the paucity and fragmentary nature of the Palaeolithic record, reconstructing meaningful models of Middle Palaeolithic lifeways is necessarily a very tentative undertaking (Rolland 1990). In fact Chase (1986:1) suggests that for the Middle Palaeolithic "*limitations of the archaeological evidence .... are so severe that the reconstruction of a subsistence system is no longer possible*". The non-specific nature of the evidence that is available, both archaeological (lithics and fauna), paleoenvironmental, and ethnographic, can be manipulated so as to present support for a variety of models, some potentially conflicting (e.g. Boyle 2000; Patou-Mathis 2000 and Pike-Tay *et. al.* 1999). The types of data that are available that can be employed in reconstructing Middle Palaeolithic lifeways patterns include: ethnographic; faunal remains (archaeological and palaeontological); isotopic analysis of human remains; lithic acquisition, use, and discard patterns; site distribution; and rare examples of organic (mainly wood) artifacts.

Data on faunal remains have been used to try to analyze subsistence behaviours in order to understand the nature of animal acquisition and use and the seasonality of such activities. However, the faunal data are severely limited due to the typically fragmentary nature of the remains, the difficulty in distinguishing cultural from natural (e.g. other predator's) deposits, and the fact that assemblages from most sites are palimsests, representing long spans of time and the mixing of multiple occupations. Some researchers have directed their research to specifically addressing the first two problems (e.g., Conard and Prindiville 2000). The last issue applies to the lithic data as well and currently there are no real solutions for dealing with this lack of resolution. The implicit recognition of this fact is reflected in researchers commonly lumping together data from different assemblages whose ages span the Late Pleistocene. This means that any realistic model-building must necessarily remain very general and will not address much of the potential variability that might have existed within the Middle Palaeolithic and between different regions.

Isotopic analysis of Middle Palaeolithic human remains have provided more direct evidence of subsistence behaviours during this period (e.g., Bocherens 1999; Richards *et. al.* 2000; and Richards *et. al.* 2001).

With respect to aspects of lifeways, the available lithic data has been employed in research into technological adaptations (e.g., Turq 1992; Boëda 1986), Middle Palaeolithic tasks (e.g., Anderson-Gerfaud 1990; Beyries 1988), types and levels of group mobility (e.g., Riel-Salvatore and Barton 2004; Rolland 2001; Feblot-Augustins 1993, 1997, 1999), and game acquisition (e.g., Boëda 1999; Shea 1988).

Reconstructing models of Middle Palaeolithic lifeways is also a difficult undertaking because of a lack of general model building and subsequent testing for the Palaeolithic. Beyond basic Human Behavioural Ecology, there is virtually no established framework from which to begin such an undertaking. However, while one might have to agree with Chase's sentiments about the limitations of the available evidence, I would suggest that this only limits the level of detail that can be included in our models of Middle Palaeolithic lifeways: it does not prevent us from beginning to construct general or provisional ones. Examples of such general models have been put forward by Rolland (2001; 1996, 1981), Boyle (2000:350-53 - with respect to subsistence), and Patou-Mathis (2000), who employed a wide variety of data from 323 Middle Palaeolithic sites from France to Russian Georgia, collected over 10 years.

It is recognized here, and must be stressed, that such model building involves a number of assumptions and even the construction of quite generic models does strain the limits of the available data. However, it is also a necessary component of the design theory approach and at least identifies variables that can be refined in future work and establishes models that can tested, modified, and improved. While undoubtedly entailing some inaccuracies resulting from the paucity of evidence, the model presented here has remained general enough so as to provide genuine, albeit tentative, support for some suppositions about Middle Palaeolithic adaptations and they allow the identification of those constraints that would have affected the design of Middle Palaeolithic stone tool technologies.

Mousterian Adaptations

Serious attempts at reconstructing Lower and Middle Palaeolithic lifeways are a relatively recent thing. One of the major barriers to carrying out this type of research is the significant decrease in the preservation of organic materials the older the time period in question. One of the main differences often cited between the Middle and Upper Palaeolithic periods is the comparative abundance of items of worked bone, antler, and ivory in assemblages of the latter. There are notable examples of bone artifacts in Middle Palaeolithic contexts (e.g., Salzgitter-Lebenstedt [Gaudzinski 1999; Tode 1982] and Bilzingsleben [Mania et al. 1999; Mania 1995; and Mania et al. 1994]), these are relatively rare examples and the degree of modification to the original bone is quite limited.

While there does appear to have been a significant difference in the degree of use of bone, antler, and ivory between these two periods, there can be little doubt that some organic raw materials, especially wood, were used by Middle Palaeolithic (and earlier) people (Gaudzinski 1999; Mania et al. 1999; Mania 1995; Anderson-Gerfaud 1990; Beyries 1988; Tode 1982; Tromnau 1982; Valoch 1982). Unfortunately these materials do not survive well, resulting in a data set that leaves unclear to us the degree of importance of these raw materials in Europe prior to the Upper Palaeolithic. In general, however, it seems likely that, with respect to raw material for tools, wood, rather than bone and ivory, was the dominant organic medium used throughout the Middle Palaeolithic and earlier.

A second, related, problem with the available data set is that the older the deposits the greater the potential for post-depositional processes (natural or cultural) to affect the integrity of the original patterning within assemblages and to destroy some sites altogether. Such processes can introduce significant biases into assemblages, reducing the level of confidence that can be placed in their potential contribution to cultural interpretations, and significantly affect patterns of site visibility, and thus our view of their distribution.

A third potential problem, considered more significant by some than by others, is that for the Mousterian (of western Europe at least) we are talking about a subspecies morphologically different from modern humans. Because we are dealing with the material remains, and asking questions about the behaviour of Homo *sapiens neanderthalensis* it can be argued that the use of ethnographic analogy (i.e., from modern Homo *sp.*) must be limited. The lack of evidence for symbolism in Middle Palaeolithic contexts has been used as positive evidence for a lack of linguistic abilities and for generally lower cognitive abilities relative to modern humans (McBrearty and Brooks 2000; Chase and Dibble 1987, although see Hayden 1993). While the old truism "the absence of evidence is not evidence of absence" must be acknowledged and the fact exists that there are many extant (and recently disappeared) cultures who would potentially leave behind even less evidence of symbolic thought and behaviour than neandertals have (if all or most of their organic material remains disappeared), the suggestion that Neanderthals were less cognitively developed than modern humans is well entrenched in the literature (e.g. Gargett 1999 and 1989; Chase and Dibble 1987; and Binford 1985) and, therefore, must be taken into account. There is the possibility, given more weight by some researchers than others, that if Neandertals did not have similar cognitive abilities or patterns as modern humans, their behaviour may not have mirrored that of modern hunter-gatherers in similar circumstances and they may have responded in a manner that has no direct modern human analogs.

However, current data indicates that during the Middle Palaeolithic morphologically modern human groups in the Middle East were making and using exactly the same types of stone tools as their Neandertal neighbours and there is no evidence of any other significant behavioural differences between these groups at this time. This would strongly suggest that the apparent differences in material culture (and associated behaviours) between the Middle Palaeolithic and the early Upper Palaeolithic are not the result of intrinsic biological differences between the two subspecies, but are strictly cultural and context dependent. The changes in behaviour that mark the Upper Palaeolithic from the Middle (e.g., the overt symbolism represented by cave paintings and the increase in the specialization and reliability of tool kits), whether they are imported or *in situ* developments, more likely reflect adaptations to some significant change in circumstances, such as increased population density or; perhaps, socio-cultural responses to the emergence of prolonged contact/competition/interaction with a different subspecies; or, more likely, a more complex combination of different circumstantial factors (e.g., Rigaud 1997; Hayden 1993; Otte 1990; Reynolds 1990; Rolland 1990; Trinkaus 1989:5-9).

While it is difficult to argue that modern hunter-gatherer analogs can be readily applied to hominid behaviour throughout our evolutionary history, to suggest that Neandertals fall outside this application requires an argument as to why we would draw the line at this particular time and not earlier, or later.

If we do apply to Middle Palaeolithic contexts, interpretations based on some of the general patterns that have been recognized among more recent hunter-gatherer groups we could make some general predictions about Neandertal adaptations. Among recent hunter-gatherer groups a gradation in adaptive strategies has been recognized that is defined by highly residentially mobile 'foragers' at one end and more logistically oriented, less mobile 'collectors' at the other (as initially defined by Binford 1978, 1980; but see also Bettinger 1991:64-70 and Habu 2004:7-16). The nature of such adaptations is mainly a response to the spatial and temporal distribution of exploitable resources in a region with given technologies. In some regions, exploitable resources are fairly evenly distributed in both time and space; that is to say they are available in relatively consistent quantities over time and throughout the region. Groups living in such regions will face little difficulty in matching their patterns of movement to available resources. No matter where or when they move they will encounter resources, and when these have been depleted they can move to an adjacent area where they can reasonably expect to find new resources. Little organizational effort or planning is required other than relatively frequent residential moves in response to resource depletion in the immediate vicinity of the current site. Such groups have come to be referred to as 'foragers' and this settlement pattern is sometimes referred to as 'circular' (e.g., Lieberman and Shea 1994) in contrast to that of 'collectors' discussed below (Binford 1980). Forager adaptations are most closely associated with regions and biomes in which the exploitable resources, while not necessarily rich in terms of raw biomass, are fairly evenly distributed in time and space (Bettinger 1991:66-67).

In regions where, due to marked seasonality and extremes of temperature and precipitation, resource productivity is not temporally or spatially homogeneous, human adaptations necessarily become more complex (Hayden 1981:347-49). Where resources, although potentially very rich, are unevenly distributed in time and space, hunter-gatherer groups are faced with times and locations within their seasonal cycle where resource availability is limited. In such regions, hunter-gatherers can employ different methods for dealing with these two incongruencies. To address temporal incongruencies, storage can be used. Groups accumulate, where and when available, bulk quantities of plant or animal resources that are then stored at base camps for those times when resources are seasonally unavailable. Spatial incongruencies are dealt with, in part, by modifying settlement patterns. Rather than taking on the risk involved in moving the whole group from one area where resources are depleted (either because of exploitation or due to natural seasonal patterns) to an adjacent area in the hope that there will be sufficient resources to sustain them there, the group will maintain a more permanent residence from which small, specific task-oriented groups will be sent out to collect resources to be brought back to the central residence. This has been referred to as a 'radial' pattern of movement, compared to the circular one of foragers. While the central residence of collectors may be maintained for significantly longer than forager base camps, these too must be moved eventually as resources in the exploited region become depleted. The 'collector's' approach is more complex, but allows a group to more effectively exploit a much larger region, which is more likely to produce resources in quantities sufficient to sustain them. The use of long-term storage, however, can effectively tether a group to specific locales and result in a decrease in mobility choices (Bettinger 1991:67-70; Soffer 1989: 722; Binford 1979, 1980).

In reality, the settlement strategies of most hunter-gatherer groups typically fit somewhere between the forager-collector extremes, depending on the specific conditions or nuances in the climate, seasonality, or resource abundance and availability of their region. Furthermore, as there are no strict criteria that allow us to draw a definable line between "foragers" and "collectors", discussions of hunter-gatherer settlement patterns in the literature can be confusing. Here it is viewed strictly as a gradation, which includes strict foragers, who practice the highest level of residential mobility (move as frequently as 45 times per year – Binford 1980:7), but also groups who would still be categorized as foragers, but who tend to practice a limited degree of logistical collecting. This is to say that they may make limited use of specialized task groups who begin to carry out resource exploitation activities that take them away from their home base for slightly longer periods than is typical of strict forager adaptations and move there residence as few as five times per year (Binford 1980:7-8). Likewise, there can be collectors who practice a significant degree of sedentism, based largely on well developed storage technology, but there can also be groups who tend to fall more in the collector end of the continuum, but whose degree of residential mobility is quite high relative to that of the former. There will be groups who employ(ed) both logistical and 'mapping-on' strategies, and storage technologies to different degrees (Binford 1980:12)

While there was significant variability in climatic conditions over the course of the Middle and Late Pleistocene in Europe, the dominant climatic conditions in the Middle Palaeolithic were temperate and very often extreme in terms of temperature and aridity (typically cold and dry) and degree of seasonality (Stringer and Gamble 1998: 46-50; Bradley 1995). Today, most regions of the world with such conditions are marked by significant heterogeneity in the temporal and spatial distribution of resources. If Middle Palaeolithic hunter-gatherers followed the general pattern observed among more recent groups, such as some groups in the Arctic, Subarctic and the North American Great Plains who employed intensive storage practices, we might expect them to have most closely resembled the collector adaptation.

However, although storage (particularly of meat) could have been practiced in the Middle Palaeolithic (the predominantly cold climate would have facilitated it) and evidence of it has been claimed in the past (e.g., François Bordes often referred to pit features in cave sites as meat caches, Dibble 2004 personal communication), there is no conclusive evidence that it was (Gamble 1999: 230). While it is certainly possible that storage methods might have been used that would leave little archaeological trace (e.g., hanging meat in trees), the lack of any identifiable evidence seems to indicate that either it was not practiced at all or was employed only intermittently, unsystematically, or on a very small scale (e.g., Stringer and Gamble 1998: 164-66). It appears at this point that Middle Palaeolithic adaptations did not typically employ this risk-reduction method.

It is also likely that over much of Pleistocene Western Europe the quantities of available animals did not reflect those typical of similar modern climatic regions. Pleistocene Europe likely had a remarkably high animal biomass unequalled in contemporary environments; especially during particular climatic periods when steppic grasslands were the dominant vegetational biome (Butzer 1964:138; Rolland 1981:33, 1996: 137; Gamble 1999:231-34, 1986:111). During such periods, large herds of medium to large mammals (particularly reindeer, bison, and horse) may have significantly lowered the temporal and spatial incongruity of food resources often associated with colder temperate environments. This would have reduced the degree to which hunter-gatherers would have had to organize their settlement patterns to coincide with resources and resource distribution and, during much of the Pleistocene, may have allowed for more forager oriented adaptations. This is examined in more detail below.

Diet

Large Mammal Use (hunting vs. scavenging?)

It is recognized that the archeological record will inevitably be biased in favour of the preservation of the remains of large mammals. However, based on the abundance of remains it is still apparent that large mammals must have represented an important component of Mousterian subsistence, and isotopic analysis supports this (Bocherens 1999; Richards *et. al.* 2000; and Richards *et. al.* 2001). Plants may well have made up a notable portion of Mousterian diets (perhaps to a degree similar to traditional North American Plains and Subarctic groups), but unfortunately, there are very little positive data with respect to this (Hardy 2004). The evidence for the exploitation of small animals is, likewise, very limited (Chase 1989, 1985; Stiner et. al. 1999, 2000; Burke 2000), but there are some rare examples of sites where small mammals appear to have played a significant role, such as Salpêtre de Pompignan (NE of Marseilles) where rabbit was the most common faunal remain (Boyle 2000:342).

The nature of the acquisition of large mammal resources is an important question. Several alternatives have been presented by various researchers (e.g., Chase 1989; Rolland 1990; Stiner 1995; Speth and Tchernov 1998; Gamble 2000; Burke 2000; Boyle; Patou-Mathis 2000; Gaudzinski 2000). Middle Palaeolithic people may have relied mainly on scavenging to acquire large animal remains (e.g., Binford 1982 and Chase

1989) or they could have intentionally hunted large mammals following a number of different strategies (Gaudzinski 2000, 1996; Gaudzinski and Roebroeks 2000; Farizy et al. 1994; Jaubert et al. 1990; Burke 2000; Boyle 2000; Patou-Mathis 2000; Kozlowski 1990). While Binford (1982:178) stated that, in the face of our lack of understanding of the factors affecting the formation of Palaeolithic faunal assemblages, his "judgment" is that during the Middle Palaeolithic scavenging was an important part of Palaeolithic subsistence. He also feels that hunting of migratory herd animals was also common, but only involved the killing of individuals and did not occur in the form of mass kills. Furthermore, his suggestion that scavenging was an important, if not the main, component of Neandertal subsistence was based on the idea that Middle Palaeolithic faunal assemblages were dominated by head and lower limb elements (a pattern that he suggested was indicative of scavenging) and on the interpretation that much of the surface damage on bones in the French sites of Combe Grenal and Grotte Vaufrey (and the South African site of Klasies River Mouth) was from carnivore gnawing. Subsequent research (e.g., Speth and Tchernov 1998; Marean and Kim 1998; Bratlund 1999: 441; and Gaudzinski and Roebroeks 1999) has indicated that much of the data that suggested head and lower limb domination of assemblages was due to excavator biases in the assemblages studied and, furthermore, several high-profile faunal analysts have directly refuted Binford's interpretation that the bone damage at the French sites was not from butchering practices (Grayson and Delpech 1994; Chase 1986, 1988; and Marean and Kim 1998). In fact there seems to be little evidence at this point that supports the interpretation that scavenging was the dominant practice, although it must have certainly been practiced at times (Stiner 1995).

There are a number of lines of evidence that can used to argue that hunting was a common practice in the Middle Palaeolithic or earlier. The recovery of several wooden spears from Lower and Middle Palaeolithic contexts (e.g. Schöningen, Germany -- Thieme 1999 and Lehringen, Germany), and evidence of jump sites, such as at Cotte de Saint-Brelade, where elephant and rhinoceros were killed (Villa 1991:206), are direct evidence that hunting was practiced in Europe.

That Mousterian groups actively hunted large game is also well supported by characteristics of the Middle Palaeolithic faunal record (Richards *et. al* 2000:7665-66). In general the evidence indicates various levels of selectivity of prey, a behaviour that is not in line with scavenging. First of all, there are a number of well-documented sites where the faunal assemblages are dominated by a single species, in some cases almost to the exclusion of all other species available in the region at the time (Kozlowski 1990: 429). Examples of these include: Mauran, La Borde, Coudoulous (Boyle 2000 and Farizy *et. al.* 1994), and Il'skaya (Hoffecher and Cleghorn 2000) where bovids heavily dominate; Hortus and Lazaret with predominately ibex (Boyle 2000; Marean and Kim 1998; Jaubert *et. al.* 1993 and Jaubert *et. al.* 1990); and Salzgitter-Lebenstedt where reindeer dominate (Gaudzinski 2000).

Furthermore, many faunal assemblages indicate that within a species there was a certain degree of selection of prey. Salzgitter-Lebenstedt is also an example of this, where the selection for adult reindeer is clear (Gaudzinski 2000 and Gaudzinski and Roebroeks 1999).

Finally, it is argued by some that the sheer quantities of faunal remains at some sites preclude their accumulation being due to scavenging. They argue that such quantities could only represent a regular supply of animals exploited by well-established hunting methods (e.g. Gardeisen 1999; Marean and Kim 1998; Farizy and David 1989; and Jaubert *et. al.* 1990).

Within the current literature, the majority of faunal analysts working on Middle Palaeolithic assemblages accept the idea that hunting was the dominant method for acquiring animal resources, although some scavenging was likely practiced during certain climatic episodes and in certain regions (see especially Stiner 1994),.

The Nature of Middle Palaeolithic Hunting

Hunting can be carried out with a variety of techniques and strategies. In terms of techniques, the term 'hunting' is used here in the most inclusive manner and includes both the popular concept of hunting, in which participants actively pursue game with some form of manual weapon, as well as more passive techniques like trapping. It seems likely that either or both of these general techniques could have been employed by Middle Palaeolithic people, but more specific types of these will not be discussed.

In terms of hunting strategies, three different types are commonly referred to in the literature (e.g., Chase 1985; Binford 1984:215-18;):

1/ *Opportunistic or Encounter Hunting* involves the exploitation of animals if and when they are randomly encountered. People would not set out to specifically exploit a certain animal species at a specific time.

2/ *Specialized Hunting* represents a focused exploitation of a specific species at a specific time and often includes the targeting of a specific sex and age group(s). This would involve paralleling and/or anticipating the movement of exploited species across the landscape. Different species may be sought after, particularly at different times of year or in different regions, although the move towards specialization tends to result in the exploitation of a reduced number of species.

3/ *Purposeful Eclectic Hunting* refers to the exploitation of a variety of species but in a purposeful manner. People would set out to specifically exploit different species at different times.

Opportunistic Hunting in the Middle Palaeolithic

It has been traditionally accepted that any hunting that was practiced in the Middle Palaeolithic would have mainly been an opportunistic form. The faunal assemblages at many sites tend to support this in the wide variety of species and sizes of game that are represented within individual levels. Level G of le Moustier (included in the study here) with at least 12 different species present and levels J3 and I2 of Pech de l'Azé IV, each with at least 11 different species (LaQuay 1981), are good examples of this. The wide range of species recovered from Middle Palaeolithic sites across Europe include (among others): mammoth *(Mammuthus primigenius)*, rhinoceros (*Coelodonta antiquitatis* and *Dicerorhinus hemitoechus*), wild ass (*Equus hydruntinus*), bison (*Bison sp.*), aurochs (*Bos primigenius*), horse (*Equus przewalskii*), reindeer (*Rangifer tarandus*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), fallow deer (*Dama dama*), ibex (*Capra ibex*), chamois (*Rupicapra rupicapra*), and wild boar (*Sus scrofa*), and predators such as bear (*Ursus sp.*), wolf (*Canis lupus*), fox (*Vulpes vulpes*), and hyena

(*Crocuta crocuta*), and some assemblages include quantities of small mammals as well. While individual component assemblages cannot be realistically viewed as temporally discrete and undoubtedly often represent mixing of multiple events and occupations, the strength of the patterning in Middle Palaeolithic faunal assemblages supports the suggestion that site components containing a number of different species reflect a general exploitation by individual groups of multiple species. This would be the more logical interpretation, as opposed to the suggestion that a component with the remains of few individual animals of a number of different species represents the mixing of inhabitations by different groups who each specialized in hunting one or two of these animal species. This would be particularly so for site components exhibiting a single Mousterian industry.

Such assemblages would indicate that the people who created them tended to exploit whatever species presented itself during each hunting event, with little or no specific prey objective in mind at the time they set out. However, ecological theory predicts that, with all else equal, larger game would have been the preference in terms of returns on time and energy invested.

Specialized Hunting in the Middle Palaeolithic

There are some assemblages which appear to reflect a certain degree of focus on the hunting of specific prey species. These assemblages seem to reflect either a specialized hunting approach or purposeful eclectic hunting with different sites being used to exploit specific prey species. The species exploited in such assemblages are all medium to large herd mammals (especially reindeer, horse, bison, and red deer - Patou-Mathis 2000).

Within the Middle Palaeolithic, Patou-Mathis (2000) sees specialized hunting to be somewhat more common in Western Europe and in northern parts of Central Europe (specifically Germany and Poland), and, in fact, sees a notable decrease in it from OIS 7 through to OIS 3. In general, she sees specialized hunting to be more common during more temperate periods (OIS 7 and 5e) and cold maximums (OIS 2, Upper Palaeolithic), which may also simply be a reflection of changes in the availability of different species.

Examples of Western European assemblages dominated by a single species include Lazaret, with red deer and ibex comprising 82% of non-predator remains (Valensi 2000); Les Canalettes, dominated by red deer (Boyle 2000); Mauran with almost 100% bison (David 1994; Brugal and David 1993); and La Borde with 90+% aurochs remains (Jaubert *et. al.* 1990).

There are, however, notable examples of single-species dominated assemblages in Eastern Europe as well. The sites of Il'skaya I and Il'skaya II comprised between 86 and 100% bison (*Bison priscus*) (Hoffecker and Cleghorn 2000). The faunal remains in the four levels in the site of Starosele in western Crimea include between 80 and 90+% horse remains.

These differing patterns in prey selection may simply reflect responses to changes in the types and availability of prey species that occurred with climatic changes or with different site locations. We might hypothesize that the trend towards specialized hunting in warmer periods reflects an overall flattening of spatial and temporal variability in resource availability (mosaic biome patterns associated with some Pleistocene periods -- Rolland 1996), reducing risk overall, and freeing groups from the pressure to apply a "catch as catch can" approach to food acquisition. Single-species dominated assemblages during extreme cold periods may simply reflect availability within a specific region at that time. While more accurate (and confident) placement of these assemblages in specific oxygen isotope stages is necessary to resolve these questions, the data (species represented in assemblages compared to what was available within the region) suggest that at many of these sites the species that were focused on by hunters did not well represent the array of species that would have been available to them (Boyle 2000).

Another interpretation that may fit the available data equally well is the idea that, rather than the Neandertal hunters being specialized; their sites were specialized (Gardeisen 1999:1155). That is to say that the geographic location of sites made them logical locations (natural traps, ambushes, game sighting, or intercepting migrating herds) for exploiting a specific species and killing one or more individuals each time. A single group may exploit different species at different times by taking advantage of different "specialized" sites. The specific locations of many Middle Palaeolithic sites might be a reflection of certain resource options. During colder periods, sites such as Pech de l'Azé

I-IV, Roc de Marsal, Abri Chadourne, and les Merveilles provide ready access to upper plateau biomes and allow monitoring of game movement through the valleys below (Rolland 1996). Of course, along with changes in climate and associated floral and faunal species, the types and ranges of prey species available around specific sites would change.

The implication of these data is that Neandertals, rather than lacking any real foresight or planning ability, were in fact readily capable of modifying their approach to game acquisition to suit both their circumstances and the size, behaviour, distribution, and variability of the game available in any specific time period (Patou-Mathis 2000; Boyle 2000; Burke 2000; Rolland 1999). The data now seem to indicate that the variability and complexity of Neandertal subsistence was far more marked across Western Eurasia and throughout the Middle Palaeolithic than was previously envisioned (see Burke 2000: 281-84 [preface to special volume] for a brief summary of this). This ability to adapt to changes in types and variability of game species would tend to be best served through the employment of generalized tool kits which would allow a great degree of flexibility (Otte 1999: 249). While there are sites, and perhaps climatic periods, where a single prey species was focused on, there is no evidence that the corresponding lithic technology was any more specialized than at those sites or during those climatic periods when there appears to have been a broader prey selection.

The Use of Fish Resources

Although several fish species, in particular salmonids, were present, and in fact may have been abundant, in the rivers in the interior of SW France during different climatic periods in the Middle Palaeolithic, there is limited evidence that fish were heavily exploited by Middle Palaeolithic people. Among modern Arctic and Subarctic groups fish often make up a large portion (up to 80% in some cases - Kelly 1995:67) of the meat diet. However, fish remains are rarely recovered from Middle Palaeolithic deposits (although they do not tend to preserve well and may not often be taken from the procurement location to a campsite) and no fish procurement technology has been recognized that would suggest that fish were regularly exploited. Specialized technologies are necessary in order to exploit fish to any significant extent beyond chance procurements (Hayden et. al 1987). Unfortunately, while isotopic analyses have indicated that Neandertal diets compared most closely with mammalian carnivores, the studies do not distinguish between animal protein from mammal prey and animal protein from freshwater fish (Richards *et. al.* 2000 and Bocherens 1999). While there is some evidence that fish were occasionally exploited in the Middle Palaeolithic, for example at Grotte XVI in the Dordogne region (Rigaud, Simek, and Ge 1995) and l'abri des Canalettes (Patou-Mathis 1993), they were likely a minor dietary component at best.

Use of Plants

Use-wear analysis (e.g., Beyries 1988; Anderson-Gerfaud 1990; Keeley 1987; Hardy 2004; Shea 1988) has indicated that wood was at least one of, if not *the* dominant material to which many racloirs, notches, and denticulates were applied. Considering the context of these tools, (specifically, habitation rather than special task sites) I expect few archaeologists would disagree that this likely represents the working of wood as a raw material rather than the collection/processing of a food resource. Ethnographically, chipped stone tools are rarely employed in the processing of plant foods (e.g., Hayden 1979). That wood was a commonly employed raw material by Palaeolithic people is also supported by the discovery of wooden implements (spears/javelins?) of considerable age from at least three different European sites. These include: a wooden "spear" associated with the remains of an elephant at the site of Lehringen in Germany and dated to the Riss-Würm Interglacial (Movius 1950), the tip of a yew "thrusting spear" recovered from the Clacton channel in England and dated to isotope stage 7 (Champion et al. 1984: 38), and the more recent discovery of 4 spruce implements, including three "throwing spears", from a German coal mine dated to around 400 kya (Thieme 1997, 1999).

As virtually no hard evidence has been collected so far with respect to the use of edible plants in Middle Palaeolithic sites (Jäger and Schäfer 1999; Mason and Hather 1993; Chase 1986:4; Soffer 1985), any models of use must rely heavily on potentially applicable ethnographic data and on a basic understanding of the repertory of plant resources available in southwestern Europe during the last interglacial and into the first half of the last glacial period. It is recognized that in more northerly latitudes (and presumably their environmental equivalents in less northerly latitudes during glacial periods) where the quantity and variability of plants is relatively low, animal resources in general may represent the more reliable food source and must necessarily take on a more important role (Stringer and Gamble 1998: 161; Gamble 1986; Hayden 1981: 357). This may be particularly so for southwestern Europe during the Late Pleistocene when "optimum [animal] biomass conditions" prevailed (Rolland 1981: 33), mainly in the form of large herd mammals (Gamble 1986, 111). However, while on the whole plants may not be abundant or varied enough to provide a reliable subsistence *base* in such environments, those *individual* edible plant species that are available will still represent more reliable resources than *individual* game animals in that they can be counted on to be in the same location at the same time each year (and not run away when approached)(Hayden 1981:357).

During the last interglacial (OI stage 5e) a much wider variety of potential plant food resources would have been available (figure 4.1). The abundant deciduous forests would have included fruit and nut-bearing trees such as oaks, beech, chestnut, walnut, and hazel. However, some of these require a significant degree of processing before they are edible and there is no evidence to indicate such practices in the Middle Palaeolithic. Perhaps of greater potential use would have been the herbaceous plants available at this time. These are mainly r-selected species with high productivity levels and which are often fruit bearing; in particular berries and nuts (Gamble 1986). Those edible plant resources that would have had some presence in Pleistocene Europe at different times and in different regions include: wild apple (Rosaceae *Pyrus malus sylvestris* L.); wild pear (Rosaceae *Pyrus communis/pyraster* L.); wild cherry (Rosaceae *Prunus avium* L.); raspberry (Rosaceae *Rubus idaeus* L.); blackberry (Rosaceae *Rubus fruticosus* L.); wild strawberry (Rosaceae *Fragaria vesca* L.); hackberry or nettle tree (*Celtis australis* L.); hawthorn (Rosaceae *Crataegus azarolus* L.); rose hip (*Rosa canina* L.); elderberry (*Sambucus nigra* L.); water chestnut (*Trapa natans* L.); bilberry (*Vaccinium myrtillus* L.); wild carrot (*Daucus carota* L.); and thistle (*Carduus crassifolius* L.)

While the issue of returns on energy expenditures may arise with attempts to rely heavily on resources such as these, if the abundance and density is great enough they could contribute significantly to a subsistence base. It would seem reasonable to expect that, where available, people would have exploited at least those plant items that require little or no preparation or modification (e.g. roots, berries, and some nuts), and perhaps also those that may have required minor preparation (e.g. tubers, like wild carrots or thistles). Some of these resources, specifically nuts, would have also lent themselves well to storage, at least in the short term, although there is no evidence for this (Soffer 1989). In the early glacial period (Würm I) with the reduction in deciduous forests there would have been a decrease in the variety and quantity of plants of potential food value to people. Some herbaceous plants (e.g., berries) would have continued on, especially in protected river valleys, into the increasingly steppic environs of the glacial period, providing some potential food resources. During interstadials, potential food plants would have increased again, but in general plants would have probably been a minor component of people's subsistence throughout the Würm (see figure 4.1).

One potential plant food that was likely exploited throughout the Palaeolithic is the inner bark of various tree species. This is a resource that has been exploited by most recent indigenous cultures in the northern hemisphere for which this sort of ethnographic data are available. This includes every major indigenous cultural group across temperate North America, Europe and Asia. Its importance in these various regions ranged from use as a common, seasonally exploited staple to occasional use as either a "treat" or a starvation food. The range of tree species used was also quite varied and included both conifer and deciduous types, although conifer trees, where available, were apparently more readily exploited. Acquiring the soft inner bark (cambium) of a tree requires somewhat specialized tools, although of simple design. These include some sort of heavy-duty knife or chopping tool to cut slits in the outer bark surface and a somewhat more elaborate bone, antler, or wood tool (typically between 25 and 50 cm in length) with a spatulate or chisel-like tip to pry the hard, outer bark off the tree in order to expose the inner bark (Sandgathe and Hayden 2003).

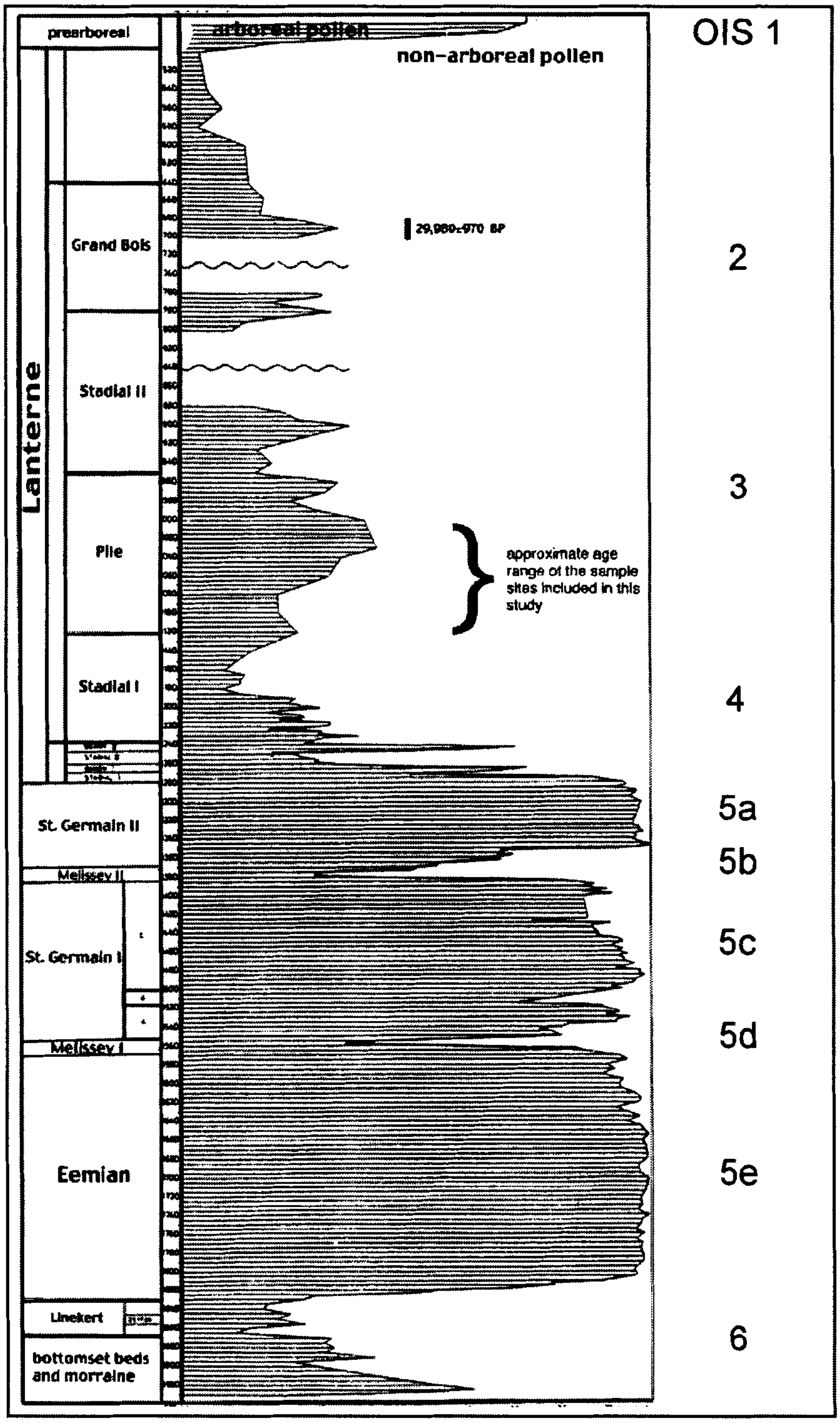


Figure 4.1 Pollen diagram from Grande Pile (N. France) for the last glacial cycle (130,000 years) with the age range of the four sample sites shown (adapted from Woillard 1978 and used by permission of the editors of *Quaternary Research*, University of Washington). The arboreal pollen includes notable levels of birch, elm, oak, hazel, spruce and pine, and lower levels of willow, poplar, holly, maple, ivy, lime, ash, alder, yew, boxwood, grape, and fir (based on the Grande-Pile (Woillard 1978) and Les Echets (de Beaulieu and Reille 1984) sequences.

Settlement Patterns

While Binford's (1978, 1980) theoretical system of settlement patterns (introduced above) can be criticized by some as being overly simplistic, it does provide a useful starting point from which to construct specific regional/temporal models of prehistoric behaviour, and it has been adopted widely among Palaeolithic researchers as a source of general descriptors of alternate adaptive strategies. More importantly, the constraints that influence patterns of mobility, resource acquisition, and duration of occupations are also potential constraints on lithic reduction strategies.

Until recently, most researchers who have addressed the issue of Middle Palaeolithic mobility have suggested that the movement of people during this period probably most closely resembled foragers or residentially mobile hunter-gatherers rather than collectors or logistically organized hunter-gatherers (e.g., Kuhn 1992; Pike-Tay *et. al.* 1999; Lieberman and Shea 1994; Altuna 1989; and Butzer 1986). However, Middle Palaeolithic lifeways across Europe, Western Asia, and the Middle East (the known distribution of Neanderthals) included adaptations to a wide variety of latitudes, altitudes, and major climatic regimes. The wide variety of environments that this necessarily includes means that there must have been a certain level of variability in the settlement patterns in Mousterian adaptations in different regions and at different time periods (Riel-Salvatore and Barton 2004; Rolland 2001; 1990: 356; Rolland and Dibble 1990). These likely ranged from strict circular or residential mobility patterns (where residential moves were very frequent and settlements were very brief and at locations of specific, individual resources -- e.g. traditional desert Australian Aboriginal lifeways) to patterns that involved a limited degree of radial or logistic mobility in which resource acquisition involved the transport of a variety of resources to habitation sites of somewhat longer duration (e.g., most Arctic region traditional lifeways). The Middle Palaeolithic archaeological record does not appear to support the idea of full-blown logistical mobility (i.e., collectors) where residential stays at a single location might last for a whole season or longer. The low concentrations of artifacts and animal remains typical of individual components of most Middle Palaeolithic sites suggests this. Middle Palaeolithic occupations were probably rarely as long as a single season, and likely typically much shorter than this (Chase 1985:2; Pike-Tay 1999:309).

However, some researchers have begun to suggest the presence of some logistically organized behaviour in Middle Palaeolithic Europe (e.g., Riel-Salvatore and Barton 2004; Hoffecker and Cleghorn 2000; Patou-Mathis 2000). While the occurrence of site components with high enough concentrations of lithics and bones to indicate long-term occupations are rare, many of the sites that contain highly diverse faunal assemblages (that tend to indicate a lack of specialization) do seem to be some sort of base camp and reflect a significant degree of collecting, at least from the immediate exploitation area (Riel-Salvatore and Barton 2004). Some researchers have also identified different types of sites: another characteristic of Binford's collector model. Conard et. al. (2000) see at least two major types of sites in Germany: kills sites, in which most skeletal elements are present (especially for larger species) and camp sites where predominantly higher utility limb bones occur which are frequently highly fragmented. These are not particularly indicative of actual collector-oriented patterns however.

In Patou-Mathis's (2000:392-93) general model, Neandertal group mobility revolved around seasonal moves to base camps, where the resources, especially game, were well known. Around these base camps a series of specialized camps were organized which included "seasonal camps" (presumably extraction sites for seasonally available resources) and hunting stations. However, this might be the closest that any researchers have come to actually modeling a collector adaptation and it seems apparent that most researchers still see the evidence supporting more strictly forager oriented adaptations (e.g., Boyle 2000).

It does seem apparent, however, that, as discussed above, some of the discrepancies between these views are due to a lack of strict, common definitions for the terms ('forager' vs. 'collector', 'radiating' verses 'circular') commonly used in the literature, and to a simple lack of clarity in researcher's descriptions of their models.

Part of the difficulty in moving towards a better understanding of Palaeolithic adaptations is a lack of data on the nature of food resources (plant and animal) in different regions throughout the Pleistocene. Undoubtedly, the different types and quantities of resources that would have typified the biomes of different regions and climatic periods would have elicited different adaptive responses and better data on these resources in different times and places are necessary. We can predict, based on current foraging theory, that in situations where resources are less patchy in time and space more forager oriented adaptations will dominate, while in situations where resources are more patchy, groups will tend to increase their level of logistical behaviour (Bettinger 1991: 64-70).

Seasonality

Analysis of the seasonality of habitations at Mousterian sites would go a long way towards better understanding the duration of individual occupation events and, of course, reconstructing basic settlement behaviour. Unfortunately, these types of analysis are few and generally allow for little generalization of Pan-European Middle Palaeolithic behaviour (e.g., Burke 2000:331; Gaudzinski 2000:402; and Pike-Tay *et. al.* 1999; Gordon 1975). The main problem with seasonality studies is the difficulty in identifying discrete, individual occupation events within site components. Traditionally, "living floors" were accepted European Palaeolithic excavations as the remains of single occupations. However, the general concept of "living floors" has been brought into serious question (Dibble *et. al.* 1997) and it seems clear at this point that this sort of resolution is unlikely to be achieved for sites of such ages. Furthermore, an MNI computed from a genuine "living floor" is likely to be too low for any reliable interpretations. Therefore, interpretations of seasonality from faunal remain evidence are applied to whole components (or even whole site assemblages). Any variation in seasonal use of the site that might exist within a whole component may be masked. A second problem is determining the role of taphonomic processes in the formation of the archaeological assemblages.

As it is, the available seasonality data (mainly dental incremental growth analysis) has identified sites across Western Eurasia inhabited during each of the different seasons, with some sites likely being inhabited for two or more seasons (though not necessarily in the same year by the same group) (e.g. Burke 2000; Conard *et. al.* 2000; Gaudzinski 2000; Pike-Tay *et. al.* 1999). This is, of course, not surprising, as people had to be living somewhere each season of the year. As to the recognition of any significant patterning to the seasonality data, it must be said that at this point none is apparent. With more data and greater resolution we may expect to see patterning. For example, there may have been a general tendency for cave sites to be occupied during colder seasons and open-air sites during warmer seasons. This tendency would necessarily have been, of course, dependent on patterns of resource availability, depletion, game movement, and rainfall patterns.

As mentioned above, it must be kept in mind that Binford's *forager-collector* model is not a strict dichotomy so much as representative of a wide scale of subsistence/settlement systems that represent adaptations to certain environmental and socioeconomic circumstances presented in a specific exploitation range. It is generally expected, however, that because foraging oriented groups generally move their residences near major resource locations in order to exploit them, tend to move their residences more frequently, and generally produce only two types of sites, residential bases and '*locations*' (very short-term, single-resource exploitation sites -- Binford 1980) they will tend to produce archaeological remains of a more generic and homogeneous nature. While specialized task sites, such as kill sites, do occur in the Middle Palaeolithic, the killing, processing, and eating of a large mammal may not all always take place at one location, for a variety of reasons, and such special task sites will not usually leave much archaeological evidence behind because of their small and ephemeral nature (e.g., Binford 1980 and for a specific example see Hayden 1978: 190-91). Most of the tasks and behaviours that contribute to the most visible aspects of the archaeological record (e.g. tool production, tool maintenance, food processing, and food consumption) often occur at the same location (i.e., base camps).

Highly mobile *forager* adaptations would require a very generalized tool kit, one that can readily be modified to suit many circumstances when and where they are encountered. Overly specialized tool kits, while more efficient under the right condition, would be potentially useless in other circumstances and would be difficult to maintain and transport under high mobility constraints.

The *forager* model and the generalized tool kit proposed to suit it would seem to be reflected in the *general* pattern observed in Middle Palaeolithic assemblages. While there is obviously some variability in the relative quantities of tool types in different sites and site components (from which so much discussion has arisen: including Bordes' industries, Binford's tasks, and Mellars' chronology), most sites contain at least some examples of all the recognized Middle Palaeolithic tool types (with limited exceptions like Mousterian handaxes, but these only occur late in the Middle Palaeolithic after perhaps 50,000 bp or later).

Collectors, on the other hand, tend to produce a variety of distinct site types over their exploitation range. The most archaeologically visible of these is the home base. This is the location where most of the group spends most of its time gearing up and where most resources are brought to be used or consumed. Some of the other sites that they produce, like quarries (applies to foragers as well), are also typically highly visible, but others tend to leave few or no archaeological remains in the record. Kill sites may leave visible remains in the archaeological record if large numbers of animals are killed, the animals are large enough, if portions of them are left behind, and if their remains survive. Some procurement behaviour and locations may remain invisible to archaeologists. This might apply to things like fishing, or berry and root collecting, unless they are accompanied by fixed features such as fishing weirs or earth ovens for cooking roots.

Recently Riel-Salvatore and Barton (2004) have proposed a potential proxy measure of the degree of mobility of a group based on the density of artifacts and proportional frequency of retouched pieces they left in a site. They argue that there should be a general tendency for both these values to have a negative relationship with mobility and, therefore, should tend to rise along with decreases in the degree of mobility practiced by a group. The general logic behind this seems valid and their data seem to reflect a certain linear distribution of site occupations along a continuum which may well reflect a segment of the theoretical continuum between strict foragers and strict collectors. Notwithstanding potential problems with the available data (e.g., even minor variability in sedimentation rates over thousands of years could significantly affect density of artifacts), the application seems robust enough to at least provide a general understanding of mobility as reflected in major differences in lithic reduction and tool production behaviour in the sites represented by my sample components.

I have plotted the data from my four study samples together with Riel-Salvatore and Barton's in Figure 4.2.

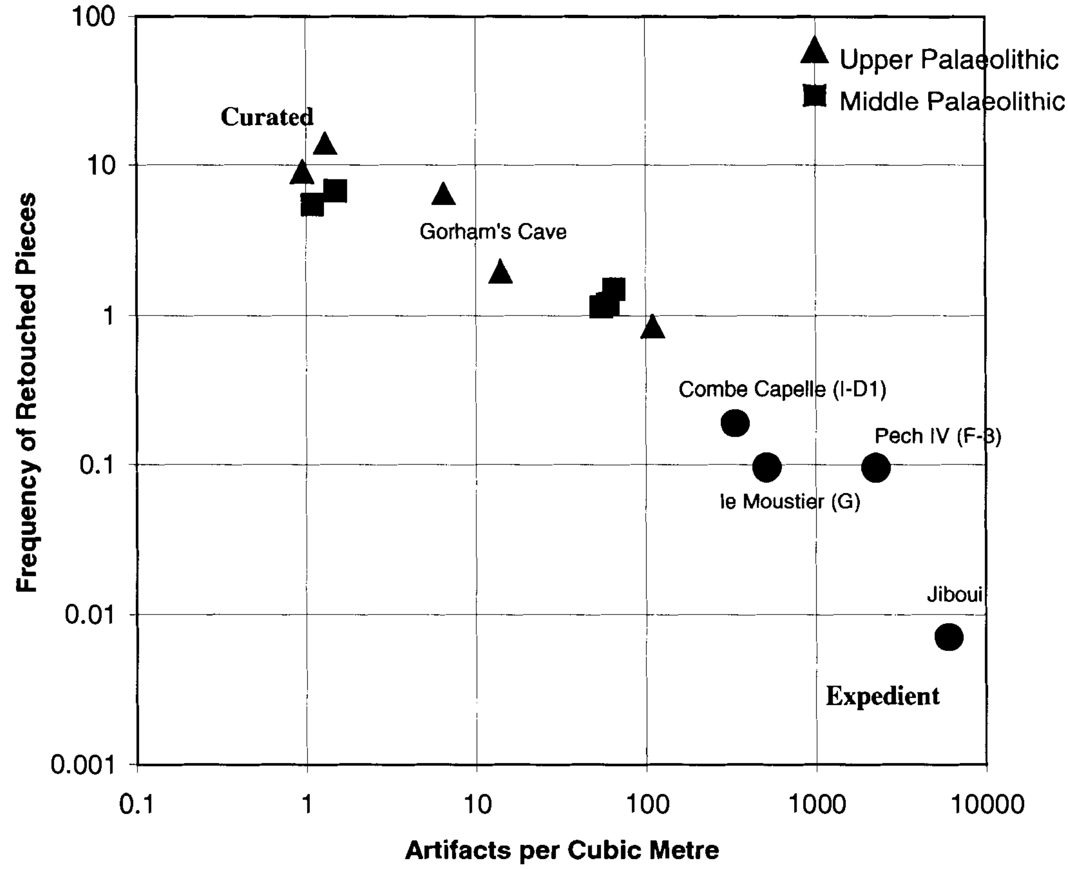


Figure 4.2 Site & component specific patterns indicating a negative linear relationship between artifact density & frequency of retouched pieces. Comparison of data from Gorham's Cave and the sites used in this study (Gorham's Cave data from Riel-Salvatore & Barton 2004)

Riel-Salvatore and Barton associate the two extremes of this linear distribution with lithic technological strategies: the upper left end of the regression is associated with 'curated' technologies and increased mobility (foragers), and the lower right with 'expedient' technologies and 'base camps' of more logistically organized groups (collectors). If these proposed associations have some validity, three of my study samples (for which I have access to all the necessary data) strongly suggest base camp occupations (at least in comparison to those occupations included by Riel-Salvatore and Barton).

There are, however, some interpretation issues. While Riel-Salvatore and Barton suggest that the relationship between the values obtained for each individual site component are best explained as representing some overall settlement pattern practiced by the group which created it, they do not give enough weight to the potential that individual components of settlement systems may represent more spatially or temporally specific behaviour. The nature of the quantities of flakes produced and frequency of retouching may be more closely associated with the type of site it is (e.g. camp site, kill site, quarry site) or where in the group's seasonal cycle the site is situated. This issue is specifically illustrated with the Jiboui data. Following Riel-Salvatore and Barton, among all the sites plotted in figure 4.2, this site would be interpreted as the most closely associated with a longer duration occupation and a collector settlement pattern. However, this high altitude site is interpreted as predominantly a lithic extraction site only inhabited for brief periods in the summer months and it is this, rather than the overall settlement pattern of the group(s) that used it, which best explains both the high artifact density and low frequency of retouch. Quarry sites may, however, be a notable exception to this overall interpretation.

In general, two different interpretations could be presented to account for the pattern exhibited in figure 4.2. Either, the plotted components represent occupations of different groups practicing different settlement patterns along the forager-collector continuum (the interpretation favoured by Riel-Salvatore and Barton), or groups in these time periods practiced the same general settlement pattern and these components represent different types of sites or different positions within the group's annual settlement system cycles. In this latter interpretation, those occupations with high artifact densities and low frequencies of retouched pieces would represent longer term camp sites which might be associated with relatively long (perhaps winter) occupations of forager-oriented groups as might be expected in the sheltered valleys of the Vézère during glacial winters. The occupations with low artifact densities, but high numbers of retouched pieces, would represent either extraction sites or the shorter-term occupation sites more typically associated with more residentially mobile foragers. In both cases, immediate access to raw materials is diminished resulting in the need for economization of those tools in the group's possession, which means a greater frequency of retouching. As discussed by Riel-Salvatore and Barton (2004: 261), following Kuhn (1989), one difference we might expect between the tools of logistical task groups (small groups of 'collectors' on specific resource extraction excursions) and residentially mobile foragers is that in the former case, tools would tend to be designed to be more reliable and in the latter they would be more maintainable. However, during the Palaeolithic these two characteristic are both found in the same general form: relatively large, robust flake blanks that can be repeatedly retouched.

One way to help resolve this issue is to examine the strength of the patterns at individual sites. If what we are seeing are occupations of highly residentially mobile foragers then, while we might expect occasional longer-term occupations, most of them should be dominated by low artifact density/high retouch frequency patterns. Figure 4.3 includes all the components of Pech de l'Azé IV and Combe Capelle Bas (data was not available for all the components of le Moustier). This allows us to see if the strength of the intra-site patterning suggests whether individual sites appear to have been used in the same general manner over time, or if there was any variability of note among occupations

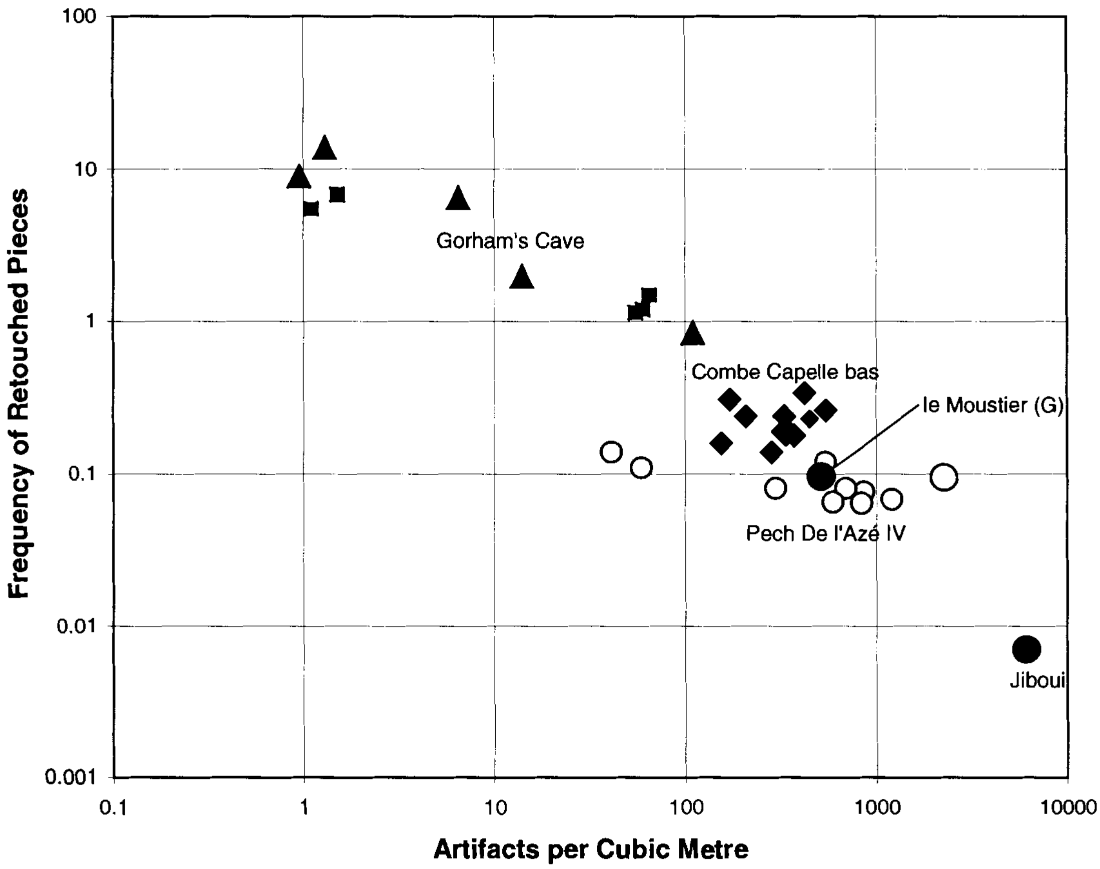


Figure 4.3 Component specific data on artifact density and frequency of retouched pieces. Comparison of data from the components of Gorham's Cave all components of two of the study sites (Gorham's Cave data from Riel-Salvatore & Barton 2004).

There is apparently significant similarity among the components of the three primary study sites. For the two sites, Pech de l'Azé IV and Combe Capelle Bas, at least, the same general pattern of tool production and use was going on in all the components throughout the history of the use of the site. This might be taken as an indication that either these sites were continually used as some sort of central residences by more logistically oriented groups, or at the very least, they played a similar role in seasonal cycle behaviour throughout their occupation histories. Considering the low frequency of exotic (or even regional) lithic raw materials and the presence of a range of different prey species within individual components, the former explanation would seem to be the more parsimonious. While the bulk of the available evidence argues against the presence of a full-blown collector adaptation during the Middle Palaeolithic, the strength of the intra-site patterning suggests that the occupants were not strictly residentially mobile foragers either. Major, multi-component sites, such as Pech de l'Azé IV, le Moustier, and Combe Capelle Bas would seem to represent some degree of central residential behaviour. More than this, the variation within and between these sites in terms of Bordian types of assemblages and Levallois Indices cannot be viewed as related to variations in mobility.

Resource Collecting

Whether French Middle Palaeolithic groups would have been more readily classified as foragers or not, it is apparent that they did practice a certain degree of collecting at some of their habitation sites. The quantities of animal remains and specific types of lithic raw materials which entered the archaeological record at many sites obviously could not represent just those materials in the group's possession when it arrived at the site, or be the result of an occupation of one or two day's duration. Much of it had to be the result of collection events carried out in the surrounding region in the course of their stay there.

At any one site, some raw materials may occur very nearby (within 1 km) and will be readily accessible whenever they are needed. At sites with poorer access to specific, fixed raw material sources a group will have to either: plan ahead and arrive there with a supply or send out special task groups to collect a supply and return to the site with it. Whether or not such tasks would have to be embedded in other behaviours (e.g., hunting or gathering of other resources) would depend on the distance to sources and on the level of time-energy stress a group was under. This stress was typically seasonally dependent among ethnographic groups. If a group was not particularly time-stressed then perhaps a small group could be sent out specifically to acquire a single resource type, like lithic raw materials. They would carry as much as they could from the source back to the habitation site. If time-stress was greater and/or potential sources were further away then a group might include the acquisition of this resource with the acquisition of other resources and so limit the potential source-locations they could visit and the quantities they could return with. This would influence the degree of raw material economization a group had to practice.

If local subsistence resources became depleted over the course of the occupation of a site then time-stress would become greater and options for the acquisition of more distant raw materials would become limited and potentially effect Levallois production. If, for example, local game was becoming scarcer and it required more time and effort to successfully acquire meat then individuals may not be free to make special excursions to recover desirable raw materials and the pressure would increase to either used existing stocks more economically, look for potential facsimiles (e.g., use poorer local raw materials or scavenge materials previously discarded at the site), or consider moving to a new habitation site.

Exploitation Range Size

Some research has been directed towards establishing an understanding of both group size and the sizes of their exploitation ranges. These have been based mainly on raw material transport data for the European Palaeolithic and must be seen as being very tenuous because of the difficulty in controlling for all the factors that could potentially play a part in how lithic items can be distributed across the landscape. For example, Gamble and Steele (1999) take the distance from source of all identifiable raw materials in specific levels at the sites of Caune de l'Arago and Grotte Vaufrey as indications of the limits of the "home range" area exploited by the people who inhabited that level. This is one possible scenario, but it must be recognized that it is also possible that the artifactual remains in each level at a site may represent the combined material remains of several different groups, all of whom used the site from time to time, and that each raw material type found in a level may have been left by a different group of people. It is also likely that individuals moved between groups (visits or moves) and that this included transport or exchange involving lithic tools or raw materials. In these scenarios home ranges would have to be significantly smaller than that computed in Gamble and Steele's scenario.

As it is, the two different methods they employ (Adaptive Kernal method and Minimum Convex Polygon method) for determining home range size give very different results. The Adaptive Kernal method, which takes into account the frequencies of the various transport distances rather than just using the maximum distances observed, suggests a "home range" size of approximately 68 sq. km. The 68 sq. km area would suggest a radius of movement of less than 5 kilometers. This would be in the same range of magnitude as the "foraging radius" around a temporary camp associated with a collector settlement pattern (re. Binford 1983b:380) or a "site catchment area" of the residential base of a forager group. Among some recent hunter-gatherers (foragers), small, daily task groups tend to forage on this scale. Gould (1980:16) observed groups of Australian aboriginal women and children travelling up to 6 km away from the camp during their daily foraging routine. Among the !Kung San, Yellen (1972), as referenced by Binford (1980: 8) mapped daily foraging trips that averaged about 15 km per round trip.

However, 68 sq. km is well below what might be considered a "home range" as it is defined and measured for modern carnivores. According to this data, for latitudes above 45° N. the average home range for a single 80 kg carnivore it would be about 400 sq. km (Lindstedt et. al. 1986). A "home range" is defined as "the area normally traversed during activities associated with feeding, resting, reproduction, and shelter-seeking", although no time span is provided.

The radii of movement suggested by the Minimum Convex Polygon (approximately 18 km for l'Arago and 25 for Grotte Vaufrey) would seem slightly more on the magnitude of the home range of a group who were at least part-time carnivores. These distances would suggest home range areas of 1000 and 2000 sq. km respectively. However, data collected by Féblot-Augustins (1997) show that through the Middle Palaeolithic, average maximum lithic raw material transfers distances were between 35 and 60 km. As radii of mobility patterns (and applying just the Minimum Convex Polygon method) these distances would suggest home range areas of between 3850 and 11,300 sq. km respectively, assuming that interband exchange of raw materials or personnel played no major part in the distribution of the lithics. A third such reconstruction of the procurement territory for Grotte Vaufrey (level VIII) suggests an area of around 3000 sq. km (Geneste 1988:464). The areas suggested by these latter two studies are approaching a different magnitude than that suggested by the carnivore data and would appear unreasonable. Its apparent that the Minimum Convex Polygon method tends to over-simplify the relationship between lithic distribution in the archaeological record and original mobility patterns. It fails to account for the factors mentioned above (overlap of the occupations of different groups, movement of individuals, and limited trade and exchange) that likely played various roles in the distribution of lithics across the Middle Palaeolithic landscape and this would serve to inflate the apparent size of computed ranges of mobility.

Gamble and Steele's computations based on the Adaptive Kernal method may be tending to over-represent just the behaviour associated with site catchment exploitation, and may under-represent any larger scale, longer-termed mobility patterns. Contrarily, the Minimum Convex Polygon method puts too much emphasis on the maximum distances that lithic materials had travelled and, therefore, produces estimates that are too high. We might anticipate that reasonable estimates of French Middle Palaeolithic home ranges was between 100 and 1000 sq. km, with perhaps the latter being more reasonable, since mobility among Western Desert aboriginal groups in Australia involves maximum home ranges of around 1000 sq. km (Hayden 2005 per. comm).

Model Summary

During the Middle Palaeolithic, small, familial groups (between perhaps 15 and 35 individuals) exploited large regions, somewhere between 100 and 1000 sq. km. Their movement around this region would likely have most closely resembled a pattern of foraging, involving 'mapping onto' specific resources and fairly frequent residential moves, but the high animal biomass typical of western Europe during much of the Late Pleistocene would have reduced the level of patchiness of resources during some seasons and resulted in adaptations that included some aspects of the collector pattern. This may have been particularly the case during winter when people and animals would have been concentrated in the river valleys for shelter, fuel, and fodder. Residential moves would have been instigated by depletion of local resources, but likely revolved more around an understanding of the when and where of specific, seasonally available resources, and a certain degree of planning in the exploitation of these. The exploitation of specific resources likely occurred both as *foraging* in the course of moving between habitation sites or at certain seasons and as *collecting* and concentrating resources at regularly frequented base camps The relative degree of importance of foraging and collecting, and the nature of the collecting while occupying the site would depend on the specific characteristics of the exploitation range, many of which probably varied with different climatic regimes. These characteristics would include such variables as what game species were available and in what quantities, topography, location and quantities of useful and necessary plant resources, location and quantities of other necessary resources like water and lithic raw materials, and the nature of the group's relationship with other groups.

While this model is very general and provides little detailed insight into Middle Palaeolithic adaptations, it does carry specific expectations for the nature of Middle Palaeolithic technology and tool kits. In general it would seem that all groups must have adopted a system of broad exploitation of resources, which exhibited two main components:

1/ The exploitation of a particularly large range of the exploitable resources (plant, animal, and mineral) that they encountered using a Middle Palaeolithic technology. There would, of course, be notable exceptions to this in situations where the successful exploitation of a resource required investments of time and/or specialized equipment that made the choice to exploit it a poor one in terms of energy returns and time taken away from the pursuit of other more energy efficient resources. In some areas freshwater fish might have fallen into this category and might have represented a poor investment of time and energy, except perhaps during periods of markedly increased availability, such as during salmon spawning runs. All resources which could be efficiently exploited with Middle Palaeolithic technology would have the potential to be exploited when encountered. With such a generalist approach, faunal assemblages dominated by one or two species would be an indication of species availability rather than of a move towards more specialized behaviours.

and:

2/ A marked degree of technological and behavioural adaptability to the potentially greatly varied conditions of the day, which *allowed* the exploitation of a variety of resources if and when they were encountered. While there are sites, and perhaps climatic periods, where a single prey species was focused on, there is no evidence that the corresponding lithic technology was any more specialized than at those sites or climatic periods where there appears to have been a broader prey selection. The current evidence suggests that Middle Palaeolithic tool kits were designed to be adaptable to a range of task types and unforeseen needs (although more and greater resolution of data in the future may expose this as an over-generalization). While there are examples of potentially more specialized *façonnage* lithic strategies (e.g., Blatsplitzen -- small bifaces common in Central and Eastern Europe), these are notable exceptions in the Middle Palaeolithic in general and during this period Western Europe, at least, is marked by a reliance on *relatively* unstandardized *débitage* technology (Otte 1990).

This type of lifeway can be contrasted to that typically described for the Late French Upper Palaeolithic Period in which groups, while still depending to a large part on a range of medium to large game, focused much more frequently on procuring large numbers of a limited range of species (often reindeer, although data from other regions, in particular Italy, indicate the emergence of broad-spectrum diets just prior to and continuing into the Upper Palaeolithic -- Stiner et. al. 2000). Rather than designing their toolkits and adapting their behaviour to allow the exploitation of whatever resources are encountered, French Upper Palaeolithic toolkits showed an increase in specialization in design. There is a significant increase in the variety of types of tools and the evidence suggests that much more time and energy was expended on producing tools that were markedly specialized and task-specific. Greater specialization of design tends to reflect the desire for more reliable tools that will allow greater confidence in their performance (Bleed 1986). Other data on the Upper Palaeolithic, especially the later Upper Palaeolithic (e.g., site sizes, frequency and/or length of occupations) indicate that settlement patterns exhibited characteristics more towards the *collector* end of the spectrum (e.g., Champion et. al 1994; Otte 1990; Strauss 1990).

The Upper Palaeolithic period occurred entirely within a glacial maximum resulting in a climate in (non-Mediterranean) Europe dominated by large herd animals adapted to steppic environments. Such circumstances may well have encouraged a move towards more specialized adaptations, but there is little evidence that such changes occurred during the colder periods in the Middle Palaeolithic.

With a more specialized adaptation, like that of the Upper Palaeolithic, the most important subsistence knowledge would be about the behaviour of the focal species; when and where it moves about the landscape and, considering its natural behaviour and reaction when encountered, how to most effectively hunt it. We might argue then that for the Middle Palaeolithic generalist adaptation detailed knowledge of their entire region of exploitation would be most important.

Chapter 5: Constraints

Constraints on Middle Palaeolithic Stone tool Production and Form

The lifeways model in the previous chapter was constructed as a framework from which an understanding of the type and nature of the constraints faced by Middle Palaeolithic groups in the development of their stone tool technologies could be developed.

Constraints that play a role in the design of a solution do not act independently, and in fact often conflict with each other. Because of these conflicts, it is possible to get a more specific idea of the designers' goals because in the design process some constraints were given greater consideration than others, indicating preferences in design direction (Horsfall 1987: 334-36). Constraints may also influence each other in feedback situations, where the degree of importance of one will positively influence the degree of importance of another (Hayden *et. al.* 1996). All discussion of problems and constraints in this thesis will be restricted to chipped-stone flake tools.

There are two different, yet sometimes overlapping, categories of constraints that would have influenced the development and use of a specific reduction technique. The first category includes those constraints that would have influenced the nature of the desired end-products, the tools. These are the factors that influence the form a flake-tool must take in order for it to fulfill its intended function. For example, a tool intended for cutting tasks must have an acute edge. Each of these constraints will be discussed first in a general sense followed by a discussion of the form they might be expected to take in the Middle Palaeolithic of France.

The second category of constraints includes those that would have influenced the nature of the tool production procedure itself. What are the factors that influence how the desired flake-tools can be produced? For example, if suitable raw materials are in short supply then a reduction strategy that is not wasteful of raw material is likely to be selected. As with the first category, these are first presented in general terms and then in reference to Middle Palaeolithic conditions.

1/ Potential Constraints on Tool Morphology

This category deals with the general form that it would be necessary or desirable for Middle Palaeolithic flake tools to have in order for them to carry out their intended function. The basic functional constraint is that tasks require tools with certain morphological criteria. It can be assumed that the Middle Palaeolithic individuals producing flake tools were capable of producing ones with appropriate morphologies. There is no reason to think that, within the limits set by the identifiable constraints involved, they would have produced anything but the most morphologically useful products possible. Constraints other than function will, however, play significant roles in end-product forms. For example, it may be necessary to produce initial flake products from which a variety of tool types must come and so flake blanks of more general morphology will be produced and this will be reflected in the final form of all the tool types. These more general forms will, however, still require certain morphological traits dictated by specific, identifiable constraints (see Hayden et. al. 1996: 11 for a more general list).

Morphological Traits - general considerations

The following attributes are logically (and experimentally) related to efficient or satisfactory performance of tools and can be expected to play important roles in reduction/core strategies. Therefore, they have been used in recording observations on flakes in the study assemblages.

Flake Size

We can probably safely assume that there is a minimum size for any flake blank below which it would not be serviceable regardless of use-action or type of material it is applied to, although the use of hafts could significantly influence this. Flakes below a certain size limit were likely considered waste and discarded by the knapper. What this minimum size would have been is difficult to guess at, and for people facing severe limitations in raw material availability, this minimum size may have been necessarily quite small. However, even when raw material economization was not a concern people might have employed flakes much smaller than what archaeologists have historically considered practically usable (Sandgathe 1998, 168; and see Hayden 1981; White 1968; and Miller 1979 for ethnographic data on this issue).

Edge Length

Tools will require working edges with lengths suitable to the task. For some tasks, such as cutting, longer segments of sharp, regular edge will be more desirable or even necessary. One can imagine the difficulty and inefficiency in trying to cut through meat or a tuber with a knife that has only a one centimeter long working edge. For other tasks, such as engraving, smaller edge segments may be necessary and regularity of the edge may not be an issue. This is illustrated by relatively modern (manual) tools designed for specific tasks like butchering meat or carving wood. While a pocket knife may function for cutting up meat and carving wood, a butcher's knife has a much longer edge and most woodworking tools have very short ones. With respect to regularity of these tool edges, in cutting meat it is often a requirement that the entire edge of the knife comes into contact with the material in a single stroke, but with most woodcarving tools this is not the case. Carving wood typically involves scraping or shearing actions, rather than cutting, and the greater the length of edge/material contact the more difficult this is to accomplish. One can imagine the difficulty in trying to push the entire edge of the blade of a pocket knife into a wood surface.

Edge Angle (or spine-plane angle)

One of the more commonly discussed attributes of stone tools, edge angle is often discussed as a morphological attribute directly related to the nature of the task (Wilmsen 1970). For cutting tasks, other considerations aside, a more acute edge is better as it will tend to cut through materials more effectively. For scraping tasks, where the edge is put under greater lateral stress (with greater acuteness being equal to greater fragility) and absolute sharpness is not necessary, a higher edge is more suitable. For all potential applications of a tool, the degree of lateral stress put on the working edge will strongly dictate how strong, and therefore how obtuse, it must be.

Within lithic analysis two different expressions of the angle of a flake margin have come to be recognized: *edge angle* and *spine-plane angle*. They both refer to the angle formed by the meeting of two adjacent surfaces of a flake, but the former is measured within only one or two mm of the edge, while the latter is a measure taken using greater portions of each opposing surface as references, generally several mm or more (fig. 5.1).

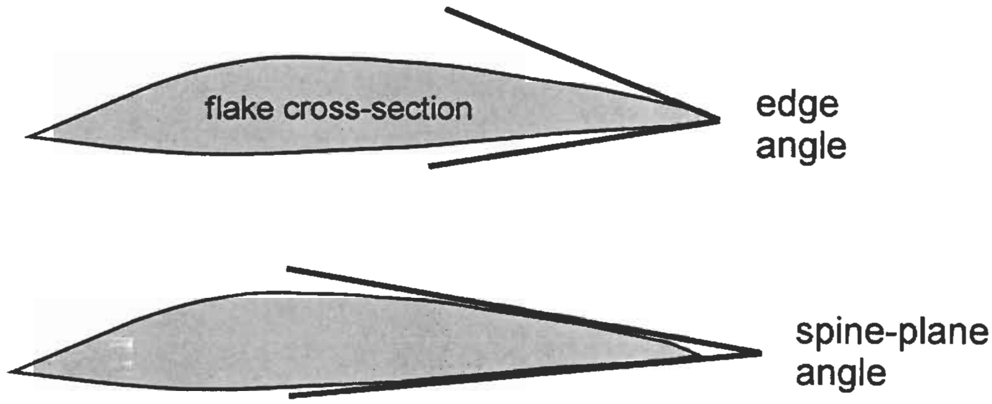


Figure 5.1 Illustration of the difference between 'edge angle' and 'spine-plane angle'.

Edge angle might be said to be an expression of how sharp an edge is, while spine-plane angle gives a more accurate indication of the actual gross morphology of that edge, and often the flake as a whole. It is common for there to be some difference between these two measures on a typical flake edge. However, they usually do not differ by magnitude and generally a lower spine-plane angle will indicate the presence of a lower edge-angle, although it is possible (and is occasionally the case) for the edge-angle to be significantly higher than the spine-plane angle (the reverse is obviously not possible).

Ventral Curvature

For certain tasks any significant ventral curvature may inhibit the effectiveness of the tool. For tasks where only a short use edge is required (e.g., sharpening spears), curvature will not likely be a major factor. Ventral curvature may be a significant factor with tools used for cutting meat. Too much ventral curvature in the flake will inhibit cutting effectiveness by reducing the length of edge that can be brought into contact with the task material at any one time. Because of the curve in the edge it cannot be pulled across the surface of a material in a straight line and actually cut into the material effectively. Again, one can imagine the difficulty in cutting through a piece of meat with a carving knife with a bent or laterally curved blade.

Robusticity

For some tasks, such as cutting or carving soft materials, more delicate flake tools may suffice. The stress brought to bear on the tool and tool edge are not significant enough to compromise the strength of even a thin flake tool. For other tasks, however, the level of stress that the tool must endure will factor into flake blank robusticity. For tasks that involve the working of harder materials the tool must be put under greater stress, both at the point of contact between the task material and tool edge and in either the grip of the worker's hand or in the tool's haft. Carving bone or ivory is one example of this. In order to withstand the necessary stress involved in this sort of task, both the tool edge and the tool as a whole must be suitably robust. For example, a tool made from a flake that is large enough to hold comfortably in the hand, but that is less than 5 millimeters thick and has edges with spine-plane or edge angles less than 20 degrees will not likely hold up to the stress involved in most woodworking.

Constraints on a Tool's Morphology

These are aspects of the specific applications of stone tools that we can anticipate will serve as important constraints on the morphology of the tools. We can produce reliable expectations about the nature of these applications and the constraints they will place on tool form from both ethnographic data and some personal experience and experimentation.

Use-Actions and Task Mechanics

The different possible task mechanics or use-actions of flake tools can be described using the common terms: cutting, chopping, scraping, boring, piercing, and carving/etching. Tasks involving the use of flaked stone tools will typically include one or more of these use-actions. All aspects of flake tool morphology could be influenced by use-action.

Cutting actions generally require tools with more acute spine-plane/edge angles, use-edges of a reasonable length, low ventral curvature, and must be large enough so that they will either fit in a haft or can be hand-held comfortably enough to apply the necessary power and precision.

Chopping tasks will generally require heavier tools with reasonably sharp edges. How sharp the edge needs to be would depend on the type of material being chopped and on the weight of the tool. A lighter tool can be made more effective for chopping tasks by employing the extra weight and leverage of a haft.

With *scraping* actions, more obtuse (less fragile) working edges are better, curvature may be desirable (or is at least less of an issue), greater robustness is required, and size depends on the same factors as with cutting actions. This is particularly so in scraping harder materials like wood.

For *boring* and *carving/etching/incising*, smaller, more specifically shaped use-edges are generally required or, at least desirable. Boring and etching, in particular, are likely to have more pointed working edges. All three of these would typically be applied to harder materials (although boring holes on hides was likely a common task) and so would tend to require greater robustness of the use-edge and the flake as a whole.

Piercing is included here to refer to the use of stone projectile tips for the piercing of animal hides. These tools require a sharp tip for the initial puncturing of the hide and sharp edges to cut a further path into the hide and underlying tissue to allow a reasonable depth of penetration and cause extensive tissue damage. Hafting these tools also puts constraints on their morphology, but the hafting constraints in this case are more limiting than with other tools because the mechanics of penetrating membranes require the bulkiness of the hafting to be kept to an absolute minimum (Hughes 1998: 357).

Middle Palaeolithic Tasks and Task Materials

Determining what use-action constraints would have played a role in influencing Middle Palaeolithic tool morphology requires a good understanding of what tasks they would have been required to fulfill. By examining the archaeological record of the Middle Palaeolithic, using appropriate ethnographic data, and through an understanding of Middle Palaeolithic environments we can establish a basic understanding of the potential range of tasks for which stone tools may have been required during this period.

The faunal remains recovered from many Middle Palaeolithic sites indicate that, while large to medium sized mammals were likely not the only source of food and raw materials, they were a very important, if not dominant, part of subsistence during this period (Richards 2000 and Bocherens 1999). Hunting and butchering must have made up a large part of the tasks carried out by Middle Palaeolithic people. (Besides the cutting of fresh hide and meat, butchering also typically includes the breaking or smashing of bones. This is sometimes necessary in the course of dismembering an animal, but the breaking of longbones to extract the marrow is an almost universal practice among hunter-gatherers and the evidence for this practice is also very common in the Mousterian. However, this part of the task is not relevant to flake tool use and will not be considered further here.) It also seems reasonable that people would have made some use of the hides of these animals, especially during the colder, glacial episodes. This would have included both the preparation (in some form) of the hides and the subsequent processing of them into items such as clothing, shelters, and containers. Other parts of the animals, such as sinews, bones, ivory, and antlers may have also been used to some extent. These items are useful in the manufacture of tools/weapons, clothing, shelters, containers, and mobiliary art, although the archaeological evidence for the use of bone, ivory, and antler in any contexts in the Middle Palaeolithic is extremely sparse and so it seems apparent that flake tools were not typically used on these materials. They can, therefore, be excluded from design considerations.

For hunters and gatherers in general, regardless of the nature of their environment, wood makes up a very important part of the material culture. This is the case in environments where wood is not overly abundant (e.g., Australia - see Gould 1980; Hayden 1981), and even in environments where wood is essentially non-existent and must come from elsewhere (e.g., the Arctic). It would seem logical to expect that wood was an important raw material during the Middle Palaeolithic as well. In Southwest France, during interglacials, woods of various sorts, including softwood conifers (e.g., pine, spruce) and hardwood deciduous species (e.g., oak, elm, boxwood, yew, maple, ash) would have been readily available in most areas (figure 4.1). Even in areas, or at elevations where these did not actually grow one would not need to travel far to find where they did. During the glacial periods the quantities, varieties, and distribution of trees would have been diminished, but in most areas (if even only in river valleys) the conifers, at least, would have been available. In fact, based on the pollen records from such sites as Grande Pile Peat Bog in Northeastern France (Woillard 1978; J. Guiot, *et. al.* 1989; Pons et. al. 1992; de Beaulieu and Reille 1992), Bouchet (Reille and de Beaulieu 1990) and Ribains (de Beaulieu and Reille 1992) in the Massif Central of France, and Les Echets in the Rhone Valley near Lyons, France (de Beaulieu and Reille 1984; J. Guiot, *et. al.* 1989; Pons et. al. 1992), a wide variety of hard and soft wood tree species were always available in some quantity.

In the sample layer, G of le Moustier, included here, pollen analysis indicated the presence of Scots pine, birch, willow, alder, and elm. The acquisition of wood suitable for a wide range of applications would not have been problematic in any period of the Middle Palaeolithic. As discussed above (Middle Palaeolithic Subsistence Model), a number of thrusting spears have been recovered from Palaeolithic contexts, indicating that wood artifacts were manufactured. The tentative dating of these items places them all in warmer climatic stages, but most, if not all, of these items are of coniferous wood and so access to suitable raw materials would not have prevented their manufacture during colder stages as well. One might also argue that the survival and subsequent discovery of items of such poor preservation potential in three different sites of such extreme ages (between 200,000 and 400,000 years) suggests that they were a common entry into the archaeological record. Hayden (1981:15-16) predicted, based on ethnoarchaeological work in Australia, that woodworking was likely the dominant task for which stone tools were produced in the French Middle Palaeolithic, and more recent use-wear analyses have demonstrated this (e.g., Beyries 1988; Anderson-Gerfaud 1990; Keeley 1980; Shea 1988).

The acquisition of non-woody plants for food or raw materials was also likely a component of Middle Palaeolithic lifeways. Food plants, such as nuts, berries, and tubers, would not have required the use of flaked stone tools in their acquisition. There is no evidence for the processing of these either and so, when and if they were exploited, they were likely just consumed as found or processed using natural rock forms. Soft inner tree bark may well have been collected for food (Sandgathe and Hayden 2003) and this would have required a sharp, robust stone knife or chopping tool to cut through the outer bark and a bark peeler, used to pry off the outer bark. The manufacture of bark peelers would have required stone tools. Non-woody plants suitable as raw materials for structures, cordage, and clothing would include grasses, sedges, and barks (the latter may technically be from woody plants, but their use and consistency would be most similar to non-woody plants). Some applications of these types of materials, such as in weaving and basketry, require the development of more sophisticated technologies for which there is no evidence in the archaeological record prior to the Upper Palaeolithic (some evidence has recently been presented for such technologies in the Upper Palaeolithic - see Soffer 2000). There are no *a priori* reasons to assume that they were not known in the Middle Palaeolithic, and baskets and weaving in general are/were very widely used ethnographically, but because of the general complexity of these technologies, it would seem reasonable to wait for evidence before including them in models of Middle Palaeolithic behaviours. It would, however, seem reasonable to allow for the use of these types of raw materials in simple applications such as the manufacture of shelters or rope/cordage. Both the acquisition and processing of these types of raw materials may well have required the use of flaked-stone tools. Flake tools could have been used to cut grasses and sedges and to cut or scrape the bark from a tree or branch. Ethnographic data also indicates the use of flake tools for scraping such fibrous materials (especially barks) in order to clean off the dry, inflexible exterior layers and to produce a more regular shape and consistency.

Use-Wear Investigations

Identifying the tasks for which Palaeolithic stone tools were employed is a subject that has witnessed some research over the last two or three decades. Keeley (1977) applied use-wear analysis to Palaeolithic tools from three Lower to early Middle Palaeolithic sites in England in the 1970s. Beyries (1988) and Anderson-Gerfaud (1990) did the same in the 1980s with Middle Palaeolithic assemblages from France. Shea (1988) examined Mousterian tools from Kebara Cave in Israel.

Keeley's results indicated that woodworking and butchering were the predominant tasks for which stone tools were used. Of the tools that Beyries (1988), Shea (1988), and Anderson-Gerfaud (1990) looked at, 64%, 38%, and 68% respectively, had indications of use for woodworking. Unlike Keeley, however, these three studies found little evidence of butchering (Beyries and Anderson-Gerfaud report it as negligible while Shea reports that 15% of the wear was from butchering). It seems logical to expect that butchering was one of the dominant tasks in the Palaeolithic and, in addressing this issue, Anderson-Gerfaud (1990, 398) suggests that this may be an issue of preservation being dependent upon specific depositional environments. I, however, am not convinced that butchering would, in most cases, produce detectable wear. Perhaps if a tool were used very extensively without being replaced or retouched, some detectable and distinguishing wear might be produced and perhaps this is what allowed the detection of what has been reported as butchering wear in some cases (e.g., Keeley 1977). It has yet to be satisfactorily explained (contra Bamforth et. al. 1990; Kamminga 1979) or described in the literature what the exact mechanics are which allow very soft materials like fresh meat to alter the surface of hard stone to a degree that polish is formed. Small chips may come off the tool edge during cutting and subsequently produce striations on the tool edge, but these chips could not be responsible for "meat-polish" (Keeley 1977, 4). I suspect that tools used for butchering fresh meat and cutting fresh hide will tend to be highly under-represented in reliable use-wear analysis studies.

Summary of Middle Palaeolithic Tasks

Based on ethnographic observations, interpretations from the surviving archaeological record, pollen records, and use-wear studies it seems likely that butchering and woodworking were the two basic tasks for which flake tools were required during the Middle Palaeolithic. Specific woodworking tasks probably included the manufacture of spears, bark peelers, digging sticks, and tool hafts. Processing hides likely also took place, but thc degree to which animal hides were modified is not clear. At the very least stone tools would have been used to cut hides up for use as covering or to make rope. Although other tasks besides these likely took place, they also likely played a negligible role in manufacture and design considerations.

Butchering Tool Constraints

In order for a stone tool to simply cut meat and fresh hide, few specific morphological characteristics are necessary. All that is required is an edge of reasonable length and of sufficient sharpness. The tool must also be large enough to be held reasonably securely in the hand or to be secured in a haft. Hafting is not necessary for this function, however. A simple, small (but perhaps at least two cm in maximum dimension) flake can work very efficiently in the butchering of most animals (Sandgathe 1998), although larger flakes provide a more secure grip which becomes particularly important in butchering because blood will make a tool slippery and more difficult to hold. For very large species, elephants and bison as examples, the hide may be thick and tough enough so as to require larger, more robust tools to cut through it efficiently. Also, for the processing of large quantities and/or large pieces of meat, larger flakes with greater proportions of cutting edges may be more efficient as they would tend to require fewer stokes than a smaller flake tool to cut through the same volume.

Contrary to some claims in the literature (e.g., Jones 1980), in my own butchering experiments (with deer) I have found an unmodified flake significantly more effective than a biface in cutting meat and fresh hide. The slightly serrated nature of a biface edge may increase its effectiveness in cutting harder materials, but it is still not as sharp as a fresh flake edge. There are some advantages that a biface may have over some flakes in cutting meat. One is a relatively long, straight edge. A common characteristic of flakes produced by some reduction technologies, especially bifacial reduction, is a significant degree of ventral curvature. If, as is often the case, the lateral margins are those selected for use, this translates into a lateral curvature which can inhibit the potential effectiveness of that edge. Flakes with a flatter longitudinal cross-section would be preferable for most tasks and perhaps a necessity in some. A second advantage of bifaces in butchering is that they tend to be heavier than most flakes and so are useful for chopping through bones or joints. However, in the Middle Palaeolithic, bifaces only appear in MAT (Mousterian of Acheulian Tradition) industries which appear to occur quite late in the Middle Palaeolithic. Two of the sample assemblages used here, le Moustier and Pech de l'Azé IV, are MAT industries, although only the former included numerous bifaces.

The Optimal Design for Butchering Tools

While almost any flake with a sharp edge could be used to cut meat, there are specific desirable characteristics for flake butchering tools. Flat flakes or blades with long, straight, very acute edges (<50°) are most suitable and, for unhafted use especially, relatively large flakes provide for a better manual grip (This suite of characteristics is most typically found together in hardhammer flakes. Billet flakes, while typically having sharper edges, also tend to be smaller and have significant ventral curvature).

Size

Any projected size parameters will be necessarily arbitrary, but I would suggest that, based on my own experimentation (Sandgathe 1998), unhafted flakes with a maximum dimension of less than two centimeters would be both difficult to manage manually, would tend to lack cutting edges of reasonable length, and are more easily lost in the inevitable mess of butchering. The maximum size for a flake intended for cutting meat, beyond which it would be too heavy and unwieldy, is likely still greater than the maximum sizes attainable for flakes from an average core. In other words, producing too large a flake was likely not an issue because of the typical sizes of raw material nodules. However, a flake between 5 and 8 centimeters fits most comfortably in an oblique power grip and anything significantly larger than this would be redundant and likely not improve effectiveness.

Hafting

Simple expedient flake knives are perfectly serviceable butchering tools and hafting is not necessary, but, depending on the type of haft, one can provide certain mechanical advantages, including the ability to apply greater pressure (which might be advantageous in cutting through joints) and the ability to slice more deeply into flesh (by replacing a bulky hand with a narrow handle which can more easily follow a blade into an incision). Two different general approaches in hafted butchering tools are common in the ethnographic record (e.g., Anderson-Gerfaud 1990 and Helmer 1987: 52). One involves the insertion of one side of a flake or blade into the side of a haft (or at least minimally into some gum, resin, or a piece of leather) so as to leave exposed a single, long cutting edge adjacent and parallel to the haft. This approach is probably best illustrated by the ulu used by North American Arctic groups. The other approach would be comparable to a modern kitchen knife, with one end of a flake or blade inserted in the end of a haft so that it is more or less parallel to the haft but an extension of it. In this case the blank protrudes exposing two potential cutting edges. Both types of knife are effective butchering tools and it may be that the selection of one over the other is a stylistic issue (perhaps in the isochrestic sense), or a function of desired use-life, processing volumes, or mobility. However, while the type of hafting employed may influence the general plan-shape of blanks, characteristics desirable in any blank would include at least one long cutting edge and relative flatness (besides reducing the effectiveness of the actual cutting edge in either approach, ventral curvature could present a particular hafting problem in the 'ulu' form).

There is significant evidence for hafting in the Middle Palaeolithic and this is discussed below.

Expedient vs Long-lived

As discussed above, fresh and unmodified acute flake edges are the sharpest and most effective edges for cutting meat. Where other constraints allow and circumstances provide, these should be selected for use over alternatives. Where other constraints do not allow the initial or continued use of unmodified edges, edges with expedient knife retouch or some other form of acute retouch (e.g., Quina retouch or inverse retouch - re. Bordes), will also serve well. Therefore, typically, whether tools used for butchering are expedient or long-lived will not be an issue of functional requirements, but will be dictated by other constraints and circumstances. In circumstances where there is an abundance of ready-made flakes at hand these may be used as expedient tools to butcher an animal. As each flake dulls from use it is discarded and replaced with a fresh one. In circumstances where ready-made flakes are at hand, but quantities may not be considered quite so expendable, a single, suitable flake may be used and resharpened till the task is finished before it is discarded. In circumstances where raw material is at a premium or where there is simply not a supply of ready-made flakes at hand (for example, during moves between residences), an even longer-lived tool, such as a hafted blade, a biface, or a Central Levallois flake (regularly resharpened and retained between uses), may be the best choice for butchering an animal (e.g., Kuhn 1992:189).

The implications are that we might expect butchering tools to take on two different forms depending on raw material availability or similar constraints such as processing volumes or mobility levels). Longer-lived and typically larger tool forms, such as Central Levallois flakes (possibly hafted), under conditions of limited access to raw material (although recycling would likely also play an important role in these conditions), and expedient forms (amorphous core products, peripheral Levallois flakes, *Éclats Débordants*?) when raw material is readily available.

Woodworking Tool Constraints

By 'woodworking' I am not referring to the cutting down or the collecting of trees or branches for fires or architectural construction materials, for which large chopping tools, rather than flake tools, would be suitable. Large chopping tools like this are rare in Mousterian assemblages, although it may be that they were discarded at locations where wood was being collected and, therefore, rarely made it into typical base camp assemblages (Hayden 1978: 190-91). Woodworking, as it is used here, refers to such tasks as whittling, carving, shaving, scraping, or boring which are carried out in the course of manufacturing items of wood (this is how Beyries [1988] and Anderson-Gerfaud [1990] defined the term in their studies as well). While each of these specific tasks may require working edges of different forms (and there is a range of hardness among different species of wood), in the working of wood in general, tools and their working edges need to be fairly robust: generally >50°.

As mentioned above, the recovery of several Palaeolithic age wooden spears suggests that these might have been one of the more common uses of wood and reasons for woodworking. Not surprisingly, most, if not all, of these were manufactured from the trunks of small, straight conifers. Throughout the Middle and Late Pleistocene a variety of conifer species would have been available in Western Europe. During glacial periods, the quantities and range of variety of conifers would have decreased (significantly at times), but there would have always been some pine, spruce, or yew available. It has been noted that the spruce used for the 400,000-year-old spears recovered in Germany

(Thieme 1997: 809) was from trees that had grown under stressed conditions. This means that they either grew up under difficult (cold) climatic conditions or else in close competition with other individual trees (thick, crowded stands) resulting in very tight annual rings and a denser overall wood structure making them somewhat harder than average spruce wood. Climatically stressed trees might be expected to be relatively common during colder climatic periods, but the date of 400,000 kya puts the manufacture of these spears in the middle of Oxygen Isotope Stage 11, a warm period with climatic conditions favourable for arboreal species. It may be that such stressed trees were specifically sought after for their combination of increased density, resiliency, and the straightness typical of such conifers. The manufacture of such spears would have involved the removal of the bark and smaller branches, the shaving of the outer surface to regularize it and reduce it to the desired diameter and weight, and the sharpening of the end.

Other specific items that are almost universal among recent hunter-gather groups and that were likely manufactured from wood during the Middle Palaeolithic include tool handles (hafts - of which some likely examples were recovered from Schöningen along with the spears), digging sticks (also a possible example from Schöningen), throwing sticks, bark peelers (Sandgathe and Hayden 2003), knapping billets, and saplings used as shelter frames. Items like these would all entail similar manufacturing steps as described above for spears. These items, however, may have been manufactured out of hard woods (billets, without doubt, and, possibly tool handles and throwing sticks) which would put more strain on the stone tools used. Other possibilities might include ornaments/mobiliary art, which could have been made out of any type of wood. These types of objects, as well as any surface decoration of other functional wood objects, require more intricate carving and surface relief work and so often involve etching and grooving. These types of use-actions also put significant stress on the tool and require more specifically shaped (usually narrow) tool edges than does simply scraping away surface layers.

Regardless of the specific type of woodworking, most types of wood (in Palaeolithic Western Europe) are hard enough so that significant pressure must be brought to bear on the tool for it to produce satisfactory results (this comes from extensive personal, though unsystematic, experimentation). If the tool or its edges are not sufficiently robust they will break. This means that the flake must not be too thin. While sharpness is good, reduced acuteness is not a serious problem in woodworking as it might be in other tasks, such as cutting meat and hides, where depth of penetration is a significant part of their intended function. Woodworking does not typically entail deep incisions in single strokes. Among the Australian Aboriginal groups studied by Gould (1980) stone flakes used for cutting meat had edge angles between 15° and 59° (with an average of 40°) and tools used for woodworking had edge angles between 40° and 89° (with an average of 67°). Hayden's (1981) data on the Australian hunter-gatherers he worked with provide an average edge angle between 70° and 75° for woodworking (adzes, chopping implements, and hand-held scrapers), with over 80% of them with edges between 60° and 85°. The spine-plane angle data for the tools among the three primary study samples shows such a bimodal distribution (see figure 8.6). Modern metal tools exhibit similar bimodal edge-morphologies. The edge of a typical steak knife is 10° to 20° while the edge of chisels designed for carving wood are between 35° and 60° (from measurements taken on a complete woodcarving set). Woodworking tool edges need to be sharp enough to shave off wood fibers as they are pulled across the wood surface, but not to slice deeply. Some experimental work by earlier researchers provides further support for this relationship between edge angle and application. Wilmsen (1968:156-8) suggested a range of 66° to 75° for heavy duty tools (such as for woodworking), and 26° to 35° for cutting tools. There are examples of modern woodcarving tools with very acute edges that are used for finer etching and incising, but the strength of the steel from which these are made allows the use of such edges for applications in which such fine edges, if they were made of stone, would break.

Because significant pressure is applied with these types of tools they typically need to be reasonably large, unless they are hafted. As the degree of pressure applied increases, it becomes more and more difficult, inefficient, and uncomfortable to use small tools (these assertions are also born of personal experience). The discomfort can be relieved to some extent by either backing the tool (with very abrupt retouch for example) or by holding the tool in a piece of leather to protect the hand, but this does not necessarily address the problem of decreasing efficiency. This problem can be dealt with to a certain extent with hafting technology. Some flakes, within a certain size range, may be too small to be used efficiently or comfortably hand-held, but may be large enough to be set securely enough in a haft so that sufficient pressure can be applied with them. Securely hafting a tool, however, still requires that the tool be of a reasonable size, especially if it is to be put under significant pressure. If the type of woodworking being carried out involves the production of more delicate or intricately shaped items, then one could expect the production of smaller, more delicate tools, or at least tools with small, delicate working edges. There is an apparent scarcity of very small flake tools, of recognizable types, in the Middle Palaeolithic, especially when compared to later periods. Microblades, burins, and gravers, common Upper Palaeolithic tools, have long been generally associated with the production of more the more intricately carved items (of bone, ivory, and antler) common in this period, and with more delicate composite tools (e.g., composite projectile tips). In Middle Palaeolithic assemblages there are some burins (mainly atypical ones, as true burins are very rare) and other tool types, such as alternate retouched becs, that may have used for finer carving, etching, or incising tasks. However, the scarcity of such lithic items in the Middle Palaeolithic may indicate a predominance of cruder or coarser types of woodworking where small delicate tools are not suitable.

(note: There is mounting evidence that small flakes were specifically produced in the Middle Palaeolithic. This evidence includes the production of Kombewa flakes, found in many Mousterian site assemblages, and the reduction of very small cores, like the Assinipodian types found at Pech de l'Azé IV and other European and Levantine sites [e.g., Bar-Yosef et. al. 1992]). The production of such small flakes might be associated with available raw material sizes to some degree, but, at least in the case of Pech de l'Azé IV, the diminutive cores and flakes recovered in the Assinipodian levels are significantly smaller than the available raw material sizes would warrant (Dibble and McPherron 2003).

Flake curvature and edge length requirements would be dictated by the specific nature of each woodworking task. In situations where long straight cuts or grooves are desired straight cutting edges would be preferable. For more intricate cutting, engraving or boring, a small chisel-like edge or a robust point would be required in, which cases length of edge and lateral curvature would not be issues. For scraping or planing the surface of wood, as in the case of forming or finishing spear shafts, high edge angles would be required and curvature of the edge may be useful, but not necessarily required. For certain aspects of this type of task, sharp-edged notches would be most effective (Hayden 1981), but these are quickly and easily produced on almost any flake edge regardless of any curvature in the flake.

The Optimal Design of Woodworking Tools

Woodworking is a task category in which fall a number of different task mechanics and so will include a range of tool types. In general they would need to be rather robust (thick and strong) with relatively high angled working edges (>50°). The higher edge angle is necessary both to strengthen the edge to withstand the necessary pressure and because for many woodworking actions a very acute edge tends to reduce the level of control that can be maintained over how it behaves on the wood surface. Modern steel woodworking chisels are produced with a variety of working edge angles and are used in ways that stone flakes could not be (e.g., hammered deeply into wood with a hammer or mallet), but chisels designed for tasks that generally involve the shaving down of wood surfaces have *relatively* high edge angles (45° to 60°). If a very sharp, low angled edge is pulled or pushed over a wood surface the edge tends to want to cut deeply into the surface making it difficult to control how much wood is removed in each stroke and making it difficult to produce even surfaces (The wood-plane is a tool designed specifically to address this problem. In this tool the steel working edge is prevented from biting too deeply by having only a thin edge of it protruding from the flat surface of the tool base that is pushed across the wood surface). Relatively high angled (yet still sharp) edges are not so inclined to cut so deeply into the wood and so better control can be maintained over how much wood is removed with each stroke. The greater the edge angle the better the control, although when an edge angle becomes too high (>90°) it no longer cuts well at all and so effective woodworking edges must be within a certain range of edge-angles. Middle Palaeolithic wood working tasks may not have involved only the shaving or planing of wood surfaces; some more complex relief work (etching and grooving) may have also been carried out, but if the manufacture of spears (and perhaps digging sticks and handles) was a dominant task then planing and shaving wood would have been the dominant woodworking actions, and should play important roles in constraining tool blank form and reduction strategies. For the initial process of turning a small tree into a spear, some form of chopper or a saw-like tool would have been most effective in cutting down the tree and removing the larger branches. The chopper need not be a formal tool form; any heavy stone with even a remotely sharp edge would suffice and could be made and discarded at the procurement site (Hayden 1981, 1977). Regularly serrated denticulates may also work well in removing branches. The next steps, removing the bark, removing the swells where branches were attached, and roughing out the shape of the spear would require a very robust flake tool with a sharp, but relatively high angled (50° and 80°) working edge similar to modern wood chisels used for shaving down wood surfaces. *Éclats Débordants*, naturally backed flakes, or flakes with retouch backing would be particularly suitable for such applications as more pressure can be exerted when needed, although hafted scrapers (chisels, adzes) would also be effective. Curvature of the working edge would not be an undesirable characteristic as it allows more of the working edge to be brought into contact with the curvature of the worked item. Curvature can be achieved by either selecting a curved flake blank or by modifying the edge. This modification can take the form of either scraper retouch (retouching an edge so that a concavity is produced) or by removing a single large flake from an edge producing a notch. Blanks selected for wood working of this nature would need to be thick, heavy, and relatively large. I would suggest, based on my own experience, that flakes smaller than around four or five centimeters in maximum dimension would not be effective. Eight centimeters or larger in maximum dimension would be desirable. Ventral curvature would not be a necessary characteristic, but may enhance tool function. For the finer finishing of wood shapes similar tools would be needed, but they would not need to be as large or robust. Scrapers or notches might serve for less demanding woodworking tasks, such as resharpening the tips of dulled spears or digging sticks.

Hafting would not be necessary, but it could be a useful practice with wood working tools because greater applied pressure is needed to work wood and certain types of hafts could provide this. The drawback with hafting these types of tools is that woodworking can dull tool edges rapidly meaning that tool blanks would have to be regularly resharpened and might have to be replaced frequently. It may be that the time and energy necessary for the frequent replacing of blanks could result in the cost of using hafts outweighing the benefits. Whether or not the use of hafts is economical in terms of time and energy may depend on the type of haft, the type of wood being worked, and the nature of the task action, and the frequency and intensity of use.

Other Task Types and Materials

Other general tasks we might expect would include the cutting and scraping of hides (fresh and dry), the cutting/working of non-woody plant materials, and possibly the working of bone and antler. Keeley (1977) found a small percentage of tools that he interpreted to have been used to work bone and to cut non-woody plant materials. Beyries (1988) interpretations included: 5% of the tools examined were used on hides and skins, 3% on antler, and 8% on meat and bone. She apparently finds no evidence of the cutting of non-woody plant materials. Of the tools that Anderson-Gerfaud (1990) examined 9% were interpreted to have been used on hides, 4% on non-woody plants, and 16% were unknown. Shea (1988) reported 12% for bone or antler, 5% for hide scraping, and 5% for cutting non-woody vegetal matter. Shea also reported that 7% of the wear was from impact (i.e., use as projectile tips). As such tasks make up a small component of Middle Palaeolithic life, few specific tools would be required to satisfy them and, therefore, such tasks will play little role in constraining blank production.

This may be an appropriate place to comment on the need for caution in taking the results of use-wear studies at face value. Many general criticisms of the technique and its varied forms have been expressed in the literature and I will not cover all these in detail here. However, even if individual researcher's experimental results are more or less reliable (e.g., Bamforth 1990; Newcomer et. al. 1986) there are other factors that make the straightforward application of these in interpreting past activities difficult. Specific "types" of tools (e.g., "scrapers", "denticulates") may have been used for more than one type of task and so the wear observed on their edges may only be that left by the last task to which they were applied. A second factor is that tools would undoubtedly be regularly resharpened as they were used and so edge-damage would rarely have a chance to develop to any great degree, which would inhibit an accurate "reading" of its actual cause (i.e., type of use-action and especially task material). A third problem is that tools used on a specific task material often inadvertently come into contact with other materials. Examples of this are butchering tools contacting underlying bone, and tools coming into contact with the work surface upon which materials are being cut (e.g. cutting hide on the ground or on a wood work-surface). A final issue is that some expedient tools may not be used long enough to develop wear traces.

If we do accept the results of these specific studies, they would support the suggestion that butchering and woodworking were by far the dominant tasks for which stone tools were used in the Middle (and Lower) Palaeolithic, but that there were a few other common tasks. The limited occurrence, reported by all the analysts, of use-wear associated with working bone or ivory is also supported by the lack of material evidence recovered from sites. Very few items of worked bone, ivory, or antler have been recovered from Middle Palaeolithic contexts.

Hide Working/Processing

The working/processing of animal hides, at whatever stage of development it was at, was likely a relatively common task in the Middle Palaeolithic (Anderson 198X; Keeley 1977). However, the degree of wear that occurs on hide scraping tools depends on the condition of the hide, the nature of the hide preparation (simple defleshing verses tanning) and, as with all tasks, the length of use. Cutting and scraping dry hides could be expected to produce detectable wear (but, see note above on issues in usewear analysis), but if the working of hides was mainly carried out when they were entirely fresh (as even slightly dried hides can produce significant wear) then this task may also, like cutting meat, be going under-detected in use-wear studies (Hayden 1990).

Cutting tools for this sort of task would require the same general morphology as those used for cutting meat; a reasonably long and sharp cutting edge. The tools used for the one task would likely work well in the other.

The general form of *scraping* tools used on hides would depend on whether they were hand-held or hafted, and on the intended results of the scraping. If more pressure and 'bite' are required (as with larger, thicker hides) then a scraper with a shorter use-edge, like an endscraper, might be more suitable. Otherwise a flake with a longer working edge that is either naturally high angled or retouched to have a higher angle, like a sidescraper, may be suitable, particularly for defleshing fresh hides. Anderson (198X) noted that evidence of hideworking was most prevalent on endscrapers, and transverse and convergent convex scrapers. Keeley (1977:126) noted that hideworking wear was the most common type of wear on sidescrapers. For the Middle Palaeolithic, it would be very useful to have some idea of what level hide working technology had reached. It may have still been a rather crude process, producing serviceable, but not fine, leather for "clothes", containers, shelter, etc..

Hide scraping tools would not need to be as robust as wood working tools, but would require relatively strong, regular, and high angled working edges (>80°). This is clearly demonstrated by the form of stone endscrapers, which are almost ubiquitous in Post-Middle Palaeolithic hunter-gatherer assemblages around the globe. That these were used as hide-scrapers is quite clear from the fact that identical tools of stone are still in use among certain traditional groups, for example in Africa (e.g., Gallagher 1977). The size of the blank would depend on both the desired size of the working edge and possibly on processing volumes. For the scraping of a small rabbit hide, for example, a small finger-held scraper ("thumbnail" scraper) might suffice. For larger, thicker hides in greater quantities one would likely need, or at least prefer, a larger, resharpenable scraper (more comfortable to hold) or a hafted one.

The majority of Middle Palaeolithic hide-processing tool requirements could have been satisfied with sidescrapers. Morphologically, these would serve well in less rigorous scraping tasks, such as defleshing. Various forms of sidescrapers, which may represent various stages of resharpening (Dibble 1984), are the most common form of retouched tool in many Mousterian assemblages. For more rigorous, later stages of hide processing, such as scraping off the hair or dried tissues, endscrapers (especially in hafted form) would be the most suitable. These are, however, a relatively rare tool type in Mousterian assemblages. For example, the number of endscrapers in the study samples used here include: Pech de l'Azé IV (level F2) has one typical; le Moustier has four typical and one atypical; Combe Capelle Bas has one typical and one atypical; and Jiboui has one typical and six atypical. (in my experience, many of the items identified by analysts as atypical endscrapers would not serve well as hide scrapers because the retouch was so irregular that it would have damaged the hide). This might be an indication that the processing of hides was not developed to the point where it typically, or perhaps regularly, included finer finishing techniques.

Plant Collection/Processing

There is, of course, little chance of the preservation of plant materials that may have been gathered and used, either as food or construction materials. However, it seems highly unlikely that plants were not collected to some degree for food and for use in constructing serviceable items (shelters, clothing, cording, baskets?). Stone tools may have been useful in the collection and modification of construction materials. For example, grasses and sedges could be gathered and cut to suitable lengths with flake tools and bark could be cut and shredded to produce cordage. However, stone tools may not have been necessary in the gathering and processing of many non-woody plants and, for those situations where they were used, specific tool types or shapes may not have been required. The same forms of cutting and scraping tools used for butchering and working wood may have been serviceable for plant gathering and processing, especially if the latter tasks were infrequent. It seems likely that tasks associated with non-woody plants would have had little influence on general tool blank form.

Hafting

There have been many different forms of stone tool hafting described in the ethnographic record (Anderson-Gerfaud and Helmer 1987) which can be classified by both the degree of importance of the haft form to tool function and simply by the general level of sophistication of the haft. For some tool types the function will put very specific constraints on the haft form. Projectiles (spears, arrows) are a good example of this. The projectile shaft must serve its own function (provide mass, balance and flight stability, a method of propulsion, etc.) in the application of the tool as whole, but must also enable the stone tip to carry out its function (provide symmetry, reduce flight drag, puncture, cut and penetrate flesh) without introducing hindrances like a thick cross-section or bulky lashing or glue. Because of these constraints and requirements hafts like these are necessarily relatively sophisticated (Hughes 1998, 357). In other tools the haft may not be a necessary component and is only employed to enhance the use of an already functional stone tool. In these cases few constraints are placed on what form and level of sophistication the haft may take. A good example of this is an unmodified flake, used perhaps for butchering, that is simply sandwiched in a piece of leather or a partially split branch which is then bound on either side of the flake.

The hafting of tools results in their being divided up into two different parts; the part secured inside the haft and the part applied to the task material. Each part may require different morphological criteria. This is why tools that were obviously hafted, especially those in which the haft has a more intricate role in tool function, often have specific modifications for the hafting (e.g., a stem or notching) that are distinct from the stone tool's form or modifications designed for task application. Regular hafting practices would tend to encourage either the use of specific forms of flake modification (like notching) or a certain level of standardization among flake blanks. This is because it is typically the hafts, rather than the stone tips, that require the most time and effort to produce. While this would be more of an issue with sophisticated tools and hafts, it still holds true for simple tool forms with simple types of hafts. The simple split branch haft, described above, may put few serious constraints on the flakes hafted in it, but if flake blanks of a standardized size and shape are produced it is easier to replace a worn one in a haft with a fresh one than it is to manufacture a new haft to fit the new flake tool. Some level of regularity in the size and shape of flake blanks would also allow greater investment in, and thus sophistication of the hafts. If one can safely assume that the haft will not have to be altered for each new blank replacement, then one will be more inclined to produce more elaborate hafts. Fitting each new blank will require only minimal modification of the blank itself (thinning it or modifying its plan shape with edge retouch).

There is an alternative form of hafting to the use of wooden handles. By simply applying a large wad of vegetal resin, like the 'spinifex' used by Australian Aboriginals (see Hayden 1981) or bitumen produced in other regions, a haft can be produced for non-standardized or irregular sized and shaped flakes. Such hafts will protect the user's hand and so allow the person to apply more force without fear of injury, but do not really allow any increased leverage during use of the tool. These materials can, however, be reconstituted (although not an unlimited number of times) and so when a tool is exhausted it can be removed from the resin haft, and the resin softened and reapplied to a new tool or tool blank.

Hafting in the Middle Palaeolithic

There seems little question that hafting was employed by Middle Palaeolithic people in some regions. The stemmed/tanged bifaces of the Aterian were very likely hafted, but these are restricted in use to North Africa and similar items are not found in European Palaeolithic contexts. It is, at this point, not widely agreed upon among researchers whether hafting was practiced in the Middle Palaeolithic (or earlier) in Western Europe or not, but there are several different types of evidence supporting its use.

Edge and surface wear on flake tools has been interpreted to be the result of the tool moving in the haft during use (e.g., Beyries 1988; Anderson-Gerfaud 1990; Anderson-Gerfaud and Helmer 1987) - (one wonders, however, why the same sort of wear could not be produced by a dirty, gritty hand or leather finger guard).

The nature of fractures, on some tools, are interpreted as either of a type that would result from pressure applied to the flake tool while it was secured in a haft (e.g., Anderson-Gerfaud 1990; Holdaway 1989) or from impact (Shea 1988, 1993).

These impact fractures are associated with the interpretation, by some researchers, that Mousterian and Levallois "points" were the tips of spears. If this was the case then hafting is obviously implied. However, this interpretation of Middle Palaeolithic points is not universally accepted and some researchers would not agree, without more convincing evidence, that these were projectile tips. There are those who have presented cases for both sides of the debate (Shea 1988, 1993; Holdaway 1989; Beyries 1988; Anderson-Gerfaud 1990; Plisson 1988; Solecki 1992). Recently, more direct evidence relating to the question of Levallois point use has been presented with the discovery of what appears to be the tip of a Levallois point "embedded" in the cervical vertebra of a wild ass in Syria (Boëda *et al* 1999), although the medial flake fragment in question was found inside the neural canal and it is not clear from the illustrations or photographs provided that it had to have passed forcefully through the wall of the vertebra to have ended up there.

Another potential form of evidence of hafting is bulbar thinning. This is suggested to be a method of thinning the hafted end of a flake so that it will fit more readily into a haft (Beyries 1988). Bulbar thinning, though not a very frequent practice, is not uncommon. Several items from the sample assemblages used here had obvious bulbar thinning (see Plates 13, 14 and 15 in Appendix A).

Standardization of tool widths among some convergent scrapers has been suggested to be an indication that these were hafted (Beyries 1988). Based on the location of the wear identified by Beyries, these tools would have presumably been inserted in the ends of notched wooden handles. Thieme (1997:808) recovered two short (20-30 cm) wooden shafts from the site of Schöningen that look very much like their ends were intentionally notched, with the most logical interpretation being that these were tool hafts (flint flakes were found in close association, although details on these were not provided). Along these same lines, Limaces, occasional tools in Mousterian assemblages, very closely resemble adze 'slugs' (exhausted adze blades) from hafted adzes in Australian aboriginal tool kits.

The final line of evidence involves recent discoveries in both Eastern Europe and the Middle East (Boëda et. al. 1998) of small, but substantial Middle Palaeolithic pieces of tree sap resin and bitumen. Several pieces were recovered from the site of Königsaue in Germany, one with fingerprints and the indentation or mold left from the flake tool that had been inserted in it (Grünberg 2002).

If we accept that Neandertals did haft some tools then, depending on the type of haft, this may imply certain constraints on tool form. As discussed above, with manufactured wooden hafts it is typically the haft, rather than the stone tool, that represents the greatest investment of time and labour. This would be especially true when the stone tools are simple, unmodified (or limitedly so) flakes. Producing or modifying flakes that can be readily fit to an existing haft would be easier than producing a new haft, or significantly modifying a used one, to fit a new flake. If hafting was a commonly employed practice with Middle Palaeolithic flake tools then a certain degree of standardization among some flakes produced would be a reasonable expectation (If, however, hafts were more commonly produced by simply molding bitumen over one end of the tool and letting it dry, then constraints on tool form may be fewer). The appearance of a certain level of standardization ('regularity' may be a better term) has, in fact, long been suggested to be a characteristic of the Middle Palaeolithic that distinguishes it from the Lower Palaeolithic. This level of generalization should be viewed with caution, however, because, among other things, its accuracy may depend entirely on where one places the boundary between the Lower and Middle Palaeolithic periods (another issue lacking consensus).

The use of hafting technology also brings with it other importance considerations. If one uses unmodified flake tools in an unhafted state, and raw material economization is not a constraint, then it would be easy to simply discard the tool when the task at hand is complete or to replace it with another when it becomes too dull. If, however, one has taken the time to manufacture a haft and secure the flake tool in it (even a simple haft like molded bitumen) then it now represents a more significant investment and cannot be so easily discarded without wasted effort. A tool like this would be kept and reused over and over, with maintenance and resharpening when needed, until it was too small or too steep to resharpen. Once it could no longer be maintained it would be removed from the haft, discarded, and replaced with a new flake. Such a scenario is, in fact, well supported by Dibble's (1987) interpretation of Mousterian scraper variability. These hafted tools would have to be carried around from site to site and so, for pedestrian hunter-gatherers, could become factors as material possessions in mobility constraints. The functional advantages of hafting would be constrained by the extra weight that these tools would add during travel. To make practical sense, hafting would have to provide net benefits over the transport of functionally equivalent volumes of raw material for hand-held flake strategies.

Hafting is a realistic and effective strategy for addressing certain tool requirements. It is used by modern groups, it has been used very extensively around the world in the recent and distant past, and there is no reason to expect that it could not have been employed by European Middle Palaeolithic people in the right conditions. The evidence in favour of hafting, as presented by Beyries (1988), Anderson-Gerfaud (1990), and Anderson-Gerfaud and Helmer (1987) is not conclusive, as I see the possibility that the nature and location of the damage they attribute to hafting wear could be explained in other ways. However, when their results are viewed in conjunction with Dibble's (1987) interpretation of Mousterian scraper morphological variability a pattern emerges that strongly suggests the use of hafting of scrapers, at least. Although the results from Beyries' (1988) use-wear analysis, relative to tool types and functions, are tentative (due to her small sample sizes for each tool type), some potentially significant patterns are suggested. She found significant evidence of hafting on the symmetrical convergent scrapers, but no evidence of hafting on the asymmetrical convergent scrapers or on the non-convergent scrapers. In light of Dibble's (1987, 1984) interpretation that convergent and transverse scrapers simply represent later stages in a common process of use and resharpening of flake tools, Beyries' results may reflect a common practice of hafting these tools. It would be logical to expect that once the effort had been made to haft a flake it would then tend to be more extensively reused and resharpened. Single-edge and double scrapers (non-convergent) would represent flakes that had either been employed unhafted (and thus were more easily discarded at any point in the use/resharpening process) or else had been discarded from the haft before extensive resharpening modified the plan-view of the tool (towards convergence of the lateral edges) and, as reflected by Beyries' observations, before wear accumulated on the proximal portion of the flake from contact with the haft.

While Beyries found no evidence of hafting wear on any other tool types, it should be noted that with some types of hafted tools there might be little or no movement of the tool in the haft to produce identifiable wear. Situations where this lack of movement might be expected are when the level of pressure applied with the tool is limited and in tools where more of the flake is in the haft than out, reducing the amount of leverage that would be applied to tool in the haft during application. For tools in which more of the flake is protruding than is secured in the haft, the amount of potential leverage, when pressure is applied to the working edge, would be significantly increased. Such may have been the case with the scrapers discussed above.

Satisfying Hafting Constraints

The nature of the hafting used would have varied somewhat, at least in terms of the different functions of the stone tools. Tool types represented by double-edge and convergent scrapers would seem to have been hafted at the end of a [wood] shaft resulting in a tool closely resembling a modern knife (fig. 5.2), and in such a form could have been used for cutting. For this type of haft the most important morphological feature of the blank is that its hafted end is of a size and shape that matches, as closely as possible, the end of the haft into which it must fit. It does not have to match perfectly to work, but the closer the match the greater the potential to achieve a solid haft. In general terms, if we are talking about an elongated wooden handle (of perhaps two to three cm in diameter) then the hafted end of the flake blank should preferably be about this same width over enough of the length of the end inserted in the hafted so that a large enough portion of the blank fits into the haft to hold the blank securely. If too much of the blank protrudes from either side of the haft then it becomes more difficult to properly secure. For this type of haft, blade-like flakes (or at least elongated flakes) would be most serviceable. Roughly parallel-sided blanks of the same width as the haft would allow the maximum portion of the blank to be enclosed in the haft.

If transverse scrapers had been hafted, it would make more sense hafted in a manner that would allow them to be used as adzes or for scraping harder materials or in a manner similar to ulus used by more recent groups in the North American Artic.

While use-wear analysts have so far found no evidence of hafting on other Mousterian tool types, like notches or denticulates. It is possible that these tools were hafted in a manner that did not produce wear (e.g., the hafting was so secure that there was no movement of the blank in the haft): this might be expected with the use of resins like bitumen or spinifex. However, notches and denticulates are very similar to unhafted, expedient, short-lived, hand-held tools used by Australian Aboriginal groups and are unlikely to have been hafted.

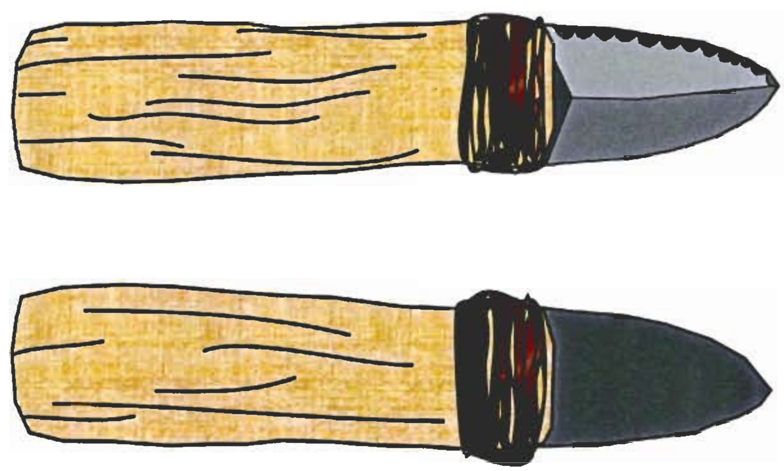


Figure 5.2 Type of haft in which blank width is an important consideration.

<u>Physiological Constraints - Hand Strength</u>

This is a constraint which has seen little scrutiny by past researchers. The suggestion here is not that this is a factor that would likely dictate whether individuals could or could not successfully practice specific technologies. Rather, it is suggested that variability in hand/arm strength and manual dexterity may affect the level of efficiency and reliability with which different technologies can be carried out, and that if certain levels of efficiency and reliability could not be achieved due to this constraint then certain technologies might need to be modified or replaced. Individual hand strength may be one of the least examined factors in stone tool technologies (but see Trinkaus and Villemeur 1991; Niewoehner et. el. 1997). Individuals with relatively little hand strength may well approach a task with different strategies than someone with greater hand strength. With respect to tool morphology we could expect that an individual with greater relative strength to be less constrained by flake size. These individuals would be better able to employ smaller and larger flakes that an individual of lesser strength would find impossible to maintain a serviceable grip on. The potential influence of variability in hand strength on other aspects of tool morphology needs to be further investigated.

Because we tend to use AMH's as benchmark analogs (whether the data comes from prehistoric contexts, ethnographic sources, or individual researcher experience) for our general perceptions and opinions about lithic technology, when we examine the behaviour of other hominid species we should take potential, significant physical differences into account. While increased hand strength does not equal increased dexterity, nor does it mean decreased dexterity and there is a potential for greater strength to allow better control in the application of force. This is particularly notable in flint knapping. While individuals with lesser hand/arm strength are certainly not prevented from successfully practicing knapping techniques, an individual with greater hand/arm strength will have a greater choice in the range of forces applied with a percussor and, perhaps even more importance importantly, will have better control and choice in how to allow the item being struck (core or tool) to absorb that force. Successful knapping depends on the choice of angle and amount of force applied, and the difference between success and failure is measured in very slight degrees of angle and force.

Hand Strength in Middle Palaeolithic Southwest France

It is more difficult to imagine this as a factor in the choice of reduction technologies than it might be as a factor in the choice of tool forms. Many of the lithic strategies carried out by Neandertals: biface production, amorphous core reduction, various types of prepared core reduction (Levallois, disc, blade), and bipolar core reduction were carried out in similar manners by morphologically modern people in later time periods. This suggests that Neanderthals were no less dexterous than modern humans, at least in the context of stone tool production. This is also supported by current research on Neanderthal skeletal morphology which indicates that, contrary to past assertions (Boule 1911-13; Sarasin 1931; Musgrave 1971), there is no reason to suggest that Neanderthals did not have the same range of manipulative postures as modern people (Niewoehner *et. al.* 1997; Trinkaus & Villemeur 1991). However, evidence has been presented on Neanderthal skeletal morphology that does indicate that, as with their limbs in general, Neanderthals had more powerful hands and that this relative increase was realized in both their power grip and precision grip (Trinkaus & Villemeur 1991:259) which would allow more powerful stroke and tool movements.

Greater general hand strength and a more powerful precision grip would potentially allow an individual to better manipulate a very small, unhafted tool that someone with lesser strength could not effectively use unless, perhaps, it was hafted. A more powerful grip on a small flake tool will also better protect the individual's hand from potential damage from sharp edges. From this point of view we might expect to see the use of smaller, *unhafted* flakes in the Middle Palaeolithic. We might surmise that the majority of the small tools typical of the later Upper Palaeolithic and Mesolithic were used in composite tool forms. However, greater overall strength would also allow the more efficient wielding of larger tools as well, in which case we might expect to see a general trend towards larger flake tools, when compared to later periods, to suit the capabilities of Neandertals. Adzes could have been larger and used with greater force for woodworking. It must also be noted that, while greater hand strength may allow an individual to effectively use a very small tool that would otherwise be unusable without hafting, this would not prevent that individual from hafting some of their tools in order to further increase the level of pressure that could be applied with them, and their potential range of applications.

It is difficult to imagine (besides being very difficult to test) exactly if and how greater arm and hand strength would have affected their knapping abilities. It is possible that this would allow a knapper to more successfully remove flakes from smaller cores. Based on personal experience with direct percussion knapping, it can be very difficult to remove flakes from a small core or tool edge when the core or tool is held free-hand (knappers can, and sometimes do, choose to brace the object being struck against something [one's leg or an anvil of some type], but this can drastically change the mechanics of the flaking process and is not always an optimal solution - Hayden [1981] noted this among Australian Aboriginal groups as well). When holding free-hand a core or tool and trying to remove flakes from it, typically, much of the force of the impact from the percussion tool is absorbed by the inadvertent movement of the arm holding the object being struck. This is not as much an issue with softhammer percussion because the speed with which these percussion tools contact the core or tool is much greater than with hammerstones and so at the point of impact there is less time for the energy of the blow to be translated into motion. Also, with large cores or tools this is not an issue because the mass of these objects prevents them from moving easily and so the energy of a blow, even with a large, slow moving hammerstone, is not so readily translated into movement and flakes are more easily formed. It is possible that a significant increase in arm and hand strength would allow a knapper to hold a small object more solidly, while trying to remove flakes from it, and thereby reduce the degree of energy lost in inadvertent movement.

Raw Material Quality

Different raw materials from which tools are made can place different constraints on tool form. With coarser grained materials cutting edges may need to be even more acute, in order to function properly, than tools of finer grained materials. If tools function less effectively because of raw material qualities, larger tools may be necessary so that greater force can be brought to bear. Some materials may be less durable as well, which may make them less suitable for some tasks (see Horsfall 1987 for a discussion of this issue with respect to grinding tools). Raw material quality likely played little or no role in stone tool strategies at the four sample sites.

The size of pieces of available raw material can have a very serious effect on tool form. If the raw material is only available in small pebble sizes and shapes, then only small flakes and small pebble tools will be possible. Raw material size and shape likely did play some role in lithic strategies at the four sites.

Raw Material Limitations in the Middle Palaeolithic

For the manufacture of simple, serviceable stone tools the only requirements are that the raw material comes in large enough nodules, is fine-grained enough to produce suitably sharp edges, that it is homogeneous in both composition and structure, and that it is brittle enough to fracture appropriately under applied pressure or force. The vast majority of stone tools recovered from Middle Palaeolithic contexts in Western Europe, and in SW France in particular, are of relatively high quality cryptocrystalline precipitate rocks, i.e. flints. Such flint is readily available almost everywhere in SW France (Hayden 1980:2; Bordes and de Sonneville-Bordes 1970-71, 67; see also Féblot-Augustins 1999). This raw material has few, if any, limitations in terms of potential tool morphology. Almost any type of flaked stone tool that has been manufactured can potentially be made from the flints typical of SW France. There are sites where other (lower quality) types of raw materials, such as quartzite, have been recovered. Quartzite does have realistic limitations in what can be made from it. These limitations do not, however, prevent the manufacture of bifaces (at least large ones, although even very delicate, pressure flaked projectile points are made from quartzite in some regions - e.g., the American Plains and Southeast), or simple flake tools of any size (within the limits of the size of the core or nodule). Producing standardized blades, especially small ones, from quartzite would be difficult and would likely have a very high rate of failure.

In the four sample assemblages from the study sites employed here, exotic raw materials are almost non-existent. Essentially 100% of the raw materials in the sample assemblages of Pech de l'Azé IV, Combe Capelle Bas, and Jiboui are immediately local (<1km). At le Moustier the raw materials come from up to 10 km away, but exotic raw materials are very rare. In terms of quality, for all four study sites, the available flint is of good to very good quality. This constraint would not have play much of a role at these sites.

2/ Potential Constraints on Tool Blank Production

The previous section addressed those constraints that influence the form of the tool blanks themselves. This section addresses those factors that directly constrain blank production strategies. Some constraints specifically affect the way in which lithic raw materials can be optimally reduced; they limit the available options in the actual production process. These include raw material availability, raw material quality, raw material size and shape, physiological capabilities, and available technologies.

Raw Material Availability

Access to suitable raw materials has become a popular area of research over the past decade (e.g., Kuhn 1992; Féblot-Augustins; Gamble 1993; Dibble 1985; Geneste 1988; Brantingham and Olsen 2000). It is understood that, at its most basic level, this potential constraint will influence the level of necessary economization of raw materials. The obvious extremes of situations are those where either there was relatively easy access to large quantities of material or those where access to even limited amounts of material was restricted. It is readily apparent that groups faced with one or the other situation will necessarily have to develop different strategies of stone tool production and use. It is likely that only rarely were groups faced with such simplified scenarios of raw material access. In reality, when we talk of availability among hunter-gatherers, we must consider more than just the simple distance from the raw material source to the location of tool production and use. Other considerations include: the relationship of all potential raw material sources to the spatial and temporal patterns of group movement in a region; seasonal variability in raw material availability (e.g., diminished access due to snow cover or frozen ground); the amount of raw material (either in cobble, core, or tool form) that a group could carry with them; whether groups had to rely solely on primary/natural sources of raw material (i.e., exposed geologic sources), or whether they counted in part on having access to materials, for tools, left at sites by previous occupants. The role that each of these factors plays in a specific group situation will influence the nature of that group's stone tool production strategy.

In terms of categorizing distances between sources of lithic raw materials and sites where they were discarded, I have employed Geneste's three levels (1988; see also Gamble 1993:35-36), which he noted from Middle Palaeolithic sites in SW France as categories of distance that had a common, directly inverse relationship with the percentage that a raw material source was represented in an assemblage.

local = within 5 km
regional = 5-20 km
exotic = 30-80+ km

Raw Material Availability in Middle Palaeolithic Southwest France

As mentioned above, good quality raw materials are available in relative abundance in drainage systems throughout most of Southwest France. Several recent, extensive studies have examined the relationship between the lithic raw materials recovered from sites and their sources in this and other regions of Western and Central Europe (e.g., Féblot-Augustins 1999; Dibble & Lenoir 1995; Geneste 1985; Turq 1992). The data collected by these researchers contribute significantly to the reconstruction of Middle Palaeolithic lifeway patterns, the degree of conscious economic planning and foresight abilities, and established traditions of land-use. The overall nature of Middle Palaeolithic mobility patterns is illustrated by the similar general nature of lithic and faunal remains recovered from most of the major sites investigated to date. Although there was an obvious accumulation of lithic and faunal materials in Middle Palaeolithic sites, when stratigraphic units at these sites are examined individually it is apparent that each occupation of one of these sites was of very short duration. The relatively small quantities of lithics and faunal remains recovered from individual stratigraphic levels, that must represent hundreds or thousands of years, preclude the possibility that occupations, even if groups were very small, could have been of any significant duration (Butzer 1986; Rolland 1999). The indication is that Middle Palaeolithic mobility occurred as frequent moves of a base camp from which task groups (whether specialized and focused on a specific goal or more opportunistic and generalized in its goals) would come and go, indicating more of a forager settlement system.

It is in large part, the nature of Middle Palaeolithic mobility, as it relates to the procurement of all resources, that will dictate the availability of lithic raw materials (assuming that trade was an insignificant factor in raw material distribution). If suitable types and quantities of raw materials are available close to (<5 km) every site that a group uses in its annual movements, the group will embed the acquisition of lithic raw materials within these movements (Binford 1980). Otherwise, they must rely on special lithic acquisition task groups carrying out forays from base camps. The ease with which a group can accommodate lithic raw material acquisition into their movements, which is dictated by the general level of abundance of lithic raw materials within a region, the degree of mobility, the amount of raw material required throughout the year, and the relationship of lithic sources to other necessary resources, will determine lithic raw material availability. Considering the degree of general availability of suitable lithic raw materials in Southwest France (Bordes and de Sonneville-Bordes 1970-71; Féblot-Augustins 1999; Turq 1989, 1990), fitting or embedding the acquisition of these materials into most patterns of mobility should not represent any serious difficulty in most regions. This is not to say that there would be no variability between different Middle Palaeolithic sites in the need to economize raw materials. Some sites were situated very near sources. At these sites, economization of raw material would be less of an issue. One way to determine degree of raw material economization is through the examination of flake to core ratios (Dibble & Lenoir 1995: Chapter 12; Dibble and Rolland 1992; and Dibble 1988). Under circumstances where economization is required, cores will tend to be reduced to a greater degree than in circumstances where there is less concern for raw material. This increase in reduction intensity will result in a larger number of flakes produced per core (Dibble 1988:193; Roth and Dibble 1998: 52). Henry (1989:147) refers to this as extending the productive life of a core. Also, frequency of retouch, while potentially related to tool function and task types to some degree, might also serve as a measure of raw material economization (e.g., Riel-Salvatore and Barton 2004). Figure 5.3 below plots frequency of retouch against flake:core ratios with the presumption that higher values of both likely reflect levels of raw material economization to some degree.

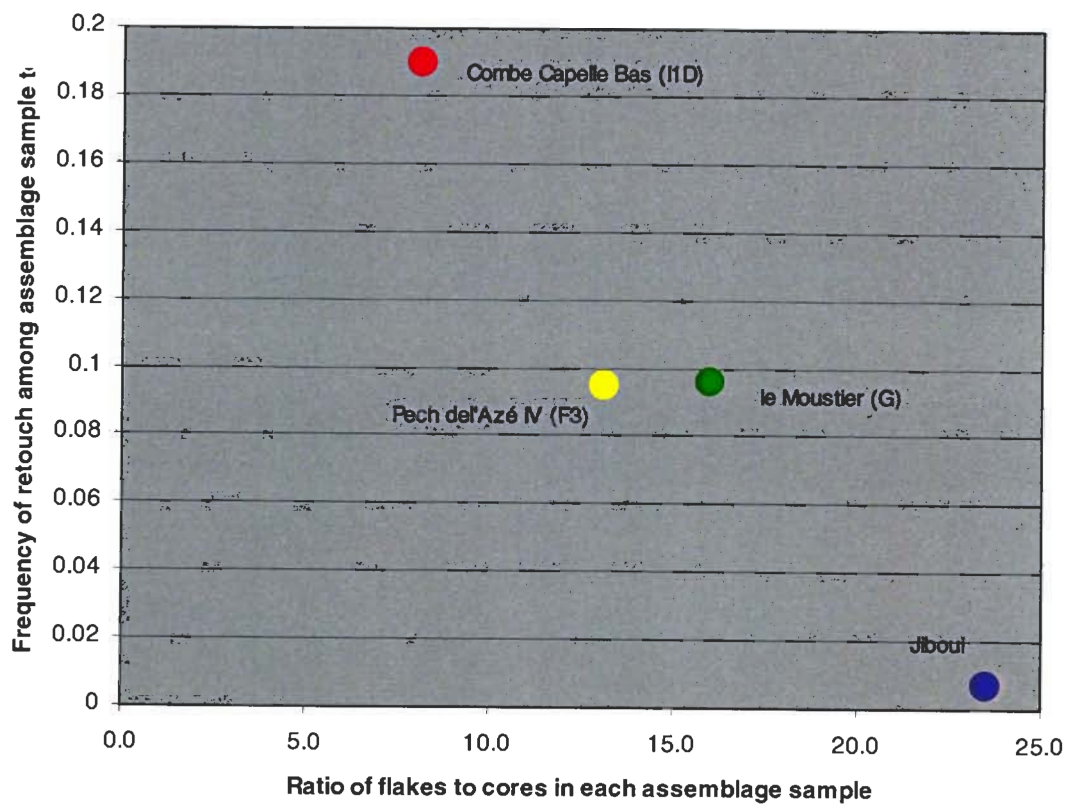


Figure 5.3 Frequency of retouch & flake:core ratios for the four assemblage samples.

The low flake:core ratio at Combe Capelle Bas makes sense as this site is situated directly on a flint source and we might expect the lowest degree of raw material economization here. For Pech de l'Azé IV, where the flint sources are also local (though not all are actually at the site), the flake:core ratio is higher. At le Moustier, where the flint comes from both local and regional sources, the flake to core ratio for level G is higher yet. At sites such as le Moustier, where lithic sources are not just local, economization may have been an important consideration and raw material for tools was either brought to the site with the group when it arrived or was brought back to the site by a task group. Jiboui has the highest flake:core ratio of the four sites in spite of the fact that it is situated very near a raw material source. However, the interpretation that this site was used simply to exploit this raw material source would explain the intensive reduction carried out there. The low frequency of retouch at Jiboui also make sense if people were generally only reprovisioning tool kits here and not carrying out any other tasks. Patterns of frequency of retouch at the other three sites is more difficult to explain. Combe Capelle Bas has the highest frequency of retouch, but large quantities of large flint nodules are available at the site. Of the three main sites, we would expect raw material economization to be least important at this site. It may be that retouching blanks relates as much to specific tasks carried out at a site as it might to raw material economization.

However, there are other factors that could have potentially affected raw material availability. These include impediments related to seasonal or climatic-phase events. During winter, snow cover or ground frost could have effectively prevented access to many sources of stone. Likewise, during warmer months, higher water levels in lakes or rivers could have also covered sources (Hayden 1987:35). As these are seasonally occurring factors, we might expect a parallel, seasonal change in types of raw materials used and/or in levels of economization. During colder and, particularly wetter (increased precipitation) climatic phases, snow cover would have occurred over larger areas and would have lasted longer (the whole year in some regions and elevations), and permafrost would have been a factor at lower latitudes than today. Patterns observable in flake:core ratios throughout the sequence at Pech de l'Azé IV may reflect changing patterns of seasonal access to raw material sources, although determining the actual relationship between the patterns in the table below and climatic phases will require a better correlation between climatic phases and the site deposits.

Level	Levallois Index	Graph of Indices	Age/Climatic Regime
F1	5.1		C. 35,000 bp - very cold & dry
F2	3.9		
F3	4.2		
F4	8.0		
G	7.1		
H1-2	5.7		
I1	13.4		
I2	18.4		increasingly cold conditions
J1	22.0		increasingly warm conditions
J2	12.2		
J3	24.3		
J3A	22.0		
J3B	21.0		
J3C	15.1		
X	13.4		
Y	14.7		
Z	12.7		c. 80-130,000 - warm and wet

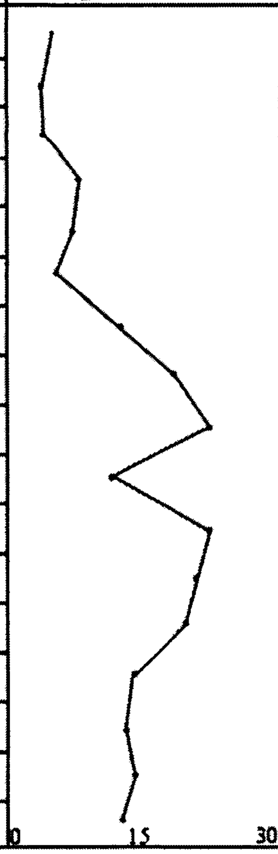


Figure 5.4 Flake to core ratios for the stratigraphic levels in Pech de l'Azé IV and the broad climatic trends associated with the depositional sequence.

The greatest flake:core ratio at the top of the deposits in a time period (in the latter half of OIS 3 and so approaching the last glacial maximum) may reflect severe stress on raw material due to increased snow cover and permafrost reducing access to many sources (e.g., Dibble 1991:36). The lowest flake:core ratios in the J layers also coincide with the use of somewhat more exotic flints. These layers, while still dominated by the typical local raw materials, include significantly larger, blade-like flakes on non-local materials which lack corresponding cores. This may reflect increased access, due to the occurrence of warmer conditions, to other raw material sources.

Raw Material Size and Shape

The size and form of raw material nodules can be a severely limiting factor in what technologies can be applied to them and the form of the products produced from them (Hayden et. al. 1996; Brantingham and Olsen 2000). In terms of size, larger nodules allow the production of larger flakes, more latitude for preparation of the core in order to produce specific flake forms, and also provide, through the course of their reduction, more opportunities to correct any mistakes that might render a smaller core useless. In general, larger nodules have a much greater range of utility than smaller ones. Very small nodules (c. <5cm), although still potentially usable, can often only be reduced using bipolar reduction techniques which can result in usable flakes, but allows for little control over their form.

However, shape is also an important variable and can often mitigate small size. Tabular or lenticular shaped nodules are typically more easily knapped than more spherical ones because they present natural striking platforms. Spherical nodules present no natural platforms from which to begin removing flakes in a controlled manner and it is necessary to use less controllable techniques, like bipolar reduction or throwing the nodule against a larger stone, in order to remove initial spalls and produce flake scars and angles on the nodule that can then serve as striking platforms for more controlled reduction. Flint, particularly in types that form in marine conditions, often occurs in complex, globular arrangements with knobby, amorphous appendages (these forms have been attributed by some to the infilling, with silica rich sediments, of burrows created on the ocean floor by crabs or other organisms -- Turq 1995). Flint in Western Europe occurs very commonly in such nodules, which are often referred to by the French as 'rognons' ('kidneys') because of their vague resemblance to internal organs. Typically, these nodules include a larger central mass, from which good-sized cores and flakes can be produced. The amorphous appendages are simply removed during the initial reduction and treated as waste. The complex form of such flint types makes their initial reduction rather easy. Simply breaking off one or two appendages provides surfaces with angles that will allow controlled flaking.

Raw Material in the Perigord and at the Study Sites

There are regions in the world where raw material quality would have been a significant constraint, but such was not likely the case in the Middle Palaeolithic of Southwest France. While some materials like obsidian, that may be the best raw material for practicing some technologies (e.g., highly standardized prismatic blade production), are not available, there is an abundance of flint (Bordes in Hayden 1980:2; Bordes and de Sonneville-Bordes 1970-71:67), including types that are serviceable for any lithic technology (including blade production). Among the types of flint available here there is wide variability in quality including some types which are very poor or even unusable for flaking, although most are of relatively high quality. There are also other material types available in the Perigord, such as quartz and quartzite, which were used on occasion in the Middle Palaeolithic (e.g. Jaubert and Farizy 1995), but these usually make up very small percentages in site assemblages. For example, at Combe Capelle Bas and Pech de l'Azé IV, flint was the only raw material used, and at le Moustier, where some of the flint comes from regional sources, non-flint materials (quartzite) make up about 0.4% of the lithic assemblage.

Raw Materials Employed at the Three Study Sites

Pech de l'Azé IV

As at Combe Capelle Bas, the most common types of flint in the assemblages of Pech de l'Azé IV are Senonian (Gray, Black, and some Blonde). The exact formations from which these come is not known yet, but sources of these materials do exist in the immediate vicinity of the site (Dibble and McPherron 2003). However, unlike the Senonian flint available around Combe Capelle Bas, the nodules around Pech de l'Azé IV tend to be smaller (5 to 20 cm) and tend to be more irregular, twisted, and complex. They also often do not include one larger central mass and the bulk of the flint in a nodule can occur as amorphous, cylindrical appendages and nodes or swells called 'pustules'. Within these various parts of each nodule the quality of the flint is, however, typically quite high.

With nodules of this form more time would be required in the initial reduction stages to extract, from the different portions of a nodule, lumps of flint that were of a usable quality and size. Also, with raw material in such size and form, the maximum size of any flakes produced from them is severely restricted from the outset.

Le Moustier

The majority of the flint employed at le Moustier (99.6%) was also Senonian. It is available in the limestone formations and the alluvial deposits throughout the Vezere Valley, including the immediate vicinity of the site of le Moustier (Soressi 1997, 2002). However, one may have to travel several kilometers to find the higher quality materials (which make up the majority of the site's assemblage) in either alluvial or original formation contexts, and much of the material used at le Moustier may have come from up to 10 km away. Like the material available at Combe Capelle Bas, this Senonian can be found in larger nodules or slabs.

Combe Capelle Bas

Combe Capelle Bas is situated on top of a source of Campanian flint. The Campanian is one of several major Upper Cretaceous formations in the Aquitaine Basin and it and the Senonian are the only ones that crop out around Combe Capelle. Both these formations are very rich in silica deposits and flint occurs as slabs, nodules and silicified sponges (the latter are not suitable for knapping). In the Couze valley, where the site is located, the Middle and Upper Campanian in particular are exposed. These deposits contain flint that can occur in very large slabs and nodules (40 to 60 cm). The most common types of flint that occur around the site are Gray, Black, and Beige Senonian Flint and Truffel Flint. While there is variation in quality, size and shape between these different flints, in general they tend to occur as oval, oblong or slightly twisted nodules between 10 and 30 cm in length, or as slabs of 5 to 15 cm in thickness (there are few of the more complex rognon shapes that are common in other regions). In terms of their suitability for knapping they are judged to be from mediocre to very good (Turq 1995: Appendix I).

Jiboui

Formations in the mountain of Belle Motte, comprising the west side of the col in which the site is situated, include layers of nodules of flint. 100% of the raw materials in the Jiboui assemblage come from this source (Tillet 2001: 94-97), which includes medium to large sized concretions, at the centres of which are nodules of high to very high quality flint.

Table 5.1 Summary of raw material quality, form & availability for all four sites.

Site	**Raw Material Distance**	**Raw Material Quality**	**Raw Material Form**
Combe Capelle Bas	Local (on site)	mediocre to very good	large slabs & nodules
Pech de l'Azé IV	Local	very good	small, irreg. nodules
Jiboui	Local	good to very good	med to large nodules
Le Moustier	Local & regional	very good	large slabs & nodules

Available Technologies

I propose that different lithic technologies or strategies represent different adaptive responses to specific circumstances and that any one technology will only be suitable in certain circumstances. At different times and different places throughout prehistory, however, only certain lithic technologies were part of the cultural repertory or were viable. Faced with a set of circumstances dictated by their lifeway, a group would have to select a lithic technology that, with possible and appropriate modifications, would be suitable. By technologies or strategies I mean here any single technique, or series of techniques, used to either produce flakes from a core for use as tools or to modify the form of a flake or a core into a tool itself. Some examples of basic technologies or strategies include: biface production (biface production can be further sub-categorized into hardhammer, billet, and pressure flaking), bifacial reduction (the distinction between these being that in the former the biface is being produced as a tool while in the latter the biface serves as a core from which flake tools are removed), blade production (with its varieties), bipolar core reduction, amorphous core reduction, Levallois core reduction, groundstone technology, and maintenance/resharpening techniques.

Available Technologies in Southwest France

Of the common types of lithic reduction technology (discussed above), there is evidence that most were available to Middle Palaeolithic people. Biface technology (both reduction and production) had been around since well back in the Lower Palaeolithic (although there is little evidence for the appearance of pressure flaking prior to the Upper Palaeolithic), as had been amorphous core reduction, and bipolar core reduction (Hayden 1980).

Prepared core technologies, such as blade production and single-surface core reduction (e.g., Levallois and disc cores), which may have had their genesis in the late Lower Palaeolithic (Rolland 1995, 1986; Tuffreau 1995), were definitely available to people in the Middle Palaeolithic. The Blade production techniques used in the Middle Palaeolithic were, however, not as precise, or as standardized as the most sophisticated technologies which appeared later at the beginning of the Upper Palaeolithic (Conard 1990; Newcomer 1975).

There is no evidence that groundstone cutting technology was available at any time in the Palaeolithic. This is not seen here as a matter of a lack intellectual or physical capabilities, but rather due to either a lack of need for the advantages of this specific technology or, more likely, the lack of the social structures and relations that, in later periods, that allowed or influenced the production of such labour intensive items (Hayden 1998; Horsfall 1987).

Pressure flaking, as it is employed in projectile point production, is a technique which only makes sense when applied to the production of small, thin tools with standardized shapes. The ability to remove the long thin flakes that make this technique so useful in the production of small, thin projectile points is seriously compromised when the technique is attempted on the edges of unmodified flakes and especially on flakes with higher angled edges.

This does not prevent the application of pressure, with either hardhammers (Steenhuyse 2004) or billets, to effectively retouch flake tool edges (expedient knife retouch), but this would not produce the type of edge generally associated with the type of *pressure flaking* traditionally associated with the term and would not require the specialized tools also associated with traditional pressure flaking. Other than grinding and pressure flaking, most other forms of maintenance/resharpening were available in the Middle Palaeolithic. These include bifacial (hardhammer or billet) resharpening, endscraper retouch, backing retouch, notching, and expedient knife retouch (Hayden 1987).

Besides the technologies that are common in many time periods and regions of the world, European Middle Palaeolithic knappers also practiced some less common ones, such as Kombewa reduction and 'sausage slice' reduction. The former involves the removal of 'Kombewa' flakes (also known as Janus flakes) from the ventral surface (usually at the bulb) of a larger flake. This results in ultra-sharp flakes. In some areas of Africa during the Early Stone Age, very large Kombewa flakes were produced (Schick and Clark 2003:11), but the Kombewa cores and flakes typical of Mousterian industries are quite small (<2 cm) (Dibble and McPherron 2003). Assuming that the regularity with which they occur in Mousterian assemblages indicates that they were intentionally produced, the task for which they were intended must have been of a delicate nature, such as more delicate or accurate hide cutting.

'Sausage slice' reduction refers to the removal of flakes from the end of flint nodules that naturally occur in tubular 'sausage' shapes. Flakes removed from the end of these nodules tend to include a large portion of cortex which results in their similarity to semi-circular sausage slices.

Other Design Considerations

There are several aspects of Middle Palaeolithic lifeways that would have factored into the design of tool forms or reduction strategies to varying degrees. These include the processing volumes involved in different tasks, the desired lifespan of tools, the reliability verses maintainability of tools, the degree of desired multifunctionality of tools, the portability of the reduction technology itself, and time constraints.

Processing Volumes, Quantities of Tools Required, and Tool Reliability, Maintainability, and Multifunctionality

The number of tools required to satisfy the tasks faced will influence the nature of the flake blank and the choice of production method. This constraint is directly related to tool morphology requirements, tool lifespan (discussed below), raw material economization constraints, mobility, seasonality, hafting, and tool maintenance techniques. If the number and rate of occurrence of tasks and the associated volumes of material to be processed are relatively low then a reduction technique that does not specifically focus on producing large quantities of tools with specialized shapes may be adopted (in general, with low processing volumes raw material economization should not be a significant issue) (Hayden et. al. 1996). In these situations, depending on weight vs. mobility constraints and tool form requirements, people could either use a number of informal flake tools, or they could use one generalized tool. The advantages of the simple, unmodified flake tools derived from less complex reduction strategies (e.g., amorphous core reduction) are that the low level of time and labour invested in their production allow them to be readily discarded after their use and they present a highly adaptable tool kit. Flakes can be modified with little effort into forms which are specialized or which could potentially serve a wide variety of tasks. The disadvantage of simple flake tools is that they are often quite small and are less maintainable than more formally shaped tools, like bifaces, and at the individual level are less versatile, especially after they have been modified once (Andrefsky 1998; Bamforth 1986; Kelly 1988). A collection of flakes may be turned into a collection of different tool types, but one flake is far more limited in its potential forms. One important advantage of specially shaped tools, designed for long-use lives, like bifaces and hafted tools, is that they are highly maintainable which allows them to be retained and used many times before needing to be replaced (Torrence 1983, 1989; Kelly 1988). The disadvantages are that they usually represent significant time and energy investments in which case it only makes sense that people then carry them with them from place to place. They may also be so specialized in form so as to be useful in only a limited range of tasks.

If there is a high volume and rate of occurrence of tasks and associated processing volumes then people are faced with differences in the nature of the constraints and how the constraints interact, which may result in different choices of strategies. If there are no constraints on availability of raw material then large quantities of simple and disposable flake tools may be produced, modified for use if necessary, used, and then discarded with little or no maintenance (Parry and Kelly 1987). If there is pressure to economize then people may invest more in the initial tool forms and adopt maintenance techniques to extend the lifespan of each tool. Two good examples of this are hafted adzes and the adoption of groundstone tools in certain regions and time periods (Hayden 1987). Torrence (1983) discussing the importance of budgeting the use of time in hunter-gatherer adaptations. In circumstances where time stress is high, either because food resources are scarce and more time must be devoted to their acquisition or the nature of the available food resources (e.g., types of plants or animals) dictates that they will require more investment of time to exploit, people will need to adjust their tool production strategies accordingly. Production and maintenance of tools would not be allowed to interfere with subsistence pursuits. If less time is available for tool production activities then groups would have to embed the acquisition of lithic raw materials within subsistence activities, make more efficient use of the time that was spent in tool production, and, as discussed above, constantly maintain tools in anticipation of use.

If time stress means that groups must make more efficient use of the time spent in producing tools, we might expect that reduction strategies that tend to produce a larger quantity of suitable tool blanks per core would be adopted. These sorts of strategies would also be associated with raw material conservation, but in this case the goal is to produce as many usable blanks as possible in the least amount of time.

Quantity of Tools Required in Middle Palaeolithic Southwest France

This constraint, perhaps more than some, is difficult to discuss in isolation from others. A major factor influencing the quantities of tools required is processing volumes, but others include the nature of tasks, individual tool lifespans, potential alternatives to stone tools, versatility/multifunctionality of tools (Hayden 1987; Bleed 1986; Shott 1986; Kelly 19).

Establishing reliable estimates of processing volumes for different tasks and resources in the Middle Palaeolithic is a difficult undertaking. Among recent hunter-gather groups the quantities of animals exploited (per person per year) is highly varied and depends on a variety of factors, climatic region and access to fish resources being the two most critical. Among Arctic and Subarctic groups 90 to 95% of the diet is meat (mammal and fish). Groups not living in close proximity to sources of fish depend much more heavily on mammals. The Nunamiut's diet, for example, is between 70 and 90% from hunting with only 10 to 20% coming from fishing. Among South Australian hunter-gatherers meat (mammal or fish) tends to make up less than 40% of the diet and among South African groups it is even less, 15 to 20% (no fish). The Australian and South African group's diets are 60 to 85% vegetarian (data from Kelly 1995:67-69 and Hayden 1981:354)

Several estimates that illustrate the significant range in dependence on hunting among extant hunter-gatherer groups have been provided by different researchers on numbers of large animals acquired per year. Among South African hunter-gatherers Wilmsen's (1982) data for the /Xai/xai (28 animals over 1 year for a group with 45 hunters) provide an average of 0.6 large animals per hunter or around 0.2 per person, and Lee (1979: 243), for the !Kung San, estimates 2-3 large animals (c. 200 kg) per hunter per year or about 0.8 animals per person. Gordon (1975) estimates that among specific Canadian Subarctic groups, 19,500 caribou per 650 people are taken each year, or 30 per person per year. Gordon's data suggests a rate of meat consumption 100 times that of the South African groups. This must be viewed as an extreme of exploitation in which only choice parts of many of the animals are selected for consumption. Binford (1978:136-139) provides several estimates (based on both informant's estimates and data collected over extended periods) of meat consumption rates among the Nunamiut in Alaska, for whom the dominant source of meat is caribou (between 80 and 90% of the diet). Taking an average of Binford's sources (and converting data on other animals into caribou equivalents), the Nunamiut were consuming approximately 6 - 7 caribou per person per year. Considering that these data were collected when the Nunamiut were consuming some (albeit very little) imported food stuffs (canned goods), this estimate of number of caribou per person is perhaps a bit low compared to pre-contact periods. An estimate of 7 - 8 caribou per person per year may be more accurate.

Data on quantities of other animal products (hide and sinew) used for clothing and shelter are not typically provided. However, it does not seem unreasonable to expect that such materials from the equivalent of 7-8 caribou per person each year would come close to satisfying such needs. Although, Burch (1972:343) points out that among Canadian and Alaskan caribou populations, parasites (warble fly larvae) make caribou skins acquired during certain seasons unsuitable as winter clothing. August is the optimal time of year for collecting caribou hides as they are in the best condition. This may apply to other medium to large mammal species as well, therefore, specific clothing requirements may result in a need to intensify the hunt for certain animals at certain times of the year. This may result in a slightly higher number of animals taken per year, although the increase is likely quite low.

While the climate of SW France during glacial periods may have no exact modern equivalents (Enloe and David 1997:53), among modern regions the Subarctic and Arctic regimes are likely the most similar. Among current or recent Subarctic and Arctic hunter-gather groups, between 70% and 100% of the diet is composed of meat (Kelly 1995:67).

Based on this and on the importance of meat in Neanderthal diets indicated by isotopic analysis of their skeletal remains (e.g. Richards et. al. 2000 and Bocherens 1999) Binford's data on meat consumption among the Nunamiut might represent rates most comparable to those of the Middle Palaeolithic in Western Europe. Seven to 8 caribou per person per year means each person would consume one caribou about every 50 days. This might be reasonable for those Arctic or sub-Arctic groups for whom non-meat resources make up less then 5% of their diet (Kelly 1995; Hayden 1977; and Gordon 1975) and who are also feeding sled dogs, but in Middle Palaeolithic Western Europe there would likely have been a slightly greater reliance on vegetable resources as well and therefore, while plants might not have been a main component of the diet, meat would have been slightly less dominant than in the Arctic. Another factor that must be considered, however, is that among recent Arctic and Subarctic groups, storage plays a very significant role in the nature of meat consumption (Binford 1978, 1980). Storage would allow a group to extend the length of time in which already acquired meat would remain consumable, reducing the pressure to acquire fresh kills. As there is no evidence of storage (at least as a common practice) in the European Middle Palaeolithic (Soffer 1989), the pressure to acquire fresh meat must have been more constant and kills more frequent. Therefore, I would suggest an average consumption of meat equivalent to around 10 or 12 reindeer per person per year. This would translate into the meat equivalent of one medium sized mammal per person every 30 to 36 days. In terms of animal butchering, this would represent fairly low processing volumes, although this is significantly higher than among Australian Aboriginal and South African hunter-gatherers, and so the rate of stone tool use per person per year for hunting and butchering would, likewise, have been higher (Hayden 1977:182 and Gould 1980:130). Cutting meat is not a particularly demanding task in terms of numbers of tools required. Tools used for butchering do not dull quickly (although initially cutting through the hide dulls the tool edge more quickly than cutting the meat) and a single tool can be counted on to last a significant length of time (Sandgathe 1998). From my own experimentation using unmodified flakes to butcher deer, I would estimate that the butchering of a medium sized animal, like a caribou, could be carried out with no more than 10 flake blanks, with little or no retouching. The use of appropriate retouching could reduce this number, although with such low demands on flake tools, selecting a fresh flake might often make more sense than using retouch. On average an individual butchering 10 - 12 medium sized animals per year might use a maximum of 120 flakes, but likely less than this. Based on these estimates, a family of five would produce no more than 600 flakes per year for butchering, but many of these would have been left at kill sites after the primary butchering had been carried out and would not make it into the assemblages of residency sites.

While hide working must have been practiced in the Middle Palaeolithic (for clothing at least, considering the Pleistocene climate of Western Europe), the evidence for it is rather slim. Endscrapers, universally associated with hide working among recent groups, are present in Middle Palaeolithic assemblages, but are not a common tool type (there are a total of 7 typical endscrapers for all four sample assemblages). Therefore, it would appear that either quantities of hides processed were low or else the degree to which they were processed was limited, or both. Side scrapers would make suitable tools for defleshing hides and may have been the primary hide-working tool during the Middle Palaeolithic as these are a relatively common type among retouched tools in Mousterian assemblages. However, they still comprise a small component of assemblages as a whole (0.04% in the sample Combe Capelle Bas assemblage, and approximately 0.01% in the other three), especially in specific Mousterian Industries. Overall, there would appear to have been a limited demand for hide-working tools.

Woodworking was likely the task with the highest processing volumes for Middle Palaeolithic people. Spears and digging sticks were likely commonly produced tools and, possibly, tool hafts as well (and possibly bark peelers and throwing sticks). The production and maintenance of these items probably represented the greatest demand in terms of tool quantities. Each hunter in a group would probably have each kept and maintained several spears at any one time. Through breakage, wear, and loss these would have required regular replacement. Among Australian Aboriginal groups that Gould observed (1980: 128), spear shafts were replaced about every three weeks because the wood dried out and became brittle. Hayden (pers. comm. 2003) estimated a replacement rate of perhaps 1 spear shaft per month. Due to the extreme aridity of the Australian desert (and perhaps the type of wood used there - eucalyptus) this rate of replacement is not likely reflective of most traditional hunter-gatherer groups. It does, however, indicate that spear shaft replacement was probably a relatively frequent task, and as hunting appears to have been more important among European Middle Palaeolithic groups a significant amount of time and quantities of stone tool were likely spent in this task.

Digging sticks were also probably kept and maintained and would also have required occasional replacement due to breakage and wear. Among the same Australian groups Gould noted that, in spite of the rigorous nature of the tasks to which these tools were applied, they were only replaced about once a year. Hayden (1981:110), however, was told by his Australian Western Desert informants that digging sticks were replaced about every two months. Digging sticks in general, though, may not have involved significant modification to the original sapling from which it was made. Removal of the bark (which may not require stone tools), removing small branches, and shaving down the knots may have been the extent of modification, although producing a pointed or spatulated tip would also be desirable. Few stone tools were likely required for this particular task

For the manufacture and maintenance of all wooden items Hayden and Gould each provide estimates of the number of stone tools each person would use per year. Based on their respective fieldwork Gould (1980:130) calculated 46 adzes and chopping tools and Hayden calculated 117 adzes and chopping tools plus another 39 hand-held flake tools (for a total of 156 stone tools) per person per year. The significant discrepancy between these calculations is likely due to several factors, including the relatively small sample sizes for both and the different degrees with which the different observed groups were familiar with and still practiced traditional technologies. An average of these two studies gives us a number of approximately 100 tools per person per year for woodworking. If, as discussed above, European Middle Palaeolithic people practiced woodworking more frequently we might anticipate a per-person-per-year total of between 100 and 200. This might go even higher with the consideration that the Australian groups rely heavily on hafted adzes. Middle Palaeolithic woodworkers may have used hafted tools and in fact, considering the similarity between Australian adze slugs (spent adze blades) and Mousterian limaces, may have used hafted adzes similar to the Australian ones, but they probably did not used adzes to the same extent (one limace was identified among the four site samples) and must have relied more on hand-held scrapers.

Lifespan of Tools

Depending on the level of economization of raw material, tools may be required to have longer use-lives. This circumstance will arise when the number or nature of the tasks for which stone tools are required puts stress on the quantities of available tools or raw materials. This may be due to either relatively restricted access to, or available quantities of, tools or raw materials or to high processing volumes.

Whether a tool is expedient (will be discarded immediately after a single task use) or is intended to be curated (will be retained, and possible maintained after each use, for later uses) can play a role in the design of tools with respect to their intended or expected lifespan. Bifacial technology has been commonly described as a strategy for increasing tool lifespan. With this technology, more time is invested in the initial production of the tool in order to make its subsequent maintenance easier and its potential use-life longer. Bifacial reduction is just one form of tool maintenance. There are several different resharpening techniques that have been employed, in different regions and time periods, that served, with varying effectiveness, to extend the lifespan of a tool (Hayden 1987). While these are separate technologies from the initial flake production, if people have access to these (knowledge, capability, and intention to use of one or more of them) then this should directly affect the nature of the initial reduction technique by creating goals for specific flake blanks suitable for specific types of edge rejuvenation and/or hafting. As the individual lifespan of a flake tool can be extended, fewer of them are needed. While only well formed bifaces and groundstone tools are typically what archaeologists think of when one speaks of curated tools, there is no reason to expect that people in the past would not have commonly selected good flakes (based on whatever criteria) to retain and carry from site to site and task to task using simple retouch techniques to maintain their serviceability, with endscrapers being a good example of this. In fact there is evidence from many European Middle Palaeolithic sites that indicates that simple flake tools were transported, possibly in a hafted state, from site to site. This evidence is mainly in the form of individual flakes and retouched tools of exotic raw materials in site assemblages (e.g. Roth and Dibble 1998; Féblot-Augustins 1992).

Lifespan of Tools in the Perigord

The lifespan of tools in the Middle Palaeolithic of SW France depends on the maintainability of the tool, which depends greatly on its basic design, and on maintenance techniques. Raw material durability is not a major issue in the Perigord as materials available here are dominated by hard flints, which do not wear down very fast. As for maintainable tool designs, Middle Palaeolithic people would have had the choice between the more maintainable (but more time intensive) bifacial reduction/biface production and simple flake tools with repeated resharpenings as illustrated by Dibble's (1987) reduction model (fig. 5.2).

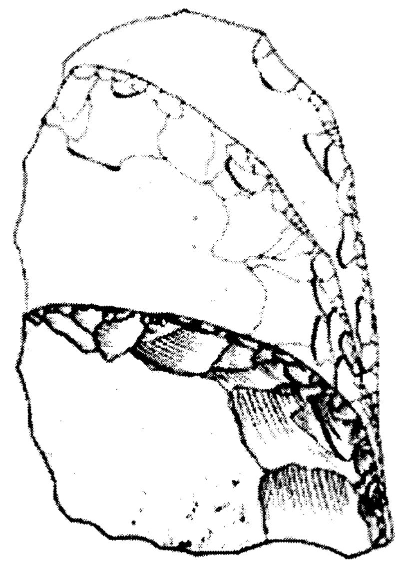


Figure 5.5 Illustration of tool resharpening process and its effect on the tool form and its potential lifespan (used by permission of Dibble 1987).

The advantages of bifaces include their reliability, versatility, and maintainability (Kelly 1988). Mousterian bifaces are reliable in that the lenticular cross-section makes them strong and their edges, being robust, do not break easily. They can be adapted to serve a variety of different tasks including both cutting and scraping actions. Perhaps most importantly, however, biface edges are easily maintained, especially with billet flaking. Edges can be resharpened with little loss of material and no change of general tool shape. With hard hammer resharpening, maintaining a working edge does entail a greater loss of material and involves a constant increase in tool edge angle, but still represents a relatively maintainable technology. Among Palaeolithic technologies bifaces may be the longest-lived tools.

Bifacial reduction flakes produced with a hardhammer (as with Acheulian bifaces) would be versatile tools. They could be used unmodified for some tasks and could also be retouched in order to make them suitable for other tasks. While they are not as individually maintainable as a biface, they do come from an easily maintained core. However, while bifacial flakes produced with a billet (as in the case of the smaller

Mousterian bifaces) are more economical of raw material and have very sharp edges, they would be unreliable for some tasks, because they are more fragile and their edges can break easily, and so would lack versatility. They would not be long-lived tools.

The lifespan of a flake tool depends on the ability to rejuvenate its edges when they dull from use, but also on the regularity of the flake's shape. A flake may start out with a suitable edge, but as it is resharpened, if the thickness or curvature of the edge changes as it moves into the flake it may become unsuitable and have to be discarded. The lifespan of flake tools would be increased, perhaps substantially, by producing them in optimal sizes, shapes, and thickness and with internal regularity of shape, which may help determine the core reduction strategy. In this respect regularity of shape would be an important consideration for increasing the lifespan of individual tool blanks. Regularity of plan-shape, thickness, and ventral curvature would be desirable characteristics.

Portability of Technology

This is a potential design consideration that has not been addressed much by researchers in lithic technology. I refer here, not so much to the portability of cores or stone tools, but to the portability of the tools necessary to carry out specific reduction techniques. Some technologies necessarily require specialized equipment to carry out successfully. For most bifacial tool strategies, soft-hammer billets are required, at least, and pressure flakers may also be a necessity if smaller, more refined tools are being produced. For the more sophisticated blade production techniques, punches are necessary. These types of technologies require the manufacture and maintenance of bone, antler, or wood billets, pressure flakers, and/or punches. This manufacturing process is time and labour intensive. It can require hours of carving, grinding, and use to achieve the optimal shapes for these tools. Hunter-Gatherers would then be obliged to carry these tools around from camp to camp. While few of these types of reduction tool kits would be particularly bulky or heavy, for pedestrian groups the decision to produce specialized tools and then curate them must represent a significant consideration of the pros and cons involved.

Portability of Technology in Middle Palaeolithic Southwest France

As Middle Palaeolithic people were highly mobile, deciding to invest significant time and energy in the manufacture of objects would necessarily require a willingness to carry the objects from camp to camp. There is already significant evidence that Middle Palaeolithic people were carrying flakes, at least, between sites (exotic raw materials in assemblages), but as they were pedestrians, the decision to add to the number of objects being carried would not have been taken lightly. The presence of well made bifaces in some Mousterian assemblages would seem to indicate that the decision was made in some times and places to begin carrying around soft-hammer billets. However, Mousterian bifaces, while often well made, are not particularly demanding in terms of reduction tools required. The biface would be roughed out with a local hammerstone and then finished with a single billet; billets of different sizes would not be necessary. Carrying around such a billet would not represent an onerous task and could simply be tied to an individual's belt.

It must be mentioned, however, that some modern knappers (Hayden and Hutchings 1989:239; Steenhuyse 2003) have noted that hammerstones of relatively soft rock types, like decayed limestone, can produce bending flakes much like antler billets. In much of Western Europe, and in SW France in particular, limestone is the dominant component of the surface geology and so is ubiquitous. If this were the case then curated billets would not necessarily have been required.

Chapter 6: Design Expectations

Design Expectations for Flaked Tool Use in Middle Palaeolithic SW France - Hypotheses

Through an examination of Middle Palaeolithic lifeways in Chapter 4 and the constraints in Chapter 5 that would have followed under such conditions I have established specific hypothetical optimal requirements for the morphology and production of flaked stone tools in Middle Palaeolithic SW France. These are summarized here:

Tool Morphology

As butchering and woodworking were the dominant tasks for which flake tools would have been used in the Middle Palaeolithic of Europe, reduction strategies would have to be designed that produced flake blanks suitable for these applications. Flake size was not likely a critical characteristic in the general design or selection of tool blanks among Middle Palaeolithic people in SW France. This is demonstrated by the intentional production and use of very small flakes (e.g., Kombewa and flakes from Assinipodian cores) at some Mousterian sites. However, for most tasks larger flakes were likely preferred and, other characteristics being equal, were likely the first ones selected from a collection of potential tool blanks. This behaviour is reflected in the ethnographic literature. Where researchers have had the opportunity to observe tool blank selection, size often plays a role in initial selection, but eventually flakes of a wide range of sizes are used (within practical limits) (e.g., Sillitoe and Hardy 2003:559; Hayden 1981: 26; White 1968:512-13; Miller 1979:402-3; Strathern 1969). It is logical then to expect a consistent attempt to **maximize flake size** (to an upper limit of perhaps 10 cm) during production, but always within the limits set by other considerations such as core size and the importance of maintaining a viable core morphology. A knapper will often have the opportunity to remove a particularly large flake from a core but will have to forgo it because at that point in the reduction of the core it would compromise their ability to remove subsequent suitable flakes without significant core reparation that would be wasteful of raw material. In general, larger flakes are better, but greater size must often be compromised due to other considerations.

For butchering tasks, edge angle, edge length, the portion of a flake's edges that are usable, and flake ventral curvature should be the most important considerations in blank selection. For cutting meat **lower edge angles** are required (≤ 60°, based on Australian Aboriginal data [Hayden 1981b], but preferably much sharper than this based on modern butchering tool attributes). With a softer task material like meat, tool edges can be relatively delicate without edge-breakage being a serious problem, but more robust flakes will be just as serviceable as long as they are still sharp. With regard to the other characteristics, flakes best suited for cutting meat and hide would have at least one **relatively long (>3cm), regular cutting edge**. Those portions of the edge adjacent to the part that actually does the cutting also need to be regular or they could interfere with the efficacy of the actual cutting edge. Significant ventral curvature would tend to pose a similar problem. **Flatter flakes** should pass more readily through the cut made in the meat and will allow more of the tool edge to be kept in contact with it with each stroke.

For woodworking tool blanks the required characteristics are quite different. Tools used to plane (shave) wood surfaces need to have **relatively spine-plane angles**; optimally >60° and <85° (based on modern woodworking tools and Australian Aboriginal data - Gould 1980; Hayden 1981b). In planing or whittling wood the portion of the tool edge that contacts the material is generally quite small and so edge length and flake curvature are not serious considerations. **Robusticity** is, however, a necessary consideration because of the significant pressure that is typically used in applying these tools. Whether they are hafted or hand held, most woodworking flake tools need to be robust to stand up to the task.

Tool Blank Production

In SW France raw material availability and raw material quality are not major considerations, especially in the Perigord. Good to very good quality flints are readily available almost everywhere. Within this region, the maximum distance that one might have to travel to acquire good quality flint is perhaps 5 km. Some of these materials, however, occur in small sizes and irregular shapes that might make the application of some reduction strategies difficult. At sites where only such materials are immediately available, groups would have to choose to either acquire their raw materials from more distant source or adapt their **reduction technologies to suit the material sizes and shapes** at hand.

For Middle Palaeolithic people physiological capabilities and available technologies would not appear to have been significant constraints. Neanderthal groups in Middle Palaeolithic Europe seem to have had knowledge of most flake tool reduction technologies and the ability to carry them out effectively.

In terms of tool needs, considering the different morphological requirements for butchering and woodworking tools, Middle Palaeolithic people either had to select slightly different reduction strategies to **produce blanks suitable for each tool type, or** use a single reduction strategy that could **produce tool blanks that satisfy the morphological requirements for both applications.**

The assumption here is that Middle Palaeolithic people designed their reduction technologies around these requirements. At the 4 study sites (and over most of Middle Palaeolithic Europe and the Middle East) they used both amorphous core reduction and Levallois reduction (or some related form of single-surface core technology like Disc/Centripetal Core) to achieve these ends.

Other Design Considerations

Although butchering would have been a common, essentially daily practice, without large-scale communal kills (for which evidence is rare) or significant storage practices (for which direct evidence is rare) the demands on stone tools, in terms of quantity, would be relatively low. The same could be said for hide processing. Woodworking would have presented the highest demands on stone tools. As with most recent generalized hunter-gatherer groups, in general, Middle Palaeolithic task processing volumes would have been low.

Because of the high mobility rates of Middle Palaeolithic groups, the portability of their technology would have been a consideration.

Hafting as a Middle Palaeolithic design consideration is difficult to weigh. While it seems quite apparent that it was practiced, the degree to which it played a part in stone tool strategies is unclear, to say the least. It can be said, however, that the characteristic that flake blanks could have that would be most beneficial to hafting would be **standardization** of size and shape.

Summary

It is suggested here that Middle Palaeolithic groups living in this area would tend to employ reduction technologies or strategies that would produce tools that would satisfy these morphological constraints:

-lower edge angles (for cutting meat)
-relatively long, regular cutting edge (for cutting meat)
-flatter (low ventral curvature) flakes (for cutting meat)
-somewhat higher edge angles (for woodworking)
-robusticity (for woodworking)

and satisfy these production constraints:

-maximize flake size during production
-suit reduction strategy to the sizes and shapes of available raw materials
-produce specific blanks individually suitable for each major tool type (cutting meat and woodworking), OR produce generic blanks that all have the potential to satisfy the morphological requirements of both applications
-some limited? standardization of product size and shape (for potential hafting)

and to potentially take into account these other design considerations:

-Processing Volumes
-Tool Lifespan
-Portability of Technology
-maintainability of some tools designed for long use-life

Satisfying These Design Expectations

Technologies Employed at the Study Sites

Based on the types of cores present, the different major lithic technologies that have been recognized in the assemblages of all the three study sites are amorphous core reduction, disc core reduction, and Levallois core reduction: all carried out with hardhammer percussors. These categories of core reduction are not always obviously discrete. While there are cores that, based on their morphology and traditional definitions, are readily classified as Levallois and there are cores that, along similar lines of reasoning, can be readily classified as disc, there are also a number of cores that are difficult to assign to one category or the other (see the discussion in Chapter 11 for more on this). This same problem often occurs when distinguishing between these reduction approaches and amorphous core reduction. In many cases the analyst cannot be sure if a specific core was reduced in a random manner and it just happens to have some similarities to a more morphologically patterned reduction approach, or if the knapper's intention was to reduce it following a Levallois or disc core reduction approach, but, due to raw material problems or knapping mistakes, ended up producing a more amorphous looking core. There is always a degree of subjectivity in categorizing cores in these assemblages.

At le Moustier and, to a much lesser degree, Pech de l'Azé IV, besides these different types of core reduction, there was also biface production. While at Pech de l'Azé IV there were very few (and mostly very poorly made) bifaces, at le Moustier bifaces were numerous and mostly of very high quality (regular and symmetrical). While the bifaces themselves were undoubtedly tools of some sort, the flakes resulting from their manufacture also have the potential to be used as tools.

Another reduction technology that was practiced at these sites was Kombewa flake production. Kombewa cores and flakes, however, generally make up a very minor component of the lithic assemblages. Quantities are not typically recorded in the literature as they are not among Bordes type list, but among the levels at Pech de l'Azé IV, for example, Kombewa flake quantities range from almost non-existent in level F2 to 12% of the total number of cores in level J3a (Dibble and McPherron 2003:14), although the latter quantity must be viewed a very atypical. While this technology undoubtedly served a specific purpose, it does not represent a major flake production strategy and cannot be seen as a major component of Middle Palaeolithic lithic adaptive strategies in this region.

There is also some direct evidence that suggests hafting was practiced to some degree at some of the study sites. In the sample assemblage from Pech de l'Azé IV there were several flake tools with thinned bulbs of percussion. This technique would seem to be only useful if the tool were hafted in a slotted handle or split branch, and not in gum or resin handles (Figure 5.1 and Plates 13, 14 and 15).

How Would These Reduction Strategies Satisfy Projected Design Requirements?

Amorphous Core Reduction

With respect to optimal flake tool morphology, any core reduction approach carried out with hardhammer percussion tends to produce relatively flat, robust flakes (Hayden and Hutchings 1989). Assuming a reasonably sized core, at least some of these will also likely be relatively large, although without a specific reduction strategy one cannot maximize the size potential of all the products. Furthermore, the odds are high that at least some will have one or more long, regular edges suitable for cutting meat and some will have one or more relatively high-angled edges suitable for woodworking. However, if no attempt is made to pre-plan and organize the process of flake removals from a core (i.e. amorphous core reduction) then, while the knapper might be able to count on producing some flakes suitable for some tasks, there is no guarantee of this and the odds are high that many of the flakes produced will not be particularly large or have any suitable edges. It does seem quite probable that there will be a wide range of variability among the flakes in terms of size and shape. Presumably, achieving some control over the nature of end-products is one of the basic reasons for the development of prepared core strategies. Besides this, with no preplanning a core can easily become unworkable (i.e., lack suitable striking platforms and/or surfaces suitable for removing a flake from) after only a few removals and its potential, therefore, wasted.

In terms of portability of the technology (in terms of any need for carrying special reduction equipment) and tool lifespans, amorphous core reduction would not appear to have any advantages or disadvantages over single-surface core approaches. The greater wastefulness of raw material associated with amorphous core reduction would, however, translate into greater transport costs.

Single-Surface Cores

This is a more general category under which both Levallois and Disc/Centripetal cores can be subsumed. Like any core reduction carried out with a hardhammer, single-surface cores produce relatively flat and robust flakes. Peripheral (or centripetal) flakes, regardless of whether they are removed from a Levallois core or a Disc core, will also almost always have at least one relatively long, regular, low-angled edge suitable for cutting tasks. High-angled edges more suitable for woodworking, though not uncommon, might not be considered a typical trait among single-surface core products (as born out in the analysis in Chapter 9), although some single-surface cores are reduced, apparently intentionally, through the removal of notably thick flakes, which will tend to have somewhat higher edge-angles, e.g., *Éclats Dèbordants*.

With some single-surface core approaches a very general degree of standardization might be expected. While in reality the degree of standardization among peripheral flakes will not be remarkable, in an optimal model of single-surface core reduction, all the flakes removed from around the periphery of a prepared core surface will meet at the centre (or overlap the centre to the same degree) which would result in their all being of a similar size (if not shape as well).

It would be expected that the central flakes removed from Levallois cores would exhibit this same suite of characteristics, but also, in general, would be larger and have even longer cuttings edges than other products.

Single-surface cores have notable advantages in terms of satisfying production constraints. In order to maximize the size of all the flakes that one can produce from a typical sub-spherical, irregular nodule its form must be modified (prepared) so as to expose as large an exploitable surface as possible. There are only two general geometric forms that the volume of a mass can take that provide such exploitable surfaces (given the mechanical constraints of flaking stone), with an adjacent surface that can serve as striking platforms, and whose form can be readily maintained throughout the reduction process. One general form is a cylinder (within this general category can be included cone and wedge shapes as well) from the side of which long, narrow flakes can be removed in a longitudinal direction, using the end(s) of the cylinder as the striking platform. This is the approach that most blade cores follow. The other general form takes advantage of the fact that the largest, flat surface that can be found within the volume of a sub-spherical mass is a plane cut through it at its maximum diameter. The resulting angle between this plane and the adjacent exterior surface readily allows the exterior surface to serve as a striking platform.

This is the approach that single-surface cores follow. A nodule of raw material is prepared so as to create such a plane from which flake products can be removed. The opposite surface is semi-spherical and is often the actual original cortical surface of the nodule. By creating the largest exploitable surface possible in a nodule of any given size, a knapper can then consistently maximize the size of the flakes removed through the course of the reduction of that nodule. Given the size of this exploitable surface, the only other limits to the size of the flakes removed from it are: the specific morphology of that surface that may limit how much of it can be removed in the form of a single flake; and the choice of the knapper to either produce a limited number of the largest flakes possible, which would require reparation of the surface between removals (and significant wastage of material -- i.e.“ classic Levallois”), or try to balance flake size with raw material economization. In this latter approach the size of the flakes can be maximized to the point that the removal of any one flake does not result in the need to rework the core surface to enable further removals. Optimally, flakes would be removed from around the periphery of the core surface in a radial fashion, each flake overlapping the centre point of the surface enough so that the central mass of the surface is removed at the same rate as the peripheral edge of the surface. This would tend to result in a general standardization of size and shape of all the flakes. Alternatively, one could combine these approaches and remove a series of somewhat smaller, but still usable, flakes from around the periphery, but with little or no overlap in the surface centre. This would result in an increase in the mass of the surface, which could then be removed as one or more larger flakes.

This reduction approach can be applied to almost any size and form of raw material (as demonstrated by Assinipodian cores at Pech de l’Azé IV). More irregularly formed nodules will require more preparation, but this would be the case for any reduction approach. Single-surface core reduction is particularly applicable to the small ‘*pustules*’ common on some flint nodules. Although they tend to be very small (c. 2 to

5cm in diameter), when broken off the main nodule these *pustules* are already in the optimum shape for a single-surface core. Likewise, the irregular, cylindrical-shaped limbs, that are also common on some flint nodules, are easily prepared so that one end can be exploited as a single surface. This is essentially the "sausage-slice" technique mentioned above. However, the advantage of reducing such small cores and using a prepared core technique is unclear.

A specific variant of single-surface core reduction common in many French Middle Palaeolithic assemblages involves the production of peripheral flakes using an oblique, rather than direct blow on the core edge. This results in a rather stubby flake with a platform that includes a large portion of the core edge. These are called *Éclats Débordants*. The intended purpose of these is not clear, but two unique characteristics of these flakes are: the long portion of core edge (which could serve as protection for the hand while the opposite edge was being used in contact with a task material), and the high angles along the edge between the two opposing core surfaces (see figure 2.4 and plates 10 & 11). The removal of these flakes does result in a rapid and dramatic increase in the central mass of the core surface of debitage, which must be addressed at some point to maintain the usefulness of the core.

In terms of portability of the technology, single-surface core reduction can been seen to have significant advantages. The technique is typically carried out using only a hammerstone; no other reduction tools are necessary. In most regions one could assume that suitable hammerstones would be readily available anywhere and that there would be no need to carry one around from site to site. Whether they could assume that there would be raw materials for stone tool production is a different question, but access to raw material does not appear to have been a significant issue in Southwest France, at least.

Bifaces as Tools

Typical, well made Mousterian bifaces would generally satisfy most of the morphological constraints outlined above for butchering and woodworking tasks. They have long, regular, robust edges with edges angles usually somewhere between 45° and 70°. While claims have been made about their efficacy in cutting meat (e.g. Jones 1980), and undoubtedly they will work in this capacity, in terms of the sharpness of their cutting edge they are distinctly inferior to unmodified flakes (Sandgathe 1998; Frison 1989). Any advantage they might have over unmodified flakes for cutting meat would be in the length of the usable edge and in the ease with which they can be grasped and greater pressure applied with them. Use-wear studies have tentatively identified edge-wear on Mousterian biface edges from cutting or scraping bone, which has been tentatively identified as being from butchering (e.g., Soressi and Hays 2004), although perhaps this is just reflecting special butchering tasks, like separating joints. However, the robusticity and edge angle would make bifaces particularly effective for woodworking and, in fact, this was the most common type of edge-wear found by Soressi and Hays (2004:10). Besides being suitable for shaving wood surfaces, Mousterian bifaces would be effective adzes, either hafted (although there is no evidence for this) or simply as hand-held chopping tools. Among Australian Aboriginal groups adzes are the most important woodworking tool (Hayden 1981, 1977; Gould 1980; Gould *et. al.*1971).

Bifaces, in general, also represent a very portable tool and technology (although their manufacture and maintenance may require curated billets). Compared to unmodified flakes, they are very long-lived tools (e.g. Hayden *et. al.* 1996; Kelly 1988).

Bifaces as Cores and Bifacial Reduction Flakes as Tools

In their general morphologies and volumetric constructions, bifaces are very similar to single-surface cores (in fact, with some items in Mousterian assemblages, it can often be difficult to decide if they are a poorly made biface or a particularly thin, disc core). However, if bifaces are used as cores (i.e. flakes removed from them for use as tools), their lenticular symmetry must be retained with the removal of flakes equally from both surfaces. Furthermore, if the biface's proportions and suitable edge-angles are to be maintained the flakes must be removed with a softhammer. Softhammers were presumably adopted sometime in the Middle Palaeolithic for biface production/reduction because of the fact that hardhammer flakes are thicker and more wedge-shaped and result in a more rapid loss of material along the biface edge without a comparable loss of material at the centre of the biface. This rapidly results in a small, thick core with very high edge angles, which is unusable (Hayden and Hutchings 1989 and Sandgathe in press).

Biface reduction with a softhammer billet does allow the consistent maximization of flake size. With some minor platform preparation, and by maintaining the regularity of the biface form by consistently removing flakes from both faces and from around all the margins, a skilled knapper can easily and consistently remove flakes that span the whole width of a biface. The major restriction in size would be in attempting to maintain the standard, teardrop plan-shape of the biface. This may limit the size of flakes removed from some locations on the biface (McPherron 2000, 1999) and make standardization of size and shape more difficult.

The dominant characteristics of bifacial reduction flakes (produced with a softhammer) are: very acute edges, thinness, and notable ventral curvature (Hayden and Hutchings 1989). This suite of traits tends to make them less than optimal for either cutting meat or woodworking. While the very sharp edges would work well in cutting soft materials, like meat or fresh hide, the ventral curvature means that straight cutting edges, preferable for cutting tasks (although, perhaps not as critical for cutting skins), will be less common than among hardhammer flakes. The thinness results in a high level of fragility, which, along with the very low edge angles, makes these poor woodworking blanks (Keeley 1977:122).

Producing bifaces of any practical size requires quite large pieces of raw material to begin with. A significant amount of waste is produced in the roughing out of the symmetrical, lenticular shape which means that one must start with a very large nodule in order to end up with a somewhat large biface. Therefore, raw material shape and size is a significant restriction in the application of biface production and bifacial core reduction.

How Would Other MP Reduction Strategies Satisfy the Projected Design Requirements?

Bipolar Core Reduction

Bipolar reduction tends to have more limited applicability. This method of fracturing stones allows very little control over the nature of the end products and how a nodule fractures with this approach is generally unpredictable. The circumstance where it is most applicable is with the initial reduction of smaller, rounded pebbles that are essentially impossible to reduce with any other method. Where raw material is only available in small, rounded pebble form, bipolar reduction may be the only option. This is, however, not generally the case in France, where in most regions there is no shortage of better raw material forms (Hayden 1980:2). This was a strategy employed in Middle Palaeolithic Italy in some regions (Kuhn 1995).

Flakes produced through bipolar reduction of small pebbles do tend to be flat and fairly robust, which would be favourable qualities. Also, their margins tend to include a large portion of cortex which could serve as hand-protection for the user. Bipolar reduction has been observed ethnographically, among hunter-gatherer groups in South West Africa, in which case the resulting quartzite flakes were used for a variety of tasks including butchering and woodworking (MacCalman and Grobbelaar 1965)

Blade Core Reduction

Traditionally, blade production strategies are not associated with the European Middle Palaeolithic. However, research over the last decade or two has brought to light a number of blade and blade-like assemblages from Middle Palaeolithic contexts (e.g., Conard 1990; Tuffreau 1982). Although the classic prismatic blade core technology associated with later time periods in various parts of the world are not found in Middle Palaeolithic contexts, there is little doubt that knappers in this time period had access to basic blade production technology.

Blades can well satisfy the morphological constraints in my model. They tend to have low edge-angles, can be produced in very flat forms, and by definition have two relatively long, regular edges. In terms of woodworking constraints, blades may not typically have edge-angles in the higher range associated with this type of task, but they can be produced with hardhammer reduction and so can be rather robust.

As discussed above with single-surface cores, blade reduction is the second of two possible approaches that allows the knapper to exploit the largest possible surface (given the constraints of the mechanics and physics of flaking stone) and thus maximize product size. Blades are also particularly versatile as tool blanks and can generally used unmodified or can be modified into major tools types. A major advantage of blade production is the ability to produce very standardized forms, in both size and shape.

One major limitation of blade production is in the size and form of raw materials that will effectively work with this strategy. A knapper has to start with fairly large, thick nodules in order to produce effective blade cores. This can also typically involve a loss of a significant portion of the nodule in the initial preparation stages. There is also a high risk of ruining the core.

Another potential constraint on this strategy is that, while blades can be produced through basic direct, hardhammer percussion, such approaches do not typically produce the level of standardization that can be achieved with more sophisticated reduction methods, such as punch techniques. However, the adoption of such techniques will result in some loss of robusticity in the products and will likely mean that the knapper will be obliged to then carry their reduction tools with them from site to site.

Resharpening/Maintenance Technologies

While resharpening strategies would not typically be considered 'reduction strategies', they do serve as important strategies for influencing the efficacy of actual reduction strategies by allowing the modification and maintenance of various reduction products. Retouching can play little or no role in the reduction process and, thus, in the form of the blanks produced, but bifacial (hardhammer or billet) resharpening, endscraper retouch, backing retouch, notching, and expedient knife retouch can all allow the modification of flake blanks into specific tool types and they can extend the lifespan of tools.

Retouching can be used to create longer, more regular tool edges. Different types of retouch can also be used to either create or maintain low edge angles (e.g., bifacial, expedient knife, and Quina retouch) or to create or maintain higher edge angles (notching and basic scraper, endscraper, and backing retouch).

Hypotheses

Several specific expectations about the application of single-surface reduction, in general, and Levallois reduction, more specifically, can be proposed. They depend strongly on the proposal that Mousterian tool kits (in SW France) should be dominated by two major classes of tools: those used for butchering and those used for woodworking. With this in mind, a number of hypotheses can be framed about why Levallois reduction occurs where it does.

The Levallois reduction strategy, and perhaps single-surface reduction as a discrete category, would be employed because:

1/ It represents cultural traditions, in which case we would expect to see both temporal and spatial patterning in its distribution.

The currently available data do not support this and this hypothesis will not be addressed in the subsequent analysis of the data.

2/ The resulting products satisfied the specific morphological requirements of one major application OR the other, and so would be employed in situations where that application (butchering or woodworking) was the dominant task. The products:

> *-are relatively robust with edges more suitable for woodworking (e.g., Eclats Débordants), or*
>
> *-have relatively low edge angles, consistently long, regular cutting edges, and are consistently flat making them particularly suitable for butchering (e.g., more classic Levallois products)*

In this case we would expect the reduction strategy to occur in circumstances (sites or components) where specific tasks dominated the activities carried out there. This hypothesis will be addressed in the analysis.

3/ The reduction technique produces a limited number of larger blanks which would serve better as long-lived tools in portable tool kits or as more maintainable tool forms in circumstances where time stress/constraint plays some role in task scheduling.

In this case we would expect the strategy to have been employed in preparation for longer hunting/foraging forays and in retooling situations, such as at quarries where just blanks (and no nodules or cores) would have been taken away, or in circumstances where a group cannot always count on having the time or raw material to produce suitable tools at the time they are needed. This hypothesis will be addressed in the analysis.

4/ The reduction technique itself, rather than the form of its products, represented a logical response to other constraints (e.g., raw material availability, raw material size and shape, processing volumes) that were encountered at different times and in different locations.

-it represents a raw material economization solution and, thus, a logical response to raw material availability constraints.

If this were the case then we would expect the strategy to be employed most consistently under conditions of restricted raw material availability, which could include a number of different circumstances. Raw material economization would be required at sites where suitable raw materials are not available locally; during certain seasons when, due to snowcover, ground frost, or water levels, raw material sources are inaccessible; and while a group is in transit between sources of raw material (e.g., moving between base camps or on longer hunting forays) and must extend the life of those materials they have in hand. This hypothesis will be addressed in the analysis.

-it present a strategy for more effectively or efficiently reducing raw materials of various sizes and shapes.

In such a case the strategy would be consistently associated with specific raw material forms (e.g., large, regular nodules or smaller, irregular nodules). This hypothesis will be addressed in the analysis.

-it is a response to increased processing volumes and the need to produce more tools at a specific time or place. The strategy produces more tool blanks (or cutting edges)

of an appropriate form per volume of raw material: it represents a maximization strategy in tool blank production.

In this case the strategy would be associated with specific events, such as a particularly large kill event, which might be associated with particularly seasons when a group may have greater access to a resource (e.g., migrating caribou or bison herds passing through their region). This hypothesis will be addressed in the analysis.

5/ The products of the strategy present a certain degree of standardization (without having to employ more difficult reduction strategies -- e.g., blade production) that makes them more suitable for hafted tool forms. While the initial manufacture of hafted tools requires greater investment of time, their maintainability extends their use-life and reduces risk in that a suitable tool is always available when it is needed.

As with Hypothesis #3, in this case we would expect the strategy to have been a response to either the need for longer-lived tools, which would either be associated with extended mobility events (e.g., hunting forays), or in circumstances where, to reduce risk, a group needs to be able to constantly maintain tools for readiness. This hypothesis will be addressed in the analysis.

Chapter 7: Data Collection and Assemblage Analysis

Introduction

The primary three sites from which data was collected, Pech de l'Azé IV, le Moustier, and Combe Capelle Bas, are all situated in the Dordogne region of Southwest France (figure 7.1). This region is well known for its large concentration of Lower, Middle and Upper Palaeolithic sites that have been well investigated. It has been a major focus of Palaeolithic research over the past 150 years and the three sites here are among some of the most widely known, with, in fact, le Moustier being the origin for the term Mousterian. More importantly, many of the sites in the region were those upon which Palaeolithic chronologies, technological schemes, and a general understanding of the Western European Palaeolithic (and the Palaeolithic in general) have been constructed and modified over the years.

These three sites were selected in particular because they have assemblages (or portions of their assemblages) that were relatively recently excavated using modern techniques and following similar standards, and because these assemblages have been well curated (both the le Moustier and Pech de l'Azé IV assemblages had been reorganized and recatalogued within the last five years). Other factors in their selection include the fact that two of them (Pech de l'Azé IV and Combe Capelle Bas) are good examples of sites where the source for the raw materials is immediately at hand, while for the third site (le Moustier) the materials came from some distance away (5 to 15 km). This allows the analysis of raw material access as a factor in lithic technological choices.

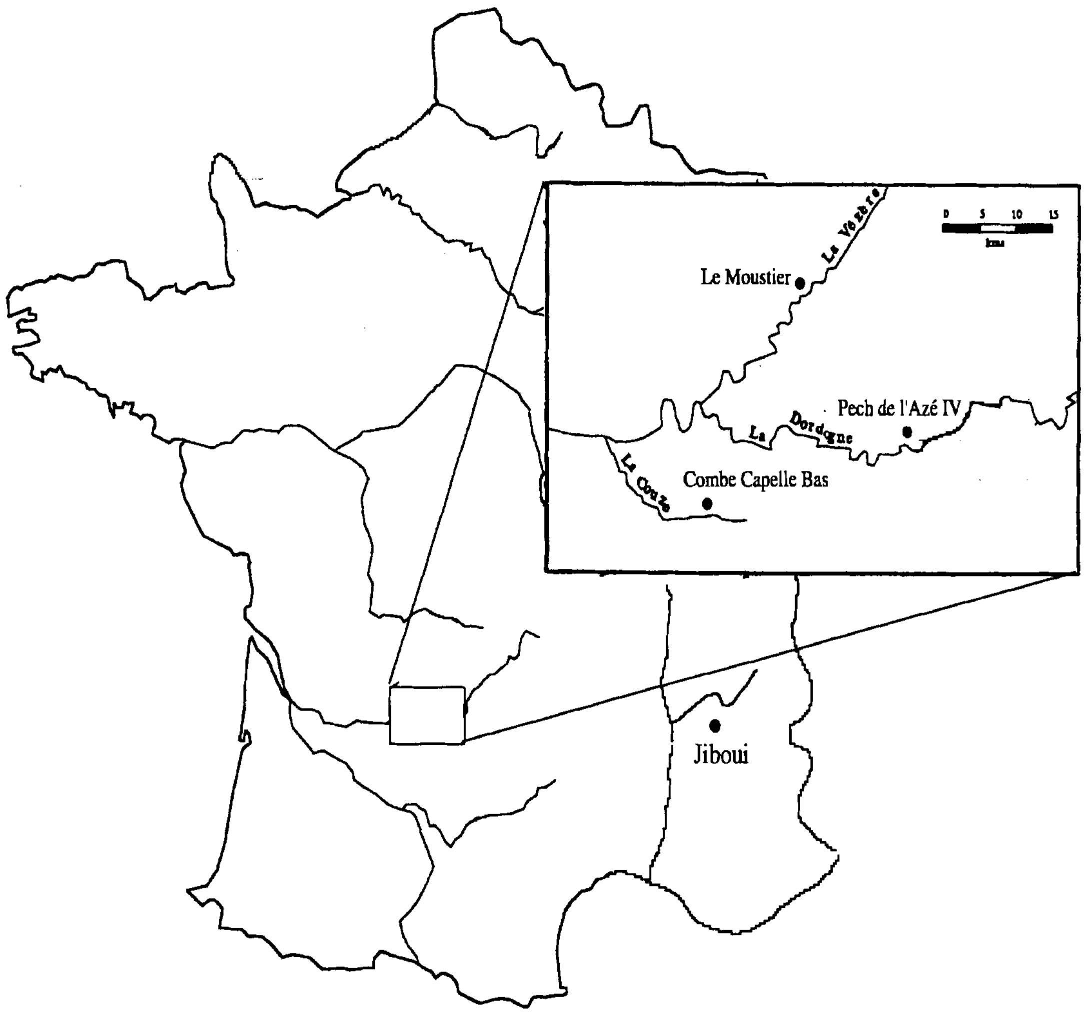


Figure 7.1 Map of France showing the location of the four sites employed in the study (use by permission of Dibble and Lenoir 1995).

The levels at each site that were sampled were selected for two reasons. The first is that they are all of similar ages (around 50 to 60 ky), which controls for climatic conditions (which, in fact, do not appeared to have been a factor in the use of Levallois technology). This time period coincides with the beginning of OI stage 3, an interstadial within the last glacial cycle, but still a cold, dry climatic regime dominated by steppic vegetational conditions.

The second reason was due to the Mousterian industries to which the components are associated. The components that were sampled from Pech de l'Azé IV and le Moustier were assigned to the MAT, with the former having few handaxes (MAT type B) and the latter having a notable presence of handaxes (MAT type A). The component from Combe Capelle Bas that was sampled was assigned to the Typical Mousterian facies. The fact that in at least one of my samples both Levallois and biface reduction had been practiced, and in at least one sample the latter hadn't, would allow me to more closely investigate any differences in the usage of these two technologies and potentially compare hardhammer and billet flake morphologies (as it turned out, very few billet flakes were recovered from the sample levels that had contained bifaces).

A fourth site was also included in the study here for mainly one reason. The three primary sites are all located in relatively close proximity and so would have always shared certain common geographic aspects, regardless of any climatic changes, such as latitude and altitude. This latter aspect is of particular interest. With significant changes in altitude come significant changes in climate, seasonality, vegetation, fauna, and access to other important resources. It was felt to be of some importance to examine a Mousterian site located at higher elevations for any notable differences in tool kits or technologies that may shed more light on the constraints that were influencing the design of these. The site of Jiboui is located in the Massif du Vercors region of the French Alps directly east of Valence and directly north of Marseilles. It was excavated from 1997 to 1999.

The Archaeological Sites

Pech de l'Azé IV

Pech de l'Azé IV is a collapsed cave site that is part of a complex of 4 Mousterian-occupation cave sites along a steep limestone escarpment on the north side (right bank) of the Dordogne River valley in SW France. It is about 5 km southeast of the major regional town of Sarlat, and is located on the east side (left bank) of an old, dry tributary of the Anea, a small tributary of the Dordogne (figure 7.2).

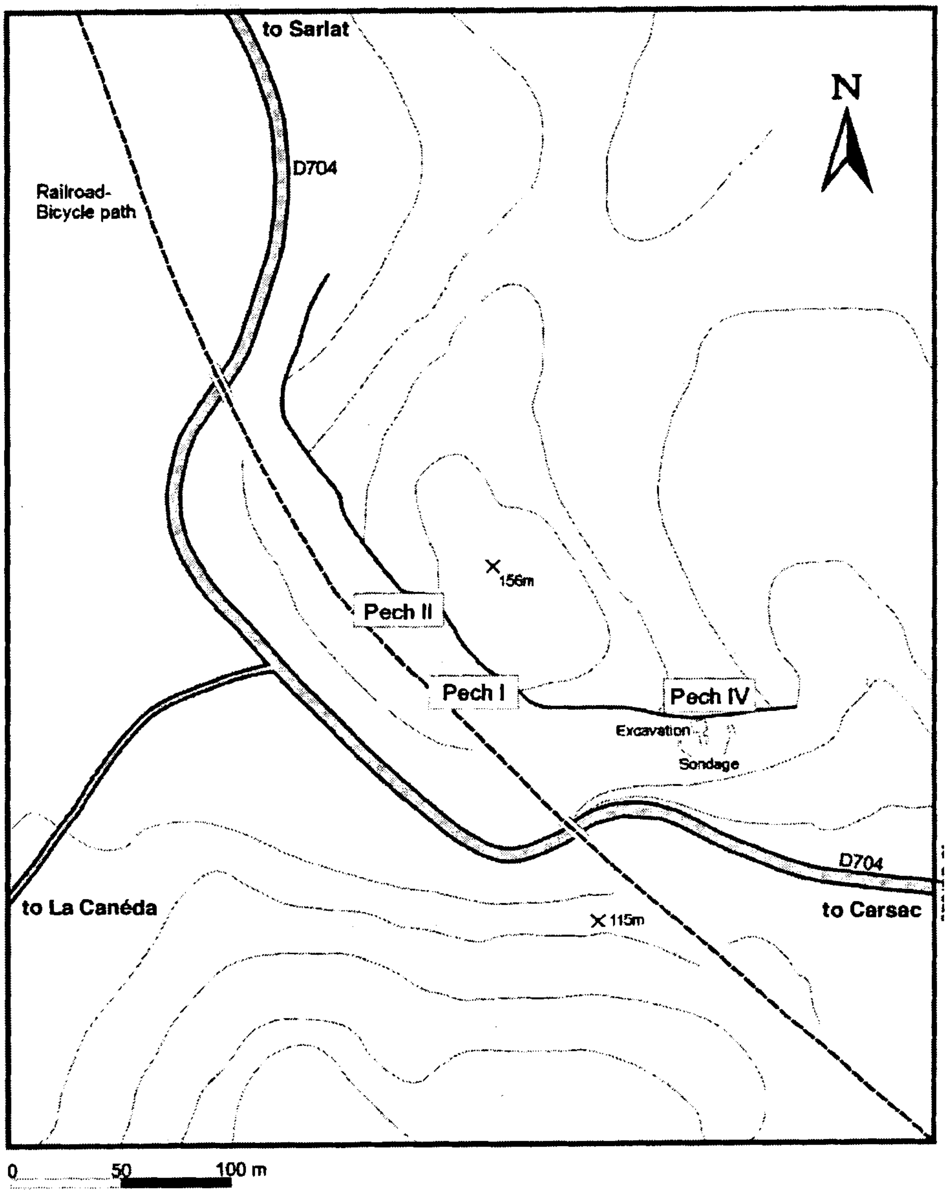


Figure 7.2 Map showing the relative locations of the Pech de l'Azé complex of sites. (unpublished figure used by permission of Dibble and McPherron 2001).

The Pech de l'Azé Complex of Sites

Pech de l'Azé I and II are two classic Mousterian cave sites at opposite ends of the same cave system. The Pech de l'Azé I opening faces southeast and the cave extends back, horizontally, about 27 metres into the cliff face, with a 14 metre, narrow section at the back which connects it to the second cave which is about 25 metres long and of a similar height. Currently, the opening of Pech de l'Azé I is about 11 metres wide by three and one half metres tall and is nicely arched.

It was noted in the early 1800s, but was first described by archaeologists in 1864 when the prehistorians, and authors of Caves of the Perigord, Edouard Lartet and Henry Christy, visited it. In 1908 the French prehistorians, Louis Capitan and Denis Peyrony, conducted a brief excavation there and found the remains of a neandertal child - long lost until just recently (Maureille 2002). In 1929-30 Raymond Vaufrey conducted more controlled excavations there, noting among other things that the whole sequence in this cave belonged to the MAT industry.

In 1948, at the urging of Vaufrey, François Bordes, along with Maurice Bourgon, took up excavating the cave, although there were little in the way of intact deposits left. In this, his first project at the site, he worked till 1951, and early on in the excavations discovered a second opening (on the west side of the ridge through which the cave system runs) into the rear portion of the system, now called Pech de l'Azé II. This entrance had been filled to the ceiling with a cone of natural and cultural deposits, and the deposits in this cave were completely intact. Bordes returned and excavated at Pech de l'Azé I and II again between 1967 and 1969, but the concentration was on Pech II. It turned out that the deposits in this cave included much older occupations than in Pech de l'Azé I, with Bordes attributing the deepest layers (levels 5 - 9), with Acheulian type assemblages, to the early Rïss glaciation (Rïss I to III - Bordes 1972). Subsequent ESR dating on animal teeth from the site tend to support Bordes' general interpretation. Levels 5 - 9 date between 260 and 140 kya, putting them in OI stages 7 and 6 (the latter half of the Rïss). Levels 2 - 4 range in age between 50 and 100 kya, putting them mainly in OIS 5 and 4 (Würm I in the traditional French sequence). In Pech de l'Azé I the whole depositional sequence seemed to belong to the later stage (Würm II to Bordes - Bordes 1976), likely early to mid-OIS 3. Bordes explanation for this significant difference between these two connected caves is one that is still tenable today. It is that originally, during the earliest occupation layers, both caves were inhabited more or less at the same time and would have, originally, both contained Rïss aged deposits. However, a period of erosion must have occurred, perhaps in OIS 4 (the lower Würm Pleniglacial), which cleared all the deposits, that had accumulated to the point, out of Pech de l'Azé I while leaving the Pech de l'Azé II deposits more or less intact. This is likely because the entrance to Pech de l'Azé II was already almost sealed and so any water was prevented from running out that way. This would also explain why when occupations of the cave system resumed they were restricted to Pech de l'Azé I. These later occupations, then, resulted in the deposits encountered by the excavators there.

Pech de l'Azé III is a very small cave found by Bordes in 1951 and situated just to the north of the Pech de l'Azé II entrance. Bordes and Bourgon (1951) found a sequence here that corresponded to the lower levels of Pech de l'Azé II.

Pech de l'Azé IV

In 1952 in the course of Bordes' first project at Pech de l'Azé I, while conducting surface surveys and shovel tests along the escarpment, he discovered the fourth site in the complex. He found it because of the significant quantities of lithic artifacts eroding out of the talus slope at the Base of the cliff about 100 metres southeast of the Pech de l'Azé I entrance. Because he was busy himself with Pech de l'Azé I, and later Pech de l'Azé II and Combe Grenal, he was not able to begin work here himself, but he did talk a friend, B. Mortureux (a local dentist), into beginning some limited work there. Between 1953 and 1956 Mortureux dug a 1 metre wide trench perpendicular to the cliff face and extending 9 metres out from it. He found the going difficult, however, because of the large pieces of éboulis (fallen rock), many of which were much wider than his 1 metre wide trench.

In 1970 Bordes was able to turn his attention to Pech de l'Azé IV and he worked there for 8 seasons, until 1977. He opened a 7 by 7 metre square that straddled Mortureux's trench and excavated most of the 1x1 metre units in this area down to a relatively flat bedrock shelf. One huge block of éboulis prevented him from taken several units in the SE corner completely down to bedrock. Bordes published a preliminary report on Pech de l'Azé IV, but unfortunately died before he could finish his analysis. His interpretation of the site was that it was the collapsed remains of a shallow rock shelter (*abri*) with multiple Mousterian components, but no evidence of any earlier, Acheulian, or later, Upper Palaeolithic, components.

He identified 18 different layers that contained Mousterian levels (fig. 7.3) that were distinguished on both geologic and archaeological criteria (Bordes 1975, 1978). The uppermost 4 levels (F1, F2, F3, F4) he assigned to the MAT, the fifth (G) he wasn't able to assign to an industry, and the lower 13 (H1, H2, I1, I2, J1, J2, J3, J3a, J3b, J3c, X, Y, and Z) he assigned to the Typical Mousterian industry. Bordes also attempted to correlate the stratigraphy between Pech de l'Azé I, Pech de l'Azé II, and Pech de l'Azé IV (Bordes 1978). He put the lower levels of Pech de l'Azé IV (G to Z) in the Würm I and contemporaneous with the upper portion of the sequence at Pech de l'Azé II (levels 2 through 4). And he placed the upper MAT levels in Pech de l'Azé IV as contemporaneous with the whole sequence at Pech de l'Azé I (all MAT as well). Better absolute dates are required to test the potential accuracy of this correlation. Also, since Bordes' work on these sites the climatic sequences typically employed in SW France and their relationship to absolute dates has been significantly revamped.

A sequence of thurmoluminescent dates was produced, on burnt flints, for the whole Pech de l'Azé IV sequence in 1982 (Bowman et. al. 1982). However, these were so obviously out of line with both the archaeological evidence and the geology that they have essentially been dismissed and are not referred to in any current literature on the site. For example, the uppermost date, from level F, was 19.6±1.6 kya, which is at least 15,000 years younger than would be reasonable. Bowman et al. (1982) felt that, in fact, all of the dates were significantly more recent than they should be.

Current Research

In 1996 a new project (McPherron and Dibble 2000) began at Pech de l'Azé IV that continues at the time of this writing. This project was designed to make the substantial collection of artifacts and faunal remains that Bordes had collected (c. 90,000 lithic artifacts and 40,000 animal bones) usable for current researchers. It was stored at the University of Bordeaux and, in terms of usefulness for research, had suffered for lack of proper curation and for lack of good dates and site formation data. Initially the project involved recataloguing all of Bordes' collection, clearing up problems of mislabeling, misplacement, and multiple ID numbers. All the provenienced items were also input into a computer database. This work was finished in 1999.

The project also included a limited amount of excavating in order to collect good dates on the sequence and to arrive at a better understanding of the site formation processes. Excavation began in the summer of 2000 and is expected to be finished in the summer of 2003.

One of the initial major contributions that this current research has provided is the fact that Pech de l'Azé IV was not a rockshelter, but was in fact a cave as well. Based on the nature, source, and direction of origin of much of the site sediments (especially in the earlier layers) recent geomorphological research (Dibble and McPherron 2003) has determined that the site is in the mouth of a collapsed cave the longitudinal axis of which was oriented SE - NW. It is quite apparent now, looking at the distribution of the artifacts in cross-section, that successive occupants at the site had to move further and further into the cave as the cave mouth gradually receded through collapse processes and events.

Currently it is unclear whether Pech de l'Azé IV is part of a cave system separate from Pech de l'Azé I and II, or if it was actually connected at one time directly to Pech de l'Azé I. The longitudinal axis of the Pech de l'Azé I and II caves runs roughly parallel to the face of the cliff and is oriented along this face in the direction of Pech de l'Azé IV. It is possible that Pech de l'Azé IV represents the eastern extremity of what was once an extended cave system that included Pech de l'Azé I and II. If this is accurate it seems unlikely that this system would have been intact when people first began inhabiting the region. More likely, that portion of the system that would have joined Pech de l'Azé IV to Pech de l'Azé I would have collapsed long before this, creating the entrance at Pech de l'Azé I and leaving a semi-intact cave mouth at the Pech de l'Azé IV location that would have served as shelter for sometime before it collapsed as well.

Depositional Sequence

The stratigraphic interpretation developed during the current research has matched Bordes' quite well for much of the depositional sequence. There have been some significant deviations, however, and where Bordes saw 18 major layers, the current project has identified 15 (Dibble and McPherron 2002 - see figure 7.3). The major processes that took place at the site and which had the most influence on the nature of its formation include: the gradual erosion and receding of the cave mouth in a northeasterly direction into the cliff face (with this process sometimes occurring as major, discrete collapse events) and depositing a wide range of éboulis clast sizes on the cave floor and at its entrance; the influx and accumulation of natural sediments, initially originating mainly from inside the cave, but later from outside the cave entrance and moving in; the accumulation of anthropogenic sediments, artifacts, and faunal remains. There are no major sterile layers evident from the initial deposits right up to the top of the Mousterian levels, although there is an obvious unconformity and period of erosion on the very top of these. It is also easily possible that there were previous occupations of the site that were completely eroded away before the laying down of level 8 *directly on the bedrock*, although no evidence of this has been found as yet.

The initial occupations, level 8 (Bordes' levels X, Y, and Z), were immediately on top of the bedrock. These initial deposits are notable for their significant charcoal and ash components. This charcoal occurs as both ubiquitous, dispersed clasts throughout the deposits, but also frequently as obvious, discrete paired lenses of charcoal and ash that must be, for lack of any viable alternative explanations, the remains of cultural behaviour - i.e. hearths. Understanding the nature of these is one of the research goals of the current project. The numerous burnt flints in these deposits should also allow the acquisition of good absolute dates. Among the lithics in this layer are many blades or blade-like flakes reminiscent of early Upper Palaeolithic cultures.

Level 7 is a thin, redeposited layer, probable a result of solufluction, that is notable for its sand and gravel matrix and the heavily eroded lithics in it. It seems most likely that this layer represents a redeposition (flow) of sediments and artifacts from further inside the cave. Bordes had noted these features, but had not set this layer apart from either the one above it or the one below it.

Level 6 (Bordes' J3, J3a, J3b, and J3c) is divided up into two sub-levels, 6a and 6b. 6b is comprised mainly of medium to very large slabs of éboulis (roof fall), which occur at various angles of incline. Those slabs that are near to vertical in orientation, and that are immediately atop level 7, often push down into 7 and have further disturbed it. This layer must represent a period of major roof collapse. The sediments between these large slabs are mainly a brown sandy-silt and the lithic component includes the Assinipodian Industry. Level 6a is really a continuation of the same fine sediments, but with fewer pieces of éboulis, especially further into the cave, and with well preserved faunal remains. The Assinipodian industry continues in 6a as well, but the lithics recovered also include a significant number of large, bladey, Levallois flakes (with no associated cores present and limited debitage of the same raw materials).

Level 5 (Bordes' J1 and J2) is also divided up into 5a and 5b. 5b is a layer of sub-rounded pieces of gravel and small cobbles. It is apparently sorted to a small degree, with the larger, less-rounded cobbles nearer the top of the layer. It is either a cryoturbated or soluflucted layer, which, like level 7, must also have been redeposited from inside the cave. 5a is a thinner layer of small fragments of burned and unburned bone that caps 5b.

Level 4 (Bordes' levels G, H, and I) is divided up into three sub-levels (which don't necessarily correspond to Bordes' levels). 4c includes high concentrations of lithics and relatively large pieces of bone. 4b is a layer of relatively extensive roof collapse, containing many small, medium, and large éboulis, especially to the SE (towards the cave entrance). 4a has significantly fewer and smaller pieces of éboulis. It has significant concentrations of lithics and bones, but mostly in discrete lenses.

Level 3 (Bordes' F levels) includes 3a and 3b. 3b is a layer of sandy silts with very high concentrations of lithics and bone (mainly in smaller fragments). Many of the artifacts and bone are significantly inclined and there is a possibility that this layer has been redeposited to a small degree (perhaps moved down slope, but not very far). 3a is very similar to 3b, but is finer grained and has fewer artifacts and bones. Level 3a has been truncated in the south half of the site. This appears to be the result of the final collapse of the small portion of cave roof, remaining at the end of the Mousterian use of the site, which left the south half of the site exposed. This allowed some of the surface deposits to be eroded away and others to be disturbed *en mass*.

Level 2 is a large, isolated pocket of slumped limestone slabs with sediments that resemble level 3, but which are very obviously not in situ.

In the south half of the site, between level 3 and 1c is an unconformity resulting from a period of erosion.

Levels 1a to 1d are of Holocene age.

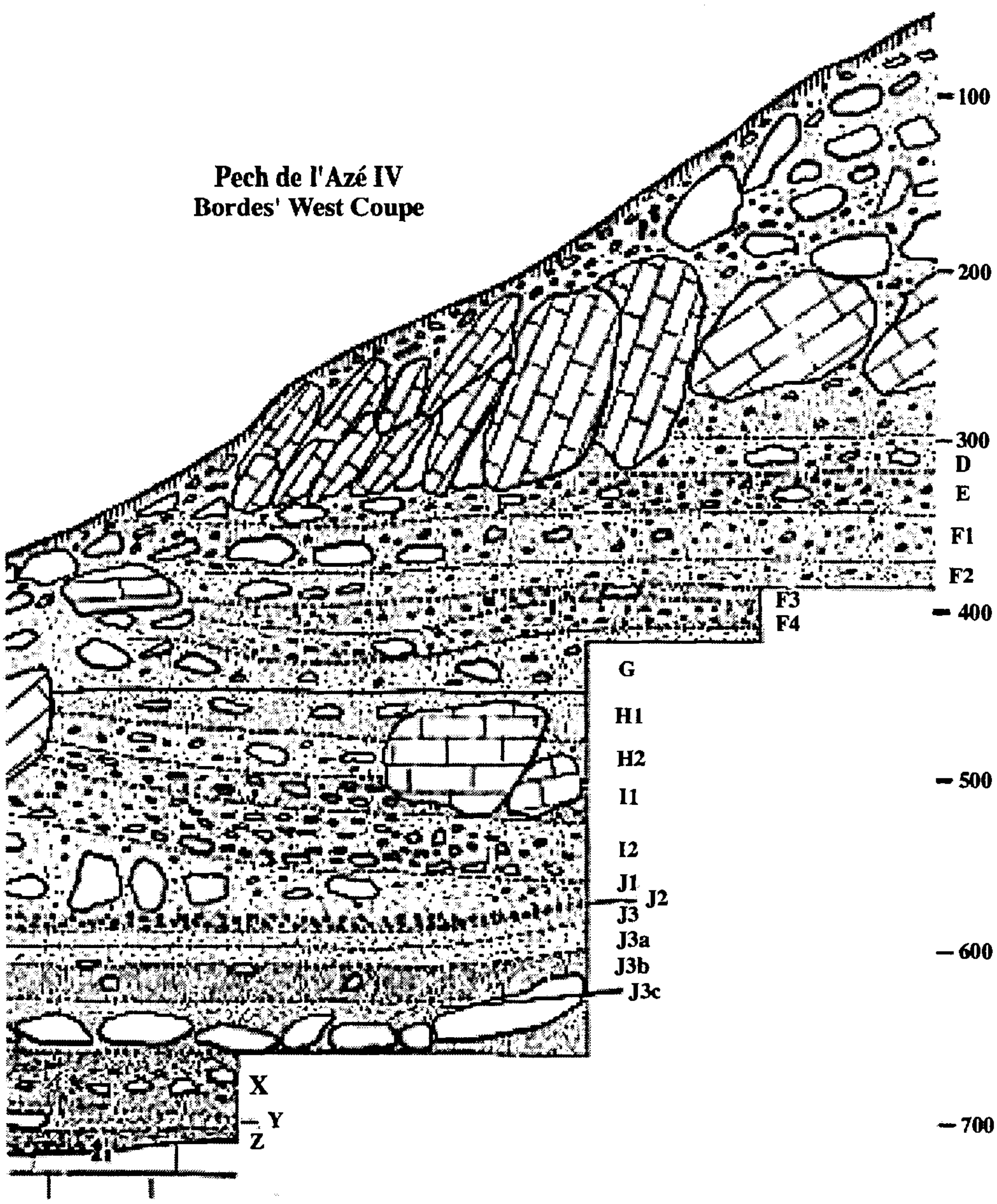


Figure 7.3 Illustration of the stratigraphy at Pech de l'Azé IV. Illustration shows Bordes' original level designations (used by permission of Dibble and McPherron 2001).

Dates, Oxygen Isotope Stages, and Climatic Regimes

As mentioned above, Bordes had assigned the lower levels of the site (levels Z to G or 8 to 4) to the Würm I or Oxygen Isotope Stage 5d to 5a (not 5e) and the upper levels (levels F4 to F1 or 3) to Würm II or Oxygen Isotope Stage 4. Whether these correlations hold up in the current research remains to be seen. The ages, in years before present, associated with these stages, while still in question, have changed significantly since Bordes' research. For example, stage 5d now appears to have begun around 120,000 years ago, which would make the initial occupations at Pech de l'Azé IV much older than Bordes had thought. However, for the purposes here Bordes assignations will be employed. In general, both stages 5 and 4 were cold (excluding stage 5e which was the last interglacial and would have been warm), but stage 5 included more marked fluctuations in temperature and precipitation and during this time period there were at least two periods that were significantly warmer and wetter. Stage 4 was of much shorter duration, but was much colder and drier, and its fluctuations in temperature and precipitation were less extreme.

Faunal Sequence

Only the fauna from the lower levels of the site have been analyzed in any detail, but all current data are summarized in the following table.

Table 7.1 The faunal assemblage by level from Pech de l'Azé IV.

Level	Lithic Industry	Species	NISP
3A	MAT	*Bos/Bison* dominant	?
3B	MAT	*R. tarandus* dominant, *Bos/Bison* increasing	?
4A	Mousterian type?	Rangifer tarandus	189
		Cervus elaphus	17
		Bos/Bison	6
		Equus caballus	6
		Capreolus capreolus	2
		Vulpes vulpes	1
		indeterminate *carnivore*	1
4B	Typical Mousterian	*Rangifer tarandus*	216
		Cervus elaphus	7
		Bos/Bison	7
		Equus caballus	2
		Capreolus capreolus	8
4C	Typical Mousterian	*Rangifer tarandus*	332
		Bos/Bison	119
		Bos primigenius	1
		Cervus elaphus	60
		Equus caballus	17
		Equus hydruntinus	1

Level	Lithic Industry	Species	NISP
		Capreolus capreolus	6
		Rupicapra rupicapra	3
		Canis lupis	1
		Vulpes vulpes	1
		Crocuta spelaea	1
5A	Typical Mousterian	*Rangifer tarandus*	29
		Bos/Bison	11
		Bos primigenius	1
		Cervus elaphus	16
		Equus caballus	6
		Canis lupis	1
		Sus scrofa	1
5B	Typical Mousterian	*Cervus elaphus*	208
		Rangifer tarandus	77
		Capreolus capreolus	103
		Equus caballus	28
		Equus hydruntinus	1
		Bos/Bison	28
		Rupicapra rupicapra	2
		Capra ibex	1
		Megaceros sp.	1
		Sus scrofa	12
		Ursus arctos	2
		Vulpes vulpes	2
6A	Assinipodian	*Cervus elaphus*	583
		Capreolus capreolus	412
		Equus caballus	77
		Equus hydruntinus	2
		Sus scrofa	66
		Rangifer tarandus	6
		Bos/Bison	21
		Bos primigenius	2
		Megaceros sp.	1
		Dicerorhinus sp.	2
		Castor fiber	11
		Ursus sp.	17
		Crocuta spelaea	1
		Indeterminate *carnivore*	1
6B	Typical Mousterian	*Cervus elaphus*	183
		Capreolus capreolus	26
		Equus caballus	24
		Sus scrofa	15
		Bos/Bison	4

Level	Lithic Industry	Species	NISP
7	Typical Mousterian	*Cervus elaphus*	125
		Capreolus capreolus	10
		Equus caballus	17
		Sus scrofa	1
		Bos/Bison	2
		Capra ibex	1
8	Typical Mousterian	*Cervus elaphus*	52
		Capreolus capreolus	8
		Equus caballus	4
		Bos/Bison	2
		Ursus sp.	1
		Canis lupus	1

In general, the fauna indicates a major climatic change from warm, in the lowest levels (8 through 6), to cold in the upper levels (5 through 3).

Raw Material Sources

The vast majority of the raw materials recovered from the components at Pech de l'Azé IV are of Senonian flint of relatively local origin; within 1 km of the site. Although this flint is of good to very good quality, in terms of its flakability, it occurs here as relatively small (5 to 20 cm) rognons, and tends to be more irregular, twisted, and complex in it naturally occurring morphology.

Levallois Presence

The degree of Levallois presence at a site or in individual components is typically indicated by computing a "Levallois Index". This is the total number of Levallois flakes, blades, & points (including retouched pieces) divided by the whole of the non-biface assemblage (flakes and retouched tools) and multiplied by 100. Levallois flakes are identified by analysts mainly by the degree to which they exhibit a radial flaking pattern. Having a facetted striking platform strengthens the identification. Levallois blades are Levallois flakes which are at least twice as long as they are wide and Levallois points are triangular shaped Levallois flakes.

The Levallois Index varies considerably among the components at Pech de l'Azé IV. At this time it has only been computed for each of Bordes' levels and not for the level designations of the current project. For the lowest levels, X, Y, and Z, the Levallois Index is around 13 or 14, for all the J levels it is between 15 and 25, for the I levels it is between 13 and 18, for H1 and H2 it is around 6, for G it is 7, and for the F levels it ranges from 4 to 8.

le Moustier

The site of le Moustier includes two major rock shelters located in the village of le Moustier on a prominent rocky spur formed by the confluence of the Vezère River (a major tributary of the Dordogne) and the small Moustier River. le Moustier is about 10 km upstream from the town of Les Eyzies and about 22 km straight northwest of the Pech de L'Azé sites (figure 7.4).

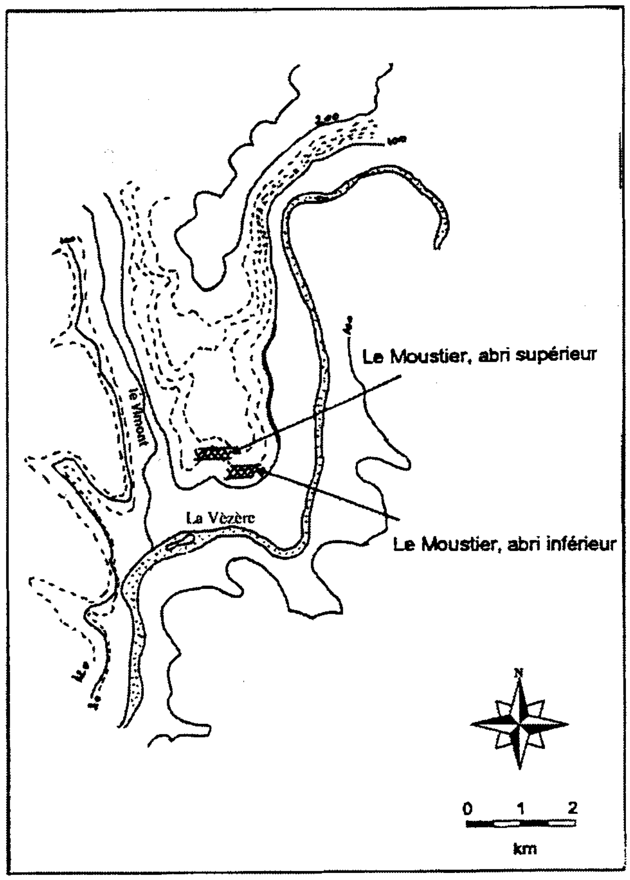


Figure 7.4 Map of location of the upper and lower rockshelters of le Moustier. (used by permission of Soressi 1997).

The shelters, one directly above the other, are in the cliff-face of the rocky spur. The lower shelter is at the level of the present village and can be viewed from the street. Its roof (or what is left of it) forms part of the bench, 13.5 metres above the bedrock of the lower shelter, upon which the deposits of the upper shelter have accumulated (figure 7.5).

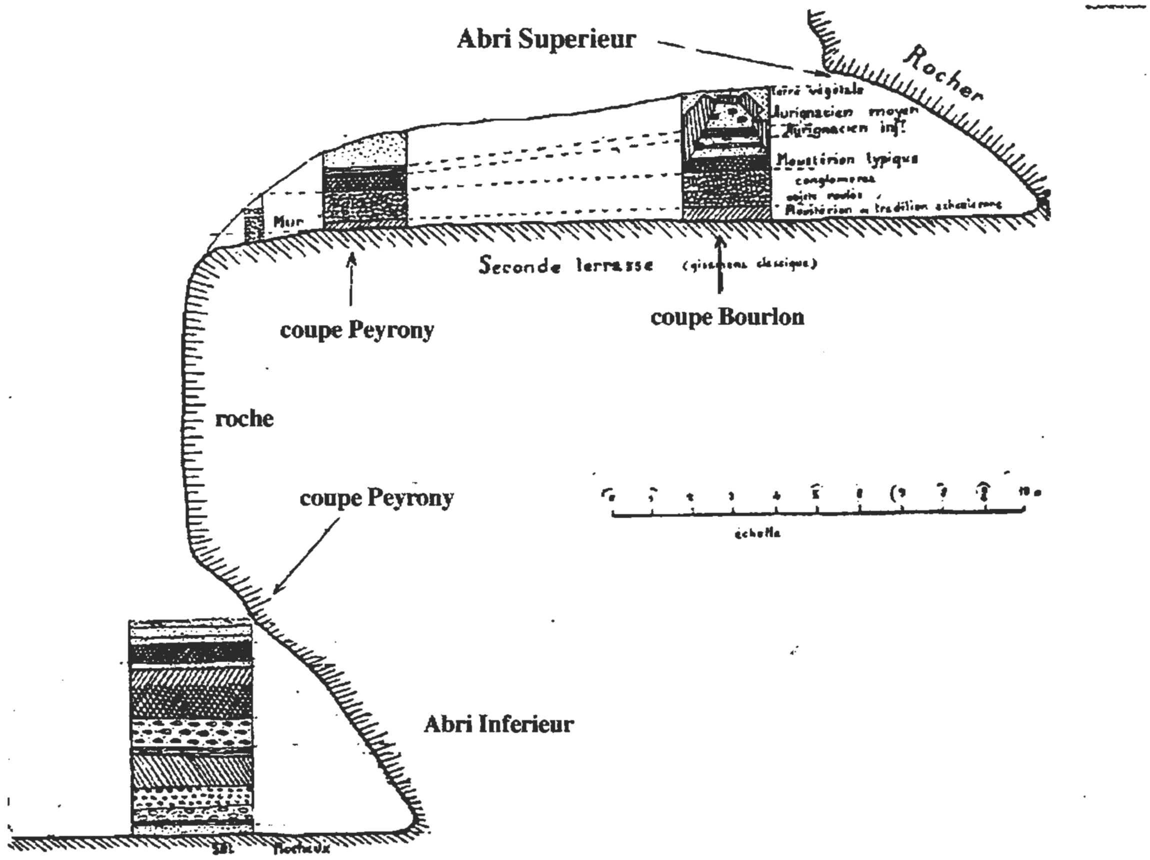


Figure 7.5 Illustration of the upper and lower rockshelters at le Moustier. (adapted from the original in Peyrony 1930).

The first excavations at le Moustier were carried out in the upper shelter (often referred to as the "classic" Mousterian rock shelter or abri) in 1863 by Lartet and Christy (Laville et. al.1980; Peyrony 1930). It was from this initial work at this site that de Mortillet named the industries of the Middle Palaeolithic the "Mousterian". Subsequent excavations by Peyrony and others (e.g. Bourlon) in the early 1900s completely removed all the deposits from the upper shelter.

The lower shelter was first excavated by the German, Otto Hauser, in 1907. Hauser had a reputation as a fossil hunter rather than as a scientist conducting legitimate research, and was not seen to carry out excavation practices considered up to par at the time. Because of this, and the political conditions of the day, he was generally despised by French researchers (Trinkaus & Shipman 1994). During Hauser's excavations he recovered the remains of a neandertal individual "in a burial".

In 1910 Peyrony was able to take over the site from Hauser and continued excavating there intermittently into the 1930s. During this time he excavated most of the site's deposits, leaving only a small block as a control sample (a *témoin* or 'witness') for later researchers. Peyrony also recovered the remains of a neandertal individual. These remains were of a newborn infant and, unfortunately, were lost for many years, being only recently discovered (in 1996) among the collections stored at the Musée National de Préhistoire in Les Eyzies (Maureille 2002).

In 1961 François Bordes and Eugene Bonifay did some limited work on this block, and then in 1969 Henri Laville and Jean-Philippe Rigaud, in the course of cleaning the site up after flooding, collected some more up-to-date data on the site.

The most recent work at the site was in 1982 when Jean-Michel Geneste excavated a 30x40 cm column from the remaining block of sediments in order to collect burnt flint samples for TL dating.

Although it was the excavations in the upper shelter that inspired the use of the site name for all Mousterian industries, the excavations carried out in the lower shelter were far more methodologically rigorous and it is the data from the lower shelter that are used today by researchers.

The depositional sequence (figure 7.6), as it is currently understood, comes mainly from Laville and Rigaud's work in 1969, but follows Peyrony's original work closely. They recognized Peyrony's original 12 stratigraphic units (from A at the Base to L at the surface), that were distinguished Based on their geomorphologies, and for most of them (especially the upper 6 levels) Laville and Rigaud identified further subdivisions. They also recognized two distinct blocks of deposits. Levels A to F were predominantly water deposited sediments, presumably from regular flooding of the site by the Vézère River, which still occurs today, albeit apparently less regularly. Subsequent levels G to L were dominated more by sediments of cryoclastic origin.

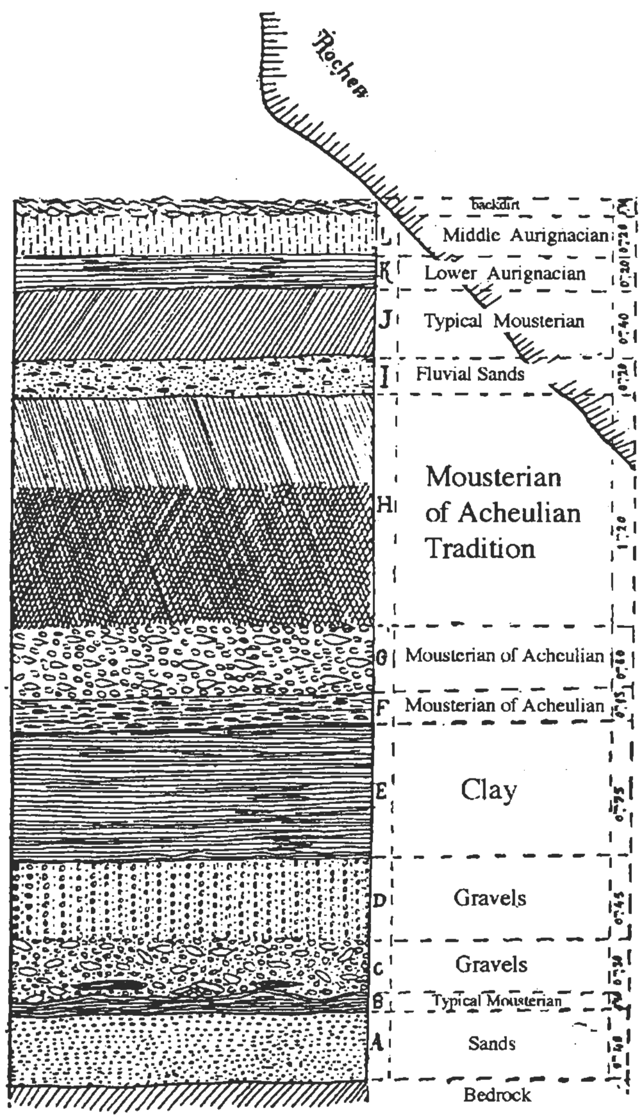


Figure 7.6 Illustration of the stratigraphy of the lower rockshelter at le Moustier. Illustration shows the level designations used by both Peyrony and Laville and Rigaud (adapted from the original in Peyrony 1930).

Based on the available evidence (which included micromorphology studies of the sediments, pollen samples, and faunal remains) they associated the lower block, levels A to F, plus level G (a well developed, but truncated, soil) with the Würm I stadial (oxygen isotope stage 5). The upper levels, H to L, they associated with the Würm II stadial (oxygen isotope stage 4), with the truncated surface of G representing a Würm I/Würm II interstadial and being a period of erosion separating the stadials.

Subsequent thurmoluminescent dating of the upper layers has suggested these associations are likely in error. Laville and Rigaud's configuration puts level G at the end of OIS 5, which is currently dated to around 70 or 75,000 years ago. (While the ability to assign absolute ages to oxygen isotope stages is still tentative, the sources of data for doing this have been steadily growing and a certain level of confidence is now thought reasonable that the dates we have are close to being accurate.) The dates acquired for level G are between 45 and 60,000 years (Valladas et. al. 1986), which make this layer too recent by 10 to 15,000 years. In fact the TL dates for the upper block place it as a whole well within OIS 3. Laville and Rigaud's interpretation that these upper levels were deposited in a cold climate like OIS 4 is slightly incongruent as OIS 3 is a *relatively* warm stage, although it was still very cold and dry by today's standards. A reexamination of the correlation between the whole of the site's deposits and specific climatic periods is obviously required.

Faunal Sequence

A more detailed quantification of the le Moustier faunal assemblage is available, compared to the other 4 study sites.

Table 7.2 Faunal assemblage by level from le Moustier (from Peyrony's excavations, courtesy of Stephane Madeleine at le Musée National de Préhistoire, les Eyzies, France).

Level	Lithic Industry	Species	NISP
L	Middle Aurignacien	*Canis lupus*	1
K	Early Aurignacien	*Rangifer tarandus*	4
		Cervus elaphus	1
		Equus caballus	2
J	Typical Mousterian	*Bos/Bison*	22
		Cervus elaphus	4
		Rangifer tarandus	6
		Capra ibex	1
		Equus caballus	1
		Sus scrofus	1

Level	Lithic Industry	Species	NISP
I	Mousterian	*Bos/Bison*	16
		Cervus elaphus	1
		Equus caballus	8
		Crocuta spelaea	1
H	MAT	*Bos/Bison*	298
		Rangifer tarandus	13
		Equus caballus	66
		Capra ibex	14
		Equus hydruntinus	68
		Cervus elaphus	1
		Capreolus capreolus	2
		Capra ibex	2
		Canis lupus	
G	MAT	*Bos/Bison*	253
		Equus caballus	4
		Equus hydruntinus	1
		Rangifer tarandus	12
		Cervus elaphus	9
		Capreolus capreolus	1
		Capra ibex	3
		Sus scrofus	1
		Dicerorhinus sp.	1
		Ursus sp.	1
		Crocuta spelaea	1
		Vulpes vulpes	1
F	MAT	*Bos/Bison*	5
		Rangifer tarandus	6
		Cervus elaphus	1
		Capra ibex	1
		Dicerorhinus sp.	2
B	Typical Mousterian	*Bos/Bison*	3
		Equus caballus	3

Mousterian Industries

Occupations in the lower layers, A to F, seem to have been generally sporadic and these deposits may have been affected by regular flooding, resulting in "scattered pockets" of artifacts and faunal remains (Laville et. al. 1980: 175-77). However, the assemblages in levels B and F were large enough to assign them to the Typical Mousterian and the Denticulate respectively.

The richer upper layers, G, H and J, were more readily identifiable to specific industries: level G to the MAT type A; H to the MAT type B; and J to the Typical Mousterian. Bordes assigned Level I to the Denticulate Mousterian. Levels K and L are predominantly Upper Palaeolithic in content, although K includes some abraded Mousterian items mixed in with its fresher-looking Chatelperronian artifacts (Peyrony 1930; Laville et. al. 1980; Soressi 1997).

Levallois Presence

Raw numbers from which a Levallois index could be computed are not available for each level. Peyrony does not provide these counts. However, the degree of Levallois presence has been computed for Level G, the focus of this study (LI = 10.1).

Raw Materials

Almost 100 percent of the lithic raw material used and left at the site is Sénonien flint. This flint can have a range of textures and qualities, but is typically fine-grained and of good to very good quality for knapping. The primary geological location of this flint is a bed that traverses the whole Perigord region from northwest to southeast, and more than two dozen outcrops are known to exist within 5 kilometres of the site of le Moustier. Typically this flint occurs as "rognons"; that is in irregular, 'kidney-shaped' nodules, common for flints formed in marine sediments. Within some marine beds these nodules can be quite large (> 40 or 50 cm in any dimension), but Sénonian flint tends to occur in nodules no larger than 15 cm in diameter (Soressi 1997; Geneste 1985; Demars 1982, 1994). Almost 80 percent of the material at le Moustier appears to be from weathered nodules or cobbles, and so is from secondary deposits (e.g., alluvial) in the region. This suggests that there are/were far more potential sources in the region than just the primary geologic outcroppings.

Combe Capelle Bas

Combe Capelle Bas is a rock shelter located in the valley of a small stream, the Couze, another tributary of the Dordogne River, entering it from the south. It is about 30 km straight wsw from the Pech de l'Azé sites and about 30 km straight ssw from le Moustier (figure 7.7). As with Pech de l'Azé IV, Combe Capelle Bas is one of a complex of sites. Roc de Combe Capelle and Abri Peyrony are situated near the top of the valley edge at the Base of a cliff. Combe Capelle and Combe Capelle Bas are at the bottom of the valley slope overlooked by the two upper sites. This complex of sites includes deposits that span the Lower, Middle, and Upper Palaeolithic.

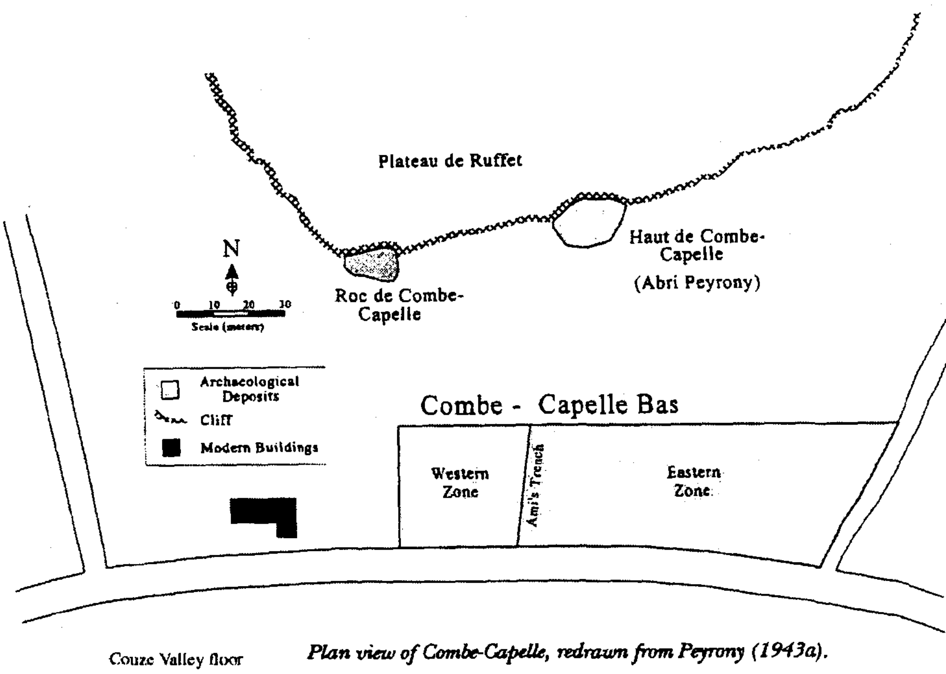


Figure 7.7 Map of the layout of the site of Combe Capelle Bas along the north bank of the river Couze.(used by permission of Dibble and Lenoir 1995).

Excavations at the Combe Capelle sites began in the late 19th century, but little of this work was ever reported on. The site of Combe Capelle Bas itself was initially discovered and excavated by Landesque in the 1880s (Chastaing 1905; Landesque 1887; Mensignacand Chabanne 1890). The German prehistorian, Hauser, who had excavated at le Moustier and other well known Mousterian sites, worked at Roc de Combe Capelle in the early 1900s and in 1909 recovered a skeleton, but essentially removed the entire site's deposits in the process. In 1910 Denis Peyrony began more systematic work at Combe Capelle Bas, and then in 1925, while Peyrony was excavating the site of Haut de Combe

Capelle, he suggested that his friend, Henri-Marc Ami, a Canadian doctor and amateur prehistorian, take up further excavations at Combe Capelle Bas. In 1926, Ami, who excavated at several sites in France, carried out extensive excavations at Combe Capelle Bas that ended with his death *at the site* in 1931 (*in fact Denis Peyrony, following Ami's instructions, removed Ami's heart for burial at the site. Unfortunately, Peyrony died before he could do this and the heart sat in a jar in his son's pantry for a few years before it was eventually cemented into a small stone fence at Combe Capelle Bas where it is marked today with a plaque, just metres from the road's edge*). Denis Peyrony (Peyrony 1943), and then Maurice Bourgon (Bourgon 1957), took over writing up and reporting Ami's work. However, the untimely deaths of both Ami and Bourgon meant that the work was never published in its entirety, although the potential importance of the site did become apparent.

In the mid-1980s Harold Dibble and Michel Lenoir began a multi-year project at Combe Capelle Bas. The main goals of the project were to get a better understanding of the lithic industry sequence at the site and to investigate raw material availability as a factor in Mousterian lithic industry variability. They began with an extensive reexamination of the existing collections and followed this up in 1987 with 4 seasons of excavations at the site.

In order to get good coverage of the site, Dibble and Lenoir initially divided the length of the site (which is over 30 metres), into three sectors (I at the Base of the slope, II in the middle, and III at the top). They then put in blocks of 1x1 m units along the edge of Ami's trench in each of these sectors. Since most of the site is situated on a slope and the stratigraphy runs parallel to this slope (except in Sector I where the bedrock and overlying sediments are more or less horizontal), this sampling of three different places along the slope allowed the excavators to view the whole stratigraphic sequence with the fewest number of 1x1 metre units.

Depositional Sequence

Since the sample used for this research was taken from the Sector I assemblage, I will concentrate on the stratigraphic sequence for this lower part of the site.

Dibble and Lenoir identified 4 main 'beds' in the stratigraphy of Sector I. They also recognized from the outset that the formation of the site would have been particularly complex due to the sloped nature of much of the upper portions of it. Down-slope movement must have been a factor, and perhaps a significant one. The sediments in Sector I also include some fluviatile deposits indicating that the Couze was higher at times and contributed to the site formation. In fact Sector I can be generally seen as a point of interfacing of these two sources of sediments, especially in the uppermost bed (I-1).

Beds I-4 and I-3 were not further subdivided. They were only exposed in a small sondage and so only a small sample of artifacts was recovered for each (173 flakes and tools for I-3, and 43 for I-4) and only a limited view of the sediments was had. Bed I-4 is well sorted and includes obvious river drifts and so appears to be almost exclusively fluvial in origin. Bed I-3 deposits are not sorted or well rounded and are interpreted to be slope-derived sediments that have been reworked to some degree by fluvial actions.

Bed I-2 includes interstratified slope and fluvial deposits. It was subdivided into levels I-2B and I-2A Based mainly on a changing content and size of limestone blocks, with larger blocks more common in the upper, Level I-2A. About 780 flakes and tools were recovered from I-2A and about 450 from I-2B.

Bed I-1 stratigraphy was even more complex with the interstratification of slope and stream deposits becoming more apparent. 7 subdivisions were recognized, including I-1E, I-1D1, **I-1D**, I-1C2, I-1C1, I-1B, and I-1A.

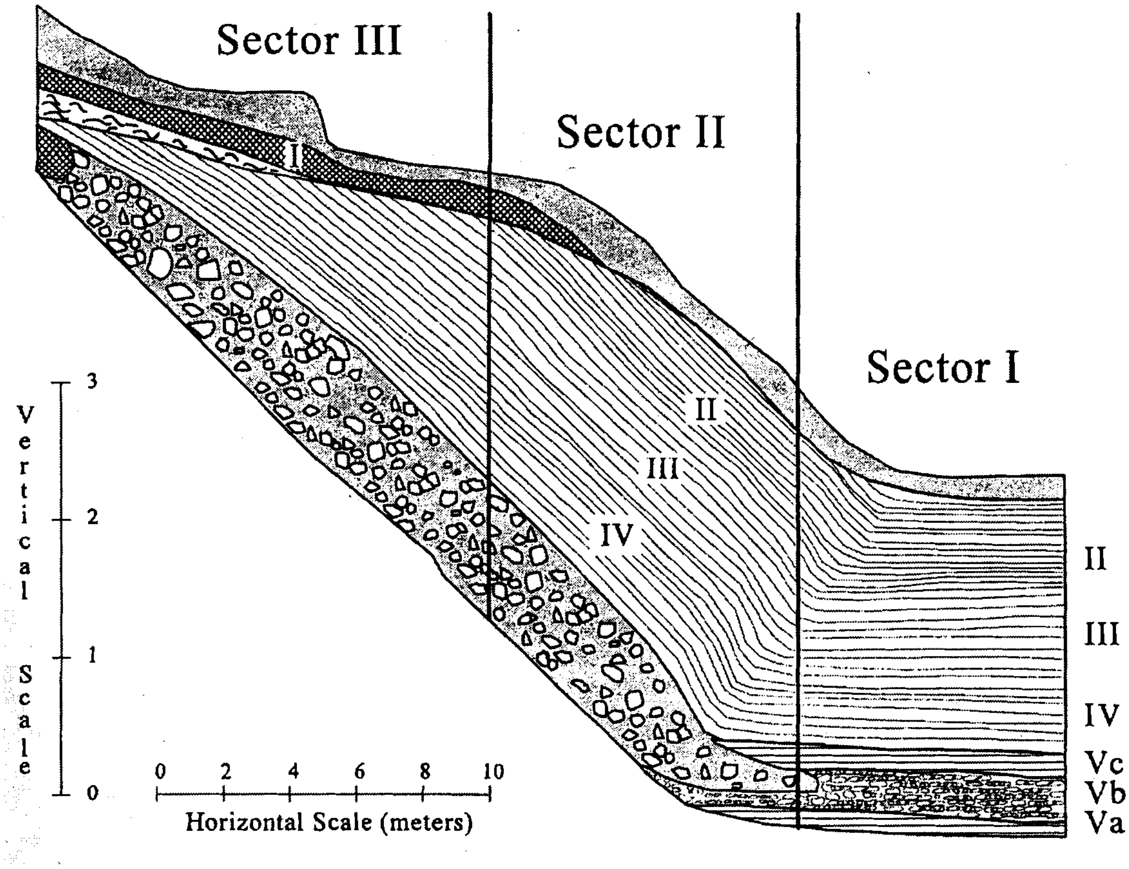


Figure 7.8 Illustration of the stratigraphy at Combe Capelle Bas. Illustration shows the slope of the deposits and Dibble and Lenoir's level designations. (used by permission of Dibble and Lenoir 1995).

Site Formation

It should be noted that Texier and Bertran (1996) carried out some sedimentological analysis at Combe Capelle Bas and have argued that the site deposits were originally deposited in a site near the top of the slope and had at some point been transported down the face of the slope by either solufluction or debris flow or both. Dibble and Lenoir (1995) agree that there was obviously some down-slope movement of the deposits, but that it was limited and that the various stratigraphic layers are discreet and internally consistent and, therefore, the observed chronological patterning is real. Dibble and Lenoir lay their (convincing) argument out in 4 major points (1995: 256-57). First, such movement would have produced deposits with industries of a homogeneous nature, which does not appear to be the case, in terms of technological differences.

Second, There does not appear to be any upslope source for these deposits. The site of Abri Peyrony, directly above the Combe Capelle excavations has an MAT industry rich in Bifaces and Levallois. Third, the lithic industries do not exhibit the level of wear and damage that one would expect from such transport (as observed elsewhere and produced experimentally). Finally, the surface topography on either side of the deposits exhibit the same terraces observed below-surface within the site deposits. Such mass movement should have smoothed these out.

Dates

Prior to obtaining several absolute (TL) dates, there had always been some disagreement about the probable age of the Combe Capelle Bas deposits. Most of the earlier researchers at the site, based on geologic data, had assigned the deposits to the Würm. Peyrony (1934) and Bourgon (1957) had correlated this site with the lower levels of le Moustier which had been associated with the Würm. Texier (1968), after studying samples of the deposits, had assigned them to Würm I. However, Breuil (Breuil and Lantier 1959) had assigned the middle slope deposits to the Rïss as have Texier and Bertran (1996) more recently. Texier and Bertran argue that the deposits are at least as old as OI stage 6 (130 to 200 kya), but more likely from stage 8 (250 to 300 kya) or even 10 (350 kya).

However, in 1990 seven dosimeters were placed in the deposits of sector I and left there for 1 year to measure the annual radiation dose rates to which artifacts in the deposits are exposed. This data was used to acquire thurmoluminescent dates on burnt flints (Valladas et. al 2003). Seven dates from the middle levels (I-2B to I-1D) within the stratigraphy of sector I were obtained, with 6 of them lumping between 50 and 60 ky, with a mean age of 51.8 ± 3.0 ky (the seventh produced a date of 37 ky). This puts these deposits at the beginning of OI stage 3 or the early Würm interpleniglacial. This period saw frequent climatic oscillations, but was generally very cold and dry, with steppic climatic regimes dominating. However, because this site is located in a river valley, it is likely that stands of trees (pine, birch, and possibly alder) were a common component of the immediate environment.

Faunal Sequence

Faunal remains were very scarce in the site deposits. Only about 50 bone fragments were recovered from the whole site and these have yet to be analyzed (Dibble per. comm. 2004).

Mousterian Industries

Although there was some Quina retouch noted and several Quina scrapers were recovered, the Quina index (percent of scrapers with Quina retouch) is quite low as was the general percentage of scrapers for the site as a whole. Following Bordes' typological criteria all the levels of the site tend to fall into the Typical Mousterian category, although all levels were notably rich in denticulates and notches. Bifaces were essentially absent as were bifacial reduction flakes. The few bifaces that were recovered from the site were found on the ground surface and there association with the underlying deposits is not clear. The use of Levallois methods at the site is also quite low, with an average Levallois Index of 2.35. Few typical Levallois flakes were recognized in the level assemblages, and the majority of the cores recovered were amorphous with removals from multiple surfaces, although there were some of apparent Levallois and disc morphologies (Dibble and Lenoir 1995: Chapter 5).

Raw Materials

The site of Combe Capelle Bas sits directly on a source of Campanian flint. This is a flint formed in late Cretaceous formations and which can occur in very large (40 to 60 cm) slabs or nodules. About 93% of the site assemblage is comprised of this material. There is also another Campanian flint which makes up another 3% of the assemblage, but its exact origin is not known. These materials are considered to be of medium to very good knapping quality (although it is the better quality materials that tend to be selected for use). The remaining 4% includes Campanian flints from alluvial sources (perhaps the river directly below the site), Senonian flint from near Bergerac, and other more minor types (Dibble and Lenoir 1995:261 and 322 to 23).

Jiboui

Jiboui is located in a small north-south oriented col at an elevation of 1620 metres in the Massif du Vercors of the Northern Alps of France. Mountain peaks in this region range between 1800 and 2800 m. Jiboui is an open-air site with a view of the major pass between the Vercors and the Diois region in the adjacent Southern Alps of France (figure 7.9).

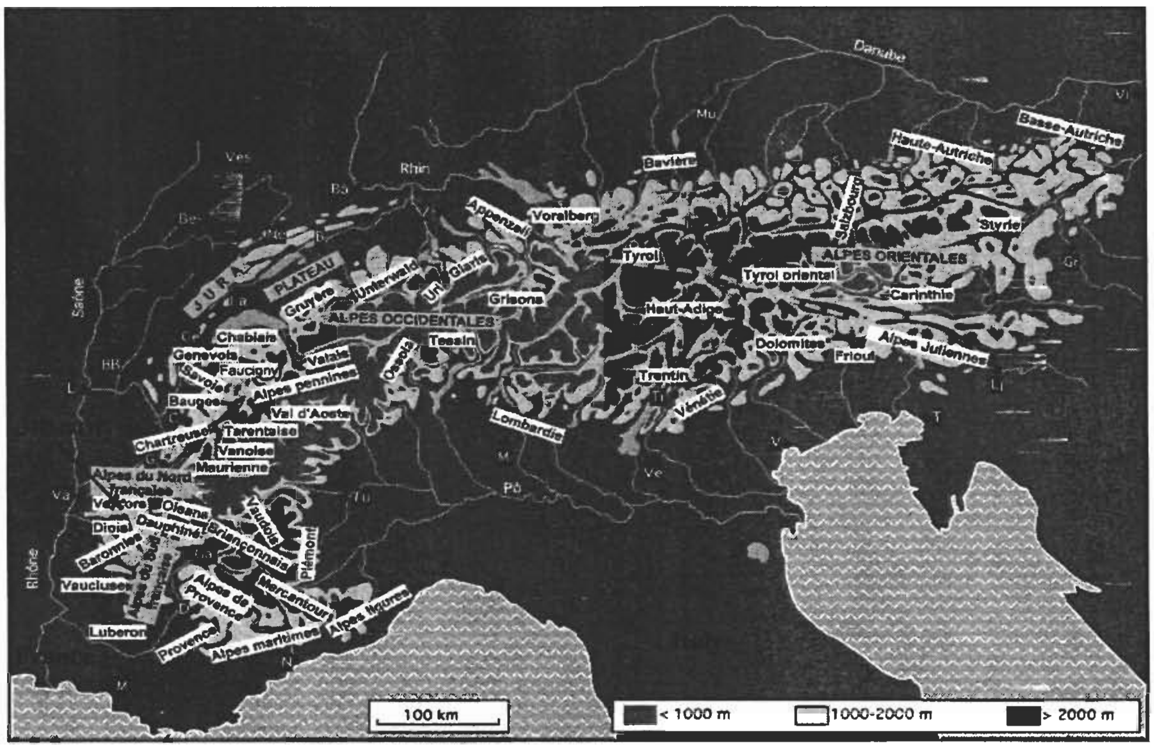


Figure 7.9 Map indicating the location of the site of Jiboui in the French Alps (from Les Alpes et le Jura, published by Éditions Scientifique GB -- used by permission of Tillet).

It was discovered in 1989 and from 1997 through 1999 10 sq. m of it were excavated, uncovering Pleistocene deposits with heavy concentrations of artifacts (Tillet 2001:94-97).

Site Formation

Currently, a detailed description of the formation of the site is not available. In general, the archaeological components are lying on top of about 3.3 metres of clay, the top of which is capped by a layer of cryoclastic rock fragments.

Above this are the 1.5 metres of yellow coloured Pleistocene deposits with approximately 20,000 Mousterian artifacts recovered from just the 10 sq. metres excavated. These must represent multiple warm season occupations for, as the excavators say, it is difficult to conceive that such accumulations could occur in just one season, and winter occupations at such an elevation (especially open-air) are not likely.

Analysis of the orientation of the artifacts indicates some slight patterning (likely due to seasonal ground-surface washing from rain and snow-melt), but not significant enough to suggest any notable post-depositional alteration of the site. This is further supported by a number of refits that suggest little real vertical movement.

Above this is a layer of Holocene deposits about 90 cm thick. This includes numerous limestone blocks and about 20 pieces of Neolithic debitage. The top of this layer includes some burned deposits, and on top of this is an organic A layer at ground surface (Tillet 2001:95-96).

Dates

A large number of the Mousterian artifacts were burned and provided two thermoluminescent dates of 48,600 ±3000 (BDX 6013) and 55,200 ±3500 (BDX 6190) years bp (giving a range of 45.6 to 58.7 thousand years bp). This puts the occupation of the site in the same general climatic period, early OIS 3, as the primary three site samples (Tillet 2001:97).

Faunal Sequence

The few bones that were included two items, identified as marmot (*Marmota* sp.), from the top of the Mousterian layer, and 5 other unidentified fragments (but probably not marmot) from the bottom of the layer (Tillet 2001:97).

Mousterian Industries

The strong scraper count, very low notch and denticulate count, lack of handaxes, and strong Levallois component of the assemblage lead the excavators to classify it as Charentian Mousterian of the Ferrassie type (Tillet 2001:97).

Raw Materials

Without any doubt, the raw materials come a very local source. Easily extractable flint nodules, of good quality, can be found in the Turonien levels at the foot of the mountain of Belle Motte, which makes up the western side of the col (Tillet 2001:97 - but see also Bressy 1998 and Bressy *et. al.* 1999).

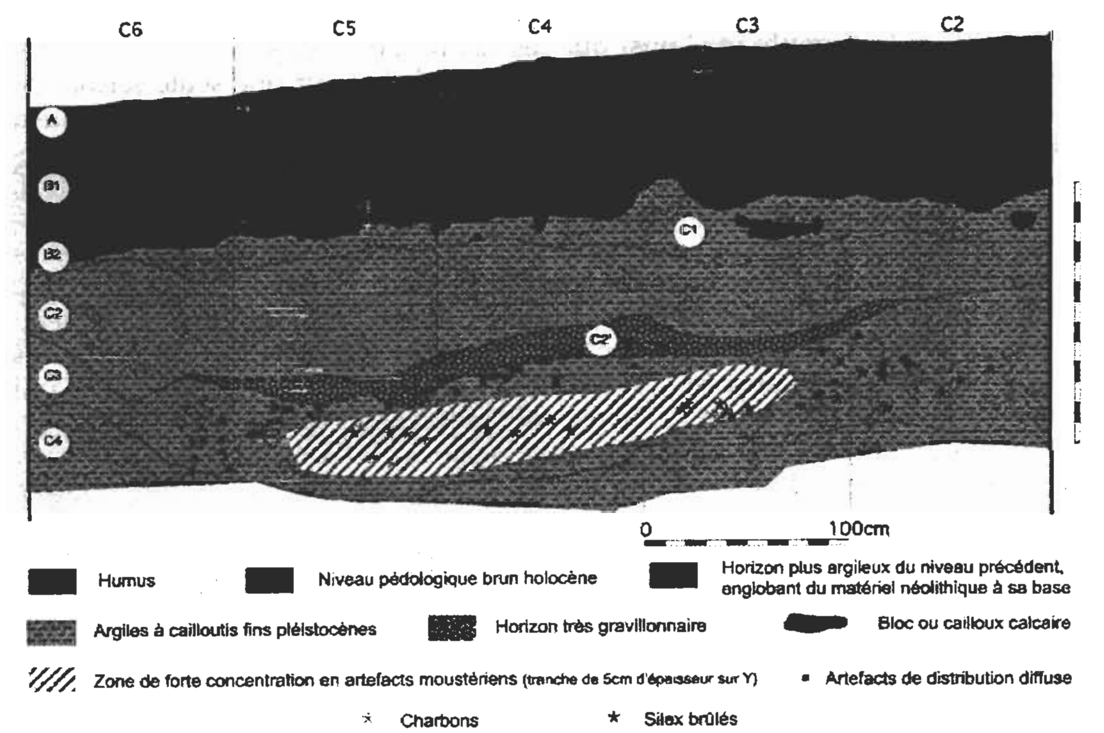


Figure 7.10 Illustration of the stratigraphy at Jiboui.
(from Les Alpes et le Jura, published by Éditions Scientifique GB -- used by permission of Tillet).

Assemblage Samples

Pech de l'Azé IV

The sample assemblage used in this study was taken from level F2 of Bordes' collection and stratigraphic sequence. This level corresponds to level 3A of Dibble and McPherron's stratigraphic sequence (Dibble and McPherron 2003). Almost any of the components from Pech de l'Azé IV would probably have worked well as samples for this study. This particular component was selected for analysis mainly because its is, at this time, better dated than the rest of the components (and is of a comparable age as the other analysis samples) and it included a fairly large assemblage from which a sample could be taken. Furthermore, like the sample from le Moustier, it represents an MAT industry, but, unlike le Moustier, it had few handaxes. Thus it might provide some insight into the relationship between the use of biface technology and other reduction strategies.

In course of their excavations Dibble and McPherron recovered 5 thermoluminescence dates on burnt flints which ranged, in thousands of years ago, from 47,000 ±6000 to 60,000 ±8000, with averages of 50,000 ±3000 (EU) and 52,000 ±5000 (LU). These dates correspond to the start of Oxygen Isotope stage 3 (early Würm interstadial - see fig. 2.3).

The climatic regime of this stage included very cold and dry, steppe-tundra conditions. The faunal remains from this level were dominated by Bos/Bison.

Bordes assigned this level to the Mousterian industry MAT(B) because of the almost complete lack of handaxes, but relative abundance of backed knives (see Dibble and Lenoir 1994), and this assignment is supported by the most recent excavations (Dibble and McPherron 2003). As with the site as a whole, the Levallois presence is low (Dibble and McPherron calculated a LI of 4.9). And, as with most of the other layers, in this level the assemblage was produced from the local, relatively small cobbles or pustules of medium to good quality flint.

The total number of items included in the study sample was 814 (335 tools, 336 complete and proximal flakes, 47 flake fragments and 96 cores) out of a total of 1902 pieces recovered by Bordes from this level.

Table 7-3 Counts of technological and tool types for level F-2 of Pech de l'Azé IV.

Type #	Type Description	**Count**
1	Typical Levallois Flake	24
2	Atypical Levallois Flake	5
3	Levallois Point	2
4	Retouched Levallois Point	1
5	Pseudo-Levallois Point	19
9	Single Straight Scraper	3
10	Single Convex Scraper	8
11	Single Concave Scraper	4
17	Double Convex-Concave Scraper	2
18	Straight Convergent Scraper	1
24	Concave Transverse Scraper	1
26	Abrupt Scraper	2
28	Scraper w Bifacial Retouch	2
30	Typical Endscraper	1
32	Typical Burin	5
34	Typical Per coir	4
36	Typical Backed Knife	19
37	Atypical Backed Knife	17
38	Naturally Backed Knife	69
40	Truncation	1
42	Notch	54
43	Denticulate	64
45	Flake w Irreg Retouch on Interior	12
46-49	Flake w Abrupt & Alternating Retouch	9
50	Bifacially Retouched Flake	5
54	End-notched Flake	1
Total		**335**

Table 7-4 Basic summaries of the level F-2 sample assemblage.

Real Count	335
Essential Count	277
Complete & Proximal Flakes	336
Flake Fragments	47
Cores	96
Sample Assemblage Total	**814**

***Component assemblage total N = 1902**

Table 7-5 Summary of indices for level F-2.

Scraper Index	6.9 (real), 8.3 (essential)
Levallois Index	3.9
Typological Levallois Index	9.6

(sample included a total of 32 Levallois flakes, retouched or not)

le Moustier

The sample assemblage used in this study was taken from level G of the stratigraphic sequence established by Peyrony (1930) and later followed by Laville & Rigaud (1976, 1973). This component was selected for analysis here because, as with level F2 at Pech de l'Azé IV, it is well dated (and of a comparable age as the other samples), but also because it had just recently been employed in another study (Soressi 1997) which meant that the assemblage itself was in a good state of organization and much of the backbround information on research at the site had been compiled by Soressi and was available to me. Level G also represents an MAT industry in which bifaces were numerous, which meant that I would have the opportunity to investigate the role that this lithic strategy might have played at this site.

Laville & Rigaud produced two thermoluminescence dates on burnt flints from level G: 50,300 ±5500 and 55,800 ±5000 years bp., with an average of 53,000 (Valladas et. al. 1986). As with the Pech de l'Azé IV level F2 dates, these dates correspond to the start of OI stage 3 (early Würm interstadial).

As with Pech de l'Azé IV, the fauna of level G was strongly dominated by Bos/Bison (table 7.1 above).

Peyrony and Laville and Rigaud assigned this level to the Mousterian industry MAT(A) because of the numerous and well made handaxes. This level, as with the site as a whole, the Levallois presence is fairly high (Soressi calculated a LI of **36.7**). In this level the lithic assemblage was produced from the regionally available, medium to large size cobbles of medium to good quality flint.

The total number of items included in the study sample was 693 (263 tools, 328 complete and proximal flakes, 61 flake fragments and 41 cores) out of a total of 1711 pieces recovered by Laville and Rigaud.

Table 7-6 Counts of technological and tool types for level G of le Moustier.
***Component assemblage total = 1850**

Type #	Type Description	Count
1	Typical Levallois Flake	37
3	Levallois Point	3
5	Pseudo-Levallois Point	3
9	Single Straight Scraper	13
10	Single Convex Scraper	8
11	Single Concave Scraper	3
18	Straight Convergent Scraper	1
22	Straight Transverse Scraper	1
25	Scraper on Interior Surface	2
30	Typical Endscraper	4
31	Atypical Endscraper	1
32	Typical Burin	2
33	Atypical Burin	1
34	Typical Perçoir	2
36	Typical Backed Knife	7
37	Atypical Backed Knife	10
38	Naturally Backed Knife	26
40	Truncation	1
42	Notch	56
43	Denticulate	23
45	Flake w Irreg. Retouch on Interior	14
46-49	Flake w Abrupt & Alternating Ret	17
50	Bifacially Retouched Flake	1
54	End-Notched Flake	7
55	Hachoir	1
62	Miscellaneous	18
Total		**263**

Table 7-7 Basic summaries for the assemblage of level G.

Real Count	263
Essential Count	191
Complete and Proximal Flakes	328
Flake Fragments	61
Cores	41
Sample Assemblage Total	**693**

Table 7-8 Summary indices for level G.

Scraper Index	10.6 (real), 14.7 (essential)
Levallois Index	10.1
Typological Levallois Index	26.7

(sample included a total of 69 Levallois flakes, retouched or not)

Combe Capelle Bas

The sample assemblage for this site was taken from level ID of Sector I of the stratigraphic sequence and excavation layout established by Dibble and Lenoir (1995). Sector I refers to the portion of the site that was excavated that is lowest down on the slope upon which the site is situated. This component was selected for analysis because it is of a comparable age to the other samples and because it was the largest assemblage of the components in Sector I and could provide a large sample.

Thermoluminescence dates were produced by Valladas et. al. (2002) for level 1D on 6 pieces of burnt flint. These ranged between 50 and 60,000 years BP, with an average of 51,800 ±3000 years bp (at 1 sigma level). As with the Pech de l'Azé IV level F2, and le Moustier Level G, these dates correspond to the start of OI stage 3 (early Würm interstadial). As mentioned above, very little faunal material was recovered.

Dibble and Lenoir assign this level (as with all the deposits) to the Typical Mousterian Industry, with relatively high percentage of denticulates. The Levallois presence is very low, with a Levallois Index of **2.0**.

Over 96% of the raw materials are of the very local, large slabs or nodules as described in the site description above.

Table 7-9 Counts of technological and tool types, level I1D of Combe Capelle Bas.

Type #	Type Description	Count
1	Typical Levallois Flake	14
2	Atypical Levallois Flake	1
5	Pseudo-Levallois Point	2
8	Limace	1
9	Single Straight Scraper	8
10	Single Convex Scraper	20
11	Single Concave Scraper	1
13	Double Straight-Convex Scraper	1
15	Double Convex Scraper	3
19	Convex Convergent Scraper	1
22	Straight Transverse Scraper	4
23	Convex Transverse Scraper	13
25	Scraper on Interior Surface	7
26	Abrupt Scraper	3
28	Scraper w Bifacial Retouch	3
30	Typical Endscraper	1
31	Atypical Endscraper	1
32	Typical Burin	1
33	Atypical Burin	2
34	Typical Perçoir	3
38	Naturally Backed Knife	3
39	Roulette	16
40	Truncation	1
42	Notch	95
43	Denticulate	32
44	Alternate Retouch Bec	1
45	Flake w Irreg Retouch on Interior	8
46-49	Flake w Abrupt & Alternating Retouch	11
54	End-notched Flake	12
62	Miscellaneous	16
64	Truncated-Facetted Piece	3
Total		**288**

Table 7-10 Basic summaries for the assemblage of level I1-D.

Real Count	285
Essential Count	251
Complete and Proximal Flakes	159
Flake Fragments	19
Cores	66
Sample Assemblage Total	**532**

***Component assemblage total =1400**

Table 7-11 Summary indices for level I1-D.

Summary Indices	
Scraper Index	22.2 (real), 25.5 (essential)
Levallois Index	3.6
Typological Levallois Index	6.7

(assemblage included a total of 19 Levallois flakes, retouched or not)

Jiboui

No samples were taken from this site assemblage. The entire lithic assemblage (less those flakes <2.0 mm in maximum dimension) is included in the analysis. Analysis of the lithic assemblage was carried out by Sébastien Bernard-Guelle and the resulting data was generously provided to me.

Table 7-12 Counts of technological and tool types for Jiboui.

Type #	Type Description	Count
1-3	Levallois Flakes	178*
6	Mousterian Point	7
9	Single Straight Scraper	4
10	Single Convex Scraper	24
11	Single Concave Scraper	4
13	Double Straight-Convex Scraper	2
15	Double Convex Scraper	2
17	Double Convex-Concave Scraper	1
18	Straight Convergent Scraper	3
19	Convex Convergent Scraper	11
20	Concave Convergent Scraper	6
21	Dejete Scraper	9
22	Straight Transverse Scraper	2
23	Convex Transverse Scraper	3
26	Abrupt Scraper	3
27	Scraper w Thinned Back	3
30	Typical Endscraper	1
31	Atypical Endscraper	6
32	Typical Burin	1
34	Typical Percoir	2
37	Atypical Backed Knife	1
40	Truncation	1
42	Notch	4
43	Denticulate	9
54	End-notched Flake	5
56	Rabot	1
62	Truncated-Facetted Piece	21
Total		**312**

***data was not collected for all flakes in the assemblage. Which means, for example, that while there are 178 (Central) Levallois flakes in the assemblage, from which a Levallois Index can be computed, not all 178 flakes can be included in all subsequent analyses.**

Table 7-11.2 Basic summaries for the Mousterian component of Jiboui.

Real Count	312
Essential Count	133
Complete & Proximal Flakes	4294
Cores	197
Sample Assemblage Total	**4624**

Table 7-14 Summary indices of the Mousterian component of Jiboui.

Summary Indices	
Scraper Index	24.7 (real), 57.9 (essential)
Levallois Index	4.0*
Typological Levallois Index	57.1

***this number will be notably deflated because only flakes <2.5 mm were excluded from the other samples, while flakes <2.0 mm were excluded here making the assemblage total higher relative to the other samples.**

Primary Site Samples - Selection Process

In terms of numbers alone, my samples represent relatively large percentages of the entire population of each component assemblage; 47% for Pech de l'Azé IV, 38% for le Moustier, and 38% for Combe Capelle Bas (sampling excluded all highly fragmented flakes because they would not have been serviceable as tool blanks if they had been broken prior to blank selection and cannot be properly analyzed if they were broken subsequent to any use. Shatter was also excluded.).

Such large percentages mean that there would be little question, just in terms of numbers, that any patterns observed in the samples would be representative of the populations. However, the samples that were analyzed were not, as a whole, selected randomly. For each component assemblage that was sampled from the three different sites, all the retouched tools were analyzed, but only a portion of the debitage, albeit a relatively large one (approximately 29%, 22%, and 26% respectively), was included. This latter selection, however, was entirely random.

This means that my sample, as a whole, is biased, but the two categories, retouched tools and debitage, can be viewed as individual samples of two separate populations. The debitage can be viewed as the original population from which the population of retouched tools was pulled (by the tool users). I sampled 100% of this latter population, and took a random sample of the former population.

Analysis of The Primary Samples

The variables that were measured and recorded were selected for analysis for their potential to illuminate potentially desirable characteristics for use. For some, specific analytical applications had been anticipated at the time of the variables were being recorded. For others, however, no specific applications were foreseen, but their analytical potential has been demonstrated numerous times by previous researchers and they were recorded on the chance that they might turn out to be of use, and a second visit to France to examine the collections could be avoided. All the variables examined and the method of their measure and recording is outlined here:

For all flakes (used or unused as tools)

1/ For all flakes that had been assigned an individual artifact **catalog number** by the original excavators, this was recorded. For all others, just the site name and level from which the sample was taken were recorded.

2/ **Length** - flake length was measured as the maximum dimension of the flake along an axis parallel to the direction of the removal impact. This orientation was not anticipated to be specifically informative over others, but was selected simply as a standard to be maintained so that all such measurements were comparable. 'Length', coupled with other metric measurements below (width and thickness), was intended to allow analyses of flake dimensions between samples and technological products, and also to allow the computation of other attributes (flake area and flake robusticity) for similar analyses. The analysis of flake morphology, as measured in terms of metric dimensions, was anticipated to provide significant insight into blank selection behaviour and differences between technological products from various reduction strategies such as Central Levallois flakes, Peripheral Levallois flakes, amorphous core flakes, bipolar core flakes, and others.

This measurement and other metric dimensions below were taken with simple, Vernier scale, contact calipers (see Dibble 1990, 1989 and Van Peer 1992 for similar examples of this approach applied specifically to Mousterian stone tools and debitage).

3/ **Width** - flake width was measured as the maximum dimension perpendicular to the flake Length.

4/ **Area** - flake area was computed after-the-fact by simply multiplying Length x Width.

5/ **Thickness** - flake thickness was measured at the thickest part of the flake (between dorsal and ventral surfaces) regardless of where this was relative to specific margins or features.

6/ **Robusticity** - the 'robusticity' of a flake was also computed after-the-fact by dividing the area of each flake by its thickness. More robust flakes will tend to be thicker relative to area, which means that the more robust the flake the smaller the resulting number.

7/ **Weight** - the weight of each flake was measured in grams (to the nearest 10th of a gram) using an electronic scale (Sartorius BA 200 in the University of Bordeaux lab and a Mettler Toledo SBg2001 at the Musée National de Préhistoire in Les Eyzies). As with metric dimensions, it was anticipated that weight might also provide insight in the morphological characteristics of different classes of flakes.

8/ **Raw Material** - The raw materials examined in all four samples were flints of various different natural sources and of varying nodule forms. During the actual analysis of each assemblage sample, specific raw material types were subjectively identified by myself, based on colour, degree of transparency, texture, cortex, and inclusions. A raw material "type" from this list was recorded for each flake. In reality, the majority of these individual types just represent minor varieties that belong to a much smaller number of major types and sources. This was established through the examination of these specific "types" by Alain Turq who is currently a leading authority on all the known lithic raw material sources of the Dordogne region. The specific "types" recorded in the analysis have little or no meaning and were not employed in any subsequent analysis. Although no specific analytical applications were anticipated for this variable, it was considered an important attribute and was recorded anyway in the chance that it might become useful in some unforeseen manner.

While there were some variations in the flints from different sources in the samples, overall they could not be divided into obvious categories based on quality. All the flint employed at these four sites was of good to very good quality and it was not felt that any analysis based on variations in raw material quality was possible.

9/ **Reduction Type** - Each flake was examined for characteristics that would tend to indicate whether it was the product of core reduction (or something more specific like bipolar core reduction) or biface production. While such distinctions are never absolute, and in some cases are almost impossible to make with any confidence, personal experience and discussions with other researchers have indicated that for the majority of flakes such distinctions can be made with a relatively high degree of confidence in the accuracy of the results (see also Hayden and Hutchings 1989).

10/ **Bordian Type** - Each flake was examined for morphological characteristics and edge modifications that would place it in one of the 64 Middle Palaeolithic types established by François Bordes (and subsequently clarified and added to by others - see Debénath and Dibble 1993).

11/ **Average Spine-Plane Angle** - For each flake, between three and six measurements were taken with a contact goniometer of the spine-plane angle of the flake's margins. For each measurement taken, the two edges of the goniometer were made to contact the flake surface for a minimum of 5mm back from the edge of the flake (as opposed to just the angle within the first one or two mm of the edge - i.e. "edge angle"). The reason for using spine-plane rather than edge angle is that, while the sharpness of a flake's edge (edge angle) would be an important consideration in tool-blank selection, much of the analysis here involves issues of flake robusticity, strength of edge, and the difference between different reduction products. Such characteristics are more closely associated with spine-plane angle.

For most flakes, points were selected around the flake margin for measure at either regular intervals (avoiding major regularities), or in the centres of naturally isolated, discrete edges. Measurements were not taken at points where edges had been severely modified by retouch or post-reduction fractures. For each flake a mean was computed for these measurements and this is what was recorded.

12/ **Platform Length** - For the vast majority of flakes their platforms or butts (the point at which they were struck that resulted in their removal from their parent core or tool) were intact. For these, the platform length was measured with calipers as the maximum dimension of the platform in the axis parallel to the width of the flake. None of the data on platform morphology was employed in the subsequent analysis.

13/ **Platform Width** was measured as the maximum dimension of the platform in an axis parallel to the Thickness of the flake.

14/ **Platform Angle** refers to the angle formed at the intersection of the dorsal surface of the flake and the surface of the platform. This angle was measured with a contact goniometer and was rounded to the nearest 5 degrees.

15/ **Platform Faceting**. Platforms were closely examined for the presence (and complexity) of flake-scar facets that might be taken as an indication of the preparation of that platform prior to its being struck for flake removal. A simple YES was recorded if platform faceting was apparent, and a NO if this was not the case. Such faceting has been traditionally associated with Central Levallois flakes.

16/ **Percussion Method**. The morphology of each flake was examined for characteristics that are diagnostic of the type of percussor used to remove it - hardhammer (stone) or softhammer (wood, bone, antler). As with reduction type, this is notoriously subjective, but, again, previous research by others (e.g. Hayden and Hutchings 1989), ongoing research (Steenhuyse 2003 and ongoing, unpublished research), and personal experience have demonstrated the potential for a high degree of accuracy here. There is some overlap between this variable and Reduction Type (#9). Although it did not turn out to be of any analytical advantage, it seemed appropriate to not presume a necessarily one to one relationship between basic reduction strategy (core vs. bifacial) and type of percussor used (hardhammer and softhammer).

17/ **Ventral Curvature**. The degree of ventral curvature of each flake was determined by holding it up for comparison to a series of arcs drawn on paper. These included 7 lines of different forms, starting with a straight one (given the designations 'S') and followed by 6 others of ever decreasing radii (given the designations 'C1', 'C2', 'C3', etc.). The curvature of these lines was based on the radii produced by curves drawn on an 8 centimetre long line with the centre of each successive curve being two millimetres further from the straight line than the preceding curve. The line designated C1, produces an arc that deviates 2mm from the centre of the 8 cm long straight line. Curve C2 deviates 4 mm from the centre of the 8 cm line (fig. 7.11).

For the majority of flakes with any ventral curvature this surface is concave and will be recorded as C1 or C3 for example. For some rare flakes, however, the ventral curvature is opposite and the ventral surface is convex, in which case they are given the appropriate radial designation preceded by a V, rather than a C - e.g. V1, V2, V3, etc.

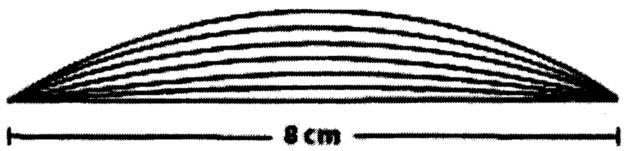


Figure 7.11 Guide used for categorizing the ventral curvature of each flake.

18/ **Flake Shape**. The plan shape of each flake was examined and categorized at two levels. The first level was the simple regularity of the shape. A 'Regular' shape was one with no (or very few) minute changes along the lengths of major, discrete edges. Flakes with 'Irregular' shapes are those with discrete edges that are interrupted by naturally occurring notches, breaks, or protuberances.

The second level involves assigning a basic 'type' of shape to a flake. These 'types' include: circular, oval, square, rectangular, triangular, and polygon. There were also two very specific flake shapes that were noted. 'Blades' were rectangular or sub-rectangular flakes that were at least twice as long as they were wide, and tended to be triangular or trapezoidal in cross-section. "Lunates' (so-called because the majority are semilunar in basic shape) was the term used to refer to éclats débordants. These are flakes removed from along the peripheral margin of a single-surface core with an oblique blow that results in the flake having a long, narrow portion of the core edge running the length of the flake.

Flake shape was anticipated to provide some measure of regularity or standardization of different product types.

19/ **Number of Usable Edges Per Flake**. The number of discrete edges on each flake, that could conceivably be used as a tool, (were sharp, and regular enough) was recorded. A 'discrete' edge is one that is isolated from other portions of the flake perimeter by abrupt changes in the direction of the edge which usually correspond with the intersection of a dorsal flake scar ridge with the flake perimeter.

20/ **Length of Each Usable Edge.** The length of each discrete, usable edge was recorded.

21/ **Morphology of Each Usable Edge.** As with flake shape, each usable edge was categorized as either 'Regular' or 'Irregular'. It was also given a basic shape descriptor: 'straight', 'concave', 'convex', or 'sinuous'.

22/ **Type of Levallois Flake.** Through visual analysis of the dorsal scar pattern of each flake, an informed judgment is made as to the nature of the core surface that it was removed from and the location on the core surface that it was removed from. If the dorsal scar pattern of a flake indicates that it represents the removal of the centre mass of a core surface then it is considered a Central Levallois flake. If its shape and dorsal scar configuration indicate that it comes from the periphery of the face of a core and it includes a significant portion of the peripheral edge of sub-circular shaped, single-surface core then it is considered a Centripetal or Peripheral Levallois flake (see Van Peer 1992) or potentially a more generic Disc core flake (see figures 2.1, 2.2, and 2.3). *Éclats Débordants* are very distinctive products of a specific Disc core approach and were recorded as such (see figure 2.4). Flakes that did not exhibit characteristics that suggested they were either Central or Peripheral Levallois flakes, or *Éclats Débordants* were recorded as non-Levallois or 'Amorphous' core flakes (this was the majority of the flakes examined).

23/ **Type of Edge Modification.** Each edge of each flake was carefully examined for any intentional modification or damage that could confidently be attributed to use of that edge.

For intentionally modified edges, the retouch was first categorized as regular or irregular (depending on the consistency in size and placement of the flaking). The retouch was then categorized by type: scraper, Quina, expedient knife, notching, backing, abrupt (i.e., not likely to be backing), bifacial, burination, or simple invasive. An example of a typical analysis sheet entry would be RRS (retouch, regular, scraper).

All unretouched edges were examined under low-power magnification (Olympus SZ60 with 10x oculars and 1x to 6.3x variable objectives) for any obvious use-wear. Using a previous developed methodology (Sandgathe 1998), any observed edge damage was only considered actual use-wear when it exhibited obvious patterning that matched that observed among a collection of experimentally produced flake tools. These unmodified flakes were applied, in controlled conditions, to a range of task materials and in a range of different motions in that were designed to mimic those tasks generally associated with Prehistoric hunter-gatherer lifeways.

The dominant form of edge-damage was microchipping, but rounding and polishing were also noted. In order to be considered actual usewear, microchipping had to include a minimum a six contiguous flakes that were all very similar in size and morphology (shape, degree of invasiveness, and type of termination - feather, step). The damage also had to be in a location on the flake that made sense in terms of practical application of the flake as a tool. Use-wear was considered 'Regular' or 'Irregular' depending on the extent of the damage and the level of standardization of the damage (which could affect the degree of confidence that it was actually use-wear). An example of a typical analysis sheet entry would be UIS (use-wear, irregular, step termination).

Photographic examples of the type of use-wear observed are provided in Appendix A: Plates 16-19.

While the reliability of the identification of usewear in this study stems mainly from the degree of rigour employed and in the degree of past experience of the researcher, the accuracy of the use-wear observations is supported by much of the subsequent analysis. If what has been identified here as use-wear were, for the most part, actually post-depositional damage, then, all else equal, we would expect that the two categories, 'unused flakes' and 'flakes with use-wear', would distribute randomly in most categories that we might expect would have played a role in the selection of flakes intended for use in unmodified form. However, we could anticipate that post-depositional damage might be more frequent on thin, more fragile edges, but sharper edges were also likely a major characteristic that was selected for among most blanks intended to be used in unmodified form. Therefore, spine-plane angle and robusticity might be poor attributes for this test. Size (with length and weight as proxy measures) is an attribute that I have proposed would be among the selection criteria for blanks, but should not directly affect the potential for a flake to incur post-depositional damage. If the damage I have identified as usewear is usewear then this group of flakes should stand out statistically from those categorized as unused. Otherwise, the damage should not be related to length or weight and the two categories should show no statistical difference. In fact for the two categories, 'unused flakes' and 'flakes with use-wear', two-sample t-tests indicate t=1.95 for length (confidence = 95%, significance = 5%) and t=2.4 for weight (confidence = >98%, significance = <2%), both of which indicate a significant non-random difference between the two categories.

Some flakes included both retouched edges and unretouched edges with use-wear. These are referred to as either "Both" or "Retouch and Usewear" in the text, tables, and figures of the dissertation. During the analysis, in such cases it was the nature of the retouch, rather than the usewear, that was recorded in detail in the regular data columns. Details about the use-wear on these flakes with both types of edge damage were entered in the Comments column.

24/ **Extent of Edge Modification**. Each section of retouch or use-wear was measured and this was recorded. If the modification was intermittent on an edge no measurement was recorded.

25/ **Angle of Edge Modification**. The angle of all regular retouch was measured with a contact goniometer and recorded.

26/ **Spine/Plane Angle of Retouched/Used Edge**. The spine-plane angle of edges with retouch or regular use-wear was recorded as this provided an indication of the nature of the original morphology of those edges that were being selected for use.

27/ **Degree to which the tool blank has been exhausted**. A visual determination was made of how much of the tool margins had been lost to retouch, use, and resharpening. This was expressed as a percentage of roughly how much the margins could have been modified in total before the flake could not be effectively retouched any more. In fact, very few of the flakes in any of the samples had even been exhausted by 10%.

28/ **Percent of Dorsal Cortex**. The percent of each flakes dorsal surface that was covered with cortex was estimated to the nearest 10%. This can provide an indication of stages of reduction sequences represented in an assemblage, among other reduction aspects.

29/ **Comments**. Finally, brief notes were made about aspects of a flake that could not be fit into any of the previous categories. For example: any elaborations on the degree of confidence that edge damage was actually use-wear or not; if the flake had been exposed to heat; if it was a particularly notably example of a Central or Peripheral flake, if there was bulbar thinning, etc.

Softhammer Flake Data

Of the four sites samples included here, biface technology was only present in the le Moustier sample (and even in this sample softhammer flakes were essentially absent, although it might be expected that many of these quite small and were not captured in the screen size used during the original excavation or were below the size-cutoff employed for lithic items that were provenienced). However, in order to attempt to arrive at any understanding of the sought-after characteristics of the flake products produced at the four sites, it is necessary to compare the characteristics of these products to the products of other available technologies, like softhammer reduction, associated with biface production. What were the characteristics of the products produced at the four sites that would have played a role in the selection of the specific reduction technologies that were employed?

To this end, an experimental assemblage of softhammer flakes (n=120) was produced and analyzed. Basic metric dimensions, robusticity, average edge angle, and ventral curvature were recorded for comparison to those collected for the archaeological assemblages.

These flakes were produced through the manufacture (by the author) of two large bifaces similar in form to typical Mousterian handaxes. One was produced from obsidian (at Simon Fraser University) and one from a flint nodule acquired in the Charente in France (and manufactured in France during the 2002 field season). In both cases, after initial reduction was carried out with a quartzite hammerstone to form large, rough biface blanks, subsequent reduction was carried out with a billet made from the tine of the antler of a North American elk (*Cervus elaphus*). The debitage from these two reduction events (including only that produced with the billet) was combined into a single assemblage (differences between the two in the recorded characteristics are negligible). As only those flakes $\geq$ 2.5 cm had been included in the archaeological samples, only those flakes of the same minimum size were included for analysis in the softhammer flake assemblage.

Chapter 8: Blank Selection Analysis

How do the sample data match the design expectations?

In this chapter, the initial section (8A) examines patterns of blank selection and use within the pooled data for all four site samples. This is followed (Section 8B) by an examination of blank selection tendencies within each individual sample. In Chapter 9 blank selection patterns based on different technological products are examined.

Summary of Hypotheses (end of Chapter 6)

Levallois reduction strategies (and perhaps single-surface reduction as a discrete category)) would be employed because either:

2/ The products of the Levallois/single-surface core reduction strategy satisfied the specific morphological requirements of one major application OR the other, and so would be employed in situations where that application (butchering or woodworking) was the dominant task.

3/ The reduction strategy produces a limited number of larger blanks, which would serve better than other products as long-lived tools in portable tool kits, or as more maintainable tool forms in circumstances where time stress/constraint plays some role in task scheduling.

4/ The reduction technique itself represented a logical response to other constraints that were encountered at different times and in different locations. It either represents a raw material economization solution and, thus, a logical response to raw material availability constraints, or a strategy for more effectively reducing raw materials of various sizes and shapes, or it is a response to increased processing volumes and the need to produce more tools.

5/ The products of the strategy present a certain degree of standardization that makes them more suitable for hafted tool forms and results in a more maintainable toolkit/technology.

8A Patterns in Blank Selection in the Combined Sample Data

This section is intended to examine general blank selection preferences among the sample assemblages. The data from the three primary sites (and the fourth site when specific data are available) are, therefore, pooled in order to allow the isolation of those patterns of selection that are common among these assemblages. In the following section (8B) analysis will focus on those patterns of selection that are unique to each site sample and, therefore, in that section the data from each sample are analyzed separately.

Flake Tool Attributes

In Chapter 6 a summary was provided of the attributes or characteristics that, based on my Middle Palaeolithic lifeways model, I suggest would have been desired by Middle Palaeolithic people in their tool blanks. There are two different points in the course of lithic reduction/tool production at which prehistoric flake tool users would have the opportunity to select desired tool blank characteristics. One is *at the point of production* when the knapper can have some influence over the resulting shape of many of the flakes produced. The degree of influence during blank production depends on several variables including; raw material type, raw material size, reduction strategy (e.g., Levallois, bipolar), reduction tool (type of percussor used), and individual skill. Within such constraints Middle Palaeolithic knappers would have designed their reduction techniques to produce flakes which exhibited desired attributes as much as possible, given other constraints (as outlined in Chapter 5) on flake form and reduction approaches.

The other point at which specific blank attributes can be selected for is *after* the reduction of a nodule when the collection of resulting flakes can be sorted through and those flakes with greater use-potential can be chosen. The intention in this chapter is to try to determine which attributes were selected for in the course of blank selection. An underlying assumption is that, while the tendency of Middle Palaeolithic knappers would have been to try to produce assemblages in which desired tool attributes were dominant, or at least common, any such desirable characteristics would also have been selected for at the time of blank selection. Thus it should be possible to detect the desired traits by comparing used flakes with unused flakes.

In order to determine the desired criteria in tool blanks we need to be able to distinguish which flakes were selected for use and which were not within flake assemblages. Edge modifications, in the form of retouch and use-wear, provide a direct indication of this selection process. This is not completely accurate since, while retouch is generally not problematic to identify, use-wear occurs with various degrees of identifiability. This is particularly the case here where only macroscopic analysis was employed. With this in mind, during the usewear analysis a strong effort was made to err on the side of conservatism in accepting whether observed edge damage was actual usewear. However, even though some used flakes undoubtedly went unrecognized and were mixed in with the unused during the analysis, any significant patterns in the differences between the attributes of used verses unused flakes should still be apparent.

Analysis of Proposed Blank Selection Criteria

Statistical Analyses

A brief background on the nature of the variables and their relationships that are analyzed below is necessary to provide a framework for the statistical applications that are employed.

The majority of the statistical analysis in this chapter and Chapter 9 involves the comparison of the means of different variables. This is based on the understanding that, presuming certain attributes were more desirable than others in the selection of stone tool blanks, the means of a attribute measurements should accurately reflect selection patterns. Therefore, if an attribute was important enough in the selection criteria, its mean should be significantly different from the mean of those items not selected for use. The validity of such comparisons relies on the data being normally distributed. However, all the samples employed here are of a size ($n = >30$) such that, based on the Central Limit Theorem, their distribution will naturally approach a normal shape (Anderson et. al. 1991: 235-38 and 285). When actually plotted, (as in the following examples) the curve is obviously normal (although it is truncated on the left because the original collection criteria included only those items ≥ 2.5 cm in maximum dimension, but this should not have any affect on the analysis).

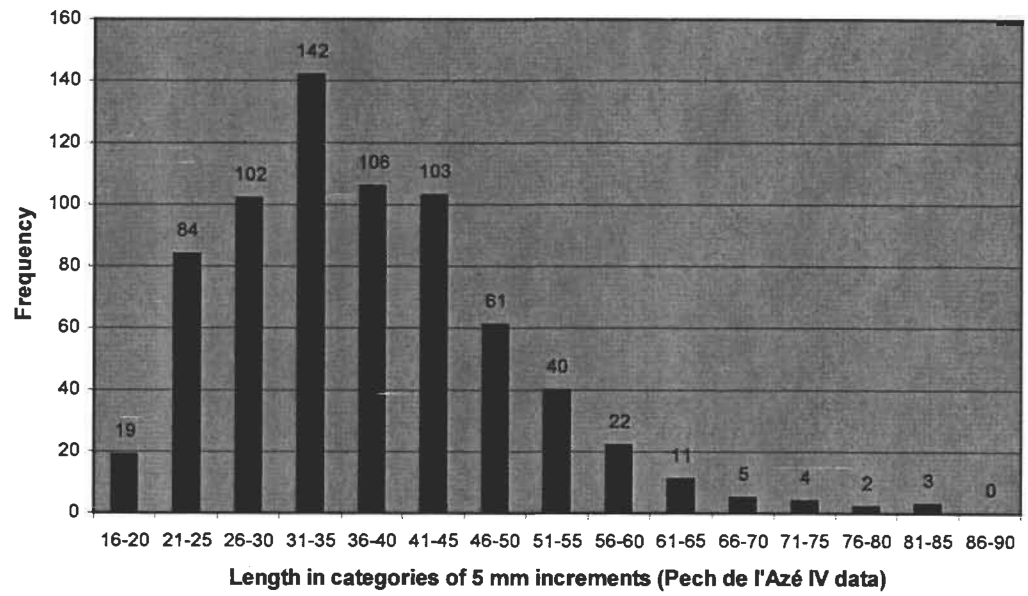


Figure 8.1 Histogram showing the normal distribution of flake length, Pech IV.

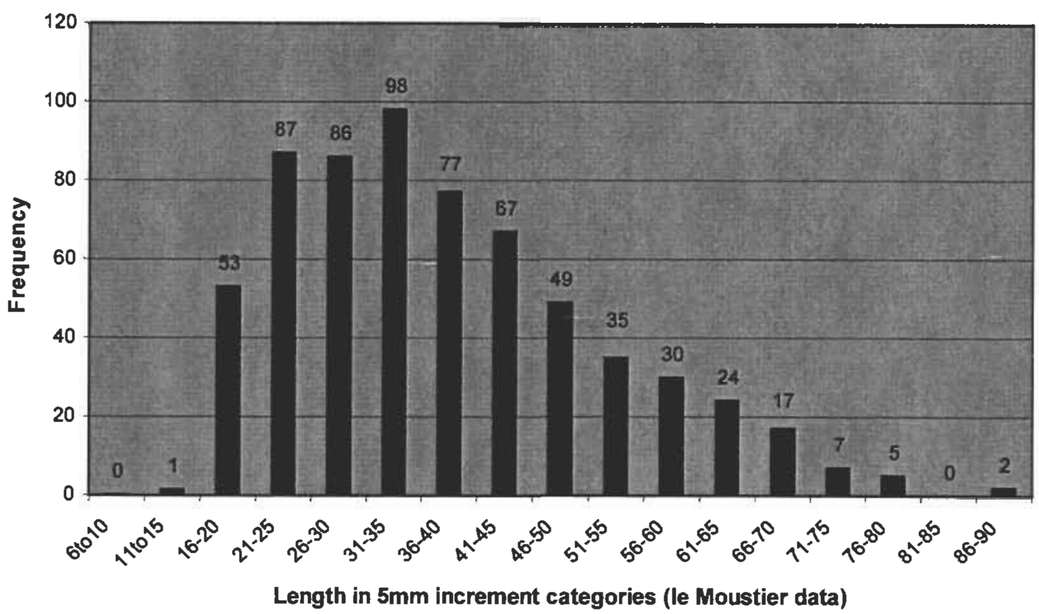


Figure 8.2 Histogram showing the normal distribution of flake length, le Moustier.

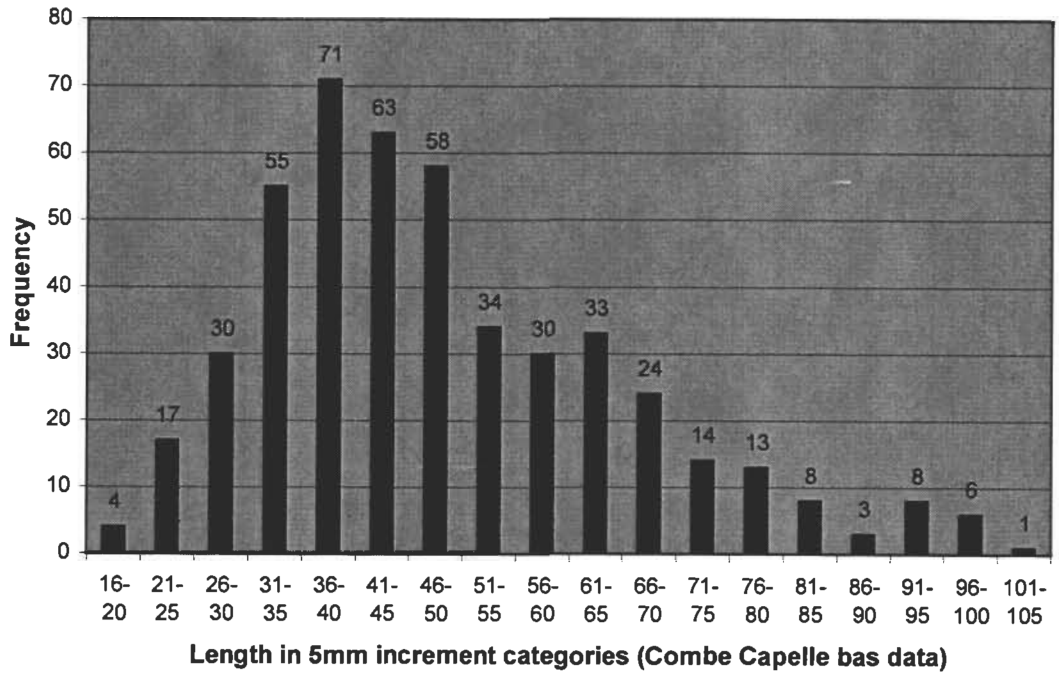


Figure 8.3 Histogram showing the normal distribution of flake length, C Capelle Bas.

The validity of any comparison of means that is intended to detect non-random patterns or relationships (that can be inferred to represent human behaviour) also relies on the assumption that there is not already any natural or direct relationship between the variables: the variables being tested must be independent for any analysis to be valid in this respect. A Pearson's Correlation Coefficient analysis was applied to the metrical data and weight (combined for the three major sites). The resulting coefficients are given in Table 8.1.

Table 8-1 Pearson's Correlation Coefficient values for the major metrical attributes plus spine-plane angle, included in subsequent analysis (from an analysis using SAS, carried out by I. Bercovitz, Statistics and Actuarial Sciences, Simon Fraser University).

	Width	Thickness	Weight	Spine-Plane Angle
Length	r=0.598 r^2=0.358 t=31.9	r=0.605 r^2=0.366 t=25.9	r=0.717 r^2=0.514 t=44.0	r=0.218 r^2=0.048 t=9.6
Width		r=0.648 r^2=0.42 t=36.4	r=0.776 r^2=0.602 t=52.6	r=0.198 r^2=0.039 t=8.6
Thickness			r=0.765 r^2=0.585 t=50.8	r=0.522 r^2=0.272 t=26.2
Weight				r=0.302 r^2=0.091 t=13.6

The r is the nature of the relationship between two variables (whether positive or negative), r^2 is the strength of the relationship, and t indicates whether the relationship is significant or not (whether or not it is due to random factors, such as sampling biases). With large sample sizes (such as I am using here) it is difficult not to have a significant correlation (t), but the strengths of these correlations obviously vary (Anderson et. al. 1991: 495-97). For example, for length and width, with an r^2 of 0.358, we can say that about 36% of the variability in flake length is due to flake width and vise versa. This suggests that there is some correlation between the two, but it is not a strong one. For length and edge angle, and width and edge angle the strength of the correlations is quite low (about 5% and 9% respectively).

The strength of some of these relationships seem quite intuitive. The strong relationship between flake dimensions and weight seems logical (longer or wider or thicker flakes will tend to be heavier), as does the rather weak relationship between the three basic dimensions (length, width, weight) and edge angle. The relatively strong relationship between thickness and edge angle also seems quite logical.

For other variables included in the subsequent analysis, such as ventral curvature and regularity of shape, their independence was assumed to be self-evident.

Size

While the analysis will focus on those attributes that have been proposed as being of most importance, as discussed in previous chapters, it is expected that other basic attributes, like size, would have played some role in tool blank selection. We can anticipate that, where given the choice, a person will, in most situations, likely select first the larger of two flakes. This pattern in selection appears to be born out by previous analyses of Mousterian flake tools (e.g., Rolland 1972). We can test potential preferences in size with the combined data from the three primary samples, and with the individual site data.

Table 8-2 Mean dimensions and weight for the three primary samples (combined) by type of use evidence (dimensions in mm and weight in grams). Used Flakes includes those with retouch and those with usewear.

	Used Flakes n=1427	**Unused Flakes** n=405
Mean Length	41.8	35.5
Mean Width	34.4	30.0
Mean Thickness	10.9	9.8
Mean Weight	18.6	12.7

Two-sample t-tests were applied to each dimension comparing the means of the Used and Unused flakes. The t values for each dimension indicate a very high level of significance and confidence (Length: t = 7.6, width: t = 7.3, thickness: t = 3.67, weight: t = 4.4) in the difference between these means. See table 1 in Appendix B.

Table 8-3 Mean dimensions and weight for Pech de l'Azé IV, level F-2, by type of use evidence (dimensions in mm and weight in grams). Used Flakes includes those with retouch and those with usewear.

	Used Flakes n=521	**Unused Flakes** (n=186)
Mean Length	38.0	36.9
Mean Width	30.5	29.4
Mean Thickness	10.7	10.5
Mean Weight	13.0	11.3

Length: t = 1.07, width: t = 1.34, thickness: t = 0.54, weight: t = 1.5

Table 8-4 Mean dimensions and weight for le Moustier, level G, by type of use evidence (dimensions in mm and weight in grams).
Used Flakes includes those with retouch and those with usewear.

	Used Flakes n=501	Unused Flakes n=152
Mean Length	39.6	29.9
Mean Width	32.1	25.1
Mean Thickness	9.0	7.2
Mean Weight	13.7	6.5

Length: t = 7.5, width: t = 7.4, thickness: t = 4.6, weight: t = 5.5

Table 8-5 Mean dimensions and weight for Combe Capelle Bas, level I-1D, by type of use evidence (dimensions in mm and weight in grams).
Used Flakes includes those with retouch and those with usewear.

	Used Flakes n=398	Unused Flakes n=67
Mean Length	49.2	44.2
Mean Width	42.0	42.7
Mean Thickness	13.4	14.1
Mean Weight	31.9	30.8

Length: t = 2.3, width: t = 0.35, thickness: t = 0.82, weight: t = 0.23

Table 8-6 Mean dimensions and weight for the Mousterian component of Jiboui (dimensions in mm and weight in grams).
Usewear data are not available for the Jiboui assemblage.

	Retouched Flakes n=65	Unretouched Flakes n=2963
Mean Length	49.3	31.5
Mean Width	38.8	26.8
Mean Thickness	11.6	7.8

Length: t = 11.3, width: t = 7.9, thickness: t = 5.8, weight: n/a

Table 8-7 Mean dimensions for the four study sites combined data.
Usewear data are not available for the Jiboui assemblage. Therefore, retouch is used here to define categories of use in all four assemblages.

	Retouched Flakes n=845	Unretouched Flakes n=4017
Mean Length	46.3	32.8
Mean Width	38.2	27.3
Mean Thickness	12.5	8.2

Length: t = 27.0, width: t = 25.3, thickness: t = 23.9, weight: n/a

The data in Tables 8.2 to 8.7 indicate a general trend towards the use of larger flakes in these assemblages, as the means of the measurements for the retouched flakes are consistently greater than for the unretouched flakes (with two exceptions, width and thickness in the Combe Capelle Bas data). For the Pech de l'Azé IV and Combe Capelle Bas assemblages the difference in size between the used and unused flakes is not particularly strong (as shown by the t-test results).

However, it has also been discussed above that (above some practical minimum) size probably does not play an overly dominant role in blank selection (only 1 flake <11 mm in maximum dimension exhibited any use-wear, although not all small flakes were provenienced during excavation of these sites).

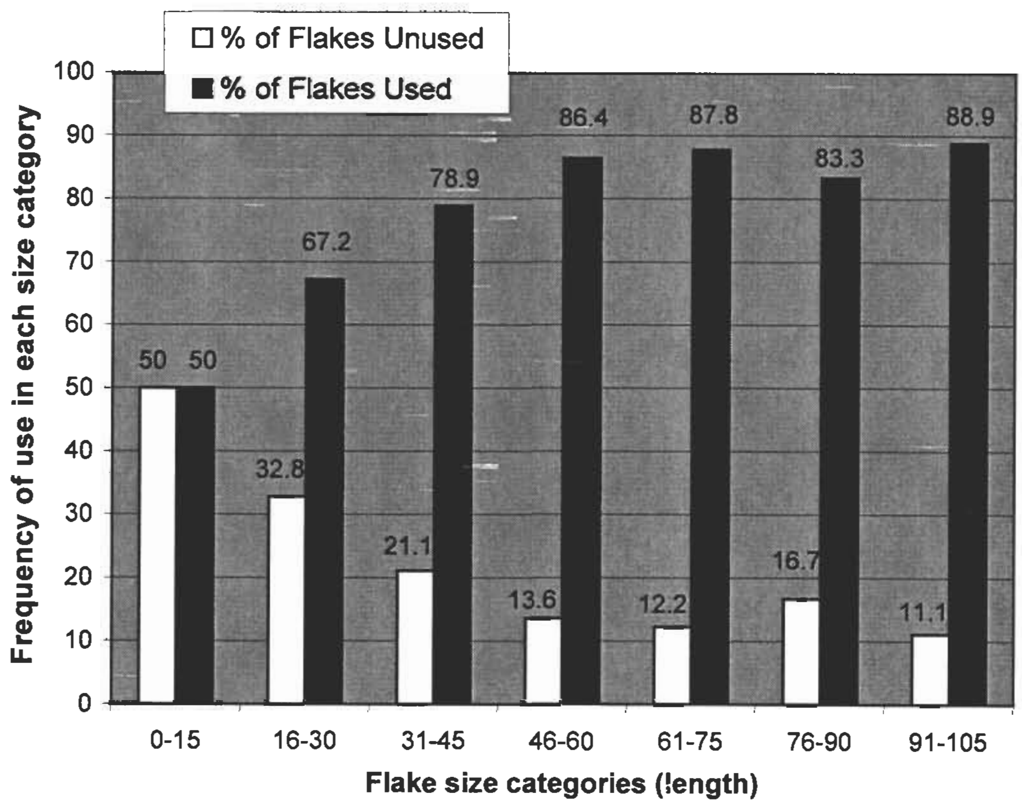


Figure 8.4 Percentage of flakes with evidence of use, by categories of maximum size (length in mm). (for all three primary site samples)

Figure 8.4 illustrates that, while there was a strong trend to select the larger flakes from an assemblage, some small flakes were used and some of the largest flakes were not. Size was obviously a factor, but apparently did not completely supersede all other considerations.

The difference in size between the unused flakes and those with just usewear is significantly lower than between unused and retouched flakes, although in applying a two-sample t-test to the pooled data for the three primary sites (for which usewear data are available) we still see a statistically significant difference in the mean of some, though not all, dimensions; t=0.29 for width; t=3.0 for thickness; and t=2.4 for weight. This indicates that when it came to the selection of flakes for use in unmodified form, sized was much less of consideration.

Table 8.8 Basic metric data for flakes with just retouch, flakes with just use-wear, and flakes with both, for the primary sample sites.

	Just Retouch n=526	Both Ret & Usewear n = 253	Just Usewear n=649
Mean Length	45.7	46.8	36.7
Mean Width	38.7	37.0	29.8
Mean Thickness	13.2	11.2	8.9
Mean Weight	27.6	21.3	10.3

Two-sample T-tests were applied to each dimension comparing the means of the retouched flakes with both the flakes with just use-wear and with those with both retouch and use-wear. The T-values for the just retouch verses just use-wear means indicate very high level of significance and confidence (L = 10.8, W = 12.5, Th = 14.7, and W = 12.2). The T-values for the just retouch verses both retouch and use-wear means indicate some significance and confidence, though at low levels, for Length (T = 0.89) and Width (T = 1.62), but higher levels of significance and confidence for Thickness (T = 4.68) and Weight (T = 2.73).

Table 8.9 Basic metric data for flakes with just retouch, flakes with just use-wear, and flakes with both, for Pech de l'Azé IV.

	Just Retouch n=164	Both Ret & Usewear n=79	Just Usewear n=278
Mean Length	38.9	43.3	35.9
Mean Width	32.3	33.5	28.6
Mean Thickness	12.2	12.0	9.5
Mean Weight	16.0	18.5	9.6

Table 8.10 Basic metric data for flakes with just retouch, flakes with just use-wear, and flakes with both, for le Moustier.

	Just Retouch n=97	Both Ret & Usewear n=140	Just Usewear n=265
Mean Length	42.2	46.6	35.0
Mean Width	35.3	37.2	28.2
Mean Thickness	10.9	10.2	7.7
Mean Weight	20.5	19.5	8.2

Table 8.11 Basic metric data for flakes with just retouch, flakes with just use-wear, and flakes with both, for Combe Capelle Bas.

	Just Retouch n=264	Both Ret & Usewear n=35	Just Usewear n=106
Mean Length	51.2	55.3	42.8
Mean Width	44.0	43.9	37.0
Mean Thickness	14.7	13.2	10.4
Mean Weight	37.4	34.6	17.6

The same general patterns can be seen in the individual site samples as well, although there are some apparent differences between them in the overall mean dimensions.

An obvious pattern is that the mean dimensions for the flakes with just usewear is very similar to those for the unused flakes in tables 8.2 to 8.5. This might be reflecting several different aspects of blank selection. It may be reflecting that flakes that were used in an unmodified form tended to be selected in a more random manner from among random waste flakes. It may also be a reflection that, of all flakes selected for use, it is the larger ones that tend to be used more extensively and are more likely to be resharpened rather than replaced.

Spine-Plane Angles

An initial note: "average spine-plane angle" was computed as a mean of four to five different measurements taken around the perimeter of each flake, but not directly on any edge damage. This was a measure of "spine-plane" angle, rather than "edge angle". It is not argued here that one would necessarily be *a priori* a more or less effective measure of tool selection behaviour, as flaked stone tool users may or may not have made a conscious distinction between these two traits, and typically, though not always, they are very similar. However, I do think that spine-plane angle is the more informative characteristic for analyzing tool selection behaviour in which the strength of the tool edges and tool robusticity likely play important roles. Spine-plane angle provides a more accurate description of the morphology of the flake as a whole. It is also necessary to use spine-plane angle when measuring edges that exhibit microwear, as it is often not possible to accurately measure the angle of such wear with just a regular contact goniometer.

I have proposed that angle of the tool edge (expressed as spine-plane angle here) would be one of the more important criteria in selection of blanks for tools. However, Table 8.12 below indicates little difference in the mean spine-plane angle between unused flakes and used flakes (retouched and usewear). There is some apparent difference, however, between retouched tools and flakes that just exhibit just use-wear.

Table 8.12 Means for the average spine-plane angle per flake on used and unused flakes for all three primary site samples.

Categories of Use Evidence		Mean	SD
Unused Flakes (n=388)		40.3	12.9
All Used Flakes (n-1390)		39.1	10.7
flakes with just retouch	(n=495)	42.1	10.7
flakes with both retouch & usewear	(n=249)	38.7	9.6
flakes with just usewear	(n=646)	37.0	10.6

With ∞ degrees of freedom, the t-value for the means of the Unused and All Used is 3.4 indicating a high degree of significance (<0.1%) and a high degree of confidence (>99.9%). The 2-Sample t-value for the means of the Just Retouched and Just Use-wear is 8.1 and the 2-Sample t-value for the means of Both Retouched & Use-Wear verses just Use-wear is 6.9, both of which indicate very high degrees of significance (0.1%) and a high degree of confidence (>99.9%).

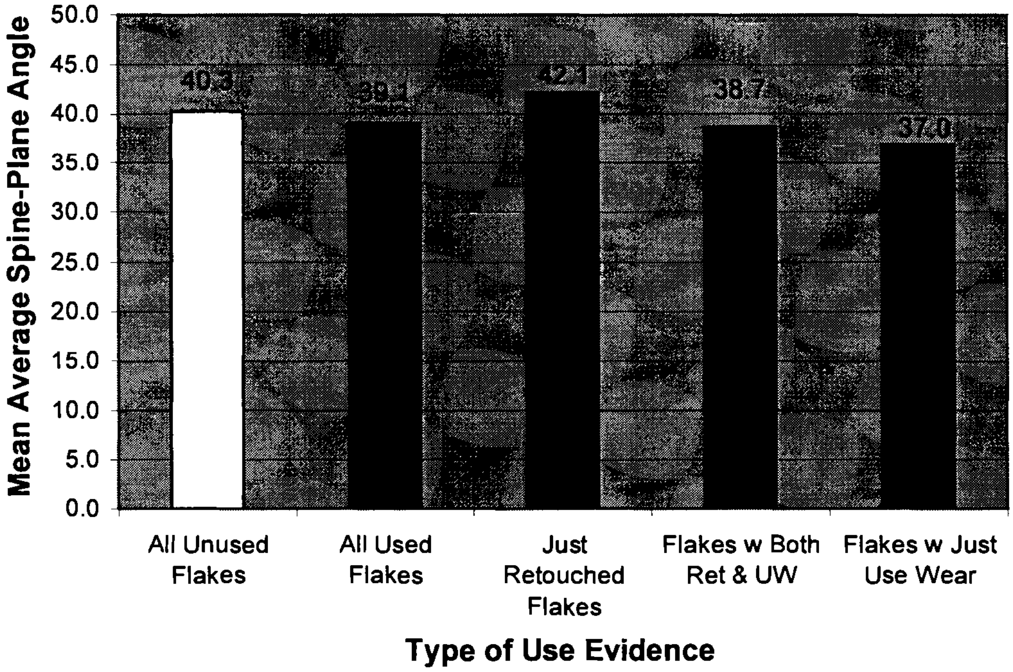


Figure 8.5 A graphic presentation of the mean average spine-plane angles among the categories of flakes exhibiting different evidence of use.

These data indicate that, in fact, there was some conscious selection of blanks based on spine-plane angles, at least between flakes that are retouched and those used unmodified. However, when viewing the tools (retouched and flakes with just use-wear) as a whole, the mean spine-plane angle approaches very closely the mean for all the unused flakes, because the individual means for the retouched and use-wear flakes bracket the mean for the unused flakes.

It is not surprising that there is some difference in the flakes selected for use with retouch and those selected for unmodified use. Based on the available ethnographic data outlined in previous chapters, tool edge (spine-plane or edge angle) preference is generally task specific. Cutting tasks, of which butchering was the dominant Middle Palaeolithic one, require lower edge angles (*note: edge angle has to be equal-to or greater than its associated spine-plane angle, so a flake edge with a relatively low spine-plane angle can, potentially, have a relatively high edge angle. However, the two are typically different by degrees rather than magnitude and a person looking for higher or lower edge angles could effectively rely on selecting flakes based on spine-plane angle,* *which is more visually obvious*) while woodworking, the other dominant Middle Palaeolithic task, generally requires greater spine-plane angles (more robust edges). Since the two dominant Middle Palaeolithic tasks each require potentially different ranges of edge angles we cannot simply examine the data on spine-plane angles for a single preference among the used flakes. The range of respective edge/spine-plane angles for cutting and woodworking tools in the ethnographic literature (Gould 1980; Hayden 1981) do overlap, but a reasonable cutoff point between these two ranges is perhaps 55°, and this is supported by the data in Figure 8.6.

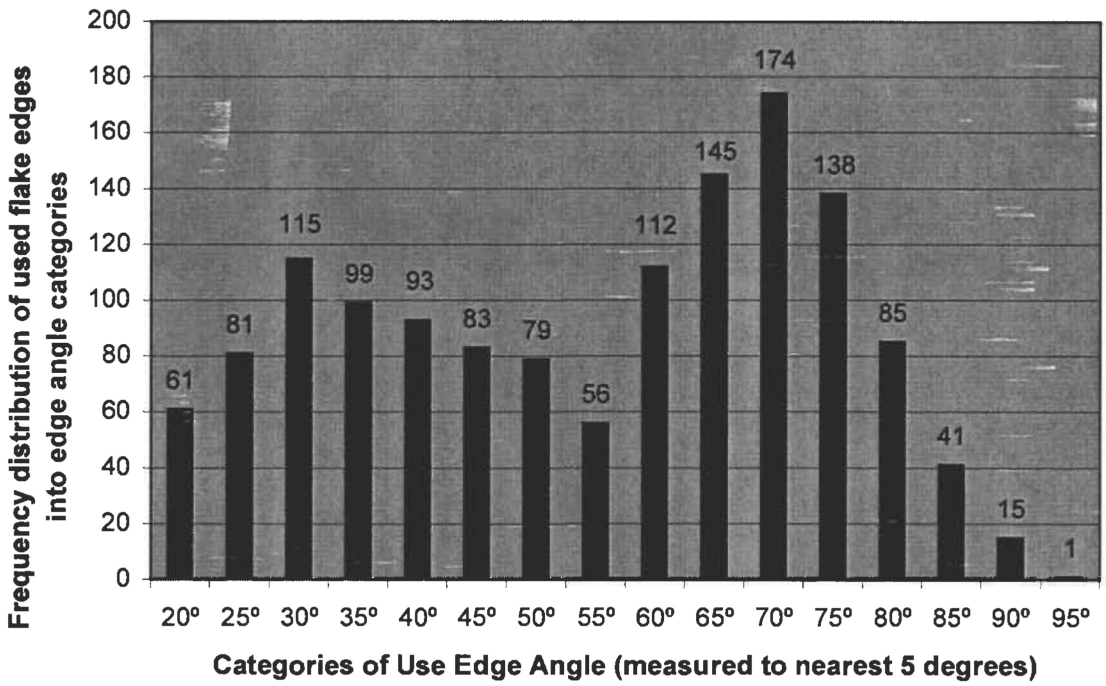


Figure 8.6 A histogram of the frequency distribution of flakes (retouched and with usewear) into categories of angles of the used edge.

This is intended as a proxy measure of the desired angle of the tool edge. Therefore, in the case of retouched edges the actual angle of the retouch was measured, and in the case of edges with usewear the spine-plane angle was measured. This is based on the idea that the retouch was intended to modify the edge to suit the task (not actually established yet) and that unmodified flakes were selected (in part) for the naturally occurring angle of the edge. The natural angle of the unmodified tool edge includes both an 'edge angle' and a 'spine-plane angle', either of which should provide a reasonably accurate idea of the desired edge morphology. Accuracy in the measuring of the actual edge angle of usewear is difficult and, though it was included in the analysis, it was not recorded for all of the flakes with usewear because the results were often questionable. Spine-plane angle was recorded for all flakes and, its is suggested here, would be the more reliable indicator of the tool user's preference anyway as the angle of the usewear itself is the result of incidental, rather than intentional, modification.

Figure 8.6 demonstrates a significant bimodality among the angles of the actual use edges and the division between them is clearly around the 55° point. Although the relationship between tool function and type of edge modification (retouch or use-wear) is not clear at this point, it is not unreasonable to expect that there is some relationship between task type and the choice to retouch or not. Specifically, retouch tends to increase the angle of an edge (although there are exceptions of note) and so might be more readily associated with scraping tasks (especially woodworking) while unmodified, and therefore sharper, edges are more likely associated with cutting tasks. This relationship between intentional edge modification (retouch) and any association with higher tool edge angles is further examined in the following figure using the 55° cutoff point.

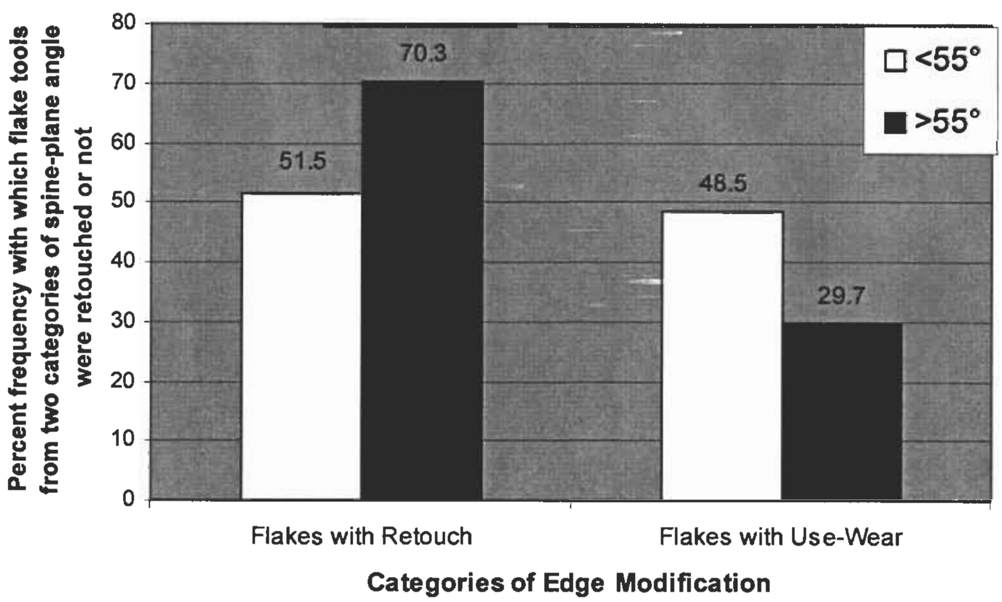


Figure 8.7 The percent frequency with which flake tool edges were retouched relative to the spine-plane angle (≤55° and >55°) of each edge - for primary site samples. (Chi-squared value $x^2 = 13.2$, degrees of freedom = 1, which indicates a significance level of < 0.1% and a confidence level of > 99.9%).

While figure 8.6 used both angle of retouch and spine-plane angles of used edges depending on whether it was retouched or not, figure 8.7 examines just the spine-plane angles for all used edges. Based on this, there is an apparent relationship between the initial spine-plane angle of a tool edge and any subsequent decision to retouch or not. While the tendency to retouch flake edges with spine-plane angles $\leq 55°$ appears to be fairly random (51.5:48.5), there is a significant tendency to retouch those flake edges with spine-plane angles $>55°$ (70.3:29.7). The initial question is whether this retouch simply represents the resharpening of a dulled edge or the intentional pre-use modification of the *angle* of the edge to suit a specific task. The fact that there were a number of different types of retouch employed in the Palaeolithic (e.g., scraper retouch, Quina retouch, expedient knife retouch) tends to support the latter. If edge angle was not an issue then the type of retouch employed should have been generic. Furthermore, if just sharp edges were required then less abrupt forms of retouch (e.g. Quina retouch and expedient knife retouch) would have been consistently employed. It seems most likely that the angle of edges employed in specific tasks was an important consideration. Based on this, in many of the tables presented below, the used flakes are separated into those that were retouched and those that exhibited use-wear only, with the assumption that this dichotomy likely represents, to some extent, cutting verses scraping tools (although this is certainly not established).

This tendency to alter some tool edge angles indicates specific tool-form preferences, and figure 8.7 suggests that these desired morphological preferences were also selected during blank selection and not just added to the blank following selection. Tables 8.13 through 8.18 below, further examine patterns of edge modification relative to average spine-plane angles.

The spine-plane angle data in the following tables are divided into two categories of spine-plane angles starting with a cutoff of 35 degrees. This is somewhat arbitrary and one could just as easily have started at 20 degrees, but the intention is to look for patterns of selection based on spine-plane angles, and the categories used below (between 35 and 60 degrees) should span the ethnographic range of task-specific requirements (if no patterns had been detected using these categories one could then have examined a wider range of spine-plane angle categories).

Table 8.13 Distribution by type of edge modification in two categories set at 35° (from average spine-plane angle per flake). Chi-squared value for Used verses Unused x^2 = 4.51, and for retouched verses use-wear x^2 = 38.5.

	Total	≤ 35°	% of Total	> 35°	% of Total
Unused Flakes	388	167	**43.0**	221	**57.0**
Flakes w just Usewear	646	354	**54.8**	292	**45.2**
Flakes w Ret & UW	249	133	**53.4**	116	**46.6**
Flakes w just Retouch	496	181	**36.5**	315	**63.5**

Table 8.14 Distribution by type of edge modification in two categories set at 40° (from average spine-plane angle per flake). Chi-squared value for Used verses Unused x^2 = 9.7, and for retouched verses use-wear x^2 = 36.4.

	Total	≤ 40°	% of Total	> 40°	% of Total
Unused Flakes	388	224	**57.7**	164	**42.3**
Flakes w just Usewear	646	463	**71.7**	183	**28.3**
Flakes w Ret & UW	249	170	**68.3**	79	**31.7**
Flakes w just Retouch	496	270	**54.4**	226	**45.6**

Table 8.15 Distribution by type of edge modification in two categories set at 45° (from average spine-plane angle per flake). Chi-squared value for Used verses Unused x^2 = 8.9, and for retouched verses use-wear x^2 = 33.2.

	Total	≤ 45°	% of Total	> 45°	% of Total
Unused Flakes	388	276	**71.1**	112	**28.9**
Flakes w just Usewear	646	536	**83.0**	110	**17.0**
Flakes w Ret & UW	249	200	**80.3**	49	**19.7**
Flakes w just Retouch	496	339	**68.3**	157	**31.7**

Table 8.16 Distribution by type of edge modification in two categories set at 50° (from average spine-plane angle per flake). Chi-squared value for Used verses Unused x^2 = 10.0, and for retouched verses use-wear x^2 = 19.7.

	Total	≤ 50°	% of Total	> 50°	% of Total
Unused Flakes	388	323	**83.2**	65	**16.8**
Flakes w just Usewear	646	592	**91.6**	54	**8.4**
Flakes w Ret & UW	249	227	**91.2**	22	**8.8**
Flakes w just Retouch	496	411	**82.9**	85	**17.1**

Table 8.17 Distribution by type of edge modification in two categories set at 55° (from average spine-plane angle per flake). Chi-squared value for Used verses Unused x^2 = 13.5, and for retouched verses use-wear x^2 = 7.7.

	Total	≤ 55°	% of Total	> 55°	% of Total
Unused Flakes	388	346	**89.2**	42	**10.8**
Flakes w just Usewear	646	620	**96.0**	26	**4.0**
Flakes w Ret & UW	249	237	**95.2**	12	**4.8**
Flakes w just Retouch	496	457	**92.1**	39	**7.9**

Table 8.18 Distribution by type of edge modification in two categories set at 60° (from average spine-plane angle per flake). Chi-squared value for Used verses Unused x^2 = 4.3, and for retouched verses use-wear x^2 = 6.5.

	Total	≤ 60°	% of Total	> 60°	% of Total
Unused Flakes	388	367	**94.6**	21	**5.4**
Flakes w just Usewear	646	639	**98.9**	7	**1.1**
Flakes w Ret & UW	249	245	**98.4**	4	**1.6**
Flakes w just Retouch	496	480	**96.8**	16	**3.2**

These data further suggest a fairly strong relationship between the average natural flake edge (spine-plane angle) and the type of edge modification it ultimately acquired. The relevant pattern is in the difference between the retouched flakes and those with just use-wear, and that this pattern is stronger when the spine-plane angle data is separated at a lower cutoff point. In particular, there seems to be a preference for flake blanks with lower average spine-plane angles to be used as unmodified tools. It would seem most likely that these tools were used for butchering (or other cutting tasks) as this would be in line with the expectation, outlined above, that flakes selected for cutting tasks would, generally, have lower edge angles (and spine-plane angle by association) and would be less likely to be retouched (at least initially). The retouched tools exhibit average natural spine-plane angle characteristics similar to the unused flakes.

Of further interest is the fact that those flakes with both retouch and use-wear, while falling between just retouched and just use-wear flakes, are much closer in distribution to the flakes with just use-wear.

note: In viewing the data presented here it must be kept in mind that, besides spine-plane angle of the use-edge, the range of variability in the morphological attributes of all the flakes was set at the point of production and that it was from this established collection of blanks that tools were selected. Therefore, any patterns in preferences for tools cannot be absolute. For example, even if there was a general preference to use completely flat flakes, 100% of the tools used cannot be completely flat because it can be anticipated that the number of flakes required for use will be greater than the number of completely flat flakes in the produced assemblage.

Ventral Curvature - "Flatness"

While flatness is not a necessary characteristic for flakes used for woodworking, it is a desirable characteristic for flake tools used for most cutting tasks, especially butchering. Therefore we might expect a general selection bias for flatter flakes (lower ventral curvature) considering that butchering was likely one of the two dominant Middle Palaeolithic tasks.

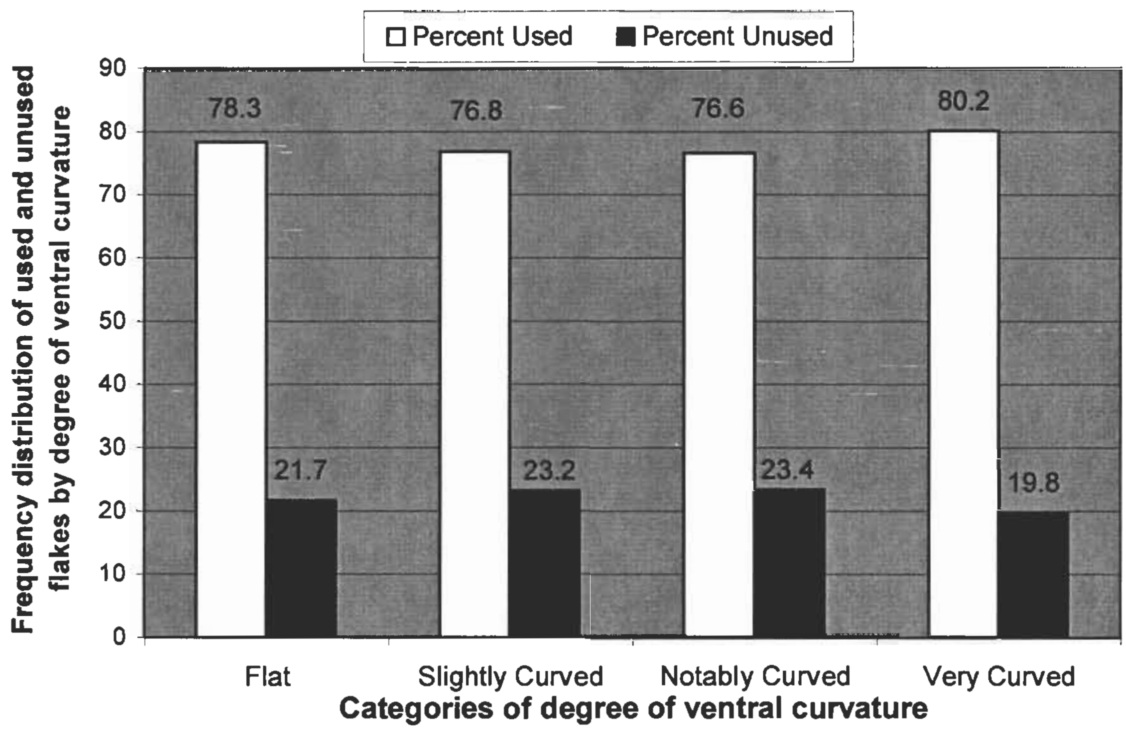


Figure 8.8 The percentage of flakes in general categories of ventral curvature that was used and unused for all three sites samples (each pair of columns combined equals 100%).

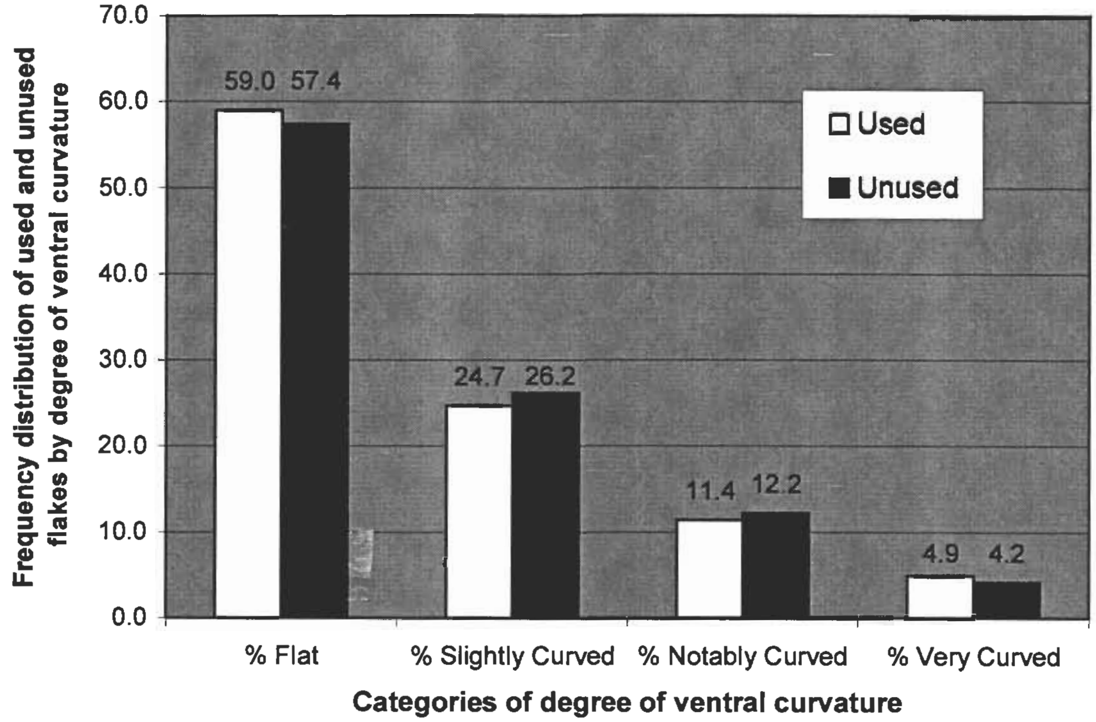


Figure 8.9 Distribution by percentage of Used and Unused flakes into categories of ventral curvature. (all the 'Used' columns combined equal 100%, and all the 'Unused' columns combined equal 100%).

Contrary to expectations, these data indicate that there was no obvious preference for flatness among tool blanks as an all-inclusive category (i.e. all tools regardless of type of use) as flakes of all curvatures seem to have been used with approximately the same frequency. In Figure 8.9 between 75 and 80% of the flakes *in all categories of ventral curvature* were used. As well, in Figure 8.9 used and unused flakes are equally represented in each of the different general categories of ventral curvature. It may be that hardhammer flakes, regardless of their specific technologic production method, may be flat enough so that further selection from among them for this attribute is not necessary. We can examine this in the experimental softhammer flake data.

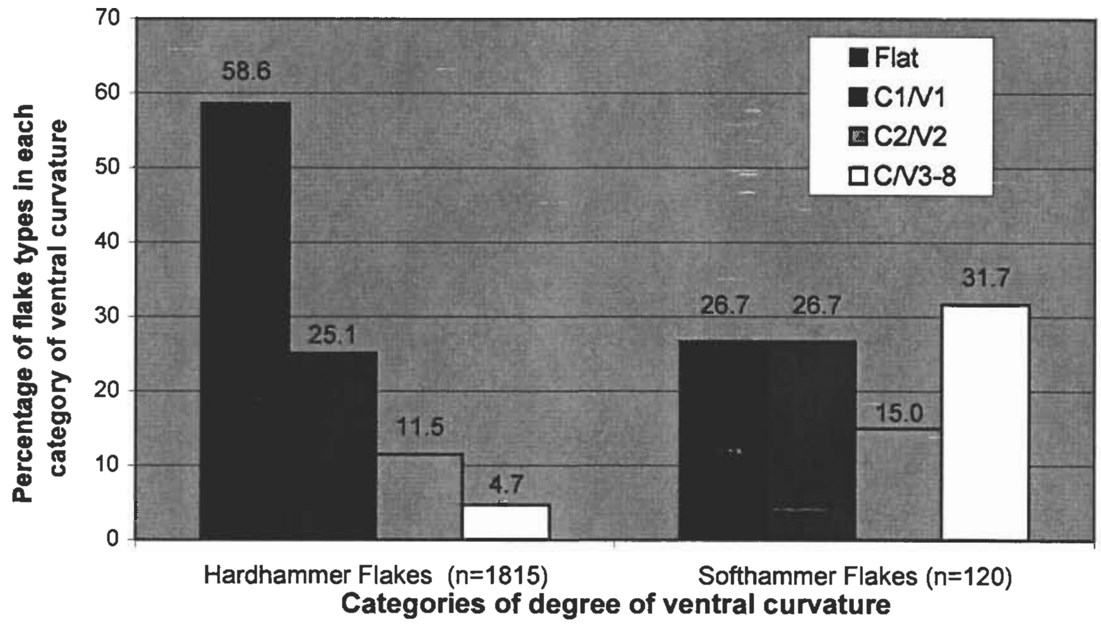


Figure 8.10 Comparison of ventral curvature of hardhammer and softhammer flakes (experimentally produced). (C1/V1 = 'slightly curved', C2/V2 = 'notably curved', C/V3-8 = 'very curved')

Figure 8.10 indicates a significantly higher degree of curvature among the softhammer flakes than the hardhammer flakes in the archaeological samples. This is not surprising and was discussed in the chapter on constraints. The perception that billet flakes are more curved is confirmed here. The general distribution of the hardhammer flakes is an exponential decrease in the numbers of flakes of increasing ventral curvature, with close to 60% of the flakes being entirely flat. Among the softhammer flakes there is a more gradual fall off in numbers with increased curvature (the gradient would be more notable if the C/V3-8 category were broken up into its original individual ones). Almost a third of the softhammer flakes were "very curved". It should also be noted that among the softhammer flakes there were none in the 'V' category. That is to say that none of them were 'negatively' curved, with a concave dorsal surface.

It is possible that flatness was selected only for those flakes intended for butchering (or similar cutting tasks) and that by viewing all used flakes (retouched and use-wear flakes) as a group this preference is being masked. Therefore, based on the reasoning outlined above (suggesting that the unmodified flake tools likely represent cutting tools), the used flakes are divided below into retouched flakes and flakes with just use-wear.

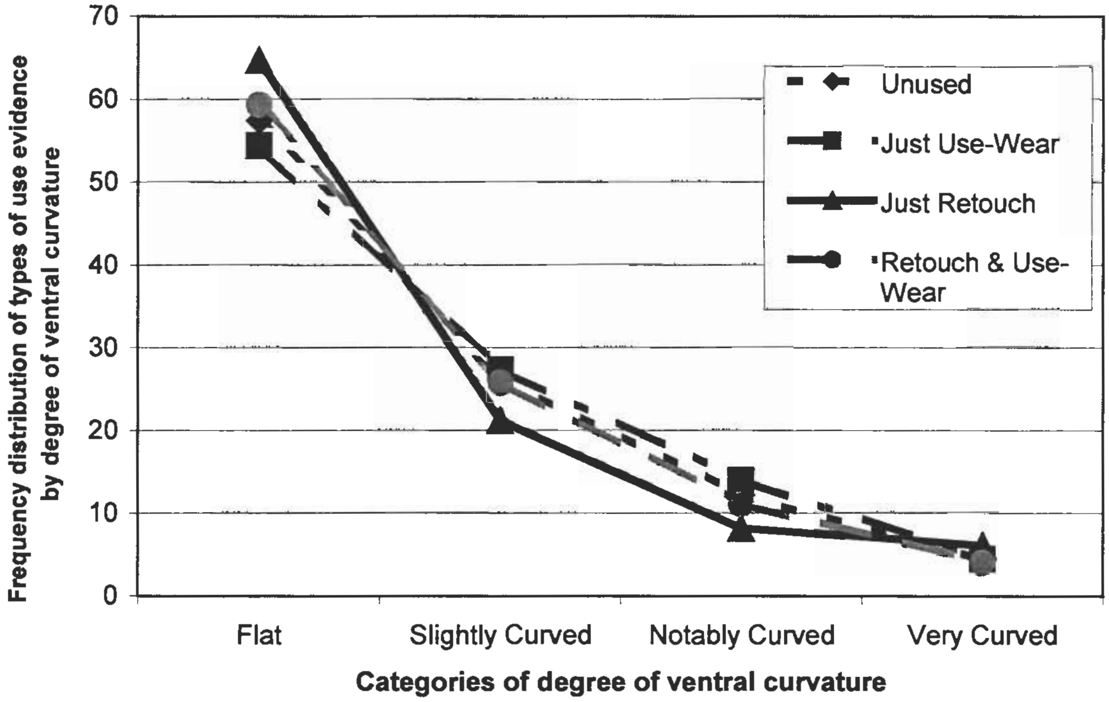


Figure 8.11 The percentage of unused and used flakes by specific categories of ventral curvature for all three primary sites. ('Retouch & Use-Wear' refers to those flakes that exhibit both)

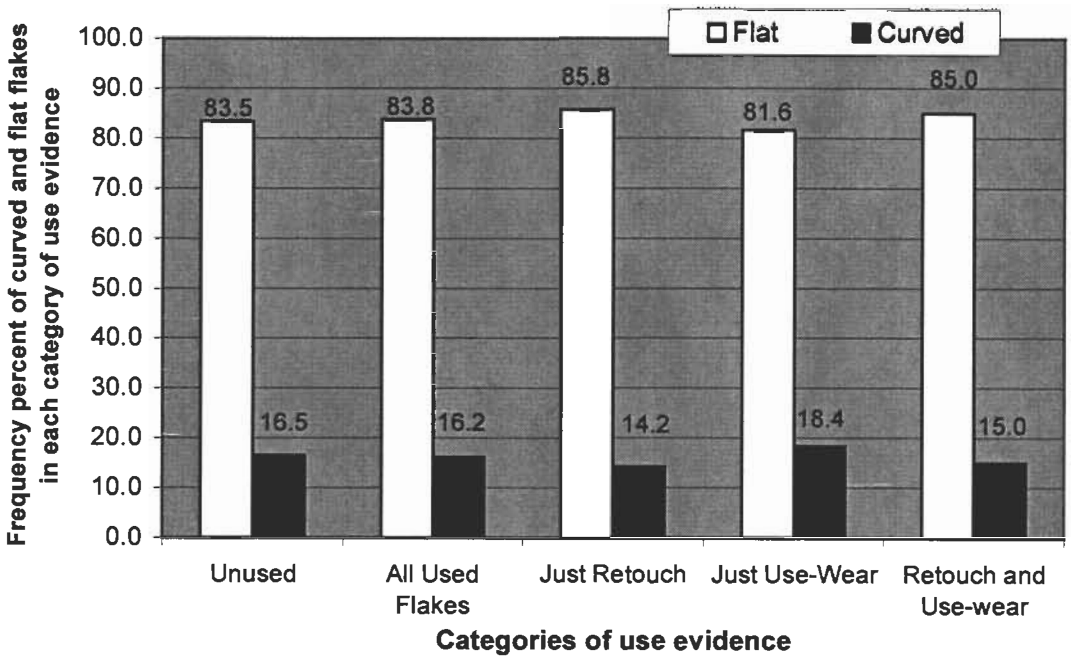


Figure 8.12 The percentage of unused and used flakes (of specific types) by general categories of ventral curvature for all three primary sites.
In this Graph 'Flat' combines the original analysis categories of S, C1, and V1; 'Curved' includes C2/V2 to C/V3-8). (Chi-squared values here indicate no significance between the Unused and Used flakes, but there is some significance (x^2 = 3.98) between retouched flakes and flakes with just use-wear.

Based on figures 8.11 and 8.12, there is no notable difference between any of the use-evidence categories in degree of ventral curvature. If there is any potential preference for flatness at all, it was among flakes that were retouched. This suggests that flatness, at least on its own, was not specifically selected for among potential tool blanks. This is particularly evident in that the distribution of the unused flakes, a collection that should reflect undesirable traits the strongest, is very similar to the used flake distributions, and in fact has a greater weighting in the flat categories than the flakes with use-wear.

Edge Angle and Ventral Curvature

While there does seem to be a preference for flake blanks with lower average edge angles for tools that are not retouched, it is also apparent that there are other attributes that will tend to be uniquely selected for among butchering verses woodworking tools. These should, therefore, be examined together.

For most retouched flakes the angle of the retouch was recorded and for flakes with use-wear, or for retouch that was too small to get a reliable measure, the spine-plane angle was recorded for the used edge. The expectation here is that flakes intended for butchering would be selected for low ventral curvature and a relatively acute edge (that would not be modified), while for flakes intended for woodworking, flatness would not be in the selection criteria and either flakes with a more obtuse edge would be selected or the existing edge would be retouched to give it a greater angle and greater strength. Thus, it is hypothesized that there should be a relationship between ventral curvature and the angle of use-edges.

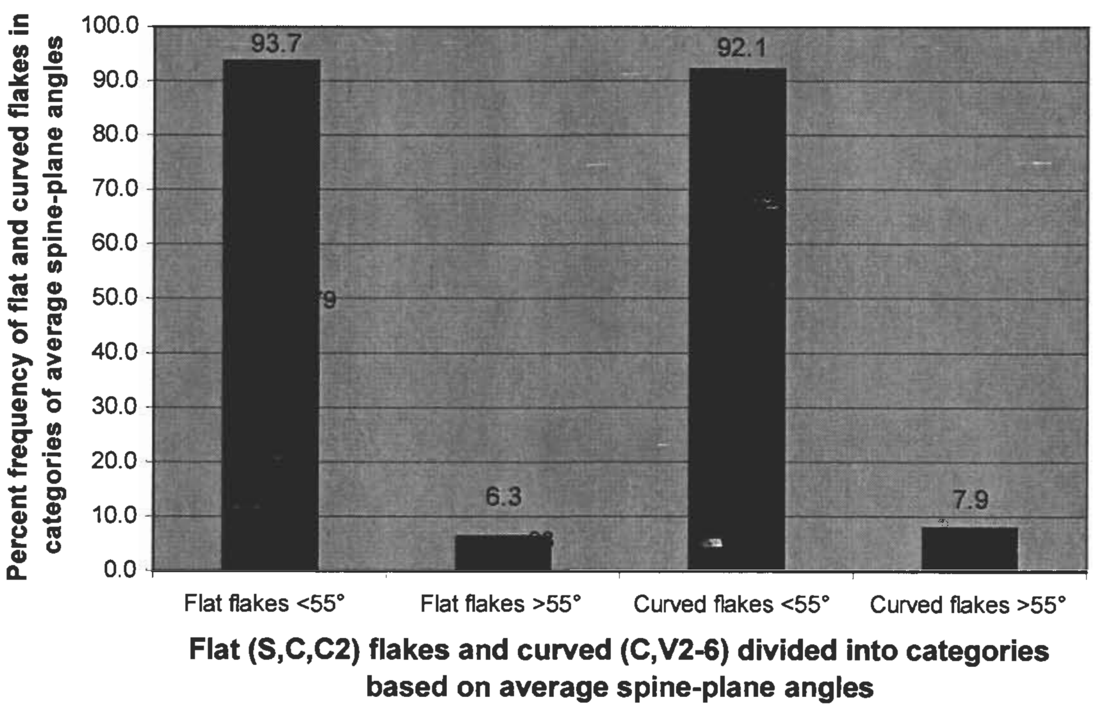


Figure 8.13 Percent frequency distribution of flat and curved flakes into categories based on average spine-plane angle.

Figure 8.13 illustrates that there is essentially no difference between flat flakes (S, C1, and V1) and curved flakes (C,V2-6) in their relative frequencies of average spine-plane angles in the two categories ≤55° and >55°. In the face of the previous data on ventral curvature this was an expected pattern. We can now examine the patterns of use of flakes in these two categories of ventral curvature and average spine-plane angle.

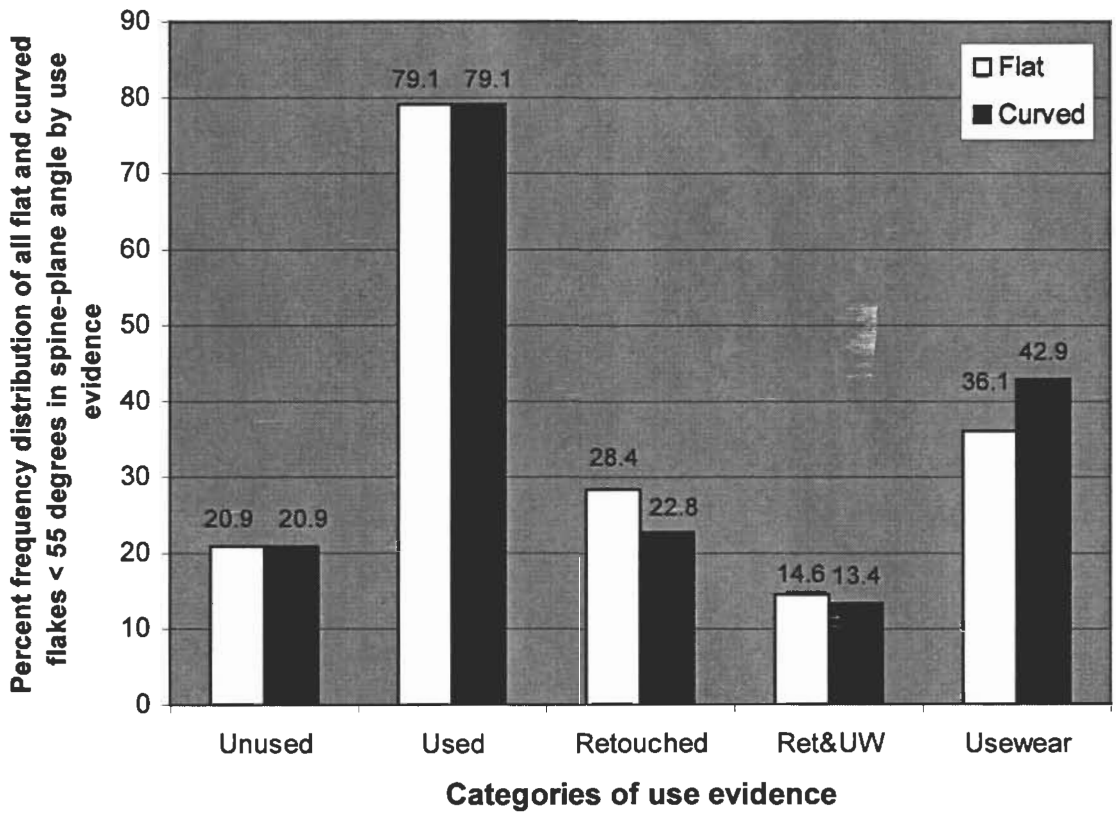


Figure 8.14 Percent frequency distribution into categories of use evidence of all flakes ≤55° in average spine-plane angle, divided into flat and curved flakes.

Figure 8.14 indicates that among flakes that have an average spine-plane angle of ≤55° there is essentially no difference in patterns of selection for use as tools. In fact they have exactly the same frequencies of selection for use. The differences in frequencies of type of use would appear to be rather negligible.

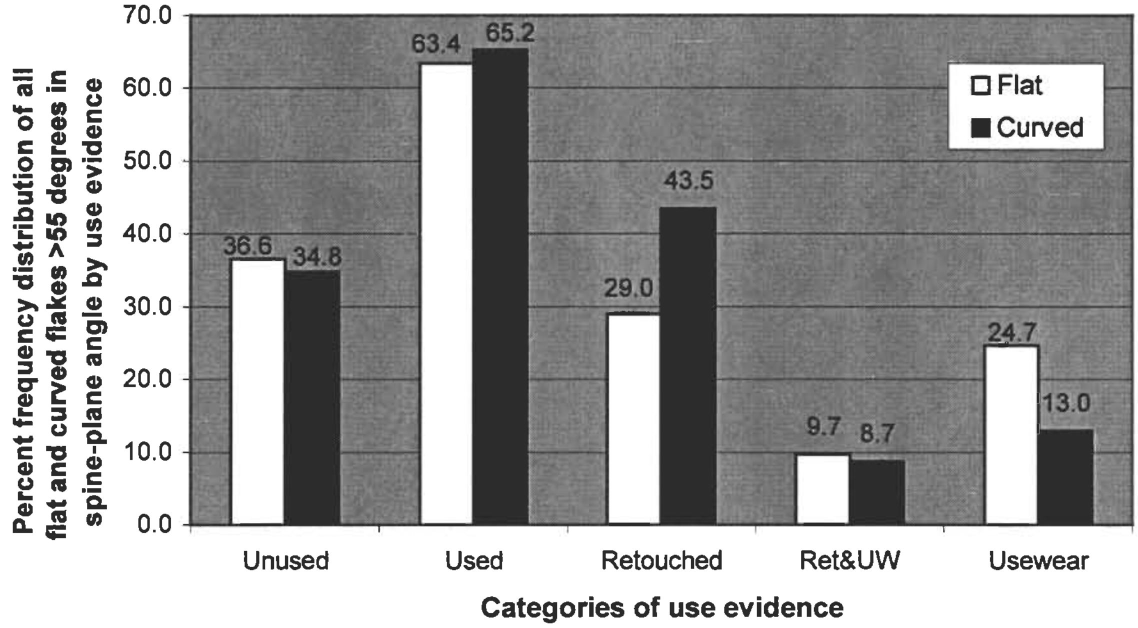


Figure 8.15 Percent frequency distribution into categories of use evidence of all flakes >55° in average spine-plane angle, divided into flat and curved flakes.

Figure 8.15 indicates a similar general pattern of frequency of use among flakes that have an average spine-plane angle >55°. The frequency of selection for use of the flat and curved flakes remains almost identical.

There are two major differences between the graphs. The first is that there is a somewhat greater frequency of use of the flakes that have an average spine-plane angle of ≤55°. This is likely just a reflection of the generally higher use of flakes with lower average spine-plane angles, and has no real connection to ventral curvature.

The second is that there is a notable difference in the patterns of selection between retouched flakes and those with just usewear. While not dramatically different, there does appear to be a tendency to select flatter flakes for use as unmodified tools and more curved flakes for retouched tool.

Regularity of Edges

Number and Length of Usable Edges per flake

As discussed previously, the length and regularity of a flake blank's edge are expected to have been important attributes for flakes intended for cutting tasks, but not for woodworking flakes (where typically either only a small portion of an edge is used or the edge is modified prior to use). Therefore, because at least the one major class of tools (those intended for cutting) will require longer, more regular edges, it can be expected that, among the unretouched used flakes as a whole, there will be a general bias towards the selection of flakes with relatively long, regular edges.

Number of Usable Edges Per Flake

In the collection of data on the sample assemblages a "usable" edge was defined as a discrete section of flake margin with consistent, regular morphology along the length of that section. The length of the section was not a major consideration and data on up to five such sections per flake were recorded (the limited of five was simply a function of analysis time and recording space, although very few flakes had as many as five usable edges). Therefore, as one measure of regularity, since the number of flakes with no usable edges at all is negligible, we can use the number of usable edges per flake as a measure of the occurrence and potential preference of edge regularity in flakes as a whole.

Table 8.19 Number of usable edges per flake by use-evidence for all sites.
(data exclude broken flakes).

	Used Flakes (n = 1417)	**Unused Flakes** (n = 403)
Mean number of edges	2.3	1.8

With ∞ degrees of freedom, two-sample t-value = 2.56, which indicates a significance level of 1% and confidence level of 99%.

The slightly higher average number of usable edges per flake among the used flakes indicates that edge regularity was at least of some consideration in blank selection. By breaking these data down into categories of actual numbers of usable edges per flake we can get a better look at this blank selection tendency.

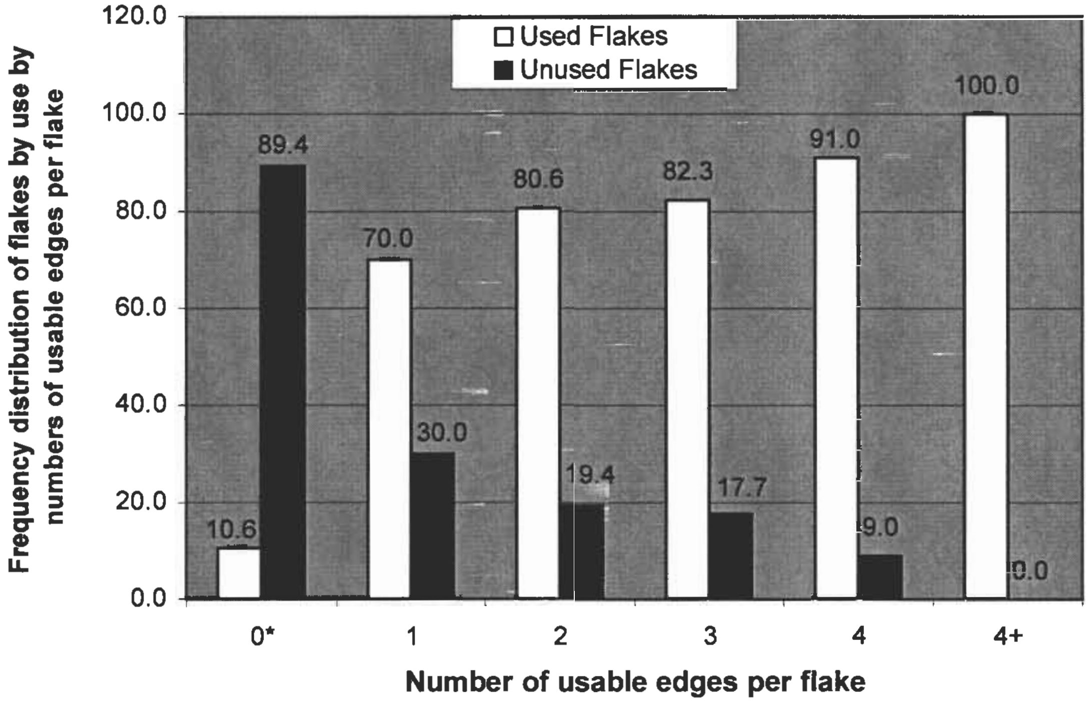


Figure 8.16 Number of usable edges per flake by use-evidence for primary sites.

* there are some flakes on which none of the edges could typically be considered usable, but yet had been retouched or had irregular macroscopic use-wear - these are, not surprisingly, quite rare - there were only five out of a total of 1416 used flakes in the three primary sites. The number of flakes with more than four edges was also low, four).

The number of usable edges per flake is not, however, strongly correlated with flake size, as demonstrated by figure 8.17: a small flake has essentially the same number of discrete edges as a larger flake.

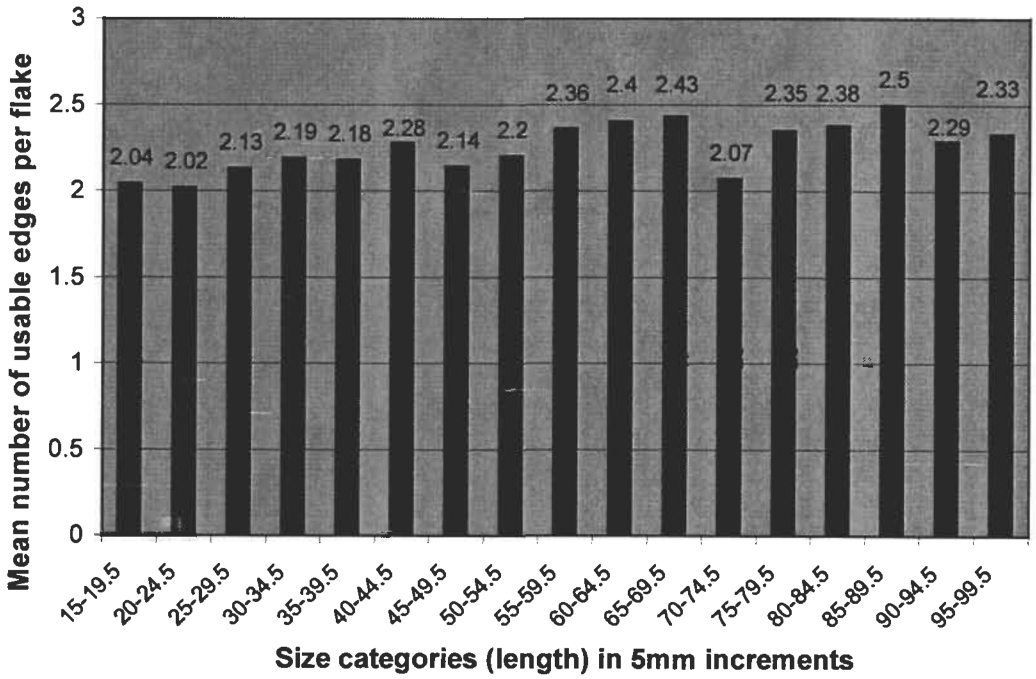


Figure 8.17 Mean number of usable edges per flake by categories of flake size. (length) in increments of 5 mm (mean = 2.35. SD = 0.14).

There is a definite tendency to select, more frequently, those flakes with a greater number of usable edges (this might initially seem like an obvious selection criteria, but knappers could also select other characteristics, like longest individual edge, which would not necessarily coincide with number of usable edges on any one flake). While the percentage of used to unused flakes is already high, there is a steady rise in the frequency of use of flakes as the number of their usable edges increases. This likely reflects the general thinking during tool blank selection that by selecting, at least initially, a blank with apparently more usable edges, the chance that it would have one or more edges suitable for the task at hand would obviously be greater and the chance that the individual would have to discard it and look for a more suitable flake would be decreased.

Greater number of usable edges is a trait that we could expect would be considered more important for longer-lived tools. It would be interesting to examine this among tools that appear to have been brought to a site in flake form (produced elsewhere), an occurrence that is not uncommon among Mousterian assemblages, but unfortunately no examples of these were recognized in the four site samples used here.

It might also be useful to try to examine the relationship between blank selection based on the number of usable edges per flake and types of tasks. As woodworking tasks tend not to require as long or regular edges as cutting tasks, it could be expected that for the former the average number of usable edges per flake will be less. Given the suggestion that edge retouching (at least in general) is likely associated more with woodworking and unmodified flakes associated more with cutting tasks, we can use type of edge modification to get at this relationship.

Table 8.20 Average number of usable edges per flake by type of edge damage for all three primary sites together.

	Retouched Flakes (n = 3265 edges)	Flakes w Usewear (n = 719 edges)
Mean number of edges	2.3	2.4

Two-sample T-value = 3.13 which indicates a significance level of <0.2% and a confidence level of > 99.8%.

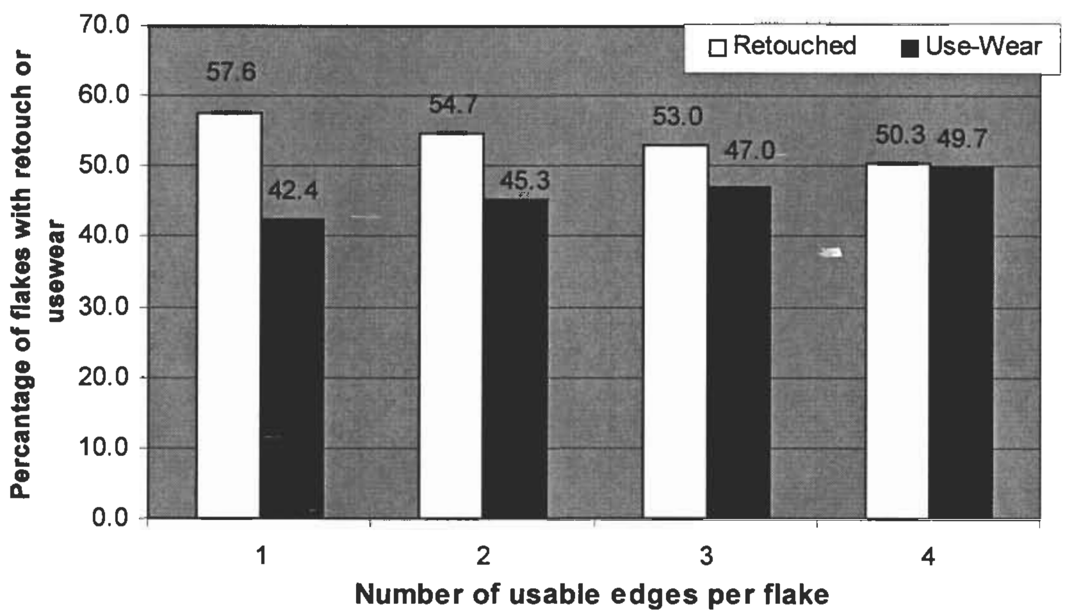


Figure 8.18 Percentage of type of use evidence by number of usable edges per flake for the primary sites
(the sum of each pair of columns is 100%). The '0' and '4+' categories are excluded here as they contained only five and four flakes respectively.

While there may be a slight trend towards selecting flakes with more usable edges for unmodified tools (cutting tasks?), in this table it is not particularly significant. Based on these data it seems likely that in the course of blank selection it is just normal behaviour to attempt to select blanks with higher numbers of usable edges, regardless of the type of task immediately at hand.

Individual Edge Morphology

To further investigate this I examined individual edge morphologies in relation to what type of edge modification they incurred. The initial analysis included the classification of all usable edges on each flake into 'regular' and 'irregular', based on the presence, absence and size of any irregularities. Figure 8.19 below indicates the percentage in each category of use of regular and irregular edges.

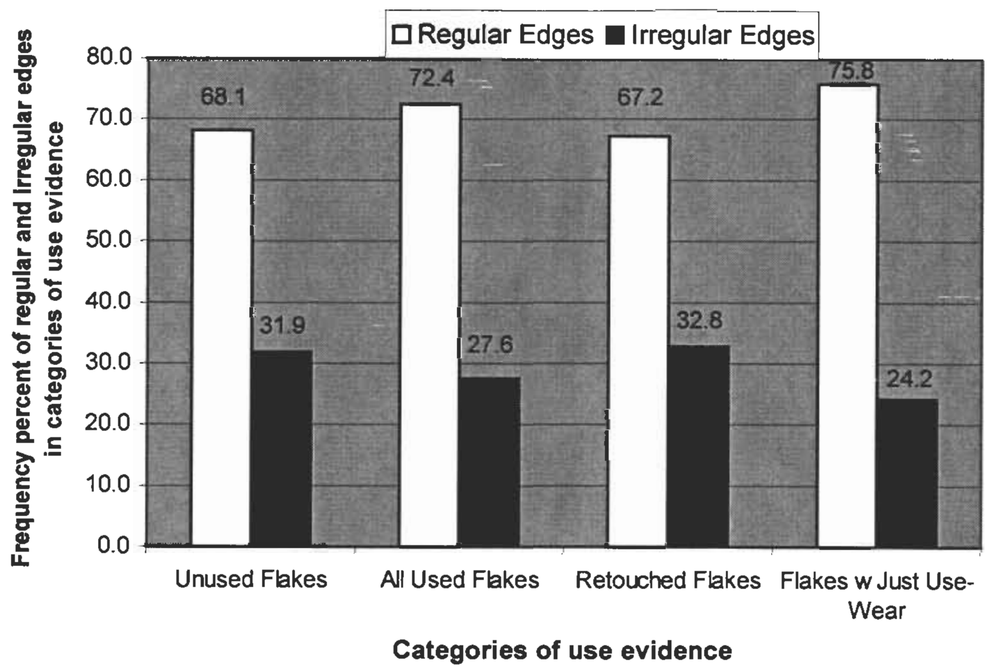


Figure 8.19 Percentage of regular and irregular edges out of total number of usable edges (n=3217) for all flakes by type of use evidence (primary sites).
Chi-squared values are 7.3 for Unused verses All Used, and 22.7 for Retouched verses Use-Wear.

While there is a slightly higher occurrence of regular edges among the used flakes, it is not particularly significant. Of slightly greater significance is the trend to select blanks with more regular edges for tools that are not retouched. The most significant aspect of these data is that the distribution of flakes with retouch is very similar to the distribution of the unused flakes. It must be noted, however, that the retouch itself will have altered the number of regular and irregular edges in the assemblage to some extent.

Edge Length

The length for each usable edge and the total length of all usable edges were recorded for each flake. These values will, however, be directly correlated with flake size (in general, the larger the flake, the longer the individual edges) and so just examining mean edge lengths makes it difficult to separate selection for edge length from simple selection for larger flakes. Therefore, an examination was made of the frequency that the longest usable edge was selected for use when faced with the option of multiple usable edges of varying lengths on a flake. This is summarized in table 8.21.

Table 8.21. The frequency of selection of lengths of edges for use relative to the options available on each flake.
This data is for all three primary sites (this data is not available for Jiboui).

Edge Selected for Use (from usable edges per flake)	**Number of Examples**	**% of Total Examples**	**Summary Groupings**
Longest of two	217	**34.6**	**58.0%**
Longest of three	122	**19.4**	
Longest of four	25	**4.0**	
Second longest of two	123	**19.6**	**42.0%**
Second longest of three	65	**10.4**	
Second longest of four	8	**1.3**	
Third longest of three	41	**6.5**	
Third longest of four	12	**1.9**	
Fourth longest of four	15	**2.4**	
Total	**628**	**100.0**	**100.0**

The data in Table 8.21 suggest some preference for flake blanks based on length of edge. More often than not the longest available edge is selected for use over the other options. However, 58.0% is not an overwhelming trend, and it is apparent that the length of the use-edge was not a strong factor in edge selection. This is particularly apparent in that almost 30% (28.5%) of the time the shortest available edge was selected for use.

However, according to my model, edge length should not be as significant a criterion in the selection of blanks for woodworking tasks as it would be for cutting tasks. Flakes intended for cutting tasks generally need to have longer (and more regular) edges. Therefore, with the continued tentative association between retouch and scraping and unmodified flakes with cutting, these categories of tools are examined for edge-length data below.

Table 8.22. The frequency of selection of lengths of edges for use, among flakes with just usewear, relative to the options available on each flake. This data is for all three primary sites (this data is not available for Jiboui).

Edge Selected for Use (from usable edges per flake)	**Number of Examples**	**% of Total Examples**	**Summary Groupings**
Longest of two	68	**30.9**	**49.5%**
Longest of three	38	**17.3**	
Longest of four	3	**1.4**	
Second longest of two	52	**23.6**	**50.5%**
Second longest of three	25	**11.4**	
Second longest of four	1	**0.5**	
Third longest of three	20	**9.1**	
Third longest of four	5	**2.3**	
Fourth longest of four	8	**3.6**	
Total	**220**	**100.0**	**100.0**

Table 8.23. The frequency of selection of length of edges for use, among flakes that were retouched, relative to the options available on each flake. This data is for all three primary sites (this data is not available for Jiboui).

Edge Selected for Use (from usable edges per flake)	**Number of Examples**	**% of Total Examples**	**Summary Groupings**
Longest of two	149	**36.5**	**62.5%**
Longest of three	84	**20.6**	
Longest of four	22	**5.4**	
Second longest of two	71	**17.4**	**37.5%**
Second longest of three	40	**9.8**	
Second longest of four	7	**1.7**	
Third longest of three	21	**5.1**	
Third longest of four	7	**1.7**	
Fourth longest of four	7	**1.7**	
Total	**408**	**100.0**	**100.0**

Tables 8.22 and 8.23 indicate that there is notable difference in patterns of selection of length of use edge between retouched flakes and flakes with just usewear. In fact, among unretouched tools, selection relative to edge length appears random, while there is a definite tendency for selection of longer edges for retouched flakes. This relationship between retouched tools and the selection for longer edges is further demonstrated in figure 8.20.

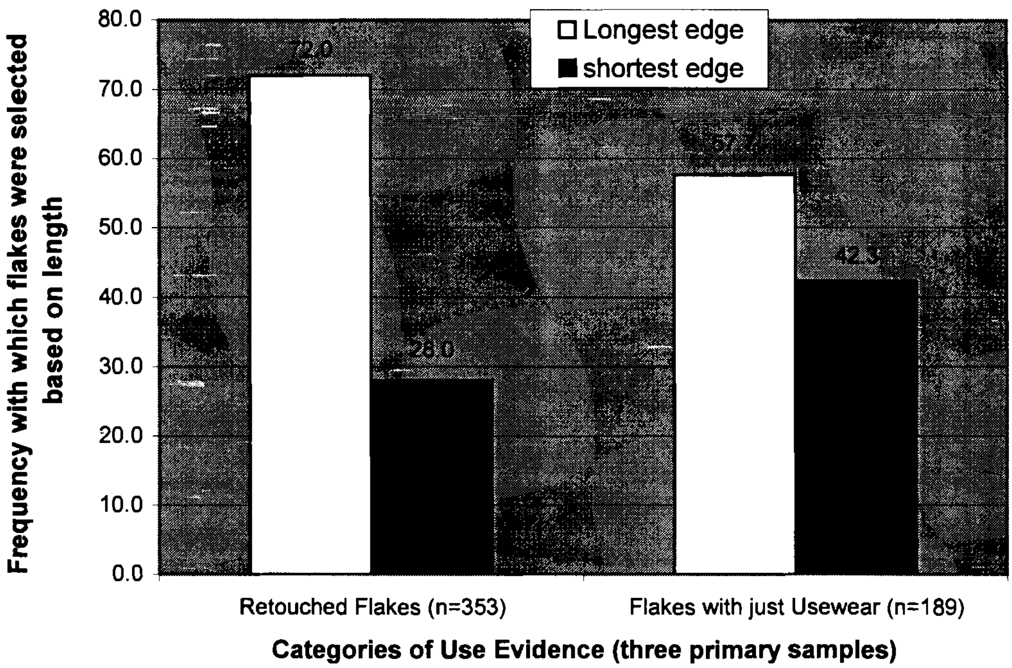


Figure 8.20 The association between whether a tool was retouched or not and the frequency with which the longest or shortest available edge on each flake was selected. Chi squared analysis of this relationship, $x^2 = 11.4$, with 1 degree of freedom, indicates a significance of <0.1% and a confidence of <99.9%.

This would suggest that, contrary to my initial assumption, flakes intended for use in tasks which did not require edge retouch *did not* generally require longer edges than those that were retouched. While the spine-plane angle data above support the idea that there was unique selection criteria employed for blanks that were used unmodified and blanks that were retouched, the data brings into question the association I have been suggesting between unmodified edges and cutting tasks and retouched edges and scraping tasks. It may be that edge retouching was employed on cutting as well as scraping tools.

Another possibility is that, in fact, the suggestion that unmodified flakes were used for butchering is correct, but such tools were essentially seen as so disposable that little time was spent in the selection process. Almost any flake would be picked up and used for butchering, with little prior close examination, and if its performance was less than satisfactory it could readily be replaced.

It may, therefore, be useful to examine the relationship between the lengths and morphologies of used edges. Blank selection may be more closely tied to the recognition of appropriate combinations of suitable edge attributes. The following table examines the relationship between edge morphology and whether the edge was selected for use or not.

Table 8.24 The relationship between the regularity of available usable flake edges and the whether they were selected for use or not.

Of those flakes amongst which the longest available edge was selected		For flakes amongst which other than the longest available edge was selected	
Edges selected	**Edges not selected**	**Edges selected**	**Edges not selected**
70.2% regular	69.9% regular	67.6% regular	72.9% regular

It is seems apparent from these data that regularity of the edge played little role in tool blank selection (although another possibility is that the criteria I employed for designating an edge useable or not was too rigorous and resulted in my category "usable" being overly inclusive. My category might have included a greater portion of all the tool edges than the tool-users themselves might have considered usable, which means my categorization might fail to detect any patterns of selection based on this attribute).

The data indicate that either longer edges were preferred for tools that were retouched, more so than for those that were used unmodified, or it may also be that the traditional assumption holds true: that retouching (or at least some types of retouching) was simply edge resharpening and not pre-use edge modification to suit an application. In this traditional interpretation, retouch on a tool indicates that it, unlike flakes that simply acquired some use-wear, was used for a more extended period of time and so required occasional resharpening. This interpretation would explain the correspondence between retouching and longer tool edges as a general tendency to select flakes with longer edges as blanks that are intended to be more purposeful or longer-lived implements.

Robusticity

One of the main expectations, based on my constructed model, was that robusticity would have been an important attribute for Middle Palaeolithic flake tools because of the importance of woodworking tasks and the significant stress put on tool-edges in these tasks. Stronger, 'beefier' tools would stand up to significant pressures applied to their edges and so should be preferable. Therefore, I had anticipated that robusticity would have been generally selected for in Palaeolithic tools, and given the suggested association between retouched tools and woodworking and unmodified tools and cutting, greater robusticity might be more closely associated with retouched flakes.

However, because of the direct mechanical relationship between robusticity (expressed here as the ratio of thickness to area) and spine-plane angle, and because the data examined above indicate a preference for blanks with lower mean spine-plane angles (e.g., Table 8.12), I expect that, if there are any patterns in the data here, then contrary to my expectations, they should indicate a selection for less robust flake blanks.

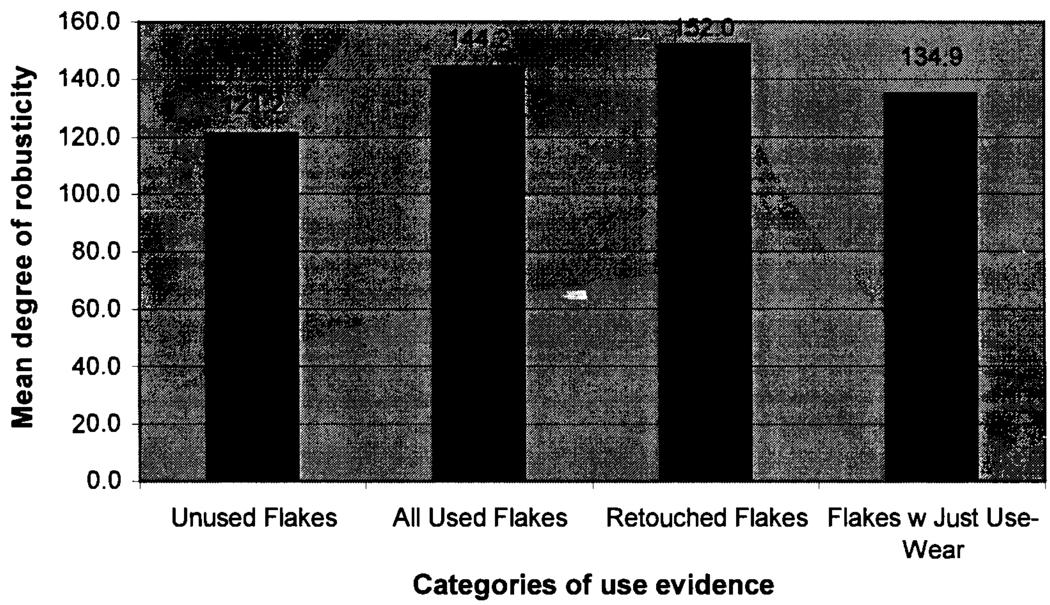


Figure 8.21 Robusticity by Use Evidence for all three primary sites (*lower numbers = more robust*). (data excludes two outliers, 7.6 and 644.0 - both used). Two-sample T-values are: 6.1 for Unused vs All Used, and 4.6 for Retouched vs Use-Wear.

Contrary to my original expectations, but in agreement with the edge-angle data, it is apparent that tool blank selection favoured less robust flakes in general. Furthermore, retouched flakes, which I had been tentatively associating with woodworking tasks, are less robust than those with just use-wear. Perhaps, if hafting was commonly employed for retouched tools, this would tend to limited the desired thickness of blanks.

In addressing the general pattern for the selection of less robust flakes, it could be suggested that, as with flatness, while robusticity was a desirable attribute for flake tools, hardhammer flakes are as a whole robust enough and there would be no need to further select, from among these, flake blanks that were more robust. The mean robusticity of the experimental softhammer flakes is 414.7. This indicates a much lower degree of robusticity compared to all the archaeological samples (which appear to include only hardhammer products).

However, there is no getting around the desirability of woodworking tools to be more robust than those used for butchering meat, and so it is evident that the association that has been made here between retouching and woodworking tools, on the one hand, and the lack of retouch and cutting tools on the other cannot be assumed. Blanks with naturally higher angled edges may have commonly been employed, unmodified, in woodworking.

Summary: Blank Selection Tendencies Common to the Primary Site Samples

Size/Dimensions:

- larger flakes are preferred, but size does not dominate the selection criteria.

-more consistently, retouched tools are larger than unmodified tools.

-tools with both retouch and use-wear have the greatest average length. Initially this might be taken as simply an indication of degree of intensity of use of larger flakes, with unmodified flakes representing those that were used for the shortest period of time and flakes with both retouch and use-wear representing those that were the most intensely used. However, there are marked differences in the mean average spine-plane angles between retouched and unretouched tools, which suggests that these were treated as two different classes of tools at the point of blank selection.

Spine-plane Angle:

-when angle of retouched edges and spine-plane angle of unmodified use-edges are analyzed together we see a bimodal distribution indicative of two general classes of tools.

- among unmodified tools alone, there was consistent selection for lower spine-plane angles.

Ventral Curvature:

-there were no apparent preferences based on ventral curvature.

Regularity of Edges:

Number of usable edges per flake

- tool blanks were selected for based, in part, on the number of usable edges, but there is no obvious correlation between this and type of use evidence (retouch or usewear).

Edge Length

-there is some indication that flakes that were selected for use as retouched blanks tended to have longer use edges.

Regularity of edges

-there is no apparent tendency, based on my criteria, to select more regular edges for use.

Robusticity:

-there is a preference for less robust flakes among the retouched tools.

This highlights an interesting contradiction. While there is an apparent preference for less robust flakes among the retouched tools, there is also a preference for lower edge angles among the unmodified tools, while, in general, lower edge angles and lower robusticity should be directly correlated. The implication is that there are two specific, separate selection criteria affecting the nature of the assemblages of used flakes.

8B Sample-Specific Patterns in Blank Selection

In this section I will examine the data for each site sample individually in order to detect any site-specific patterns in blank selection criteria. This will allow some distinction between those attributes that were sought after in generic Mousterian flake tools, and those attributes that might have been more sensitive to specific circumstances. The attributes will be dealt with in the same order as in the preceding section.

Size

The combined data for the three site samples above indicated a consistent tendency (for all metric attributes: Length, Width, Thickness, and Weight) for larger flakes to be selected for use more frequently than smaller flakes. There is an obvious preference to select the larger of two flakes for use, when given the choice. However, it is also apparent that this is not an absolute as indicated above. The table below presents this data for each of the three site samples.

Table 8.25 Mean dimensions and weights for the 4 site samples by use evidence (with t-values). Use-wear and weight data are not available for Jiboui. (dimensions in mm and weight in milligrams).

	Pech de l'Azé IV			Le Moustier			Combe Capelle Bas			Jiboui		
	Used	**Not used**	**t =**	**Used**	**Not used**	**t =**	**Used**	**Not used**	**t =**	**Ret.**	**Not ret**	**t =**
L	38.0	36.9	**1.1**	39.6	29.9	**7.5**	49.3	44.2	**2.3**	48.9	31.5	**2.7**
W	30.5	29.4	**1.4**	32.1	25.1	**7.4**	42.1	42.7	**0.3**	38.5	26.8	**0.2**
Th	10.7	10.5	**0.5**	9.0	7.2	**4.6**	13.5	14.1	**0.7**	11.5	7.7	**0.4**
Wt	13.0	11.3	**1.5**	13.7	6.5	**5.5**	32.0	30.8	**0.2**	n/a	n/a	**n/a**

The attributes Length and Weight in Table 8.25 above do indicate a general trend towards the use of the larger flakes in these assemblages as the averages of the measurements for the used flakes are consistently (though not always markedly) greater than for the unused flakes.

The first item of note is that among the Jiboui flakes we see the greatest overall difference between the two categories of flakes. This is likely due mostly to the lack of use-wear data and that in this table we are seeing for Jiboui only the difference between retouched and unretouched flakes. The inclusion of use-wear data may bring the difference down to be more in line with the other site samples.

A second item of note is that this trend toward higher averages among the used flakes does not remain consistent for the Width and Thickness measurements. In the Combe Capelle Bas sample the averages for these two dimensions for the unused flakes is slightly higher than the used flakes. However, the difference in the means between the Used and Unused is not particularly strong. In fact, using length ÷ width as an index for bladeyness, Combe Capelle Bas flakes are the least bladey, which could, however, result in the need to specifically select longer, narrower flakes if this characteristic were desirable for some tools.

The significantly higher t values for all the le Moustier dimensions would seem to indicate that the selection process at this site was more rigorous than had occurred at the other three sites.

It is also notable that in table 8.25 the data for Pech de l'Azé IV initially stands out in that the averages between the used and unused flakes are not significantly different for any of the attributes. This can be best explained by the form of the raw material available at this site. Access to only smaller, irregular shaped nodules would mean that the range of sizes of flakes that could be produced would be lower compared to the other two sites. This is supported by comparing the standard deviations and the standard errors of these attributes for all flakes (used and unused) across the four site samples (table 8.26).

Table 8.26 Standard Deviation (SD) and Standard Error (SE) of the Length, Width, Thickness, and Weights of all flakes for each site sample (data on weight for Jiboui was not available).

	Length		Width		Thickness		Weight	
	SD	SE	SD	SE	SD	SE	SD	SE
Pech de l'Azé IV	12.1	0.45	9.6	0.36	4.3	0.16	13.6	0.51
Le Moustier	14.6	0.57	10.7	0.42	4.3	0.17	14.5	0.57
Combe Capelle Bas	17.1	0.79	15.5	0.71	6.6	0.30	37.3	1.72
Jiboui	12.3	0.22	9.9	0.18	3.7	0.07	n/a	n/a

It is apparent that the dimensions of the flakes in the Pech de l'Azé IV sample assemblage as a whole were less variable than the other two primary samples, and raw material form most easily explains this. The size and form of the raw material do not allow for a significant degree of variability in the dimensions of flake products. Based on this, if similar patterns of unmodified tool use were practiced at Jiboui, then, considering the similar lack of variable in the Jiboui sample as a whole (i.e., standard deviations similar to Pech de l'Azé IV), we might expect to see a similar lack of variability between all used and unused flakes (if use-wear data were available).

Table 8.27 below compares the dimensions of the retouched and unretouched tools for the three primary sites (data is not available for Jiboui on unretouched tools).

Table 8.27 Mean dimensions and weights by type of use-modification for each of the site samples (dimensions in mm and weight in grams).

	Pech de l'Azé IV			Le Moustier			Combe Capelle Bas		
	Ret n=164	Both n=79	UW n=243	Ret n=97	Both n=139	UW n=236	Ret n=264	Both n=35	UW n=299
L	38.9	43.3	35.9	42.2	46.6	35.0	51.2	55.3	42.8
W	32.3	33.5	28.6	35.3	37.2	28.2	44.0	43.9	37.0
Th	12.2	12.0	9.5	10.9	10.2	7.7	14.7	13.2	10.4
Wt	16.0	18.5	9.6	20.5	19.5	8.2	37.4	34.6	17.6
	t values			t values			t values		
	Just Ret vs uw	all Ret vs uw	Just Ret vs both	Just Ret vs uw	all Ret vs uw	Just Ret vs both	Just Ret vs uw	all Ret vs uw	Just Ret vs both
L	2.7	4.2	2.4	4.6	8.0	2.3	4.5	4.8	1.3
W	4.1	5.0	0.9	6.3	9.2	1.3	4.1	4.1	0.04
Th	1.6	7.6	0.3	6.5	7.6	1.2	6.0	5.8	1.3
Wt	5.2	6.2	0.6	7.4	9.1	0.4	4.7	4.8	0.4

See Student's t distribution table, Appendix B, to see the specific level of significance and confidence for each of these values. For all of these relationships (degrees of freedom = ∞) a value of ≥ 3.3 indicates a significance level of <0.1% and a confidence level of >99.9%. A value 1.3 still indicates a significance level of <20% and a confidence level of >80%.

One basic pattern is that the retouched tools are larger than the unmodified tools. This is consistent across all three dimensions (and by weight). As with the used verses unused data, the Pech de l'Azé IV sample has the least degree of difference between the retouched and unmodified tools.

Perhaps of more significance, however, is that the tools with both retouch and use-wear have the greatest average length of all three categories, but they do not show a correspondingly equal increase in the other dimensions (or in weight), which would be the case if blanks were simply selected based on greater size. Either the corresponding dimensions (width and thickness) increase only a small amount, or else they remain lower than among the retouched tools. Based on the assumption that those tools that had multiple edges used (both retouched and unmodified on a single tool) represent optimal tool-blank forms, this suggests that longer, narrower (blade-like), and thinner blanks were most sought after.

Spine-Plane Angles

Examination of cross-sample spine-plane angle data (Section 8A above) does indicate a general association between the natural spine-plane angles of blanks and the subsequent decision to retouch them or not (assumed at this point to represent task-specific requirements). The intention in this section is to see if that same pattern exists in the data for the three sites individually.

Table 8.28 Percent distribution by type of edge modification in two categories of spine-plane angles set at 55° for each site sample. (from average spine-plane angle per flake).

Type of use evidence	Pech de l'Azé IV (n=610)			Le Moustier (n-479)			Combe Capelle Bas (n=395)		
	% ≤ 55°	% > 55°	m>	% ≤ 55°	% > 55°	m>	% ≤ 55°	% > 55°	m>
Unused	86.5	13.5	**43.0°**	95.0	5.0	**35.5°**	83.6	16.4	**43.8°**
Just Usewear	90.7	9.3	**40.7°**	99.2	0.8	**32.5°**	92.5	7.5	**37.6°**
Just Retouch	84.6	15.4	**46.3°**	91.1	8.9	**39.6°**	89.8	10.2	**41.1°**

Data for the used flakes (retouched and usewear) comes from the spine-plane angle on the used edge. Data for the unused flakes is the mean spine-plane angle (averaged from several edges). To demonstrate that there is a reasonable degree of comparability of these two data-sets, the mean spine-plane angles for the three site samples are: Pech de l'Azé IV are 40.3° for just usewear and 45.6° for just retouch; le Moustier are 33.3° for just usewear and 38.5° for just retouch; and for Combe Capelle Bas are 37.5° for just usewear and 41.0° for just retouch. One can see that these are very similar to the values in this table.

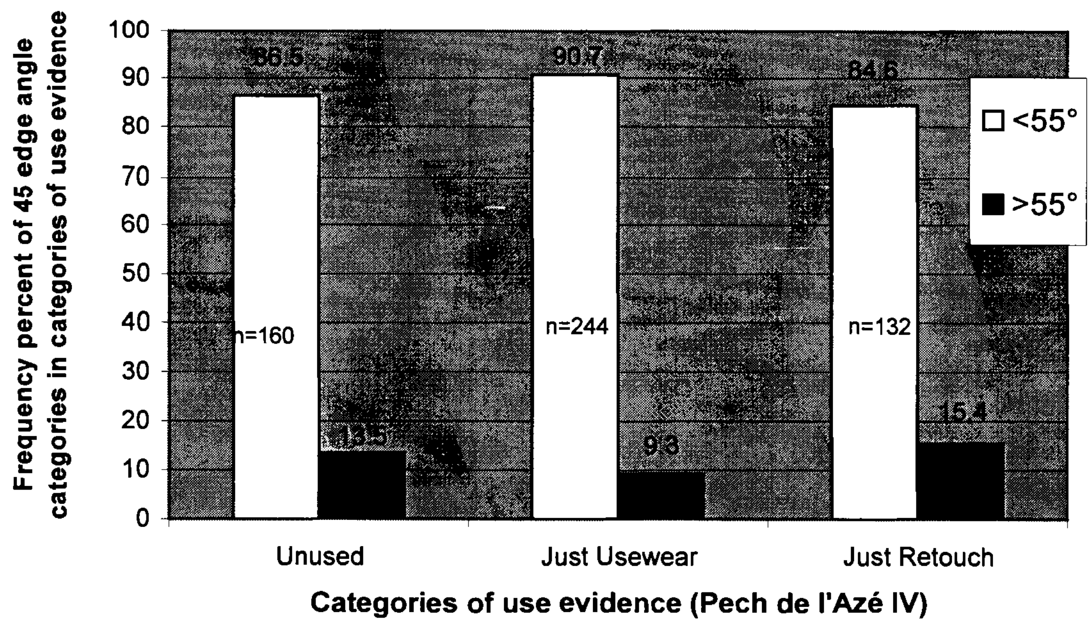


Figure 8.22 Percentage of flakes with average spine-plane angles of ≤55° or >55° in each category of use modification for Pech de l'Azé IV.

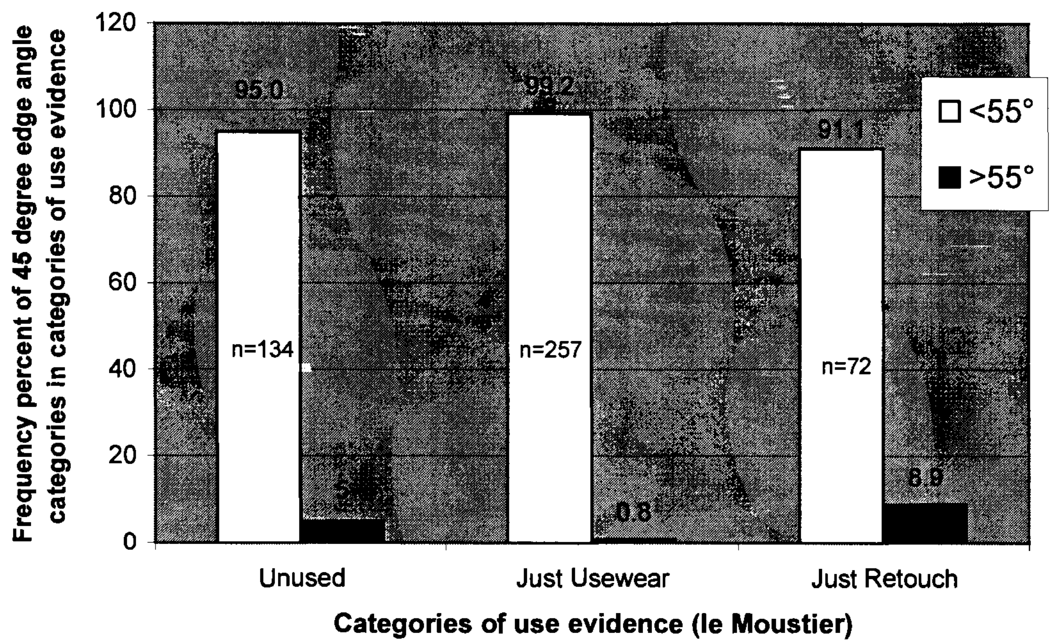


Figure 8.23 Percentage of flakes with average spine-plane angles of ≤55° or >55° in each category of use modification for le Moustier.

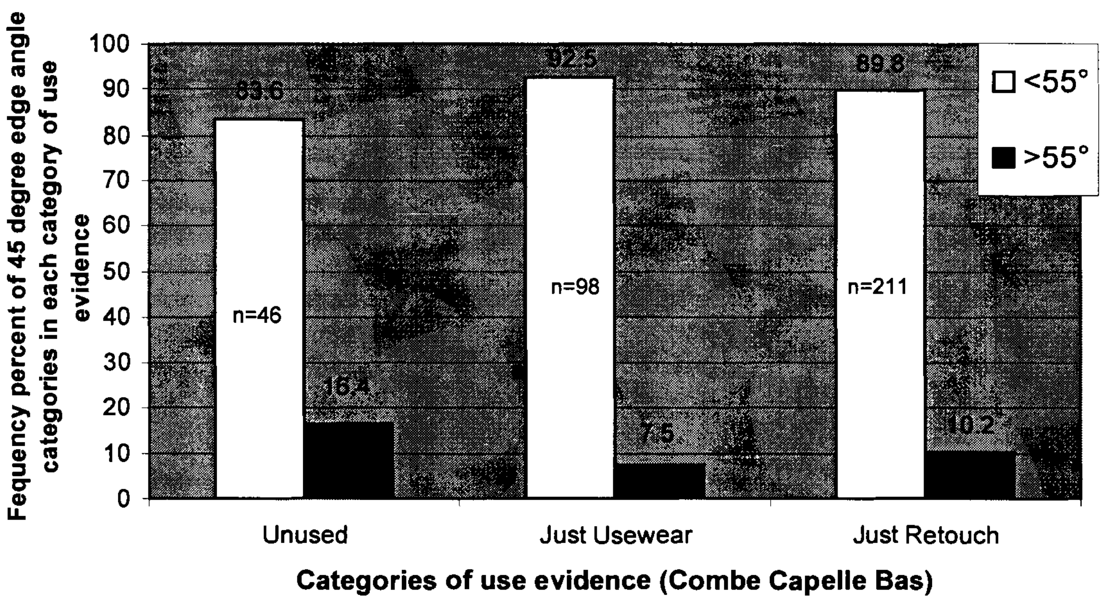


Figure 8.24 Percentage of flakes with average spine-plane angles of ≤55° or >55° in each category of use modification for Combe Capelle Bas.

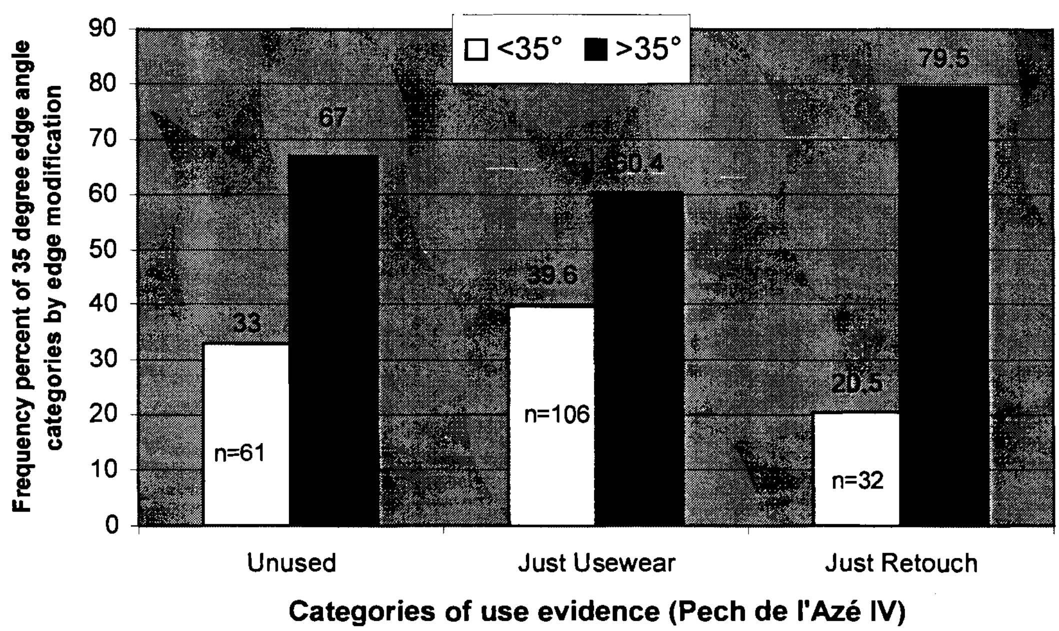


Figure 8.25 Percentage of flakes with average spine-plane angles of ≤35° or >35° in each category of use modification for Pech de l'Azé IV.

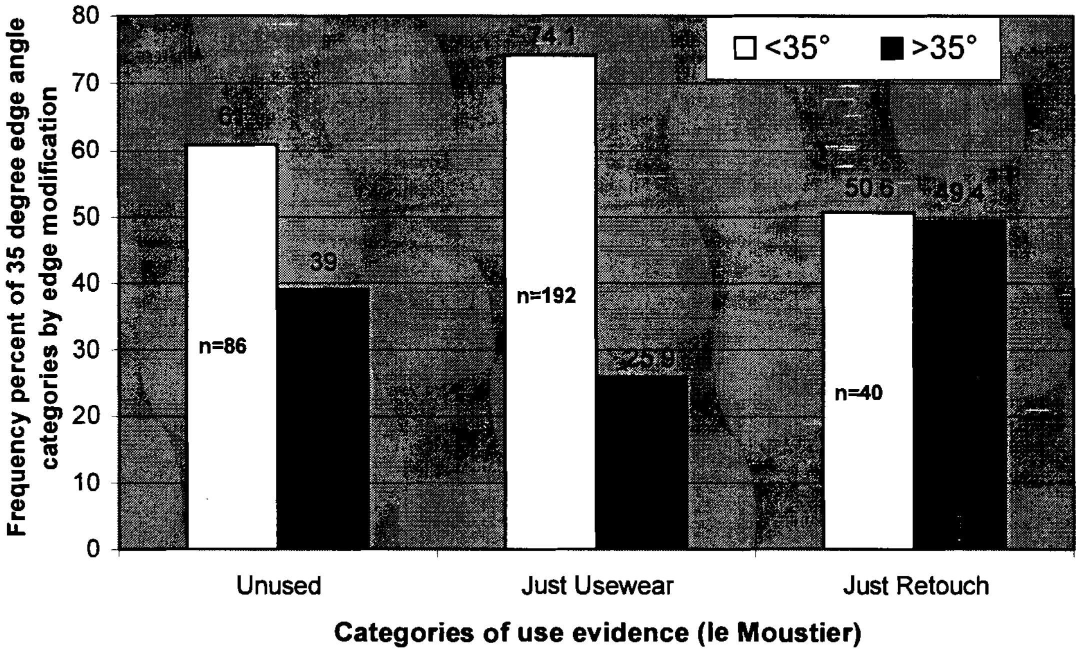


Figure 8.26 Percentage of flakes with average spine-plane angles of ≤35° or >35° in each category of use modification for le Moustier.

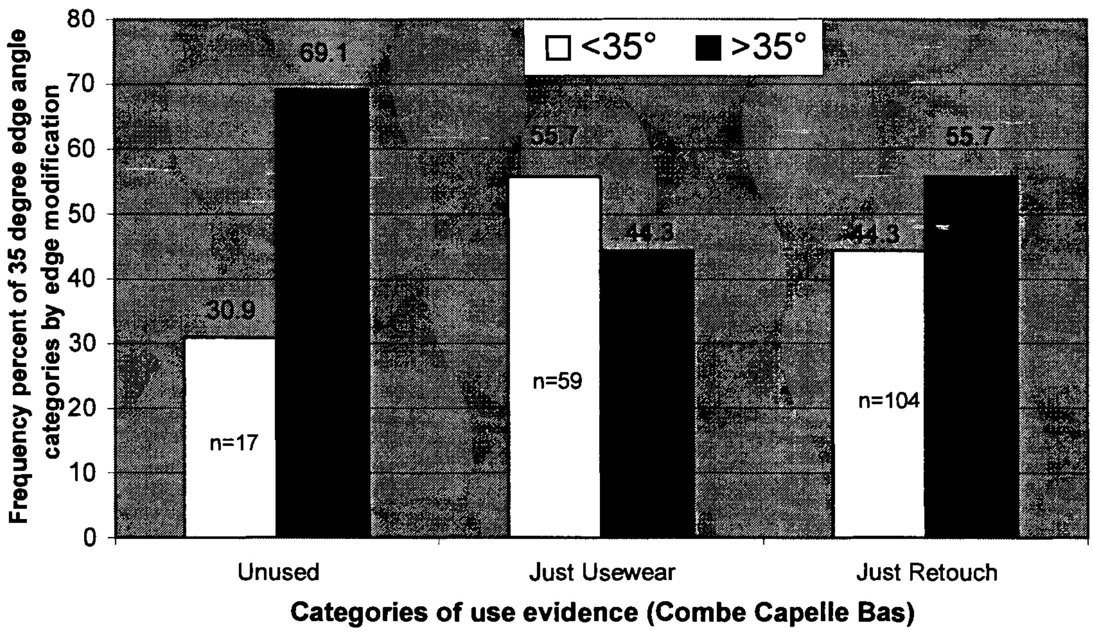


Figure 8.27 Percentage of flakes with average spine-plane angles of ≤35° or >35° in each category of use modification for Combe Capelle Bas.

Figures 8.22, 8.23 and 8.24 indicate that there might have been a slight preference to use flake blanks with lower average edge angles for unmodified tools, but the differences between the three categories of use evidence in all three site samples is fairly consistent. However, somewhat stronger patterns are apparent when the edge angle data is separated at a lower angle cutoff point (figures 8.25, 8.26 and 8.27).

There are two points of difference between the three samples in the 35° cutoff tables. First of all, the percentages of all flakes ≤ 35° in the le Moustier sample are significantly higher than in the other two site samples. This is readily explained by the fact that the average spine-plane angle for the le Moustier sample as a whole is significantly lower (average spine-plane angles for all flakes are: Pech de l'Azé IV 43°, le Moustier 35°, and Combe Capelle Bas 40°). This may relate to the fact that the use of the Levallois reduction technology at le Moustier is higher than at the other two primary sites and *Eclats Débordants* are more prevalent in the Pech de l'Azé IV sample, but this will be addressed later (Chapter 9 and 10).

The second item of note is that, for all three samples in both tables, the percentage of flakes with use-wear that have angles below the cutoff point is always higher than the percentage for the unused flakes and flakes with retouch. However, for Pech de l'Azé IV and le Moustier, the percentage of retouched flakes in the lower angle category (≤35° or ≤45°) is close to, but lower than, the percentage of unused flakes in this category (with one exception being Pech de l'Azé IV in the 35° table where this percentage is significantly lower), while in Combe Capelle Bas the percentage of retouched flakes in the lower angle category is significantly higher than the percentage of unused flakes in this category. This seems best explained by a tendency to generally select lower edge angles for both unmodified *and* retouched tool blanks at Combe Capelle Bas. The prevailing preference is for lower edge angles for unmodified tool blanks.

Edge Data: Number, Length, and morphology of Usable Edges per flake

Regularity of Edge Morphology

Collectively, the data of the three primary samples indicated an apparent selection for flakes with a greater number of regular, more usable edges, but a selection for longer individual edges only among retouched tools. Here I have examined the sample data by individual site. As mentioned above, in the collecting of data on the sample assemblages the "usability" of an edge was judged mainly on the presence or absence of long, regular, reasonably sharp sections. Therefore, as a measure of regularity, since the number of flakes with no usable edges at all is negligible, I have used the number of usable edges per flake as a measure of the occurrence and potential preference of edge regularity.

Table 8.29 Mean number of usable edges per flake by use-evidence for the three primary site samples.

	Pech de l'Azé IV		Le Moustier		Combe Capelle Bas	
	Used (n=1154)	**Unused** (n=331)	**Used** (n=1200)	**Unused** (n=281)	**Used** (n=911)	**Unused** (n=107)
Mean # edges	2.2	1.8	2.4	1.85	2.3	1.6

The data here mirror that observed for the data collectively. At all three sites, tool blanks were selected based, at least in part, on the number of usable edges they exhibited.

It could also be useful to examine the distribution of usable (regular) edges by type of edge damage.

Table 8.30 Mean number of usable edges per flake (and standard deviation) by type of edge damage for all three primary site samples.

	Mean number of edges	SD
Unused Flakes	1.21	**0.98**
Retouched Flakes	1.34	**0.90**
Flakes w Usewear	1.78	**0.96**

Table 8.31 Mean number of usable edges per flake by type of edge damage for the primary sites.

	Pech de l'Azé IV		Le Moustier		Combe Capelle Bas	
	m # edges	**SD**	**m # edges**	**SD**	**m # edges**	**SD**
Unused	1.34	**0.95**	1.30	**0.98**	1.00	**0.97**
Just Usewear	1.35	**0.92**	1.15	**0.86**	1.37	**0.90**
Just Retouch	1.68	**0.96**	1.92	**0.94**	1.79	**0.96**

Broken down into type of edge damage it is apparent that the selection went beyond just a preference for more usable edges on a tool blank. There are no apparent major differences in blank selection for each site, but for all three sample assemblages the preference for more regular edges per flake is most strong for those tools that were not retouched. For Pech de l'Azé IV the retouched tools have very similar numbers of usable edges as the unused flakes. For le Moustier there are fewer usable edges per flake on the retouched tools than on the unused flakes, and for Combe Capelle Bas there are significantly more. The general preference, for all three site assemblages, for blanks with more usable edges to be selected for tools that were not retouched could be explained by a general tendency to be less concerned about edge morphology during the selection of blanks that will be retouched because the tool user intends to modify potential use-edges to suit the task requirements.

Edge Length

The combined data for the three sample assemblages presented above, indicated that there was a greater tendency to select the longest available edge on a flake that was to be retouched than one that was to be used unmodified. Here I will examine the data for the samples individually to see if this pattern holds true for all three sites.

Table 8.32 The frequency of selection of edges for use, relative to the lengths of the available edges on each flake, for all unretouched tools , Pech de l'Azé IV .

Edges Selected for Use (from usable edges per flake)	**Number of Examples**	**% of Total Examples**	**Summary Groupings**
Longest of two	19	**33.9**	**48.2%**
Longest of three	6	**10.7**	
Longest of four	2	**3.4**	
Second longest of two	18	**32.1**	**51.8%**
Second longest of three	6	**10.7**	
Second longest of four	0	**0.0**	
Third longest of three	1	**1.8**	
Third longest of four	2	**3.4**	
Fourth longest of four	2	**3.4**	
Total	**56**	**100.0**	**100.0**

Table 8.33 The frequency of selection of edges for use, relative to the lengths of the available edges on each flake, for all retouched tools in the in the Pech de l'Azé IV sample.

Edges Selected for Use (from usable edges per flake)	**Number of Examples**	**% of Total Examples**	**Summary Groupings**
Longest of two	39	**60.9**	
Longest of three	14	**21.9**	**85.9%**
Longest of four	2	**3.1**	
Second longest of two	5	**7.8**	
Second longest of three	2	**3.1**	
Second longest of four	0	**0.0**	**14.1%**
Third longest of three	1	**1.6**	
Third longest of four	1	**1.6**	
Fourth longest of four	0	**0.0**	
Total	**64**	**100.0**	**100.0**

The Pech de l'Azé IV data indicate that, while selection based on use edge length is basically random among unretouched tools (tools with just usewear), there is a strong tendency to select for longer edges among tools that are retouched. This is paralleled by the fact that among the unretouched tools, 37.5% of the edges selected were the shortest available, while among the retouched tools this percentage is 9.4.

Table 8.34 The frequency of selection of edges for use, relative to the lengths of the available edges on each flake, all unretouched tools , le Moustier .

Edges Selected for Use (from usable edges per flake)	**Number of Examples**	**% of Total Examples**	**Summary Groupings**
Longest of two	29	**26.1**	
Longest of three	23	**20.7**	**46.8%**
Longest of four	0	**0.0**	
Second longest of two	25	**22.5**	
Second longest of three	14	**12.6**	
Second longest of four	1	**0.9**	**53.2%**
Third longest of three	13	**11.7**	
Third longest of four	3	**2.7**	
Fourth longest of four	3	**2.7**	
Total	**111**	**100.0**	**100.0**

Table 8.35 The frequency of selection of edges for use, relative to the lengths of the available edges on each flake, for all retouched tools in the le Moustier sample.

Edges Selected for Use (from usable edges per flake)	Number of Examples	% of Total Examples	Summary Groupings
Longest of two	43	27.7	
Longest of three	36	23.2	55.5%
Longest of four	7	4.5	
Second longest of two	30	19.4	
Second longest of three	20	12.9	
Second longest of four	3	1.9	44.5%
Third longest of three	9	5.8	
Third longest of four	3	1.9	
Fourth longest of four	4	2.6	
Total	155	100.0	100.0

The le Moustier data also indicate an apparent lack of concern for edge length among the unretouched tools (36.9% of those selected were the shortest available edge). Among the retouched tools there is perhaps a slight preference for longer edges, but it is not as strong as for the Pech de l'Azé IV data. Among the le Moustier tools, 27.7% of the selected edges were the shortest available on a flake.

Table 8.36 The frequency of selection of edges for use, relative to the lengths of the available edges on each flake, for all unretouched tools, Combe Capelle Bas.

Edges Selected for Use (from usable edges per flake)	Number of Examples	% of Total Examples	Summary Groupings
Longest of two	20	37.7	
Longest of three	9	17.0	56.6%
Longest of four	1	1.9	
Second longest of two	9	17.0	
Second longest of three	5	9.4	
Second longest of four	0	0.0	43.4%
Third longest of three	6	11.3	
Third longest of four	0	0.0	
Fourth longest of four	3	5.7	
Total	53	100.0	100.0

Table 8.37 The frequency of selection of edges for use, relative to the lengths of the available edges on each flake, for all retouched tools in the Combe Capelle Bas sample.

Edges Selected for Use (from usable edges per flake)	**Number of Examples**	**% of Total Examples**	**Summary Groupings**
Longest of two	67	**35.4**	
Longest of three	34	**18.0**	**60.3%**
Longest of four	13	**6.9**	
Second longest of two	36	**19.0**	
Second longest of three	18	**9.5**	
Second longest of four	4	**2.1**	39.7%
Third longest of three	11	**5.8**	
Third longest of four	3	**1.6**	
Fourth longest of four	3	**1.6**	
Total	**189**	**100.0**	**100.0**

Among the Combe Capelle Bas tools, there is perhaps a slight selection bias among the unretouched tools based on edge length, but it is not strong, and again the percentage in which the longest available edge was used was relatively high (34.0%). Among the retouched tools the bias is increased somewhat, but again it is still not particularly strong (26.5% on the shortest available edge).

Of the three sites Pech de l'Azé IV shows the strongest tendency for edge length to factor into the selection of retouched tools. This may be a due to the Pech de l'Azé IV flakes being the smallest on average, thus making it necessary to be more selective among the available flakes edges for retouched tools. In none of the samples does it appear that edge length played much, if any, of a role in the selection of unretouched tools.

Ventral Curvature - "Flatness"

In analyzing the data as a whole there was no apparent selection for tool blanks based on qualities of ventral curvature. Here I analyze the data for each site to see if there was any site-specific preference for ventral curvature in blank selection. Any such preferences might relate to specific site functions.

Table 8.38 Distribution by degree of ventral curvature (in discrete categories) for the sample assemblages from each site and for all sites together
(as a control from which to interpret the data for used & unused categories of flakes in Table 8.30).

	Total	**Flat**	**%**	**C1/V1**	**%**	**C2/V2**	**%**	**C/V3-6**	**%**
Pech IV	703	369	**52.5**	187	**26.6**	94	**13.4**	53	**7.5**
Le Moustier	647	384	**59.4**	163	**25.2**	77	**11.9**	23	**3.6**
Combe Capelle	460	309	**67.2**	103	**22.4**	38	**8.3**	10	**2.2**
All sites	1810	1062	**58.7**	453	**25.0**	209	**11.5**	86	**4.8**

Table 8.39 Distribution by degree of ventral curvature (in discrete categories) for the used and unused flakes from each of the three primary sites.

		Total	**Flat**	**%**	**C/V1**	**%**	**C/V2**	**%**	**C3-6**	**%**
Used	Pech IV	517	281	**54.4**	125	**24.2**	68	**13.2**	43	**8.3**
	Le Moust	497	287	**57.7**	135	**27.2**	57	**11.5**	18	**3.6**
	C Capell	395	264	**66.8**	88	**22.3**	35	**8.9**	8	**2.0**
Not used	Pech IV	186	88	**47.3**	62	**33.3**	26	**14.0**	10	**5.4**
	Le Moust	150	97	**64.7**	28	**18.7**	20	**13.3**	5	**3.3**
	C Capell	65	45	**69.2**	15	**23.1**	3	**4.6**	2	**3.1**

As with the data as a whole, based on these tables, for the individual site samples there was no difference between the sites in preferences for qualities in ventral curvature. Tool blanks were not selected based on any lack of curvature as the distribution of used and unused flakes by ventral curvature is very similar to the distribution of each entire sample assemblage by ventral curvature; in terms of ventral curvature, tool blanks were apparently selected randomly at all three sites.

Standardization

The term standardization, like 'curation', can be loaded, with the intention to convey a high degree of formality in the behaviour of the toolmakers and users. Here I am using it in the simplest manner; that is to suggest that tool users maintained a conscious understanding that there were certain morphological characteristics that were desirable in all (or at least most) of their flake tools. However, at times there may also be other considerations (a specific, individual characteristic like size, edge angle) that can take precedence over any suite of commonly preferred characteristics. There may only be a general tendency, rather than a concerted effort, to produce assemblages and select blanks that exhibit common morphological patterns. By standardization I am referring to any *tendency* to decrease the degree of variability in more than one aspect of the morphology of all the flake blanks. There may be (and actually are) preferences in individual characteristics, such as size. The data above indicate a general preference for the use of larger flake blanks. However, just greater size cannot be considered standardization of form. It would require the non-random occurrence of two or more non-correlating attributes among the used flakes to indicate some degree of standardization. Elongation, referred to here as bladeyness, would be an example of this. Bladeyness represents a relative increase in one dimension, length, relative to another, width, and can provide specific advantages over regular flakes, such increased length of individual edges and greater ease of hafting.

Standardization can involve various attributes, including the plan shape of the flakes and their general size or any individual dimensions. As with all the individual flake or assemblage attributes discussed above, if some sort of standardization was a desired characteristic then it may have been selected for at the point of flake production first. A reduction strategy or technology would have been designed in part to produce flakes with the desired degree and type of selected attributes. However, it can be assumed that if there was some desired standardization for tool blanks then this would also be reflected at the point of blank selection

Tables 8.31 - 8.33 below provide the means, ranges, and standard deviations of the primary metric attributes, weight, average edge angle, robusticity, bladeyness, and flake shape for the used and unused flakes in each of the primary site samples. These data are examined here for any significant patterns of regularity in any attributes that may indicate any trends towards standardization in blank selection.

Table 8.40 Means, ranges, and standard deviations of the primary metric attributes of the Pech de l'Azé IV sample assemblage, broken into categories of use-evidence.

Variable			Range	Mean	SD
Length	Unused		82 (20-102)	36.9	11.7
	Used		81 (16-97)	38.0	12.2
		Retouched	80 (16.5-96.5)	38.9	12.4
		Usewear	67.5 (16-83.5)	35.9	10.6
Width	Unused		63 (13-76)	29.4	9.2
	Used		62 (11-73)	30.5	9.7
		Retouched	54 (14-68)	32.3	9.3
		Usewear	62 (11-73)	28.6	9.0
Thickness	Unused		21.5 (2.5-24)	10.5	4.5
	Used		30.5 (2-32.5)	10.7	4.3
		Retouched	28.5 (4-32.5)	12.2	4.3
		Usewear	22.5 (2-24.5)	9.5	3.7
Weight	Unused		88.6 (1.2-89.8)	11.3	12.7
	Used		161.0 (0.8-161.8)	13.0	13.8
		Retouched	160.3 (1.5-161.8)	16.0	16.8
		Usewear	59.4 (0.8-60.2)	9.6	8.8
Edge Angle	Unused		55 (20-75)	42.6	11.7
	Used		60 (20-80)	42.7	10.7
		Retouched	50 (20-70)	45.7	9.5
		Usewear	60 (20-80)	40.5	10.7
Area	Unused		5349 (351-5700)	1135	722
	Used		6244 (255-6499)	1218	749
		Retouched	5289 (308-5597)	1301	748
		Usewear	3920 (255-4175)	1074	613
Robusticity	Unused		321.4 (28.6-350)	117	57.6
	Used		482.4 (30.6-513)	118	55.3
		Retouched	268.5 (34-302.5)	110	49.3
		Usewear	279.4 (30.6-310)	118	51.9
Index of Bladeyness (w/l)	Whole Sample		2.0 (0.3-2.3)	0.84	0.3
	Unused		1.4 (0.3-1.7)	0.83	0.3
	Used		2.0 (0.3-2.3)	0.85	0.3
		Retouched	1.9 (0.4-2.3)	0.87	0.3
		Usewear	1.6 (0.3-1.9)	0.83	0.3

Regularity of Flake Shape

		Regular	%	Irreg	%	broken	%	Total
Unused		82	**44.6**	100	**53.8**	4	**2.2**	186
Used		232	**44.5**	276	**53.0**	14	**2.7**	521
	Retouched	61	**37.2**	94	**57.3**	9	**5.5**	164
	Usewear	142	**51.1**	132	**47.5**	4	**1.4**	278

Table 8.41 Means, ranges, and standard deviations of the primary metric attributes of the le Moustier sample assemblage, broken into categories of use-evidence.

Variable			Range	Mean	SD
Length	Unused		60 (10-70)	29.9	12.0
	Used		81 (6.5-88)	39.6	14.6
		Retouched	68 (20-88)	42.2	14.5
		Usewear	71.5 (6.5-77)	35.0	12.6
Width	Unused		53.5 (9.5-63)	25.1	8.4
	Used		73 (12-85)	32.1	10.7
		Retouched	67 (18-85)	35.3	11.6
		Usewear	51 (12-63)	28.2	8.5
Thickness	Unused		17.5 (1.5-19)	7.2	4.0
	Used		28.5 (1.5-30)	8.9	4.3
		Retouched	27 (3-30)	10.9	5.2
		Usewear	24.5 (1.5-26)	7.7	3.7
Weight	Unused		57.8 (0.4-58.2)	6.5	8.2
	Used		134.1 (0.3-134.4)	13.7	15.5
		Retouched	132.7 (1.7-134.4)	20.5	23.1
		Usewear	69.8 (0.3-70.1)	8.2	8.4
Edge Angle	Unused		45 (20-65)	35.5	12.4
	Used		60 (20-80)	34.9	9.3
		Retouched	45 (20-65)	38.5	10.2
		Usewear	40 (20-60)	33.3	9.5
Area	Unused		3920 (143-4063)	813	596
	Used		5731 (91-5822)	1366	904
		Retouched	5445 (378-5823)	1607	106 6
		Usewear	4760 (91-4851)	1042	623
Robusticity	Unused		258.6 (41.3-299.9)	118	53.8
	Used		613.7 (30.3-644)	154	73.0
		Retouched	344.5 (57.1-401.6)	149	64.9
		Usewear	613.7 (30.3-644)	142	71.3
Index of Bladeyness (w/l)	Whole Sample		1.8 (0.4-2.2)	0.88	0.3
	Unused		1.6 (0.4-2.0)	0.91	0.3
	All Used		1.8 (0.4-2.2)	0.86	0.3
		Retouched	1.4 (0.4-1.8)	0.86	0.3
		Usewear	1.8 (0.4-2.2)	0.87	0.3

Regularity of Flake Shape

		Regular	%	Irreg	%	broken	%	Total
Unused		38	**25.0**	80	**52.6**	34	**22.4**	152
Used		157	**31.3**	286	**57.1**	58	**11.6**	501
	Retouched	22	**22.7**	57	**58.8**	18	**18.6**	97
	Usewear	94	**35.5**	148	**55.8**	23	**9.4**	265

Table 8.42 Means, ranges, and standard deviations of the primary metric attributes of the Combe Capelle Bas sample assemblage, broken into categories of use-evidence.

Variable			Range	Mean	SD
Length	Unused		75 (18-93)	44.2	17.9
	Used		83 (19-102)	49.4	16.8
		Retouched	79 (19-98)	51.2	16.9
		Usewear	82 (20-102)	42.8	14.4
Width	Unused		95 (11-106)	42.7	17.0
	Used		91.5 (14.5-106)	42.2	15.3
		Retouched	89 (15-104)	44.0	16.0
		Usewear	64.5 (14.5-79)	37.0	12.0
Thickness	Unused		29 (3-32)	14.1	7.3
	Used		41 (3-44)	13.5	6.4
		Retouched	40 (4-44)	14.7	6.8
		Usewear	27.5 (3-30.5)	10.4	4.5
Weight	Unused		223.3 (1.3-224.6)	30.8	39.5
	Used		289.2 (1.6-290.8)	32.0	37.1
		Retouched	289.2 (1.6-290.8)	37.4	41.3
		Usewear	101.8 (2.3-104.1)	17.6	18.2
Edge Angle	Unused		50 (20-70)	40.1	13.3
	Used		60 (20-80)	39.7	10.7
		Retouched	60 (20-80)	41.0	10.9
		Usewear	55 (20-75)	37.5	10.4
Area	Unused		8775 (341-9116)	2085	1627
	Used		8542 (285-8827)	2199	1402
		Retouched	8542 (285-8827)	2370	1470
		Usewear	4716 (340-5056)	1663	995
Robusticity	Unused		308.1 (44.7-352.8)	145	66.3
	Used		478.7 (37.3-516)	167	75.6
		Retouched	442.3 (37.3-479.6)	164	69.8
		Usewear	466.9 (49.1-516)	166	81.8
Index of Bladeyness (W/L)	Whole Sample		2.1 (0.3-2.4)	0.92	0.3
	Unused		1.6 (0.3-1.9)	1.03	0.4
	All Used		1.9 (0.5-2.4)	0.91	0.3
		Retouched	2.0 (0.4-2.4)	0.90	0.3
		Usewear	1.4 (0.3-1.7)	0.91	0.3

Regularity of Flake Shape

		Regular	%	Irreg	%	broken	%	Total
Unused		10	**14.9**	46	**68.7**	11	**16.4**	67
Used		89	**22.0**	257	**63.5**	59	**14.6**	405
	Retouched	50	**18.9**	172	**65.2**	42	**15.9**	264
	Usewear	31	**29.2**	62	**58.5**	13	**12.3**	106

The individual sample data seem to generally follow the same basic patterns. One notable specific is that the level of difference between the used and unused flakes is much lower in the Pech de l'Azé IV sample than in the other two. This might simply be a product of the flakes in the Pech assemblage being smaller on the whole, compared to the other two sites, because of raw material constraints, and this provided a significantly lower range of variation from which to select tool blanks.

The only significant deviation from the basic trend to select larger flake blanks for use is in the Combe Capelle Bas data. Here, while there is the same selection trend, common to all four sites, for the longest and thinnest flakes, the width dimension does not increase accordingly. The used flakes of this sample have a lower mean and range of width than the unused suggesting a preference for longer, narrower flakes for use as tools. This might just indicate a slightly greater tendency than the other two sites to select longer, narrower flakes, but this tendency is slight in all three sites and is likely just a reflection of the general trend to select flakes with longer individual edges. It would be logical for flakes exhibiting longer individual edges to be somewhat more bladey.

Overall, there are no detectable patterns of standardization among any of the samples.

Robusticity

Analysis of the data collectively made it apparent that tool blank selection favoured less robust flakes in general, but not so robust as to be as fragile as billet flakes. Here I will examine this for each sample individually. (Again, the ratio of thickness to area is used here as a measure of the robusticity of a flake, with lower values representing greater robusticity.)

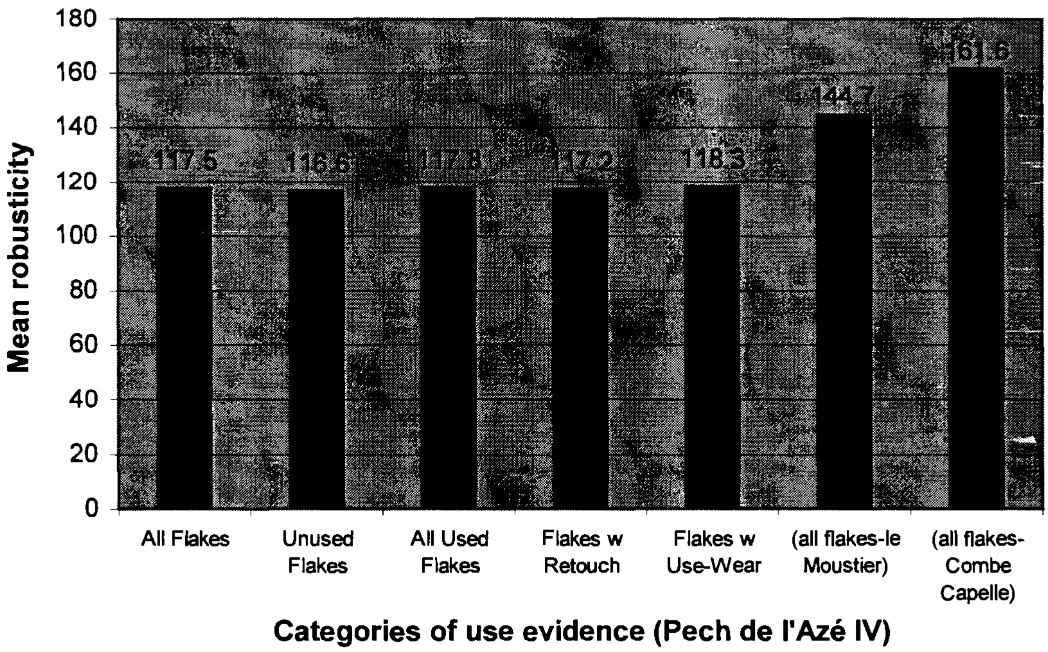
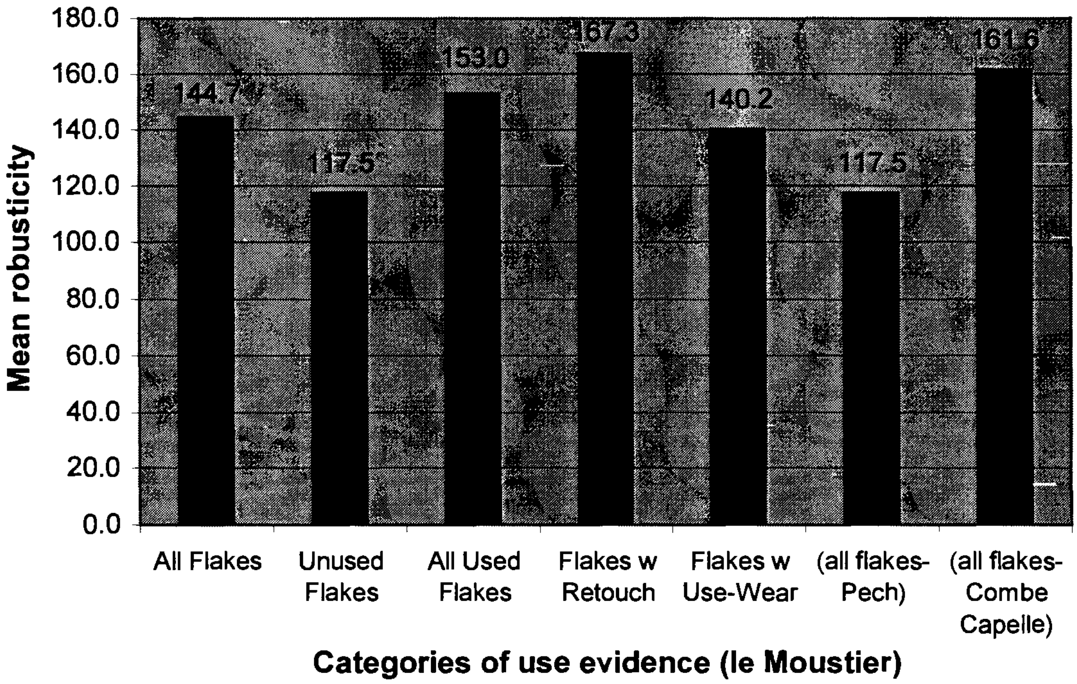


Figure 8.28 Degree of robusticity by use evidence for Pech de l'Azé IV (excluding two robusticity outliers - 7.6 and 644.0 - both used). The mean robusticity value for all flakes from le Moustier and Combe Capelle Bas are included for comparison.



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igure 8.29 Degree of robusticity by use evidence for le Moustier. The mean robusticity value for all flakes from Pech de l'Azé IV and Combe Capelle Bas are included for comparison.

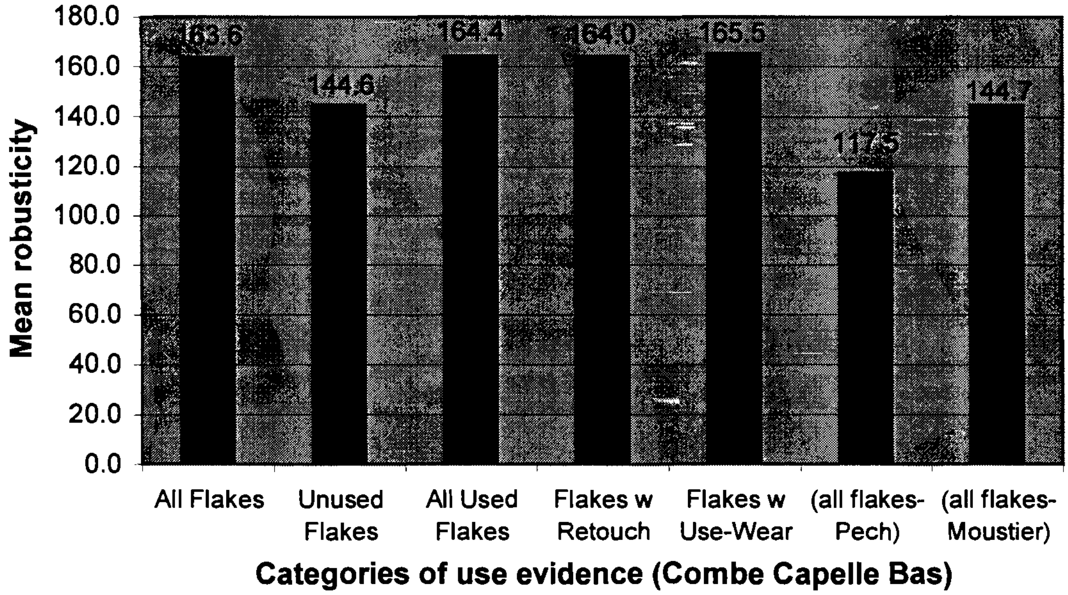

Figure 8.30 Degree of robusticity by use evidence for Combe Capelle Bas. The mean robusticity value for all flakes from Pech de l'Azé IV and le Moustier are included for comparison.

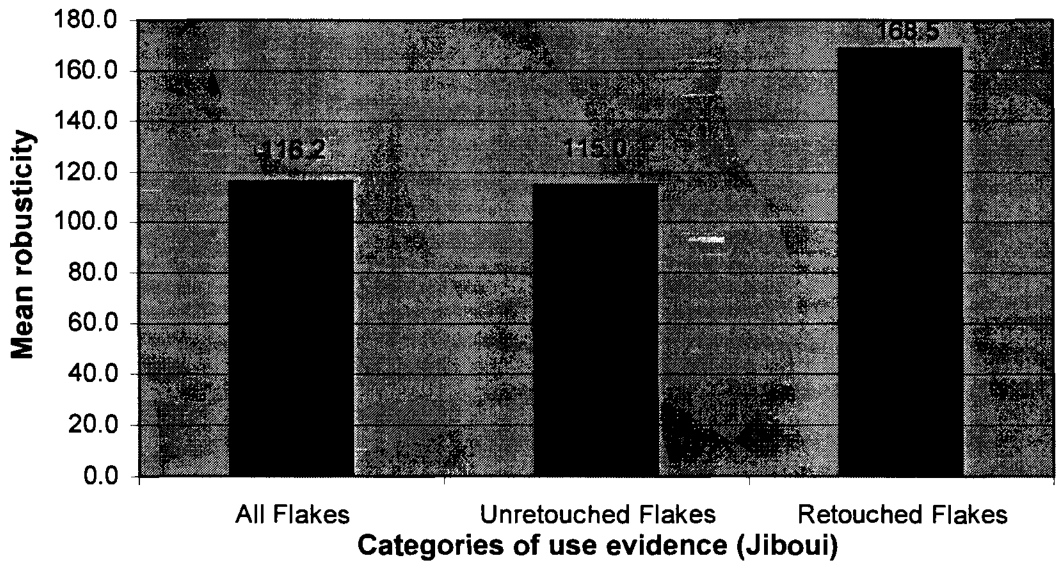

Figure 8.31 Degree of robusticity by use evidence for Jiboui (data on use-wear is unavailable).

These data suggest that there are some significant site-specific patterns in the role that robusticity played in blank selection. For Pech de l'Azé IV, the assemblage as a whole is far more robust than in the other two primary sites, although similar to Jiboui, and there is almost no difference in robusticity between unused and used flakes, and only a small difference between retouched and unretouched tools. At this site robusticity apparently played no part in tool blank selection criteria. For le Moustier there is a significant difference between the used and unused flakes, with the used flakes being far less robust. However, there is still only a marginal difference between retouched and unretouched tools. For Combe Capelle Bas there is also a significant (though less so) difference between used and unused flakes and almost no difference between retouched and unretouched tools. At these latter two sites, tool blanks were apparently selected from the available flakes products based on their more limited degree of robusticity. At Jiboui, though our data are again more limited, there is a strikingly high difference (compared to the other sites) in the robusticity of the retouched tools verses the robusticity of the sample as a whole.

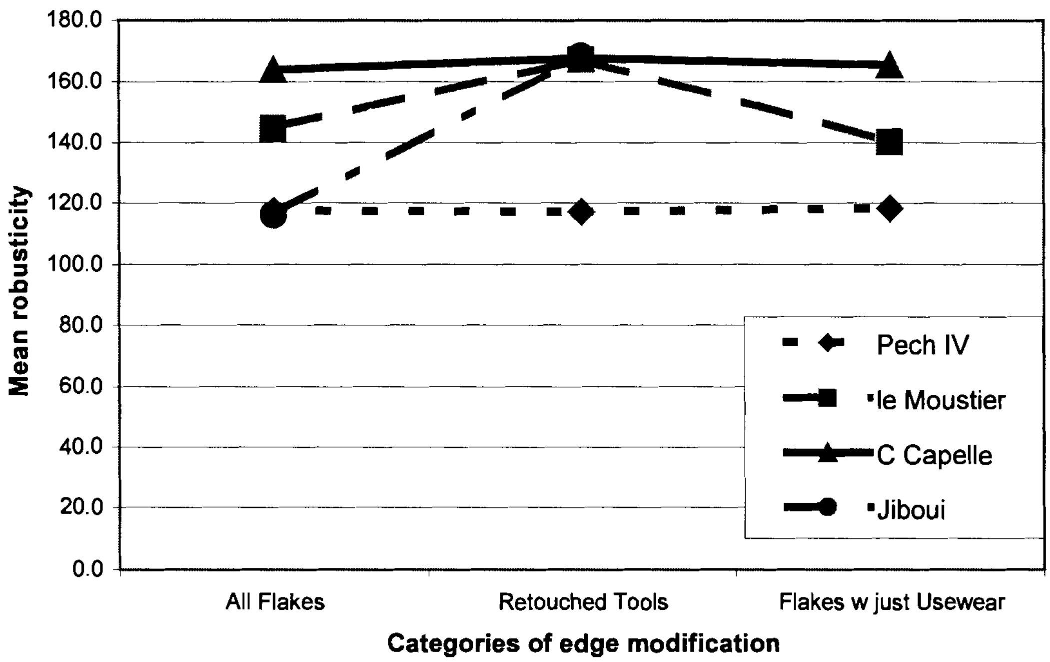

Figure 8.32 Degree of robusticity in retouched tools verses all flakes.

Also of interest is the lack of variability in the robusticity between all the flakes in the Pech de l'Azé IV and those that were retouched, and the significant degree of similarity in the robusticity of the retouched tools in the other three sites, le Moustier, Combe Capelle Bas, and Jiboui. These would seem to be strong patterns in need of explanation. The lack of apparent selection for less robust blanks for retouched tools in the Pech sample may, as is suggested with blank size at this site, be a result of raw material form. The small size and irregular form of the raw material essentially precludes the production of relatively large, more gracile flakes, perhaps regardless of reduction technique. At Combe Capelle Bas, the large, regular flint nodules available on-site may make it easy to produce a relatively large percentage of large flakes that are also less robust without necessarily using more organized core reduction techniques. At le Moustier and Jiboui the raw material form, or specific task constraints may require the application of prepared core techniques to ensure the production of at least some large, low-robusticity blanks. It may also be that the position of these two sites in the mobility cycle influenced the production of blanks intended for longer-lived tools. For such tools, greater size, optimal degrees of robusticity, and edge angle would be important.

At le Moustier, the significant difference in robusticity between the retouched and unretouched tools strongly suggests two different tool categories, presumably representing different task type, are represented.

I have argued elsewhere in this study that a certain degree of robusticity was an important aspect of Middle Palaeolithic tools. However, this characteristic appears to be provided by simply practicing hardhammer reduction. Within the range of morphology observable among hardhammer flakes it would seem that, in the selection of blanks for retouched tools at least, Middle Palaeolithic people preferred larger flakes with longer, sharper edges, which generally translates into lower robusticity. This preference does not appear to extend as strongly to tools that were not retouched.

Summary of Blank Selection Attributes

Size/Dimensions:

As with the combined data, there is at least a slight (in the case of Pech de l'Azé IV), preference for larger flakes for tool blanks. The most obvious difference in flake dimensions between the four site-samples is that the Pech de l'Azé IV data exhibit the least (almost no) variability in dimensions between used and unused flakes, while Combe Capelle Bas shows more, and le Moustier shows even more. At Jiboui we see the greatest difference between unretouched flakes and retouched tools, which is significant, but without use-wear data it is difficult to make clear comparisons to the primary samples. Potential explanations for these patterns are discussed in the following chapter.

Spine-Plane Angle:

When viewing the data in two broad categories with the cutoff point at 35°, the percentages of all used flakes ≤ 35° in the le Moustier sample are significantly higher than in the other two site samples. This is most readily explained by the fact that the average spin-plane angle for the le Moustier sample as a whole is significantly lower (average edge angles for all flakes are: Pech 43°, le Moustier 35°, and Combe Capelle 40°). Potential explanations for these differences in average spine-plane angle will be discussed in the following chapter.

Ventral Curvature:

As with the data collectively, among the individual site samples there were no apparent preferences based on ventral curvature qualities: blanks were not selected for based on any lack of curvature.

Regularity of Edges:

Number of usable edges per flake

-There are no apparent differences between the three sample assemblages in preferences for numbers of usable edges per flake or for more regular (verse irregular) edges per flake.

Edge Length

-The data for each of the three samples indicates the same general patterns observed for the collective data. There appears to be little effort made in selection for longer edges among tools that were used unmodified, but some apparent effort made in this respect for tools that were retouched. This pattern was strongest for the Pech de l'Azé IV sample.

Standardization:

-The only notable site-specific pattern is that the degree of variability between the used and unused flakes is much lower in the Pech de l'Azé IV sample than in the other three. Pech de l'Azé IV does have the highest degree of bladeyness at 0.84, (le Moustier = 0.88, Combe Capelle Bas = 0.92) and, if length of individual edges is an important selection criteria, this may have something to do with the lower level of difference between the used and unused flakes in this sample.

Overall, none of the sample assemblages is particularly bladey. A true blade (defined as a flake that is at least twice as long as wide) must have an index value of 0.5 or less (width ÷ length). On average, these assemblages more closely approach the value of 1.0.

Robusticity:

The data suggests that there are some site-specific patterns in the role that robusticity plays in blank selection. For Pech de l'Azé IV, robusticity apparently played no part in tool blank selection; the difference in robusticity between the unused, retouched and unretouched tools is very low. At le Moustier, the used flakes are far less robust than the unused, although there is still only a marginal difference between retouched and unretouched tools. For Combe Capelle Bas there is also a significant difference (though less than with le Moustier) between used and unused flakes and almost no difference between retouched and unretouched tools. At these latter two sites, tool blanks were apparently selected from the available flakes products based on their more limited degree of robusticity. At Jiboui we see a very significant difference in robusticity between the retouched tools and unretouched flakes. The most interesting pattern here is that the degree of robusticity of these retouched tools and those of le Moustier and Combe Capelle Bas are almost identical. The decision to employ specific reduction techniques may be a response to raw material constraints on acquiring large flake blanks of suitable robusticity.

Summary of Site-Specific Patterns of Blank Selection

Pech de l'Azé IV

At Pech de l'Azé IV there is little or no influence on blank selection in terms of size or robusticity. Spine-plane angle also apparently plays a less significant role as the tendency for flakes with lower average angles to be selected for tool blanks (retouched or not) is weaker than in the other site samples. A majority of used flakes have average edge angles of $\leq 45°$, but unlike the two other primary samples, in the Pech de l'Azé IV sample the tendency towards selecting sharper edged flakes is not apparent when the sample is divided into $\leq 35°$ and $>35°$ categories. Here the majority of used flakes fall into the $>35°$ category.

Edge length appears to play a greater role in the selection of retouched tools in this sample than in the other two primary samples.

le Moustier

The le Moustier sample shows the strongest patterns in preference for larger flakes with lower average edge angles for tool blanks. The spine-plane angle pattern can be explained, at least in part, by the fact that, compared to the other two primary samples, this sample has the lowest average spine-plane angle (by a large margin) for the assemblage as a whole. The strong preference for larger flakes for tools, however, is more significant as, in fact, Combe Capelle Bas has the largest mean flake dimensions for its assemblage as a whole.

The le Moustier sample as a whole has a relatively low level of robusticity. However, there is still a strong selection of even less robust flakes for use as retouched tools. Robusticity seems to play only a minor role in selection for unmodified flake tools.

Edge length does not appear to play much a role at all in this sample, whether in the selection of unmodified or retouched tools.

Combe Capelle Bas

This sample lays somewhere between the other two primary samples in terms of blank selection criteria. There is a slight preference for larger flakes for tool blanks, but it is not nearly as marked as for le Moustier, although Combe Capelle Bas has a significantly larger mean size of flakes in its assemblage as a whole to begin with.

Compared to Pech there is a slightly stronger tendency to select sharper edged flakes for tools, though this tendency is not as strong as observed for the le Moustier sample.

The Combe Capelle Bas assemblage as a whole is the least robust among all the sample sites (including Jiboui), but there is still a strong selection for even less robust flakes for tool blanks. Unlike le Moustier, there is little difference in robusticity between the retouched and unretouched tools.

As with the other two primary samples, edge length seems to play little or no role in the selection of unretouched tools, but it does appear to factor in somewhat in the selection retouched tools, although not as much as with le Moustier.

Jiboui

Much of the data collected for the three primary site samples is lacking for this site (e.g., spine-plane angle, ventral curvature, edge morphologies, use-wear, individual edge length). The only major pattern observable for this site is that for retouched tools there was a significant tendency to select low robusticity blanks, a pattern common to all four site samples.

Chapter 9: Morphological Comparison: Tool Blanks and Technological Products

In this chapter I will examine the nature of the products of the different reduction technologies employed in the four site samples, Levallois, *Eclats Dèbordants* production, and Amorphous Core, to see how well each might satisfy the criteria that appear to have been sought after in the flakes that were selected for use as tools. Which reduction technologies best provide the sought-after blank attributes?

The technological product categories included in the following graphs and tables include Central Levallois, Peripheral Levallois, Amorphous Core, and *Eclats Débordants*. *Eclats Débordants*, while quite distinctive, are considered to be a form of Disc Core by most researchers (based on personal discussions). However, there are also forms of Disc Core reduction which produce products that are not typically distinguishable from Peripheral Levallois flakes and, therefore, some flakes categorized as the latter may actually be products of the former. It should also be noted that no flakes were examined which could be identified as being the result of other core reduction strategies such as, Biface, Bipolar, or "Sausage Slice" reduction.

Much of the data dealt with here are not available for Jiboui. Therefore this site will only be included in a limited number of the following analyses.

Frequency of Use by Technological Type

The most basic measure of the relative usefulness of different technological products is in the frequency with which they were selected for use. The data in figure 9.1 indicate that, while certainly not overwhelming, there was a slightly greater intensity of use of the Central Levallois products across the three primary site's combined data, although the non-Levallois products did supply the bulk of the tool blanks.

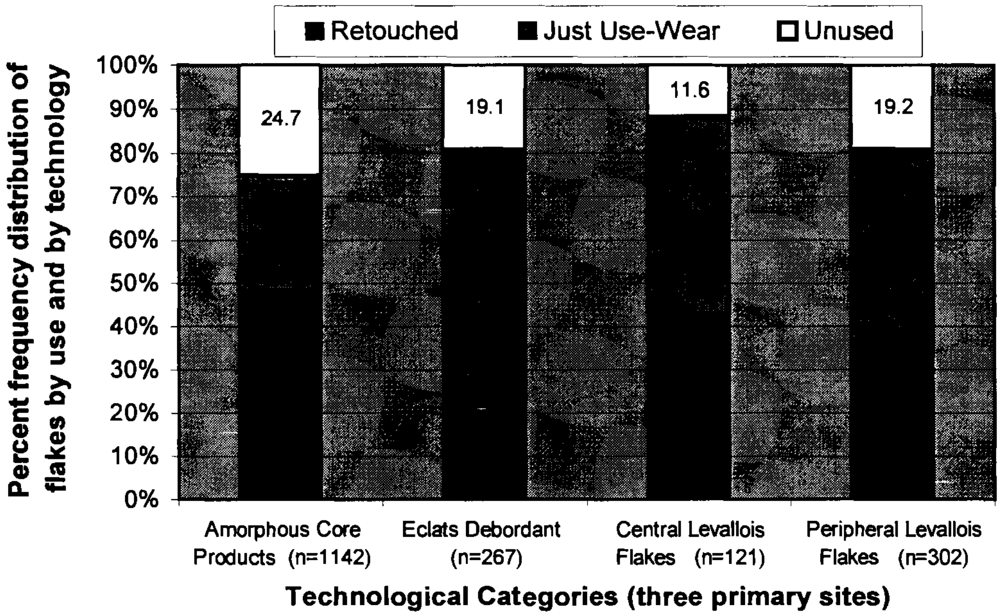

Figure 9.1 Frequency of use of technological products in the primary samples.

We can examine the frequencies of use for each of the primary site samples as well, to see if the general pattern is consistent.

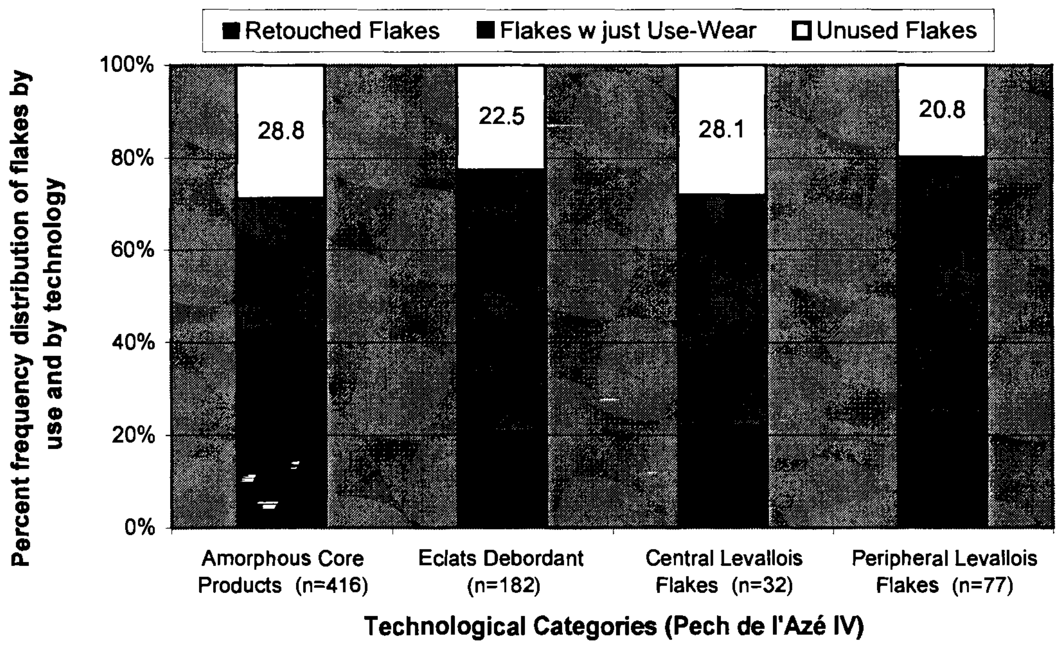

Figure 9.2 Frequency of use of technological products in the Pech IV sample.

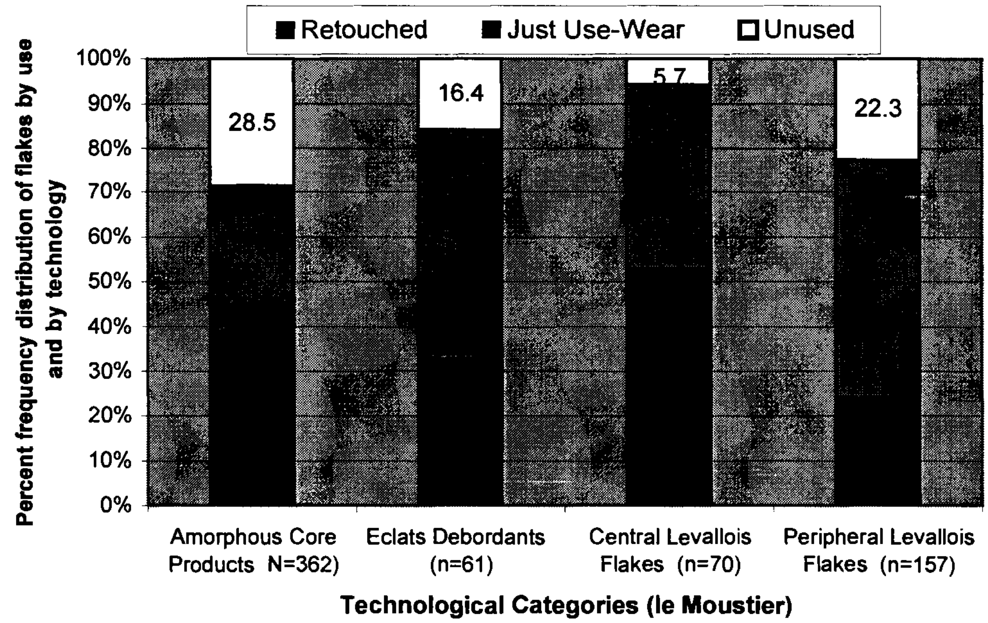

Figure 9.3 Frequency of use of technological products in the le Moustier sample.

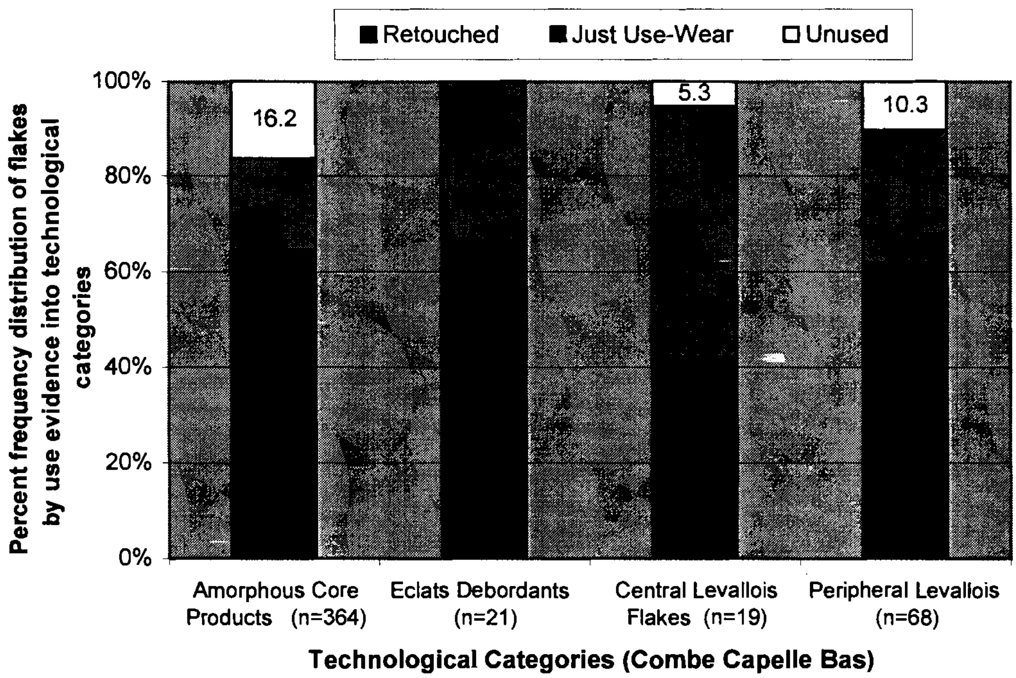

Figure 9.4 Frequency of use of technological products in the C Capelle Bas sample.

For le Moustier and Combe Capelle Bas the general pattern does remain consistent: Central Levallois flakes are used most intensively, followed by Peripheral

Levallois flakes and *Eclats Débordants*, and then Amorphous Core flakes. However, in the Pech de l'Azé IV data it is the Peripheral Levallois flakes and *Eclats Débordants* that are most intensively used, followed by the Central Levallois and Amorphous Core products, although the difference between these latter two categories is negligible.

There is also a stronger tendency for the Levallois products and *Eclats Débordants* to be used as unmodified tools and a greater tendency for Amorphous Core products to be used as retouched tools.

There is an obvious tendency in the Le Moustier sample where, among the primary sample sites Levallois was most intensely employed, for a greater bias in blank selection based on technological type. While the bias towards the selection of all Levallois products over non-Levallois products is slight, there is a more significant bias towards the selection of Central Levallois flakes over Peripheral ones. This is most marked in the frequency of retouching.

If we examine retouching alone the data from Jiboui can be included. Table 9.5 presents the combined data on retouching from the three primary sites and table 9.6 for all four sites.

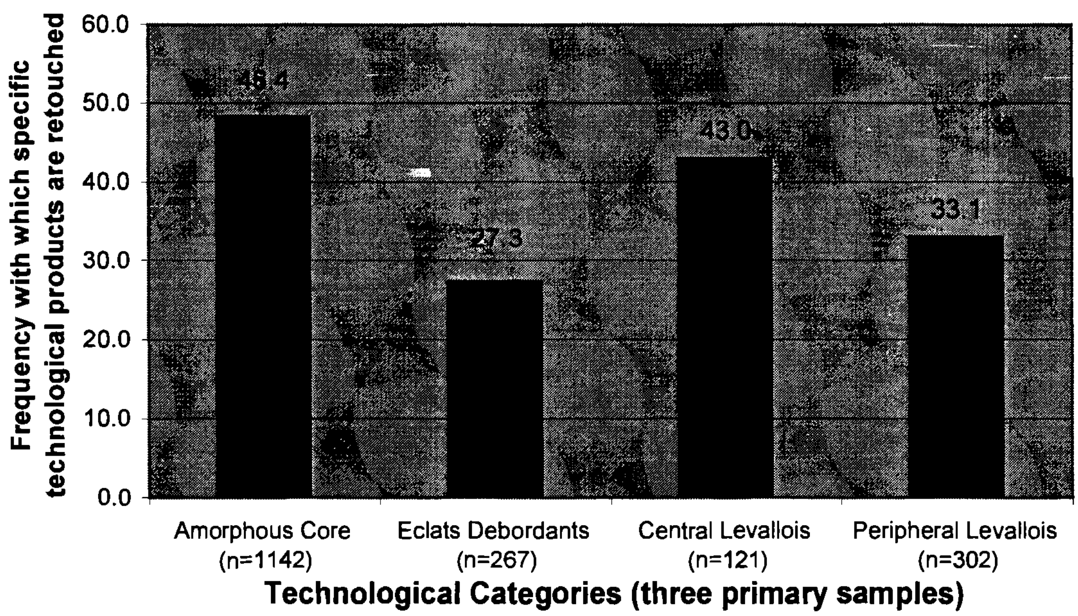

Figure 9.5 Frequency of retouching of technological products in the primary samples.

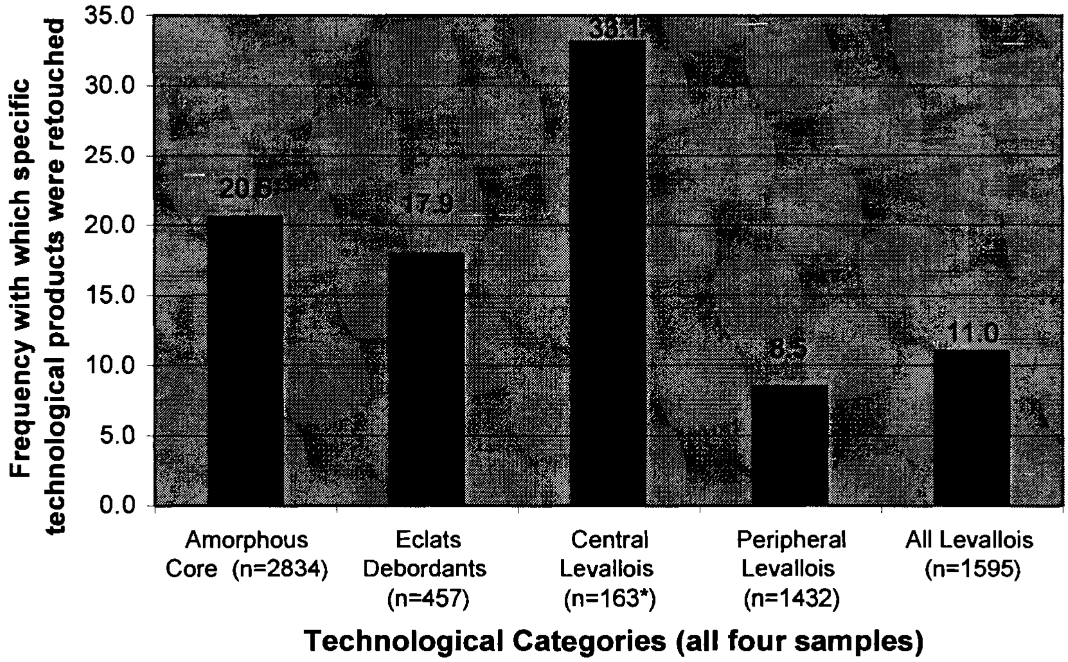

Figure 9.6 Frequency of retouching of technological products in all four samples.
*While there were 178 Central Levallois flakes in the Jiboui assemblage, only 52 of these had complete data collected on them that will allow their inclusion in the analyses.

It is apparent that retouching blanks was practiced much less frequently at Jiboui than at the three primary sites (at least in the components sampled) and, because of the large size of the Jiboui assemblage, this significantly changes the relative frequency of retouch as a whole. Looking at all four samples, it is apparent that Central Levallois flakes had the highest frequency of retouch. However, Levallois flakes were more frequently used unmodified (67.7% of all Levallois products in the three primary samples exhibit usewear).

Overall, however, it is the Amorphous Core flakes that comprise the most tools. Undoubtedly, there were some Levallois reduction products in the sample assemblages that went unrecognized as such and so were categorized as Amorphous Core, but even accepting this, there was obviously a strong reliance on Amorphous Core reduction at all four sites.

Size (combined data and by individual site sample)

The data presented in chapter 8 indicated that, while size was not an overriding factor in blank selection, it was consistently included in the selection criteria. While some of the smallest flakes were used, there was a strong tendency that the larger a flake was the more likely it would be selected for use. Among flakes of the largest size category almost 90% were used.

Here I examine the nature of the size (mean dimensions) of the products of Levallois and non-Levallois reduction in order to see if there is a correlation between what appear to have been desired tool attributes and the types of products produced with the two different reduction techniques employed.

If size of blanks were the only influencing factor in the production of tool blanks, knappers would simply have had to consistently seek out the largest flint nodules and remove the largest possible flakes from them with no regard for raw material economization. This was obviously not the case and the blank selection criteria examined in the previous chapter bears this out. If the Levallois strategy represented some advantage in terms of size of its products, it would have to be because it had the potential to maximize both size and some other consideration(s) (e.g., quantity of suitable products, edge morphologies, total edge length per flake, longer individual edges). It would provide some balance between two or more constraints.

Table 9.1 Maximum dimensions (all four sites) and weight (three primary sites) for technological products (dimensions in mm and weight in grams).

	Amorphous Core (n=2807)	**Eclats Débordants** (n=454)	**Central Levallois** (n=173)	**Peripheral Levallois** (n=1419)
Mean Length	35.6	38.9	47.7	31.3
Mean Width	30.1	30.7	35.3	27.0
Mean Thickness	9.4	10.4	8.7	7.4
Mean Weight	20.6	11.6	16.1	10.4

Table 9.2 Maximum dimensions (in mm) and weight (in grams) for Pech de l'Azé IV technological products.

	Amorphous Core (n=416)	**Eclats Débordants** (n=182)	**Central Levallois** (n=32)	**Peripheral Levallois** (n=77)
Mean Length	38.0	37.1	39.4	36.6
Mean Width	31.0	28.5	32.6	29.1
Mean Thickness	10.6	11.3	8.0	10.5
Mean Weight	13.6	11.0	11.1	10.7

In the Pech de l'Azé IV sample the differences between the Amorphous Core, *Eclats Débordants*, and Levallois products are negligible and this seems to be reflected in tool blank selection. There is very little difference between the four categories of products in terms of their frequency of use. In fact, when it comes to retouching tools the preference was definitely for the Amorphous Core products, and among tools that are not retouched the preference was for the *Eclats Dédordants* and Levallois products. This does suggest the existence of two different categories of tasks. However, the Levallois products do not provide any notable advantages in terms of size in this sample.

Table 9.3 Maximum dimensions (in mm) and weight (in grams) for le Moustier technological products.

	Amorphous Core (n=362)	**Eclats Débordants** (n=64)	**Central Levallois** (n=70)	**Peripheral Levallois** (n=157)
Mean Length	37.0	38.7	49.0	32.2
Mean Width	30.8	29.2	35.0	28.0
Mean Thickness	9.0	9.9	8.8	7.0
Mean Weight	13.7	11.3	15.7	7.0

Table 9.4 Maximum dimensions (in mm) and weight (in grams) for Combe Capelle Bas technological products.

	Amorphous Core (n=364)	**Eclats Débordants** (n=21)	**Central Levallois** (n=19)	**Peripheral Levallois** (n=68)
Mean Length	49.6	41.9	62.9	41.5
Mean Width	43.4	36.9	42.7	37.7
Mean Thickness	14.3	12.3	9.3	11.0
Mean Weight	35.5	17.5	26.4	18.0

Table 9.5 Maximum dimensions (in mm) for Jiboui technological products (each metric dimension was not necessarily recorded for every flake).

	Amorphous Core (n=1770)	**Eclats Débordants** (n=75)	**Central Levallois** (n=64-77)	**Peripheral Levallois** (n=1125-1224)
Mean Length	32.0	44.3	45.6	30.3
Mean Width	26.9	38.0	35.4	26.1
Mean Thickness	8.2	10.1	8.7	7.0

As a whole, the Levallois products do not provide any significant advantage over the non-Levallois products in terms of size. The average size of all Levallois products is 37.7 in the Pech de l'Azé IV sample (compared to 37.0 for the other products), and 45.3 (compared to 49.6 for the other products) for the Combe Capelle Bas sample. However, while not so significant in the Pech de l'Azé IV sample, the Central Levallois flakes are notably larger, on average, than the other products, and this may have played a role in blank selection for certain tasks and, more importantly, the decision to use the technique. This may be especially so at le Moustier and Jiboui where the Levallois technique was more prevalent. At Combe Capelle Bas, however, where the use of the Levallois technique was negligible, this does not seem likely, or at least cannot be clearly demonstrated. While the central flakes had a very high use-frequency, this was also the case with all the Peripheral Levallois and Amorphous Core flakes as well.

If, according to the traditional interpretation, the Central flakes were the intended production goals of the Levallois technique then it would appear that their main function was as unmodified tools.

Spine-Plane Angle

Average Spine-Plane Angles

The blank selection data presented in chapter 8 suggested little difference in average spine-plane angle between unused flakes and all used flakes, but it does indicate a fairly strong relationship between the average natural spine-plane angle of a flake blank and the type of edge modification it ultimately acquired. In particular, there seems to have been a preference to select flake edges with lower average spine-plane angles to be used unmodified.

Unmodified flakes are the most common tool type in two of the three primary samples. In the Pech de l'Azé IV and Le Moustier sample data, flakes with just use-wear makeup 39.3% and 40.6%, respectively, of the total assemblage, while flakes with just retouch are at 23.2% and 14.9%, and flakes with both use-wear and retouch are 11.2% and 21.3% respectively. In the Combe Capelle Bas sample the retouched flakes are more common, making up 55.9% of the sample, while flakes with use-wear and flakes with both types of edge damage makeup 22.5% and 7.2% respectively.

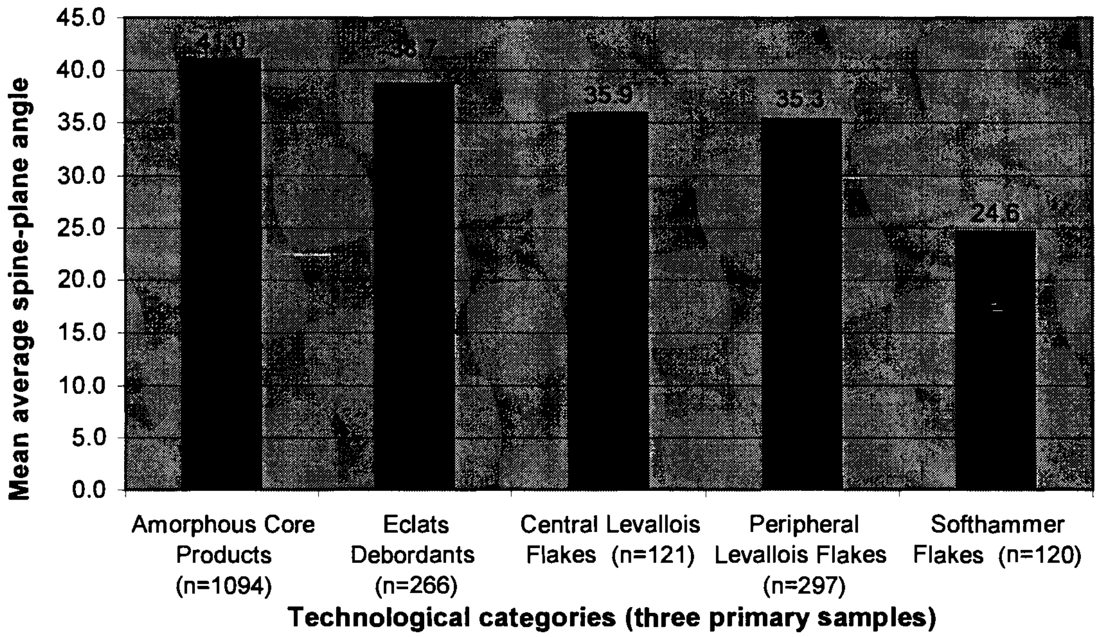

Figure 9.7 Mean average spine-plane angles (all flakes) for all three primary Sites.

Figure 9.7 indicates that Levallois reduction does present an advantage compared to non-Levallois products in this respect, generally producing flakes with lower average spine-plane angles. The average spine-plane angles of the Levallois products are most closely in-line with the spine-plane angles of the unmodified flake tools (although the range among all three categories is not that great).

Table 9.6 Mean 'average spine-plane angle' (all flakes) by individual site sample (primary samples).

	Amorphous Core	Eclats Débordants	Central Levallois	Peripheral Levallois
Pech de l'Azé IV	43.9	40.7	40.9	41.6
Le Moustier	36.7	34.3	33.8	32.2
Combe Capelle Bas	41.8	35.0	35.3	35.1

Viewing the archaeological samples individually we can see that, while the pattern of lower average spine-plane angles among the Levallois products is fairly consistent, the strength of this pattern is different for each site. In the Pech de l'Azé IV sample the difference between Levallois and non-Levallois products is almost negligible. It is slightly more marked in the le Moustier sample (though still not great), and is most apparent in the Combe Capelle Bas sample. This may reflect problems in trying to employ Levallois reduction with smaller, less regular raw material nodules, such as those found in the Pech de l'Azé area. Nodule size, and perhaps more so, nodule shape, may hinder the effective use of this reduction strategy.

It should also be noted that the experimentally produced softhammer flakes have the lowest average spine-plane angles, by a large margin, at 24.6°. If sharper edges were the single driving criteria then these would be the logical choice.

Ventral Curvature

The blank selection analysis showed no indication that ventral curvature was a factor in tool-blank selection, in spite of what I have argued to be a reasonable expectation for selection for flatter blanks. I have suggested that the lack of apparent selection for this attribute may be because of an overall lack of significant ventral curvature among hardhammer flakes in general. This is examined here by comparing the ventral curvature of the different products.

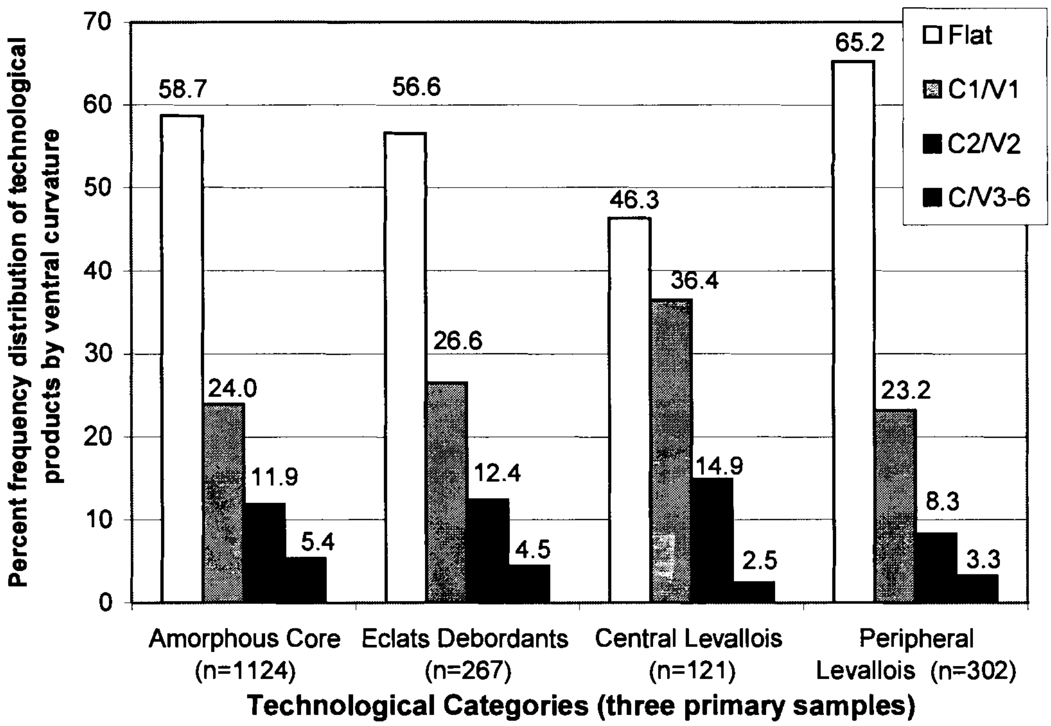

Figure 9.8 Distribution by technology into categories of ventral curvature for all three primary sites.

Viewing the data collectively, the indication is that there is no significant difference between the different technological products in terms of ventral curvature, although there is some difference between the Central and Peripheral Levallois.

Table 9.7 Distribution by technology into categories of ventral curvature, Pech IV

Categories of Ventral Curvature	Amorphous Core (n=412)	Eclats Débordants (n=182)	Central Levallois (n=32)	Peripheral Levallois (n=77)
Flat	52.7	51.1	40.6	59.7
C1/V1	25.0	29.7	40.6	22.1
C2/V2	12.6	14.3	15.6	14.3
C3-6/V3-6	9.7	4.9	3.1	3.9

Table 9.8 Distribution by technology into categories of ventral curvature, le Moustier

Categories of Ventral Curvature	Amorphous Core (n=356)	Eclats Débordants (n=64)	Central Levallois (n=70)	Peripheral Levallois (n=157)
Flat	59.3	60.9	45.7	65.0
C1/V1	23.0	23.4	37.1	25.5
C2/V2	14.0	10.9	14.3	5.7
C3-6/V3-6	3.4	4.7	2.9	3.8

Table 9.9 Distribution by technology into categories of ventral curvature, C Capelle Bas.

Categories of Ventral Curvature	Amorphous Core (n=353)	Eclats Débordants (n=21)	Central Levallois (n=19)	Peripheral Levallois (n=68)
Flat	65.2	90.5	57.9	72.1
C1/V1	23.8	9.5	26.3	19.1
C2/V2	8.5	0.0	15.8	7.4
C3-6/V3-6	2.5	0.0	0.0	1.5

The same pattern is apparent in all three site samples. There are few major differences in ventral curvature of the different technological products between the samples. The only notable difference is that in the Combe Capelle Bas sample the number of completely flat Peripheral Levallois flakes and *Eclats Débordants* is notably higher than in the other two site samples, but among all the samples 80% or more of the flakes are in the two categories of lowest ventral curvature.

Edge Lengths

Mean Total Length of Edges Per Flake

The blank-selection data indicated an overall preference for flake blanks with greater total lengths of usable edge, but this is mainly among retouched tools. It also indicated that, in fact, contrary to my initial assumption, the length of use edges tended to play a role in the selection of tools that were retouched, but did not in the selection of unmodified tools.

The following tables provide the mean total length of edge per flake for each of the technological projects. However, this number is not particularly informative on its own as it will be directly correlated with flake size. To overcome the size bias, tables 9.10 to 9.13 provide a value (mean total length of edge per flake) for each category of technological products that is corrected for by dividing it by mean weight. This provides a more accurate indicator of usable edge per flake for the different technological products and allows cross sample comparisons that were otherwise meaningless because the different raw material size and form at each site influenced mean product size. Weight was selected here as the closest proxy, among the measured variables, for raw material volume. Essentially, the corrected value is the mean length of usable edge produced per milligram of raw material reduced.

Table 9.10 Mean total length of edges per flake (sum of all individual edge lengths on each flake) by technology for all three primary sites.

	Amorphous Core (n=1090)	**Eclats Débordants** (n=264)	**Central Levallois** (n=121)	**Peripheral Levallois** (n=299)	**All Flakes** (n=1774)
Mean total length of edges per flake	58.7	51.1	92.0	55.4	59.3
Mean weight	20.6	11.6	16.1	10.4	17.3
length of usable edge/flake/weight	2.85	4.40	5.70	5.30	3.40

The corrected values in table 9.10 indicate a notable advantage among all the Levallois products. The high value for the Central flakes was predictable, but the notably high value for the Peripheral flakes was not expected. Also of note is the relatively high edge length-to-size value of the *Eclats Débordants* compared to the Amorphous Core products.

Table 9.11 Mean length per edge and mean total length of edges per flake (sum of all individual edge lengths on each flake) by technology for Pech de l'Azé IV.

	Amorphous Core (n=397)	**Eclats Débordants** (n=179)	**Central Levallois** (n=32)	**Peripheral Levallois** (n=77)	**All Flakes** (n=685)
Mean total length of edges per flake	52.5	52.0	76.8	55.1	53.8
Mean weight	13.6	11.0	11.1	10.7	12.5
length of usable edge/flake/weight	3.86	4.73	6.92	5.15	4.30

Table 9.12 Mean length per edge and mean total length of edges per flake (sum of all individual edge lengths on each flake) by technology for le Moustier.

	Amorphous Core (n=344)	Eclats Débordants (n=64)	Central Levallois (n=70)	Peripheral Levallois (n=156)	All Flakes (n=634)
Mean total length of edges per flake	52.6	47.0	90.2	52.3	56.1
Mean weight	13.7	11.3	15.7	7.0	12.0
length of usable edge/flake/weight	3.84	4.16	5.70	7.47	4.68

Table 9.13 Mean length per edge and mean total length of edges per flake (sum of all individual edge lengths on each flake) by technology for Combe Capelle Bas.

	Amorphous Core (n=349)	Eclats Débordants (n=21)	Central Levallois (n=19)	Peripheral Levallois (n=66)	All Flakes (n=455)
Mean total length of edges per flake	71.9	56.4	124.0	63.2	72.1
Mean weight	35.5	17.5	26.4	18.0	31.9
length of usable edge/flake/weight	2.03	3.22	4.70	3.51	2.26

Looking at the uncorrected values (row #1 in each table) there are some significant differences among the technologies in the total lengths of edges on their respective products. (The overall higher numbers for Combe Capelle Bas likely reflect the larger size of the raw material forms.) It is apparent that the Levallois strategy, if only in the Central flake, does provide products with greater average combined edge lengths per flake. Total length of edges per flake was a characteristic that was selected for consistently among tool-blanks that were ultimately retouched compared to tool-blanks that were not intentionally modified. In contrast, *Eclats Débordants*, provide lower total length of edge per flake, which is not surprising as their defining morphology includes a significant portion of core edge around their margin. In fact, these numbers for *Eclats Débordants* were higher than I expected considering this basic aspect of their morphology. The fact that these products present a relatively high quantity of usable edge per flake (except in comparison to Central Levallois flakes) in spite of their basic morphology is interesting. It suggests that this reduction strategy might, in fact, be quite a reliable method for producing flakes with, perhaps not high, but at least one consistently usable edge opposite a thick margin of core edge. Given the added benefit that the core margin could provide protection for the user's hand these products might be a logical option for certain applications.

One other notable pattern in the above tables is that these numbers for average total length of edges/flake match well the relative use of Levallois at each site. Le Moustier, with the highest Levallois Index shows the greatest difference between Levallois and non-Levallois. Pech, with a low use of Levallois shows some notable difference, and for Combe Capelle, with a very low Levallois presence, the non-Levallois flakes show a greater average total length of edges/flake than the Levallois. What this actually means is not clear. It may be that the pattern is due to some other factor and matches relative Levallois Indices by chance.

In examining the corrected values a significantly different pattern emerges. The corrected values indicate that the *Eclats Débordants*, with the lowest uncorrected values in all three samples, are significantly more edge-length:size efficient in their form than they had appeared to be when edge-length was examined alone. There is an even stronger change for the Peripheral Levallois flakes, which were second lowest in the uncorrected values in two of the samples, but which are second only to the Central Levallois flakes in the Pech de l'Azé IV and Combe Capelle Bas samples, and are the highest by a significant margin in the le Moustier sample. This is particularly interesting in that the le Moustier sample shows the strongest Levallois use.

Edge Morphology

Number of Usable edges per flake

As illustrated in Chapter 8, this attribute is not directly correlated with flake size.

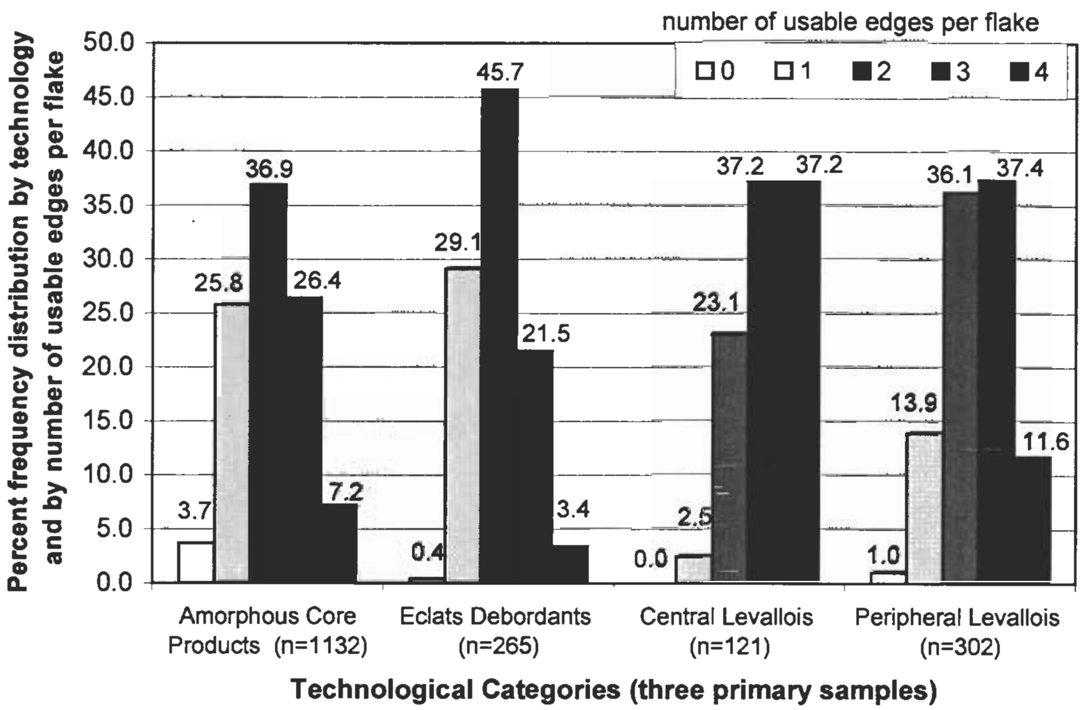

Figure 9.9 Number of usable edges per flake by technology for the primary sites.

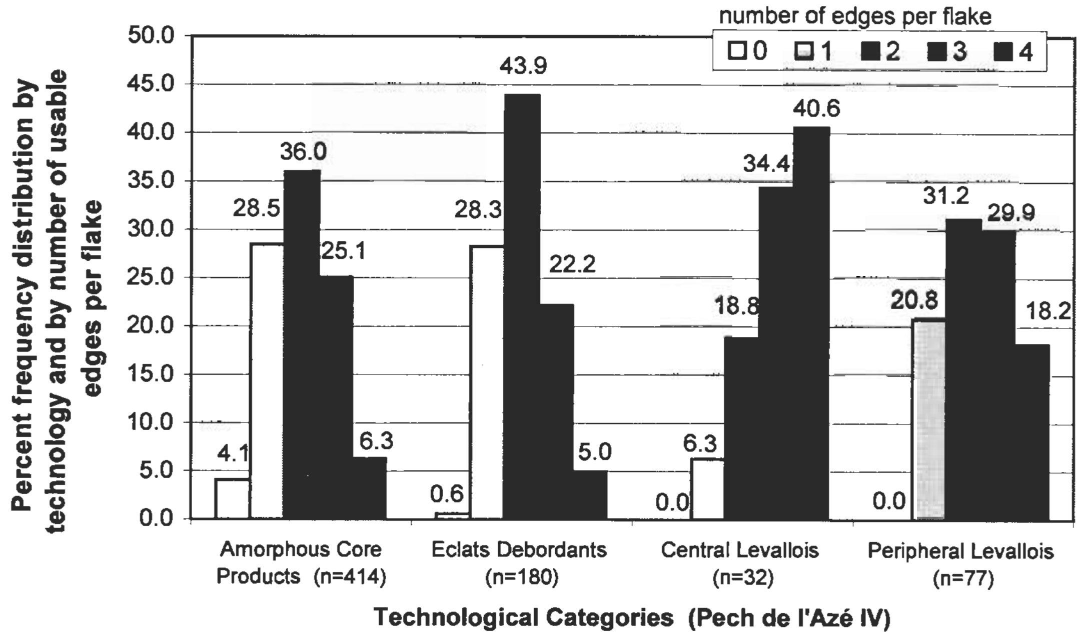

Figure 9.10 Number of usable edges per flake by technology for Pech de l'Azé IV.

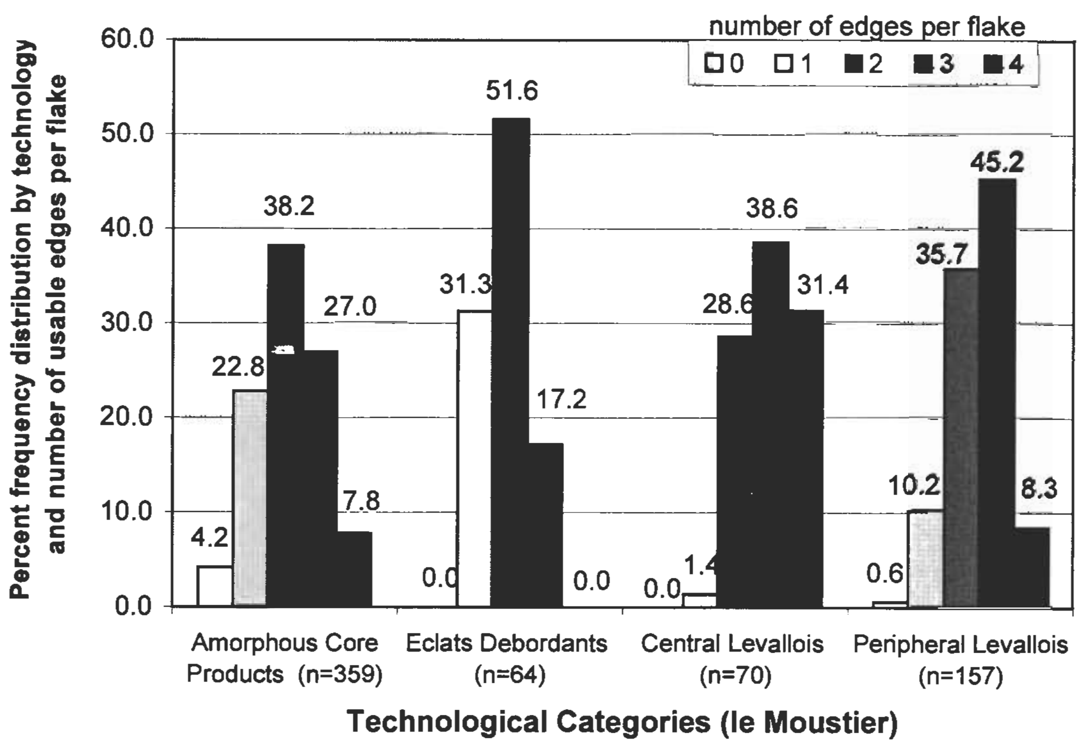

Figure 9.11 Number of usable edges per flake by technology for le Moustier.

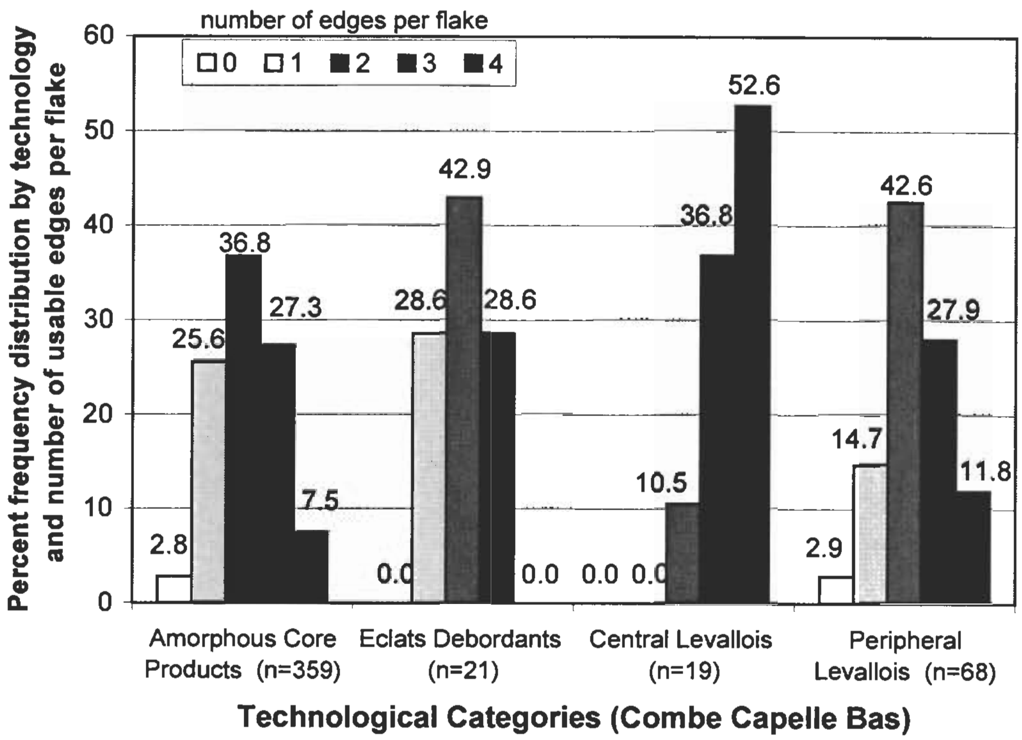

Figure 9.12 Number of usable edges per flake by technology for Combe Capelle Bas.

The same pattern is apparent in both the collective and individual site data. The Amorphous Core products seem to have a fairly normal distribution with a mean of approximately two edges per flake. The *Eclats Débordants* also have a mean centered on two edges per flake, but in contrast, the frequency of just one or two usable edges is significantly higher. This is precisely what would be expected given the nature of their general morphology.

Among the Levallois products, however, and especially the Central flakes, there is a consistent and notable tendency to have higher percentages of flakes with three or more usable edges. Levallois reduction does present an advantage in terms of the number of usable edges per flake that the knapper could expect to have in the resulting assemblage. Just in terms of this characteristic, the difference between the reduction strategies may suggest that it would be under conditions where there was a need for raw material economization, or to limit time spent in acquiring and processing stone, that one might choose to use the Levallois strategy.

The blank-selection analysis indicated a connection between the selection of blanks with higher numbers of usable edges and unmodified tools. This suggests that perhaps it was in situations (e.g., types of sites or certain seasons associated with specific tasks, such as long distance hunting forays), where the knapper sought blanks for use as unmodified tools, that the Levallois technique was mainly employed.

Regularity of edges

This attribute was examined in the blank-selection analysis mainly to determine any trends that distinguished retouched from unretouched tools. While this does appear to play a role in whether the tool blank will ultimately be retouched or not, in general there was little difference between the unused flakes and all the used ones. However, because there is an apparent bias towards the selection of more regular edges for unretouched tools, the relationship between this attribute and reduction technology is examined here.

Table 9.14 Edge morphologies (regular vs irreg.) by technology for the three sites combined (total refers to number of edges not number of flakes).

	Total	**Regular**	**% total**	**Irregular**	**% total**
Amorphous Core	2223	1519	**68.3**	704	**31.7**
Eclats Débordants	515	405	**78.6**	110	**21.4**
Central Levallois	357	274	**76.8**	83	**23.2**
Peripheral Levallois	712	522	**73.3**	190	**26.7**

Levallois products do not a have a significantly higher occurrence of regular edges than the other products, and, in fact, it is the *Eclats Débordants* which show the greatest degree of regularity in edge morphology (though still not remarkably higher than the rest).

Table 9.15 Edge Morphologies (regular vs irreg) by technology for Pech de l'Azé IV (based on number of edges, not number of flakes).

	Total	**Regular**	**% total**	**Irregular**	**% total**
Amorphous Core	808	534	**66.1**	274	**33.9**
Eclats Débordants	362	281	**77.6**	81	**22.4**
Central Levallois	99	62	**62.6**	37	**37.4**
Peripheral Levallois	185	126	**68.1**	59	**31.9**

Table 9.16 Edge Morphologies (regular vs irregular) by technology for le Moustier (based on number of edges, not number of flakes).

	Total	Regular	% total	Irregular	% total
Amorphous Core	704	498	**70.7**	206	**29.3**
Eclats Débordants	117	91	**77.8**	26	**22.2**
Central Levallois	195	160	**82.1**	35	**17.9**
Peripheral Levallois	382	290	**75.9**	92	**24.1**

Table 9.17 Edge Morphologies (regular vs irreg) by technology for C Capelle Bas (based on number of edges, not number of flakes).

	Total	Regular	% total	Irregular	% total
Amorphous Core	711	487	**68.5**	224	**31.5**
Eclats Débordants	36	33	**91.7**	3	**8.3**
Central Levallois	63	52	**82.5**	11	**17.5**
Peripheral Levallois	145	106	**73.1**	39	**26.9**

Table 9.15, 9.16, and 9.17 suggest that, among the Amorphous Core and Peripheral Levallois products, there are no significant differences between the three site samples in terms of regularity of usable edges. However, of note is that, except for the Central Levallois flakes in the le Moustier sample, *Eclats Débordants* edges are consistently more regular than the edges of the other products.

Another item of note is that, while in basic flake shape (plan-view), Central Levallois flakes do exhibit a significantly higher degree of regularity than both Amorphous core and Peripheral Levallois flakes (in accordance with the traditional view and as is illustrated in Table 9.20), in terms of regularity of usable edges, Central Levallois flakes present very little advantage over other products. This is surprising in the face of the traditional (although mainly anecdotal) presumption that one of the major advantages (and reasons for using Levallois reduction) was the greater regularity of its margins compared to other reduction products, including Levallois "preparatory" flakes.

Standardization

The blank-selection data indicated little tendency towards decreasing the degree of variability among those flakes selected for use. However, there is an apparent selection for two morphological attributes that are potentially conflicting. There is a preference for larger flake blanks and for lower spine-plane angles. Tool users were trying to maximize the size of their tool blanks, but at the same time had a preference for lower edge angles. This would put specific stress on the need to maintain decreased robusticity in products. Table 9.20 below compares the basic metric data among the different products.

Table 9.20 Comparison of the basic variability among technological products the primary sites.

Variable			Range	Mean	SD
Length	Amorphous Core		92 (10-102)	**41.4**	16.2
	Eclats Débordants		80 (17-97)	**37.9**	11.8
	All Levallois		83.5 (6.5-89)	**39.2**	14.1
		Central	70 (19-89)	**48.6**	14.2
		Peripheral	77 (6.5-83.5)	**35.4**	12.2
Width	Amorphous Core		96.5 (9.5-106)	**34.9**	14.2
	Eclats Débordants		55 (12-67)	**29.3**	8.9
	All Levallois		62 (11-73)	**31.9**	10.0
		Central	46 (20-66)	**35.6**	9.3
		Peripheral	62 (11-73)	**30.4**	10.1
Thickness	Amorphous Core		42.5 (1.5-44)	**11.3**	6.0
	Eclats Débordants		22 (3-25)	**11.1**	3.8
	All Levallois		26 (3-29)	**8.8**	3.8
		Central	13 (4-17)	**8.7**	2.7
		Peripheral	26 (3-29)	**8.8**	4.2
Weight	Amorphous Core		290.5 (0.3-290.8)	**20.6**	28.5
	Eclats Débordants		122.1 (0.8-122.9)	**11.6**	11.6
	All Levallois		125.2 (0.8-126.0)	**12.0**	12.7
		Central	58.4 (3.5-61.9)	**16.1**	11.4
		Peripheral	125.2 (0.8-126.0)	**10.4**	12.7
Mean Spine-plane Angle	Amorphous Core		60 (20-80)	**41.0**	11.8
	Eclats Débordants		45 (20-65)	**38.7**	9.3
	All Levallois		50 (20-70)	**35.4**	9.6
		Central	40 (20-60)	**35.9**	7.7
		Peripheral	50 (20-70)	**35.3**	10.3
Area	Amorphous Core		8973 (143-9116)	**1584**	1226
	Eclats Débordants		6244 (255-6499)	**1156**	657
	All Levallois		5895 (91-5986)	**1338**	858
		Central	5324 (418-5742)	**1809**	930
		Peripheral	5895 (91-5986)	**1150**	749
Robusticity	Amorphous Core		615.4 (28.6-644)	**140.5**	67.8
	Eclats Débordants		401.4 (30.6-432)	**107.8**	53.2
	All Levallois		485.7 (30.3-516)	**156.6**	74.8
		Central	446.3 (69.7-516)	**209.5**	80.2
		Peripheral	339.7 (30.3-370)	**135.4**	60.7
Bladeyness (w/l)	Amorphous Core		2.09 (0.27-2.36)	**0.89**	0.32
	Eclats Débordants		1.22 (0.35-1.57)*	**0.81**	0.25
	All Levallois		1.42 (0.36-1.78)**	**0.86**	0.26
		Central	0.86 (0.36-1.22)	**0.76**	0.18
		Peripheral	1.42 (0.36-1.78)**	**0.90**	0.27

***less one outlier of 1.83 **less one outlier of 2.15**

Regularity of Flake Shape

Technology		Regular	%	Irregular	%	broken	%	Total
Amorphous Core		263	**23.0**	729	**63.8**	150	**13.1**	1142
Eclats Débordants		233	**87.3**	34	**12.7**	0	**0.0**	267
All Levallois		114	**27.0**	281	**66.4**	28	**6.6**	423
	Central	58	**47.9**	57	**47.1**	6	**5.0**	121
	Peripheral	56	**18.5**	224	**74.2**	22	**7.3**	302

The Amorphous Core products are, on average, larger than the Levallois products collectively, and so the Levallois products, *as a whole*, do not present a significant advantage in terms of blank size, although the Central Levallois flakes are the largest flake product on average in the assemblage. The most significant characteristic of the Levallois products is that they (both the Central and Peripheral flakes) are much thinner on average than the other products (also noted by Rolland 1972 in assemblages from l'Hortus), and so tend to have lower spine-plane angles. The relationship between size and thickness is further examined below.

It is notable that the standard deviations for the means of all the measured attributes are higher for the Amorphous Core than the Levallois products, a finding similar to Dibble's (1989:424). This does indicate a certain degree of increased regularity of product morphologies. Although the differences in standard deviations may not be great enough to suggest any "standardization" in the usual sense, this increased regularity of Levallois products (compared to Amorphous) alone might be argued to be enough to warrant the extra effort necessary in applying a prepared core technology. This is especially the case for thickness and, perhaps, bladeyness among the Central Levallois flakes for which the means and standard deviations are significantly lower than any other products.

Of equal interest, however, are that the overall standard deviations for the *Eclats Débordants* are as low as or lower than any of the other products except Central Levallois flakes. It might be argued that these types of flakes do begin to approach the idea of standardization of form (if not size). In fact the similarity of form among these products begins to stand out after one has examined significant quantities of them in assemblages in which they are a common occurrence (see Plates 10 and 11).

Robusticity

Flakes with a greater thinness to area ratio will, on the whole, have lower edge angles and so the preference for lower edge angles translates into a preference for less robust flakes. This may be the main reason behind the preference for less robust flakes for retouched tools as discussed in the previous chapter.

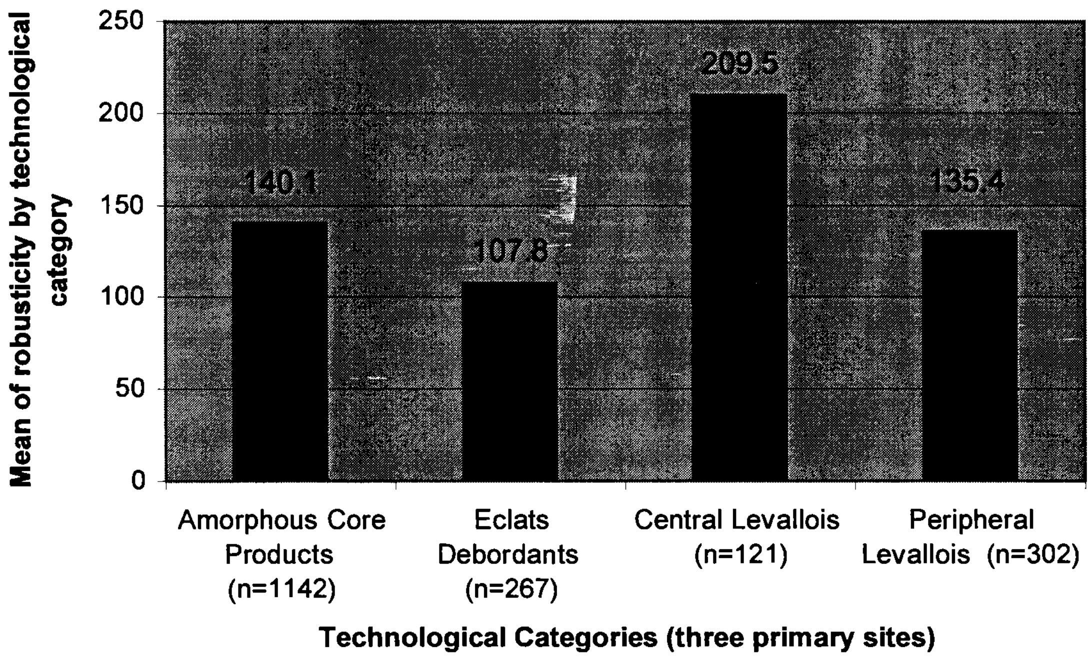

Figure 9.13 Mean robusticity by technology for the 3 primary sites.
Lower numbers = more robust. **(excluding 3 outliers - 7.6, 644.0, and 700.0 -all Non-Levallois)**

While there is a notable difference between the Levallois products (156.6 collectively) and the Amorphous Core products (140.1), of more significance is the difference between Central and Peripheral Levallois products. Central Levallois products are the least robust by a large margin and Peripheral Levallois products are more robust than Amorphous Core products. Based on this, the Central Levallois flakes should be the most highly sought after for tool blanks, especially for unretouched tools (e.g., for butchering). This is generally the case, as indicated in Figure 9.1. The Central Levallois flakes have an 88.5% use frequency, compared to 80.9% for *Eclats Débordants*, 80.8% for Peripheral Levallois, and 75.3% for Amorphous Core.

However, these differences are not particularly dramatic. Furthermore, when the type of use-modification is examined further there is an apparent tendency for Amorphous Core blanks, selected for use, to be retouched more frequently (48.4%) than Central Levallois blanks that were selected for use (43.0%). Among the different product types, there is also a greater tendency for Levallois flakes selected for use, to be used without any intentional modification (45.5% for Central Levallois, 47.7% for Peripheral Levallois, and 26.9% for Amorphous Core) suggesting that the sharper edges of these flakes were one of their desired characteristics.

Eclats Débordants are, by far, the most robust products: another pattern that seems logical given their morphology and high mean spine-plane angle, and while they have a frequency of use as high or higher than Peripheral Levallois and Amorphous Core products, their application is predominantly as unretouched tools. Of the *Eclats Débordants* identified as used, 66.2% had only usewear and only 33.8% were retouched.

Figures 9.14 through 9.17 present the relative robusticity of the different technological products for each of the four sites individually.

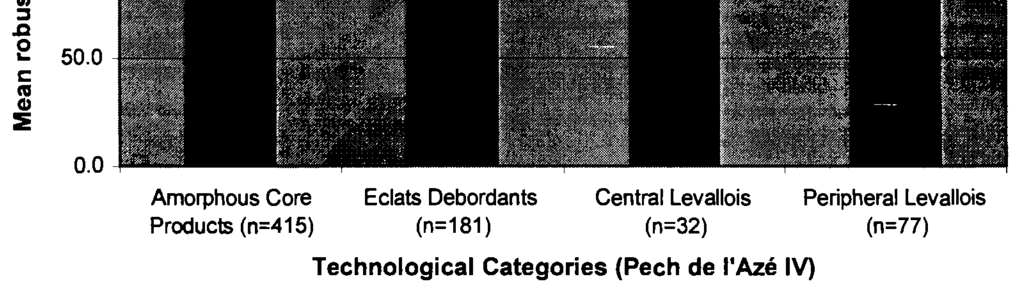

Figure 9.14 Mean robusticity by technology for Pech de l'Azé IV
(lower numbers = more robust).

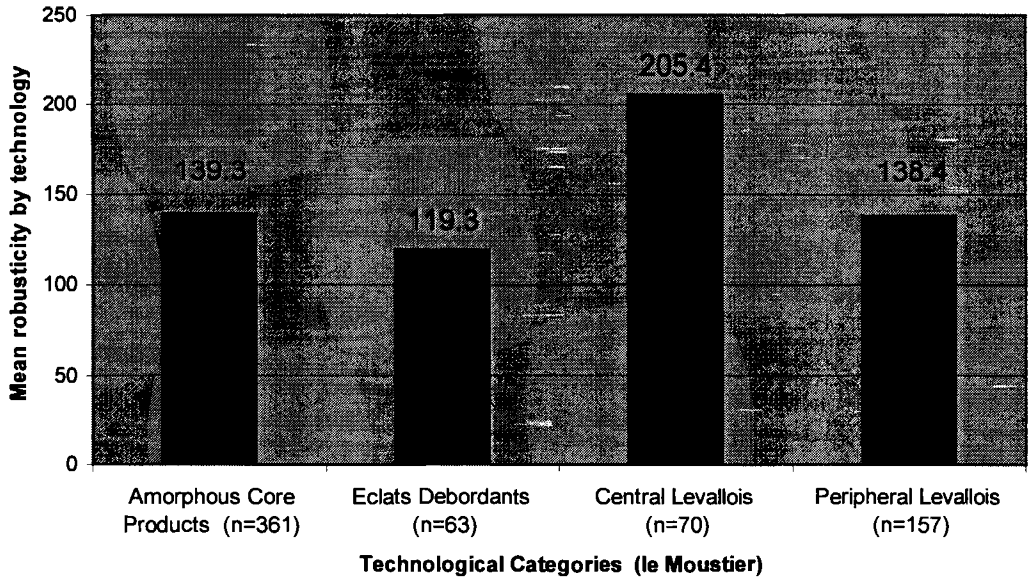

Figure 9.15 Mean robusticity by technology for le Moustier
(*lower numbers = more robust*).

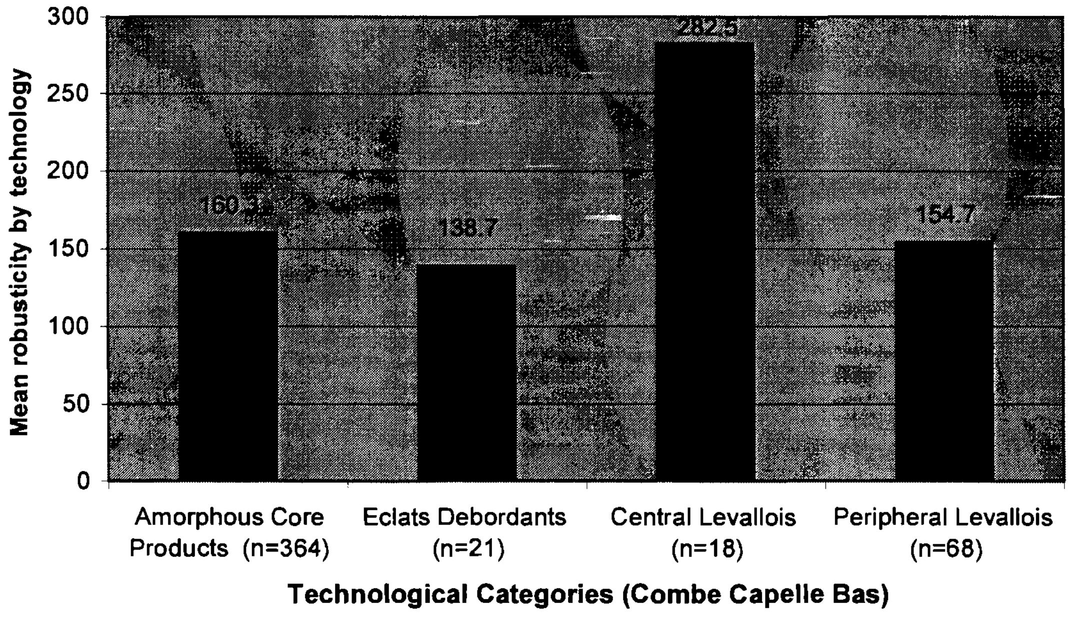

Figure 9.16 Mean robusticity by technology for Combe Capelle Bas
(lower numbers = more robust).

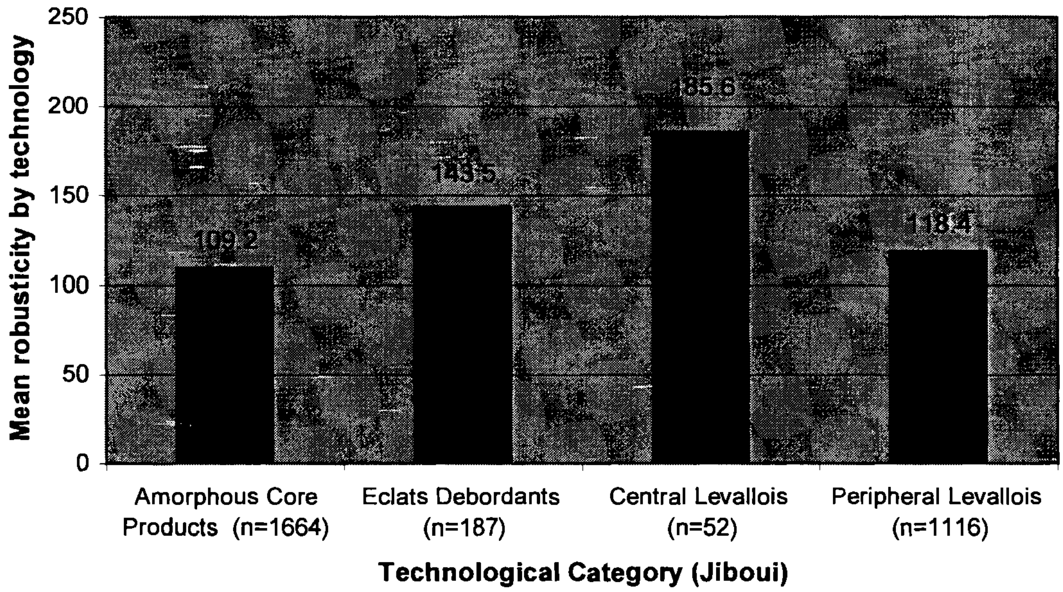

Figure 9.17 Mean robusticity by technology for Jiboui (lower numbers = more robust).

When the data are viewed by individual site we can see that, except for in the Jiboui sample, there is the same overall pattern: greatest robusticity among the *Eclats Débordants*, followed by the Amorphous Core, Peripheral Levallois and then the lowest robusticity among the Central Levallois, with the difference between Central and Peripheral Levallois flakes being particularly marked.

A pattern of interest here is that the data from Combe Capelle Bas, which has the lowest Typological Levallois Index, are most closely in line with the data from le Moustier and Jiboui, which have much higher Indices. It might be that the larger, more regular raw materials available at Combe Capelle Bas allow the production of more gracile flakes without the use of the Levallois technique. This is supported by the fact that, of all the site samples, the non-Levallois products at this site are the least robust, and are, in fact, similar in robusticity to the Central Levallois flakes of Jiboui. The cores from this site indicate that, while classic Levallois reduction was not commonly employed, some form of single-surface core reduction (Centripetal or Disc) was dominant (see Table 10.2). It was apparently very effective at producing large, relatively gracile flakes. If the use of the Levallois approach reflects a desire for larger, less robust hardhammer flakes, then, although it may be easier to apply the technique to larger raw material forms, it would seem most useful in circumstances where the raw material size and form do not allow the easy production of such flakes using more amorphous reduction approaches. We might expect the Levallois approach to be used more commonly in the face of some limitations in raw material size and form, but not necessarily in quantities available. However, there will certainly be limits to this as well. Some raw material nodules would be simply too small, or more likely, too irregular in shape, to make the application of Levallois reduction suitable. Significant irregularity in nodule shape would make it impossible to achieve any of the advantages that Levallois reduction would afford with more regular nodule forms.

Summary of Comparison of Tool Selection Criteria & Technological Products

Blank Size

While Central Levallois flakes, as a category, are the largest flake products in the study samples, there is little to indicate that the Levallois technique, *as a whole*, provides any significant advantage in terms of product size. When the Levallois products are examined as a group (Central and Peripheral flakes combined), the difference in mean size between these and the non-Levallois products is negligible. One possible inference from this is that the Peripheral flakes represent a conscious sacrifice in flake size in order to produce a limited number of maximum sized (Central) flakes: the traditional view. However, while it is apparent that size plays some role in blank selection, if this were a dominant influence we would expect all large flakes to be well used. This does not necessarily mean they would have been retouched, but they should, at least, have significant use-wear. As it is, many of the largest Levallois and Amorphous Core flakes go unretouched and/or have negligible use-wear (many lack any macroscopic evidence of use), and many small flakes indicate extensive use (retouch and use-damage).

Furthermore, there is an obvious correlation between retouching and increased blank size among the Amorphous Core products. The retouched tools have the largest mean dimensions (compared to tools with just use-wear, and apparently unused flakes).

But there is no corresponding correlation between Central Levallois flakes (the category of flakes with the largest mean dimension) and retouching. The percentage of Central Levallois flakes that were retouched for each assemblage are: 5.1% in Jiboui (9 out of 178), 21.1% in Pech de l'Azé IV, 44.4% in Combe Capelle Bas, and 53.5% in le Moustier. The percentage of flakes, other than Central Levallois flakes, that were retouched for each assemblage are: 2.5% in Jiboui, 34.1% in le Moustier, 34.9% in Pech de l'Azé IV, and 64.2% in Combe Capelle Bas. The relationship between frequency of retouch flake size is examined for two product types in the following figures.

Table 9.21 Bivariate table of 'large' (>48.5 mm long) and 'small' (•48.5 mm long) Central Levallois flakes that were retouched or not (the two categories are based on the mean length of all Central Levallois products, m=48.6).

	>48.5 mm in L	**≤48.5 mm in L**	**Row totals**
Retouched Flakes	O = 28 E = 23.2	O = 24 E = 28.8	52
Unretouched Flakes	O = 26 E = 30.8	O = 43 E = 38.2	69
Column totals	54	67	121

The Chi-squared value, $x^2 = 3.15$, with 1 degree of freedom, which indicates a 90-95% confidence level and 5-10% significance level.

Table 9.22 Bivariate table of 'large' (>41.5 mm long) and 'small' (•41.5 mm long) Amorphous Core flakes that were retouched or not (the two categories are based on the mean length of all Amorphous Core products, m=41.4).

	>41.5 mm in L	**≤41.5 mm in L**	**Row totals**
Retouched Flakes	O = 314 E = 237.6	O = 239 E = 315.4	553
Unretouched Flakes	O = 177 E = 253.4	O = 413 E = 336.6	590
Column totals	491	652	1143

The Chi-squared value, $x^2 = 83.4$, with 1 degree of freedom, which indicates a >99.9% confidence level and <0.1% significance level.

This bivariate analysis further supports a correlation between flake size and frequency of retouch, but it applies to both of the technological products examined in tables 9.21 and 9.22 (Amorphous Core and Central Levallois). In both cases, frequency of retouch is heavily distributed in the large flake category and lack of retouch is heavily distributed in the small flake category. Although size may play a stronger role in one technology or another, there is no apparent overwhelming correlation between the trend to select larger flakes for retouched tools and a specific technology. (Similar bivariate patterns occur for *Eclats Débordants* and Peripheral Levallois flakes, with $x^2 = 16.1$ and $x^2 = 26.0$ respectively.)

It may be that, compared to Amorphous Core reduction, the Levallois technique, or similar single-surface core approaches, produce a relatively high number of larger, or at least usable sized, flakes *per core*. This is to say that maintenance of a greater mean size for the majority of products AND a lower degree of variability among the total assemblage are achieved with such reduction approaches. In contrast, Amorphous Core reduction tends to produce a number of large flakes, but a greater proportion of small, essentially unusable flakes occur as well and overall there is a greater degree of variability among the products. This pattern is indirectly apparent in the consistently lower standard deviations for the Levallois product dimensions (Table 9.20). However, the best way to get at this data directly is through refit analyses that would allow the examination of all the products of individual reduction events of each technology, which this is beyond the scope of this study. Much of the evidence for these costs or benefits will also be contained in the small fraction lithics (items <2.5 cm in maximum dimension), which were not individually provenienced and not included in the analysis here.

Spine-Plane Angle

The data presented in Chapter 8 seems to indicate a preference to select, for unmodified tools, blanks with lower average spine-plane angles than those selected for retouched tools. Levallois reduction does seem to present an advantage in this respect, generally producing flakes with lower average spine-plane angles compared to the other products. This applies to both Central and Peripheral flakes, but with the Central flakes having a slight advantage over the Peripheral ones. *Eclats Débordants*, on the other hand, have the highest mean for average spine-plane angles of all the products, but were still used predominantly in unmodified form.

Ventral Curvature

There is little difference in ventral curvature among any of the products in the archaeological assemblages, although there is a significant difference between all the archaeological (hardhammer) products and the experimentally produced softhammer products. As discussed in Chapter 8, this attribute seems to have played no role in blank selection and this may be because all hardhammer flakes are essentially flat enough.

Edge Length and Morphology

In general it appears that flakes that were selected for use as retouched blanks tended to have longer individual edges and had greater average total lengths of usable edge per flake. This trend might be partly a product of the retouching actually creating longer individual edges, but this could not entirely account for this pattern in the data.

In terms of average lengths of usable edges, the Levallois strategy does not provide any notable advantage over the non-Levallois strategies. However, it does provide significant advantages in terms of the number of usable edges per flake and in average total (combined) edge length per flake. This last attribute becomes particularly significant when it is corrected for by mean flake weight. When this is taken into account the edge length characteristics of Central Levallois flakes remain significantly higher than Amorphous Core and *Eclats Débordants*, but more notably, the Peripheral Levallois flakes rise dramatically in relation to all other products. The relative value of Peripheral flakes in terms of tool edges produced relative to raw material weight is significant. While, this is also true of *Eclats Débordants* in comparison to Amorphous Core products, the high values for both Central and Peripheral flakes make the application of Levallois reduction particularly attractive in terms of maximizing length and number of usable edges per raw material quantity reduced.

With respect to flake edge data, the blank-selection analysis indicated a connection between the selection of blanks with higher numbers of usable edges and unmodified tools. This suggests that perhaps it was in situations (e.g., types of sites or certain seasons), where the knapper sought blanks for use as unmodified tools, that the Levallois technique was particularly useful.

Levallois products, including both Peripheral and Central, do not have a higher occurrence of regular edges than the non-Levallois products, although they are significantly more regular in plan shape.

Standardization

The data do indicate a consistently lower degree of variability among the Levallois products, especially in terms of thickness and length:width ratios, which could facilitate hafting. This would indicate a tendency towards increased regularity, although this is not particularly strong evidence of an attempt to produced "standardized" products, in a more strict sense of the term.

Among *Eclats Débordants*, however, the degree of variability in length and width is significantly lower and might begin to approach the idea of 'standardization'. However, it is difficult to imagine an effective way to haft these flakes using the more commonly perceived methods (i.e., attaching a handle of wood in some manner). *Eclats Débordants* could be easily hafted using moldable gum or resin, but this is true of any flake form. I would tend to argue that, as mentioned previously, the general form of *Eclats Débordants* provides natural hand protection (one advantage of hafting sharp tools) and that the low degree of variability among these flakes is due to a concerted effort to produce them in this specific form.

Robusticity

In all four samples the Central Levallois flakes are the least robust by a significant margin. Based on this, the Central flakes should generally be the most highly sought after for tool blanks used in tasks where thinness or related features are desired.

This is the case, but when the type of use-modification is examined further there is an apparent tendency, among used flakes, for Amorphous Core blanks to be more frequently retouched than Levallois blanks. Among the three product types, there is also a notable tendency for Peripheral flakes to be used without any intentional modification, which might be an indication that they were employed more expediently than Central Levallois or Amorphous Core flakes.

Individually, the four site samples show some significant patterning in robusticity. The three sites (le Moustier, Combe Capelle Bas, and Jiboui) exhibit the same pattern of similar robusticity between the Amorphous Core and the Peripheral Levallois products. Among just the Levallois products there is a very marked difference between the Central and Peripheral flakes. In the Pech de l'Azé IV sample, however, it is the non-Levallois products that are less robust than the combined Levallois products. At Combe Capelle Bas, where the Typological Levallois Index indicates very low Levallois use, the robusticity data is most similar to that of le Moustier and Jiboui, which have very high Levallois Indices.

The patterns observed for the Pech de l'Azé IV and Combe Capelle Bas data suggest that, given the constraints of raw material size and form, non-Levallois reduction techniques, primarily Disc and Amorphous Core reduction, can produce flake products as gracile as the Levallois products. With the small, irregular flint nodules at Pech de l'Azé IV the Levallois technique apparently failed to provide any advantage over the Non-Levallois reduction employed. At Combe Capelle Bas, the large, regular nodules available here allowed a non-Levallois approach to produce products that were larger and more gracile than any of the Levallois products of the four site samples. That there was any Levallois presence in these two assemblages at all may reflect occasional attempts to employ the technique in which either the results are less than satisfactory (as might be expected with the small, irregular nodules at Pech de l'Azé IV), or else the resulting products have little advantage over the products than can be more readily produced by employing an Amorphous reduction approach on the large, sub-spherical nodules available in large quantities right at the Combe Capelle Bas site.

Chapter 10: Site Specific Patterns

Blank Selection, Choice of Reduction Strategy, and the Relation of these to Site Location

This chapter addresses the site-specific conditions, or constraints associated with each site, that may have influenced the choice of reduction strategy(s) employed there. These conditions and constraints are viewed in light of any apparent relations between the morphologies of the products of specific reduction techniques and the tool-blank selection criteria that were noted in the preceding two chapters.

~~Constraint that are Common to all Four Sites~~

Available Technologies

There is one constraint that would play a part in tool production strategies that can be presumed to have been common among the groups inhabiting the four study sites, at least for the time period represented by the four study components. This is access to the same reduction strategy choices.

While blade production and biface use were not common in the Middle Palaeolithic, they were present and apparently available to groups throughout this period. This may be less so for blade technology, which has been recognized in only several sites, than for bifaces, but it is becoming more apparent that it is not an invention of the Upper Palaeolithic (Conard 1990; Tuffreau 1982). At all four sample sites (during the time periods represented by the components that the samples were taken from), the tool makers chose to employ certain reduction strategies (amorphous core reduction, single-surface core reduction, and, in one case, biface production) to varying degrees, and chose not to employ other strategies (blade core reduction, bipolar core reduction, and biface production in three cases).

While there are a few blades or blade-like-flakes in all four study assemblages, it is readily apparent that these are incidentally, rather than intentionally, 'bladey'. There is no indication that there was any attempt to consciously produce blade-like products. There are some obvious advantages to blade technology. Blade products are generally more standardized in size and form, present longer, straighter (and more regular) cutting edges per flake, and may be more versatile under some conditions. However, there is a significant trade off for these benefits. In particular, blade production requires more skill, better knapping equipment, involves greater failure rates, and tends to be more tightly constrained by raw material size and form. Determining why people chose to adopt this strategy when and where they did is beyond the scope of this study. It would require design theory-structured studies similar to this one, but applied specifically to the blade production strategy.

Level of Group Mobility

The relatively low level of technological variability in the Middle Palaeolithic, compared to later time periods, has long been put forward as an indication of a fairly generic adaptation throughout this period. While it is quite likely that there was some degree of variability, group sizes, frequency of moves, and distances travelled would likely have been of the same general magnitude. While, this does not preclude the potential that the four study sites represent different types of sites and/or held different positions within the inhabitant's annual cycles, the tool production and use patterns, and the similarity of their locations along major river valleys (figures 4.2 and 4.3) suggest that the three primary sites were occupied by groups following the same general settlement patterns and represent similar types of occupations. The fourth site, Jiboui, likely represents a specific resource extraction site. This is indicated by the low frequency of retouched pieces and perhaps by the lack of accumulation of faunal remains, which would tend to indicate very short-term occupation (although the lack of faunal remains might well be an issue of organic preservation which tends to be poorer in alpine conditions).

Site-Specific Factors

Raw Material Availability

The most important, *obvious* differences between the four sites are access to suitable raw materials, and the variable size and shape of those available raw materials.

The raw materials employed at Pech de l'Azé IV were collected from the general vicinity of the site (<1 km). While the flint itself is of quite high quality, it occurs as relatively small (five to 15 cm), irregularly shaped nodules. These are often complex, convoluted forms in which the flint rarely occurs as large, homogeneous masses.

At Le Moustier a large percentage of the raw material came from up to 10 km away, but it occurs in larger nodules or slabs (15 to 30 cm), which are of regular oval or sub-spherical shapes. It is also mostly of a high quality.

At Combe Capelle Bas all the material comes from the immediate vicinity (the site essentially sits atop the flint source) and generally occurs as large, oval nodules between 10 and 40 cm in length, or as slabs of five to 15 cm in thickness, and in terms of quality range from mediocre to very good.

At Jiboui all the material comes from an outcropping very close to the site (<1 km). While it is of good quality, it can occur in smaller nodules. (A more detailed descriptions of the raw materials used at the sites is provided in Chapter 7)

Other Environmental Constraints

As the locations of the three primary study sites are in relatively close proximity and in similar geographic circumstances and the sample components are of very similar ages, we would expect most environmental constraints to apply equally to all three. Such constraints may include seasonal access to specific resources. During winter, snow cover and ground frost may have made some raw materials temporarily inaccessible. Higher water levels in river valleys in the spring may have also made temporarily inaccessible those raw materials typically collected from fluviatile deposits. Such conditions may have made it necessary to make alternate raw material choices or employ reduction techniques that are more economical of raw material to make the most of what they did have access to.

The location of the site of Jiboui presents other issues that would not apply to the three primary study sites. Jiboui is located in an alpine environment and this would present a number of different potential constraints that could affect lithic reduction strategies. Access to sites in Alpine environments, at least during the Palaeolithic, must have been restricted to the warmer seasons. The extremes of temperature and snow-cover during the winter must have made such regions essentially uninhabitable and the snow-cover would also have made access to raw materials very difficult in some locations and impossible in others.

Site Types

There is one other major difference among the four sites. Two of them, Pech de l'Azé IV and le Moustier (at least at the time of use) had provided significant natural protection from the elements. Pech de l'Azé IV was a cave at the time of inhabitation. It may have been relatively shallow, especially during later occupations (such as the one from which this sample was taken), but would have provided protection from precipitation and wind. The Le Moustier site includes both a lower part, from which this sample comes, and an upper part, both of which were rockshelters with large overhangs that would also have provided significant protection.

Combe Capelle Bas and Jiboui, on the other hand, were both open-air sites. Combe Capelle Bas may, at one time, have had a small rock overhang above the occupation area, but this would not have existed at the time of the occupation from which this sample comes (Dibble and Lenoir 1995). Jiboui is strictly an open-air site. Its location in a *col* may have provided some general protection from the wind, but its inhabitants would essentially have been exposed to the elements, unless they had constructed some form of shelter.

Explaining Site-Specific Differences in the Lithic Data

Pech de l'Azé IV

Reduction Strategy Constraints and Options

The small size and irregular forms of the raw material available at Pech de l'Azé IV would have made some reduction strategies unsuitable. In particular, the production of blades, though not technically impossible, would have been practically impossible. By the time such small nodules had been prepared into blade core forms they would have been very small and the resulting products would have been tiny.

The small size of the raw material nodules here may have made them suitable for the application of bipolar reduction on occasion. Though no evidence of bipolar reduction was noted (either among the cores or flakes), it is possible that it was practiced occasionally at this site and the evidence has been masked by subsequent reduction of the cores and modification of the flakes. It is more likely, however, that the irregular shape of the nodules would typically provide natural striking platforms from which reduction of the nodule as a whole could be initiated.

In cases, such as Pech de l'Azé IV, where the most readily available raw materials are small and irregular, an amorphous reduction strategy may be the most logical approach (Fish 1981:379). The nature of raw materials available at this site is a circumstance that has likely varied over time. During colder climatic regimes accessing even the locally available raw materials may have been made more difficult by snowcover and/or permafrost and occupants of the site may have had a reduced choice of sizes and forms. This would explain the general increase in tool:core ratios in the occupations of the site (see Table 5.1). A similar pattern can be seen in Table 10.1 in the use of Levallois reduction at this site.

Level	Typological Levallois Index	Graph of Indices	Age/Climatic Regime
F1	19.8		C. 35,000 bp - very cold & dry
→ F2	11.6		
F3	23.1		
F4	24.1		
G	12.9		⇧
H1-2	18.8		
I1	17.4		
I2	32.1		increasingly cold conditions
J1	19.9		increasingly warm conditions
J2	19.2		⇩
J3	48.5		
J3A	59.2		
J3B	54.6		
J3C	35.9		
X	24.2		
Y	37.7		
Z	23.4		c. 80-130,000 - warm and wet

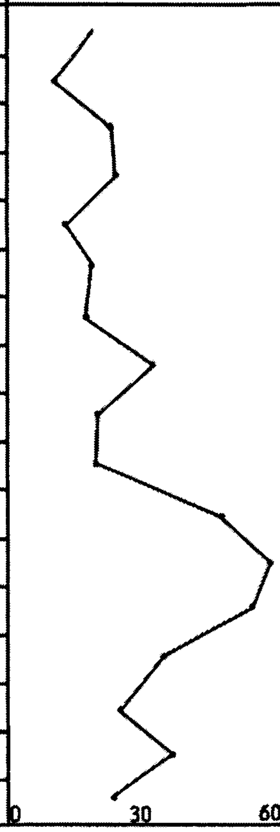

Figure 10.1 Typological Levallois Indices for each component of Pech de l'Azé IV relative to general climatic conditions.

This general reduction in the occurrence of the use of Levallois reduction at the site might also be a reflection of the gradual depletion of larger nodules in the immediately available deposits. Over the course of site occupation history, fewer and fewer larger, more regular nodules are available. As nodules become smaller and less regular (either due to actual depletion or to increased snowcover/permafrost) any advantages that prepared core strategies (like Levallois) present may be difficult to capitalize on because, as discussed with blade core reduction above, the preparation of the core would require removing so much of the core mass that what was left would be very small. The most usable flakes, in terms of size at least, would have been those removed in the initial reduction stages.

However, occasional situations may have presented themselves when it may have been worth the effort to apply more patterned single-surface reduction strategies. Rolland (1986: 123) sees Disc core reduction as being particularly applicable in circumstances where raw material availability is decreased or the raw material occurs in small sizes. Typically, in constructing a single-surface core (e.g. Levallois) from a sub-spherical nodule, a significant amount of initial preparation of the form is necessary before one reaches the point where the volumetric form of the core allows the efficient and patterned exploitation of a surface of debitage. This necessary volumetric form ("*...two asymmetrical convex secant surfaces..* [whose] .. *intersection defines a plane*" - Boëda 1995: 46), however, can occur incidentally. Relatively thick flakes, removed directly off a core or nodule, can themselves present such a volumetric form. Likewise, "pustules" (natural protuberances on some flint nodules - see Chapter 7 for a more detailed description), when knocked off a nodule basically exhibit such a form. These thick flakes and pustules often require little or no further preparation before they can be reduced as single-surface cores. These can be reduced in either a Disc core or Levallois approach. In the raw material at Pech de l'Azé IV, pustules are common and, while typically quite small, would allow very quick and easy production of a number of flat, sharp flakes, albeit, quite small ones. Small single-surface (including Levallois) cores on pustules, while not numerous at Pech de l'Azé IV, are not uncommon either.

The Levallois Index and Typological Levallois Indices, based on Bordes' system, were designed to give some impression of the level of use of the Levallois strategy in an assemblage. The first indicates the quantity of Central Levallois flakes relative to the entire lithic assemblage (not including bifaces) and the second gives the quantity of Central Levallois flakes relative to the number of retouched pieces. Table 10.2 provides these values for the sample assemblages along with the types and quantities of cores.

Table 10.2 Levallois Indices and data on core types and frequencies for all four sites (includes only complete cores).

Site, Component	Levallois Index	Typological Levallois Index	Levallois Cores	Single-Surface Cores	Amorphous Cores
Pech IV (F2)	3.9	11.6	**11.6%** (n=11)	**44.2%** (n=42)	**44.2%** (n=42)
Le Moustier (G)	10.1	26.7	**25.0%** (n=10)	**47.5%** (n=19)	**27.5%** (n=11)
C Capelle (I1D)	3.6	6.7	**14.0%** (n=9)	**50.0%** (n=32)	**35.9%** (n=23)
Jiboui	4.0*	57.1	**37.1%** (n=43)	**37.1%** (n=43)	**25.9%** (n=30)

* this number is significantly deflated as this assemblage, unlike the other three, includes items between 2.0 and 2.5 mm in length.

The Typological Levallois Index for Pech de l'Azé IV is 11.6, which, though higher than Combe Capelle Bas (6.7), is still not particularly high. If we actually examine the types of cores, however, the Levallois presence would appear to be even less important at Pech de l'Azé IV. In this sample only 11 out of the 53 single-surface cores (or 11.6% of the total number of cores) had Central flake removals and so might be safely categorized as Levallois (*sensu strictu*). This indicates that in reality Pech de l'Azé IV has the lowest usage of single-surface core strategies (if not lowest 'Levallois' usage) of the four study sites. This would tend to suggest a strong correlation between raw material size, form, and availability on the one hand and the choice of reduction strategy on the other hand, since the raw materials employed at this site were the most limiting in size and form.

The raw material sizes available at Pech de l'Azé IV may have also been a major constraint on the production of bifaces. While there are some relatively small (<6-8 cm) Mousterian bifaces (a few even recovered from other layers in this site), typically these items are >8-10 cm in length and finding nodules here large enough to produce biface of this size or larger may have been difficult, especially in the later occupations at this site. Bifaces are likely a predominantly mobile tool and, therefore, many that might have been produced here would have been carried away.

Tool Morphology Patterns

Pech de l'Azé IV tools exhibit the least differences in means of size between used and unused flakes, and they also show the lowest degree of variability (almost none) within dimensions among the used flakes. Among the average dimensions for used Pech flakes, the standard deviation was either equal to or, more often, lower than the standard deviations of the other three samples. The Pech de l'Azé IV sample also showed by far the least difference in standard deviation between the used and unused flakes (for all dimensions and weight). If the low degree of variability was only among the used flakes, one could argue that this represented a more finely tuned selection criteria. However, this, with the accompanying low degree of variability between used and unused flakes, suggests that the initial assemblage that was produced had an overall lower degree of variability in terms of its metric dimensions, and this is likely a reflection of initial raw material size and form. Any tool blanks selected from it would invariably reflect this.

The flakes in this sample also have the highest mean average edge angles (43°). For this site-sample robusticity apparently played no part in overall tool blank selection (the robusticity of all flakes in this sample = 117.5, while unused = 116.6 and used = 117.8), although it seems to have in played a role in the selection of blanks to be retouched verses those that would be used unmodified (retouched flakes = 109.5, flakes with use-wear = 118.3). There was an apparent preference for more robust flakes for retouched tools. This pattern might be partly explained by the retouching itself (and the subsequent loss of flake area to flake thickness) resulting in greater robusticity measurements.

Site Activities

The nature of the site and the nature of the evidence recovered from it tend to indicate that Pech de l'Azé IV was used as some form of base camp. The significant shelter that the site would have provided, the significant quantities of butchered animal bones, stone tools and debitage, and the numerous hearths (at least in the lower layers) suggests that occupations of this site were of relatively long duration (by forager standards). At such sites, activities would have included both the hunting (in the surrounding region) and butchering of animals and the manufacture and maintenance of tool kits. The occupants would have required stone tools for cutting up animals and for woodworking.

It is difficult to reconcile the obvious need for butchering tools in such a site component (there are plenty of faunal remains) and the overall tool selection patterns, which indicate a lack of selection for lower robusticity and lower edge angles (spine-plane angles) among all tools. This would tend to suggest that during this occupation period at the site, either woodworking was the dominant task or no effort was made to select for sharper tools for cutting meat.

Another characteristic of this site component, compared to the other three, is the significant proportion of *Eclats Débordants* in the assemblage. These are flakes removed from the periphery of a single-surface core, but, rather than a removal oriented towards the centre of the core (parallel to the radius of the core surface), the direction of removal is obliquely to the core edge (perpendicular to the radius of the core surface). This results in the removal of a good portion of the edge of the core with the flake. The presence of a long section of core-edge along one margin of the flake is, in fact, one of the defining characteristics of *Eclats Débordants* (the other is the orientation of the striking platform to this section of core edge). This gives *Eclats Débordants* the general appearance of "citrus wedges" and makes them very similar in form to intentionally and naturally backed knives (Plates 10 and 11). In fact most naturally backed knives are produced in a similar manner with the only difference being that the former has cortical, rather than facetted, core edge along the one margin (Plate 12). Depending on the configuration of flake scars on the core surface, an *Eclats Débordants* will typically have either one long sharp edge or two separate edges that form a point opposite the core-edge margin. This latter form is what Bordes had classified in his system as "pseudo-Levallois points".

In the Pech de l'Azé IV sample, 25.7% (182/707) of all the flakes are *Eclats Débordants* (not including naturally backed knives), compared to 9.8%, 4.4%, and 4.3% for the le Moustier, Combe Capelle Bas, and Jiboui samples respectively. This is such a high proportion, and the production of this type of flake requires such a specific reduction procedure, that it seems quite likely that these were intentionally produced products. It is possible that their production is related to core surface preparation in the course of predetermining the form of other flakes (i.e. they are like Levallois preparatory flakes), but the low quantities of Central Levallois flakes would not support this (unless significant quantities of these had been removed from the site). It seems more probable that these were, themselves, the intended products. The natural backing formed by the core edge along one margin makes them very suitable tools for tasks in which significant pressure is applied to the tool during use and protection of the user's hand is an issue. These flakes are also particularly robust, and are in fact the most robust technological category of all four site samples, and yet have a relatively high average total edge length to volume. In spite of having relatively low use-edge spine-plane angles (mean = 43°, compared to 40° for Central Levallois, 44° for Peripheral Levallois, and 45° for Amorphous Core products), of all the products in these site components these tools would be the most suitable, without any modification or hafting, for woodworking tasks, such as shaving down the surface of wooden shafts, because of their robusticity and natural hand protection.

An interpretation put forward here is that in this component of Pech de l'Azé IV reduction goals were focused more on the peripheral products of single-surface core strategies, and that there are likely two main reasons for this. The foremost reason is that specific forms of peripheral flakes (i.e., *Eclats Débordants*) are particularly suited to certain tasks (likely woodworking, although there is no *a priori* reason why they would not work well for butchering also). A second reason is that potential reduction options at this site were constrained by the size and form of the immediately available raw material.

This interpretation is further supported by the fact that at the other two primary sites, the Central Levallois flakes exhibited the highest frequency of use (retouch and use-wear evidence combined), while at Pech de l'Azé IV it was the Peripheral Levallois flakes and *Eclats Débordants* that were used most frequently (see tables 9.2 to 9.4).

Le Moustier

Reduction Strategy Constraints and Options

The raw materials available at le Moustier would present few problems for any reduction strategy (except for bipolar core reduction which would, obviously, not be appropriate on such large nodules - Hayden 1980). All other strategies would be available, including blade production.

Tool Morphology Patterns

Of the three primary site-samples, the le Moustier sample has the greatest difference between the mean dimensions of the used and unused flakes. This difference between used and unused flakes is further reflected by the fact this site sample has, for most dimensions, the greatest differences between the standard deviations of these two categories. The le Moustier sample also has the lowest mean average-edge-angle (35°).

Unlike at Pech, at le Moustier the used flakes are significantly less robust than the unused (robusticity of all flakes = 144.7, unused = 117.5, used = 153.0), with a further significant difference between retouched and unretouched tools (retouched = 167.3, use-wear = 140.2). At this site there was a definite preference for less robust flakes for retouched tools.

Site Activities

Le Moustier must have been a similar type of site as Pech de l'Azé IV. Along with its providing good shelter, and the abundance of butchered bone and stone tools in the deposits, there were also Neandertal burials at this site (Laville and Rigaud 1976). Like Pech de l'Azé IV, it was likely used as a base camp of some sort. Tools selection patterns were notably different here, however. Among the four sites this sample shows the strongest preference in blank selection for greater size, lower edge angles, and lower robusticity, especially for retouched tools. While the overall lower degree of robusticity and lower edge angles in this sample assemblage could be explained by the greater application of *préférential* Levallois reduction (the classic form) at this site than the other two primary sites, the further selection for these same attributes from among the available Levallois tool blanks indicates that they were specifically sought after and that this may be initially reflected in the choice of this reduction strategy. That is to say that the Levallois technique may have been employed more heavily at this site *because* its products generally exhibit lower average edges angles and a lesser degree of robusticity (if in fact these are two separate things) than the amorphous, non-Levallois reduction products. The most logical explanation for this selection, and its being different from that employed at Pech de l'Azé IV, is that the activities carried out at this site were dominated by different tasks than at Pech de l'Azé IV. If the suggested association between unmodified tools and cutting/butchering tasks has any validity then the predominant use of Central Levallois flakes as unmodified tools at le Moustier might indicate that butchering may have played a more dominant role here, or in satellite locations visited from this base camp during this occupation period. This association, however, is very tentative and has not been well supported by other data in the samples (e.g., the preference for less robust flakes with longer individual use edges for retouched tools, although these may have been hafted and used for other tasks).

A more plausible association is between the increased use of Levallois reduction at le Moustier and the slightly decreased access to raw materials at this site compared to the other two primary ones. If raw material had to be carried from up to 10 km away, some degree of raw material economization may have been employed. In terms of total length of usable edge per flake Central Levallois flakes provide a notable advantage, but even more significant is that both Central and Peripheral Levallois products have the greatest ratios of usable edge to volume of raw material reduced. The fact that these characteristics are more pronounced among Levallois verses other single-surface core products (like *Eclats Débordants*) is due, in large part, to the intermittent removal of the central mass of the core surface. Central flake removals allow the knapper to maintain a decreased level of robusticity (which translates, to a certain degree, into higher margin [edge] to flake volume) and increased regularity of shape among all the products of a core (Sandgathe 2004), and, in fact, at le Moustier it was the Peripheral Levallois flakes that exhibited the greatest total edge length by flake volume (weight). Therefore, in terms of providing desirable blank characteristics in the face of raw material economization the classic Levallois approach makes sense.

Combe Capelle Bas

Tool Morphology Patterns

The Combe Capelle Bas sample tends to fall somewhere between the first two in terms of the degree of difference between the used and unused flakes. The actual difference between the mean dimensions of the used and unused flakes is greater than for Pech de l'Azé IV, but is less marked than for le Moustier. However, the Combe Capelle Bas sample presents the greatest degree of overall variability. It has the highest standard deviations among the dimensions of both the used and unused flakes, although the level of difference between the standard deviation of the used and unused is comparable, if not lower, than for le Moustier.

The mean average-edge-angle (40°) for Combe Capelle Bas sample falls between the other two. As does the degree of difference in robusticity between used and unused flakes (robusticity of all flakes = 163.6, unused = 144.6, used = 164.4), although the Combe Capelle Bas flakes are all notably less robust than the other samples. As with le Moustier, in this sample the used flakes are less robust than the unused. The Combe Capelle Bas sample shows the least difference in robusticity between the retouched (164.0) and the unretouched tools (165.5).

Reduction Strategy Constraints and Options

As with le Moustier, the raw material forms available at Combe Capelle Bas would have been amenable to any reduction strategy. Unlike Pech de l'Azé IV the raw material would not have been a constraint on the production of Mousterian bifaces which means the choice to not produce them at this site was based on other issues.

The same applies to Levallois reduction of which, of all four sites, this one shows the least presence, as measured by the traditional Typological Levallois Index. However, while an amorphous approach to core reduction is common in the Combe Capelle Bas sample (30% of all cores), the other 70% of the cores are single-surface forms (Table 10.2). The majority of these are disc or centripetal removal cores, but 20% of these (14% of all the cores) could potentially be categorized as Levallois (*sensu strictu*). The low frequency of Central flake removals explains the low Levallois Index for this site, although single-surface strategy dominates and there is actually a higher Levallois presence here than in the Pech de l'Azé IV sample. If the removal of Central flakes represents primarily a core maintenance strategy (Sandgathe 2004), the lower frequency of this practice at Combe Capelle Bas may be reflection of a relaxed concern for raw material economization. This might indicate that activities at Combe Capelle Bas were dominated by similar tasks as at le Moustier, but that raw material constraints at le Moustier dictated the use of a more raw material efficient reduction strategy.

Jiboui

While data for Jiboui is more limited, it has by far the greatest Levallois presence. Based on proportions of Central Levallois flakes this assemblage is essentially entirely Levallois. While the locally available raw materials are not as favourable to all reduction strategies as those at le Moustier and Combe Capelle Bas, they are still typically of large enough sizes and regular enough shapes to permit the application of almost any reduction strategy. However, speculating on any association between choice of strategy and potential site function becomes more tentative here. It is most likely a quarry site and the researchers who investigated the site suggest that the site was used as a location to produce finished tools for transport and use elsewhere (Tillet, et. al. 1997). However, a significant number of the blanks produced at Jiboui were extensively retouched, which suggests that some activities requiring the use of the tools were carried out at the site. Open-air alpine sites, such as Jiboui, may have been employed in the seasonal exploitation of local resources, such as hunting alpine mammal species. Unfortunately, bone preservation at the site appears to be very poor. The few pieces of bone that survive in the Jiboui sediments are carbonized, which suggests that these survived because of this condition and that there may have been originally greater quantities of bone deposited (poor preservation of bone is common in alpine deposits). If seasonal hunting had been the primary task at the site, then the high Levallois component could reflect a desire for quantities of particularly sharp blanks for butchering.

However, tools intended for use in transit between campsites are constrained by the same need for raw material economization as would be experienced at camp sites where raw material access/availability is limited. This would be due to the pressure to reduce the risk that the group would run short of suitable tools before they had access to the next source of raw materials. Such mobile tools should be maintainable and versatile, traits best provided by relatively large flake blanks with high numbers of usable edges by weight, and greater regularity of shape, i.e. Levallois products (but especially Central Levallois flakes).

Chapter 11: Discussion and Conclusion

The goal of this study has been to identify and evaluate the constraints that were apparently influencing the decision to employ Levallois reduction or not. Based on the constructed Middle Palaeolithic lifeways model some basic hypotheses were advanced about Middle Palaeolithic requirements for tool morphology. These took the form of five different potential explanations for how Levallois (and possibly other single-surface core) reduction satisfied Middle Palaeolithic constraints on technological organization and tool blank needs (page 142). I then examined the nature of blank selection among the four site samples with the goal of trying to isolate those characteristics that were being selected for in the tool blanks (especially in the different conditions represented by each study site). I then examined these samples again, in terms of their technological products, in order to determine the relative characteristics of the products of the different reduction strategies employed at the sample sites. Comparing the characteristics of technological products to the characteristics of those blanks selected for use provides insight into how the different reduction strategies satisfied different tool form requirements. By analyzing the nature of blank selection relative to selected reduction strategies at each site, and taking into account the different circumstances at each site, some insight can be achieved into the reasons why certain reduction strategies were employed under differing conditions.

Through a comparative analysis (Chapter 8) of the used and unused flakes in the four archaeological sample assemblages I tested the importance of the different morphological attributes that I had hypothesized would be important characteristics of Middle Palaeolithic flake tools because they satisfied specific constraints. The data indicated that some of these characteristics were either not sought after at all or had likely already been satisfied by the choice to employ hardhammer reduction, to the point that further selection for them when actually selecting tool blanks was not necessary (*It is important to keep in mind that this analysis does not necessarily allow direct access to all the criteria that the knappers would have employed. Some criteria were satisfied through choices made prior to the selection of one flake from among an already existing assemblage*).

The characteristics that did not play any role in blank selection (in spite of my expectations) include ventral curvature and standardization of tool morphology. The degree of ventral curvature was consistent among all the flakes. There was no apparent difference in this respect between the used and unused flakes, between the different types of used flakes (retouched verses unretouched), or between the Levallois and Non-Levallois products. While I still expect that flatness would be a desirable characteristic, especially for cutting (verses scraping) tools, the experimental softhammer flake data supports the idea that hardhammer flakes in general are flat enough and no further selection for this attribute is necessary among hardhammer produced assemblages.

Standardization was more difficult to try to analyze because it could potentially encompass a number of different metrical attributes, and unless it is very marked for all tools, it may be masked by variability among different tool types. For the most part, while there had been selection for greater size in general, there was very little patterning in selection based on just length, or just width, or on any specific flake shape (e.g. circular, rectangular) beyond, simply, 'more regular'. There was some patterning in selection and average edge angle of flakes. However, this appears to be related somehow to 'types' of flake tools and will be discussed below.

The products that most closely approach the idea of 'standardization' are *Eclats Débordants*, which have significantly lower standard deviations for all their dimensions and weight than the other products (except for thickness among Central Levallois flakes), especially at Pech de l'Azé IV where these items were produced with the greatest frequency. One other pattern of note is that in the Combe Capelle Bas sample flakes were selected for tools largely based on maximum length, but without any corresponding maximization in width. This may be a reflection of the selection of blanks for use in hafts, but there is no other evidence to support hafting considerations as an interpretation for this specific pattern in the data, and there may be other explanations (such as selection for longer individual edges). There is, however, other evidence, in the form of bulbar thinning, to support the general practice of hafting at Pech de l'Azé IV (Plates 13, 14 & 15), and the obvious selection for thinner flakes among the Levallois products at le Moustier might also be related to hafting considerations.

There were several constraints that did influence the design of tool production in the site samples. As outlined from the beginning, these fall into two general categories: constraints on individual tool morphology (tool function constraints) and constraints on tool blank production. In general, the desired characteristics of tool blanks that were retouched include a certain level of robusticity, lower spine-plane angles, more usable edges per flake, a greater total length of usable edge per flake, and longer individual use-edges. A sufficient level of robusticity seems to be achieved simply by practicing hardhammer reduction, and, in fact among the (hardhammer) flakes produced, selection is greater for less robust ones. Some of these other characteristics do occur in notably higher frequencies among the Levallois products, but the patterns are more complex when the data are examined by individual site sample.

At Pech de l'Azé IV (level F2), the degree of difference between the flakes selected for use and those not selected is much lower than in the other site samples. This applies to flake size, spine-plane angle, number of edges per flake, and robusticity. Of the four samples this one has the least (actual) use of Levallois reduction and a connection between these two patterns seems likely. The knappers/tool users at this site apparently had different constraints acting on their tool morphology requirements and classic Levallois products did not provide any advantages. This is further born out in that *Eclats Débordants* were the most frequently used product type in this sample, although these were used predominantly unretouched. Some aspects of flake production at this site can also be explained in terms of constraints on blank production: in particular they can be attributed to raw material constraints. At Pech de l'Azé IV the lower degree of variability in tool characteristics can be explained as the result of the smaller, more irregularly shaped raw material nodules available there. Knappers would have had more difficulty preparing cores into shapes that could readily produce larger, thinner flakes. Single-surface cores are the dominant reduction strategy at Pech de l'Azé IV, but their diminutive size would limit their potential to produce flakes of more desirable shapes. While this might have been, in part, an impetus to intentionally direct efforts towards producing *Eclats Débordants*, which represent a more usable, practical tool shape within the restrictions of small sized flakes, if the tool users needed or desired blanks with those characteristics more common in other technological products (e.g., Central Levallois flakes, which are larger, less robust, and have more usable edges per flake) then, even though the raw material may have prevented the practical use of these technologies, there should still have been obvious selection tendencies for these characteristics from among the products they were able to produce. In this site component it seems that the single-surface core approach was modified so as to produce products suited to task-specific requirements, which most closely supports *Hypothesis #2*, in which it is proposed that it is morphological characteristics of the products which most strongly influenced the choice of reduction strategies. It should also be noted that, as retouching of *Eclats Débordants* was a rare occurrence (at least at these sites), it does not seem likely that these tools were employed in conjunction with any elaborate hafting technology or were seen as a particularly maintainable tool technology (*Hypothesis #5*). They may well have been employed with a very simple hafting technology in which individual blanks, when they dulled, were replaced in the haft rather than resharpened. In this latter case they should be viewed more as an expedient technology and not as individual, longer-lived, maintainable tools.

In le Moustier (level G) the selection patterns are quite different. Here there was marked selection for characteristics, like greater size, lower spine-plane angles, and decreased robusticity, that are most strongly exhibited by Levallois products. Greater size is a major characteristic of Central Levallois flakes, but Peripheral Levallois flakes strongly exhibit these other characteristics as well. It seems likely that Levallois reduction was selected for use at this site in large part because of specific characteristics of its products. The fact that these Levallois products were employed predominantly unretouched and have particularly low edge angles might be an indication that cutting tasks were the dominant task in this occupation. However, the significant difference in robusticity between retouched and unretouched tools at this site strongly suggests two different categories of tools. If the unmodified, gracile, sharper products represent a category of cutting tools, then the more robust, retouched tools may represent woodworking tasks, or perhaps hide processing. The data are, however, not strong enough to support such an association beyond simple logical trends in the data. This pattern also tends to support that it is morphological characteristics of the products which influenced the choice of reduction strategies (i.e., *Hypothesis #2*).

However, both Central and Peripheral Levallois flakes are also notable in that they provide a greater number of usable edges per flake, a greater total length of usable edge per flake, and most significantly, they provide much higher quantity of usable edge per volume of raw material reduced. These all represent advantages for raw material economization and at le Moustier, while raw material size and shape would not have been notable constraints, raw material availability might have been. The use of Levallois reduction as a form of economization would have made some sense. In this case, both *Hypothesis #3* (in which it is proposed that longer-lived, maintainable tools [i.e., larger blanks with more and longer usable edges] would be a response to time stress resulting here from reduced access to raw material or increased processing volumes) and *Hypothesis #4* (acquiring a greater number of usable flakes with greater quantities of usable edge per volume of raw material as a direct response to reduce raw material availability) could be seen as logical strategies.

Blank selection patterns at Combe Capelle Bas tend to fall somewhere between those of Pech de l'Azé IV and le Moustier, although they tend to be more similar to le Moustier. Tool/task constraints were likely similar between these two sites, but there would have been a major difference being in raw material availability. At Combe Capelle Bas, situated directly on a source of large flint nodules, less sophisticated forms of single-surface core reduction were capable of producing blanks with the desired size, edge angles and degrees of robusticity, and since there was no need for raw material economization there was no need to attempt to maximize the edge length per volume. Such circumstances provide less insight into the specific advantages of different reduction approaches.

At Jiboui we have the strongest use of Levallois reduction under circumstances where raw material constraints were also minimal. If the interpretation is correct that this site was mainly a quarry site where the production of tools intended for transport and use elsewhere was the main task, then this strongly supports *Hypothesis #3* and the idea that Levallois products, and especially Central flakes, were highly maintainable tool blanks (i.e., could undergo numerous resharpenings before being discarded) that could also be modified to suit different applications.

However, with access to more direct evidence on the use of hafting, we might discover that a major advantage of Levallois products (again, Central flakes in particular) was that their maintainability could be significantly improved through hafting techniques (*Hypothesis #5*). Strong evidence in support of this, aside from direct evidence of hafting, would be to find that the tool blanks that had been removed from sites like Jiboui had been repeatedly retouched prior to discard.

Tool Morphology Constraints and Technology

There were three attributes that occurred with significant frequencies among all, or a significant majority, of the used flakes: greater average size, a high number of usable edges per flake, and decreased robusticity. Table 11.1 provides a summary of the major attributes for each of the technological products.

Table 11.1 Comparison of the summary data for each of the technological products (data from three primary samples).

Technological Product	% Use Freq.	% Ret. Freq.	Mean Length	Mean Sp-pl >	Edge L/ flake/wt	#edges/ flake	% Reg edges	Robus-icity
Amorphous Core	75.3	48.4	35.6	41.0°	2.85	2.1	68.3	140.1
Eclats Débordants	80.9	27.3	38.9	38.7°	4.40	2.0	78.6	107.8
Central Levallois	88.5	43.0	47.7	35.9°	5.70	3.1	76.8	209.5
Peripheral Lev	80.8	33.1	31.3	35.3°	5.30	2.4	73.3	135.4

While size was obviously a factor in general blank selection, it was apparent that it was not an overly dominant one, as even quite small flakes were used, albeit at significantly lower frequencies. For flake tools that were likely (though not necessarily always) hand-held, greater size is an attribute that we would anticipate would always play a role in blank selection, regardless of almost all other factors. It is reasonable to expect that, regardless of what reduction strategy was employed for whatever other reasons, there would always be an attempt to maximize the size of the resulting flake products, within limits set by nodule size, core morphology, prehension, and reduction type. Subsequent comparative analysis of the (combined Central and Peripheral) Levallois and other technological products of the three primary samples indicated that there was no significant difference in flake size between the products of different reduction strategies. (It would be useful, however, to have all the data from individual core reduction events in order to compare the potential for different reduction technologies to maximize both flake size *and* quantity of flakes relative to the original volume of the flint nodule. This data is not available here.) Central Levallois flakes on their own, however, do provide a significant advantage in terms of size. These are typically the largest flake type in each of the sample assemblages, and they exhibit the most frequency of use (though not in retouch). At le Moustier, where we see high Levallois and Typological Levallois Indices, there is an obvious focus in tool blank selection on the Central Levallois flakes, at least compared to the other two primary sites. Given the tendency for these products to provide better size and edge morphology characteristics we might expect that the Levallois technique was selected when products with these characteristics are sought after.

There is also a direct correlation between the form of the raw material available at each site and the overall dimensions of the flake products. At Pech de l'Azé IV, where raw material constraints practically preclude the production of larger, more gracile flakes, production was focused on *Eclats Débordants* which actually provide one or two regular edges with a greater consistency than other products. It can be proposed from this that where and when raw material constraints permit, Levallois technology (in the classic form) can provide some special-use context advantages.

The data indicate a definite tendency to select more frequently for tools those flakes with a greater number of potentially usable edges (usability here does not take into account the specific regularity of an edge, just whether it has any realistic use-potential or not). This is presented in figure 11.2.

Table 11.2 Number of usable edges per flake by use-evidence for primary sites. (same as table 8.19 - data exclude broken flakes).

	Used Flakes (n = 1417)	Unused Flakes (n = 403)
Mean number of edges	2.3	1.8

With ∞ degrees of freedom, two-sample t-value = 2.56, which indicates a significance level of 1% and confidence level of 99%.

This likely indicates a general pattern of thinking, during tool blank selection, that by selecting, at least initially, a blank with more usable edges, the chance that it will have one or more edges suitable for the task at hand (or future tasks) will obviously be greater and the chance that the individual will have to discard it and look for a more suitable flake is decreased. This attribute would be particularly advantages for tools used during transport when there is no immediate access to raw material sources.

The Levallois products also provide a significant advantage in terms of greater total length of edge per flake (particularly when corrected for by volume), but not really in longer individual edges. Such morphological attributes would make Levallois products (especially Central Levallois flakes) more suitable for situations where cutting/butchering tools (i.e., large flakes with significant total lengths of cutting edge, like blades) are required. Such flakes would tend to require little or no modification prior to application. Under such task requirements the expectation would also be for an increased selection for more gracile flakes. Contrary to my initial modeling, there was actually selection for *less* robust flakes for use as tools, and this seems to be more than simply a desire for lower edge angles because of the choice to carry out hardhammer reduction when softhammer flakes are significantly sharper (as discussed previously, the problem with softhammer flakes is that they are significantly more fragile as well). As with low ventral curvature, it is likely that all hardhammer flakes also exhibit some minimum degree of robusticity, and that it is not necessary to further select for this characteristic during the actual tool selection stage.

Through a comparative analysis it was apparent that low robusticity was related more to whether the tool blank had been intentionally modified (was retouched) or not (just exhibited use-wear), but among the three primary site samples there was a stronger selection for low robusticity *among the retouched tools* compared to the unmodified tools. There are two different explanations for this pattern. The first is that we are seeing two different types of tools here. One represented by retouching and one where retouching was not employed. The second explanation is that the retouched tools represent more extensively used examples of all tool types, and that they were more extensively used because their morphology was optimum -- i.e. larger, lower robusticity. Initially I saw the former explanation as more likely in view of the data which indicated that, while retouched flakes had lower mean robusticity, unmodified flake tools had lower mean average spine-plane angles. This conflict in correlated attributes supported the idea of two separate categories of tool blanks. However, it is likely that the difference in the means of average spine-plane angles between retouched and unmodified tools is due, at least in part, to the exclusion among the former of some edges (because they had been modified) in the initial analysis. I think that the error is in viewing retouch verses lack of retouch as indicative of tool function, rather than viewing edge-angle, whether it is natural or the result of edge modification, as the important functional criteria. Edges with relatively high angles, whether natural or the result of modification, should be viewed as an essentially functionally equivalent. The same apples to edges with low angles, whether natural or due to modification. The existence of two separate tool categories is supported by the strong bimodality in the mean spine-plane angles among all the tools.

Defining Reduction Technologies

One of the main problems that has become apparent in the course of this study is in the relevance of the distinction between 'Levallois" and other forms of single-surface core reduction. I have defined and employed the former on the basis of the traditional definition, which refers to single-surface cores that include the (presumably intentional) production of Central flakes (whether as *préferential* or *récurrent* types). I have used the category '*Eclats Débordants*' to refer to particularly distinctive products of another single-surface (Disc?) core approach present in the assemblages examined here, and researchers often make reference to other forms, such as Disc/Centripetal core reduction as well. The discreteness between these strategies is, however, not always that clear. This is particularly so with Levallois and Disc/centripetal core reduction. In terms of respective flake products, the only obvious distinction is with the Central flakes produced in the former. All other products, peripheral or centripetal removals, will often be essentially indistinguishable between the two reduction types (although this also depends strongly on the views of individual researchers, which, in my own experience, can vary significantly). In terms of differentiating between cores a similar problem is apparent. If a central flake was the last removal before the core was discarded then its identification as Levallois (in its classic definition) is straightforward. However, if only peripheral flakes were removed just prior to discard (which occurs in a significant percentage of cases - see Sandgathe 2004 and Van Peer 1992) then distinguishing this core from a Disc core is not always possible. Without a central flake removal Levallois cores and Disc/centripetal cores are often morphologically the same. This must lead one to question the validity of the distinction between Levallois and Disc cores. In an assemblage of single-surface cores in which none had a central flake removed prior to discard, then categorizing this as Disc core reduction seems valid. However, this is not a common occurrence. Assemblages where the majority of the single-surface cores are the straightforward, classic Levallois type are surprisingly rare, although, typically these cores are the ones put forward (illustrated and photographed) as the *exemplar* of the reduction strategy as a whole in that assemblage. It is a classic case of the exception presented as the rule. More typically there is a mixture of cores with and without central flakes removed prior to discard. In such an assemblage, how does one decide whether the ones without central removals should be categorized as Levallois or disc? This is a common situation in the analysis of Middle Palaeolithic assemblages. Traditionally, analysts use the presence, absence, or relative occurrence of Central flakes in the assemblage as an indication of the knapper's reduction intentions, and so ultimately, classification is based on the perceived intentions of the prehistoric knapper, a tenuous approach to classification at best and one that must inevitably be discarded sooner or later. Unfortunately, under the guise of *Chaine Opératoire* analysis, direct access to Palaeolithic knappers' intentions is a claim made by many current researchers.

This conflict between apparent technological categories (i.e., all single-surface core reduction strategies, including classic Levallois vs. prismatic blade core, bipolar core, biface production, etc.) and definitions based on the morphologies of only certain reduction products ('Levallois') is manifest here in that the traditional method for indicating the degree to which the Levallois technique was used at a site (Levallois Indices and Typological Levallois Indices) failed to recognize the degree to which single-surface core reduction, in the broad sense, was employed at the study sites examined here. In light of the patterns observed in the data from these site samples, it seems that the pertinent question at this point in our understanding of these technologies is not '*what are the inherent advantages of the Levallois reduction strategy*', but rather '*what are the inherent advantages of the single-surface core reduction strategy*'. It seems quite apparent from this study that the classic *préferential* Levallois strategy is simply a variant of this more general class of strategies, which would also include *récurrent* Levallois (of unipolar and bipolar forms), Centripetal cores, and Disc cores (which can actually be bifacial and not just single-surface, but which would appear to follow the same general patterns of reduction).

The basic advantage(s) of this general strategy presumably lies in the common theme of preparing a core with two asymmetrical, hierarchical, convex surfaces and exploiting one of these as a surface of debitage and employing the other as a striking platform. The main reasons for the variants may include differing characteristics of their respective products and the size and form of the raw materials available (although in some cases tradition may also play a limited part). This organization of the variability apparent in these different techniques (as opposed to "Levallois verses non-Levallois") provides a much more reasonable view of what was going on at the study sites. At Pech de l'Azé IV (in level F2) a specific type of single-surface core reduction was employed (when raw material size and form permitted) because the resulting endproducts had certain attributes (natural backing and robust, sharp edges) that were desirable at the time. At le Moustier (level G) and Jiboui a more classic form of *préferential* Levallois was employed because it provided products (both the Central and Peripheral flakes) which were sharper, less robust, and had a greater total length of usable edges per flake, and also because it presented a certain degree of raw material economization. At Combe Capelle Bas (level I1D) the dominant reduction strategy was a cruder Centripetal or Disc core reduction. Unlike Pech de l'Azé IV, however, the focus was not on the production of *Eclats Débordants*, but on more typical centripetal flakes. Also at Combe Capelle Bas the larger size of the raw material nodules available in large quantities at the site allowed the manufacture of large numbers of relatively large flakes without necessarily employing more formal core reduction strategies.

However, one of the advantages of single-surface core strategies would appear to be the ease with which the core form and the reduction process can be modified to produce slightly different products, such as *Eclats Débor*dants and centripetal flakes. Given the degree of versatility of single-surface core reduction, such Levallois-like reduction approaches carried out on larger nodules will tend to look more like the classical version of the method. Because these larger nodules have the potential to produce larger products (i.e. flakes with greater potential and value), more effort may be expended to reduce them more carefully and efficiently. This will be particularly so when some raw material economization is warranted. For smaller and more irregular nodules the product potential is much lower and so less effort may be invested, in which case the classic Levallois method may not be employed (or at least may not look like such) and we can expect to see more centripetal flake or *Eclats Débor*dants production as the result.

Of the four study sites, bifaces were only a significant component at le Moustier. The fact that no bifacial reduction flakes have been employed as tools (or at least identified as such) in the le Moustier (or other three assemblages) suggests that Mousterian handaxes were used only as tools themselves, and not as cores as has been suggested for other biface traditions (e.g., Acheulian and Paleoindian -- e.g., Kelly 1988). Furthermore, there were, in fact, very few bifacial reduction flakes recovered from the le Moustier component at all. This strongly supports the interpretation that the bifaces recovered were produced elsewhere and transported here. These tools may then represent highly mobile items (Soressi and Hays 2004), employed as primary tools for between-camp activities because of their versatility, long life span, and the ease with which they can be effectively resharpened. With other Mousterian Industries such toolkit niches were apparently filled by flake blanks (likely Central Levallois flakes) which could be retouched numerous times before being discarded. Quina scrapers may also be examples of this latter strategy. The choice between these two approaches, bifaces vs. several flake blanks, may revolve around degrees of mobility and/or the types of tasks for which the tools will be required, both of which may be factors of differing climatic regimes or seasonality-influenced patterns of behaviour.

Conclusions

The Middle Palaeolithic lifeways model used in this study supports the view that, as has been traditionally held, Neanderthals in Western Europe were likely practicing a very generalized forager adaptation with a strong emphasis on hunted game and meat, although some of the available data indicate possible variations in this that may be reflecting some limited tendencies towards behaviours typically more strongly associated with collectors. The lithic technology employed by these Middle Palaeolithic groups would have been designed to satisfy specific constraints resulting from both the nature of their subsistence practices and settlement patterns, and from the quality and distribution of raw materials across the landscape.

Stone tools would, of course, be designed to fulfill their functional requirements, whether these are primarily cutting meat, processing hides, or manufacturing items from wood. In order to be effective, stone tools may be require to be of a specific size, or have specific requirements in terms of edge length, angle, or shape. However, the design of these tools may also have to satisfy other constraints, such as reduced access to raw materials, the potential need to process greater quantities of task materials, or the need to remain serviceable during extended periods between visits to sources of raw material, in which cases they would need to be designed to be longer-lived.

A second important consideration is that the technology used to produce the stone tools must also satisfy certain constraints. These include the availability of suitable raw materials, the quality of available raw materials, and the size and shape of available raw material nodules. Limited access to raw materials would result in the need to economize their use. Poorer quality raw materials might limit the applications of the tools produced. Smaller, more irregular nodules of raw material may limit the way in which the nodules can be reduced and limit the size and form of the resulting tool blanks.

In this study, the role that these constraints, and several others, played in the design of Middle Palaeolithic lithic reduction technologies were examined, in part, through the analysis of the lithic assemblages recovered from components of four Middle Palaeolithic sites in Southern France. The primary goal was to try to determine the inherent advantages of the Levallois reduction strategy which would result in its being selected, over other potential options, for use in specific conditions. In particular, why was this reduction strategy chosen for use, or not, at the four study sites during the period of occupation represented by the different site components under study?

With respect to the three primary sites, although artifact density and frequency of retouched pieces (re. Riel-Salvatore and Barton 2004), along with high concentrations and variability among faunal remains, suggests that they all represented some form of central residencies, some aspects of the data indicate that there were different tasks dominating in these different occupations. The intentional production of blank types with specific morphological characteristics, like *Eclats Débordants* at Pech de l'Azé IV, and blank selection at other sites weighted towards other morphological characteristics, that are best provided by other single-surface core reduction strategies, suggests that the choice of reduction strategies is also influenced by specific task/functional constraints at different sites.

Thus the choice of a specific reduction strategy at a site is not just a matter of suiting a reduction process to the form of the available raw materials, but it is reconciling the potential reduction strategies, that could be employed with the available nodule forms, with specific functional requirements of the resulting products. Which is the more dominant factor is not obvious from the data available here. However, at Pech de l'Azé IV, for example, the small, irregular form of the locally available raw materials may have precluded use of the classic Levallois reduction approach, but it did not affect the potential application of a centripetal reduction approach that would have produced typical centripetal flakes (thin, less robust flakes with very low edge-angles). However, the knappers chose to focus on a single-surface core strategy that produced the more robust *Eclats Débor*dants. At le Moustier, however, the focus was on the production and selection of larger, thinner, sharper flakes. These differences in blank choice might reflect different functional requirements and so suggest that these specific occupations of these sites emphasized different types of tasks, specifically woodworking or butchering and the bimodal edge angle distribution strongly supports the existence of two such general classes of tools. This would not be to suggest that only one or the other, butchering or woodworking, was carried out at any one time at a site, but that, for whatever reasons (specific resources available around a site or the place that that site held within a seasonal round cycle), the tasks carried out were dominated by one or the other (but, of course, likely also included other tasks like hide working/cutting, and plant collection, to lesser degrees).

There are no unambiguous indications in this data that hafting played an *important* role in tool production considerations, although the tendency to select thinner flakes and the occurrence of some bulbar thinning tends to indicate hafting was practiced to some degree. If hafting was practiced on a regular basis it may have typically involved the application of gums or resins which, unlike wooden handles, do not require more standardized blank forms.

Among the other potential constraints on tool blank production, raw material size and shape appear to be two of the most significant. This is most apparent at Pech de l'Azé IV where the most readily available raw material generally occurred in small, irregular nodules. This may have been something that changed over time at this site as there are indications of significant directional changes in reduction strategies employed at the site over its occupation history.

There is some indication that *access* to raw material was, to some extent, a constraint in the choice of reduction strategies at these sites. It is the case that the Levallois component was strongest both at the site with the most immediate access to raw material (Jiboui) and a site where raw material may have come from up to 10 km away (le Moustier). Jiboui, however, is likely a tool provisioning location and the dominance of the Levallois approach here may actually reflect a raw material economization strategy in anticipation of reduced access (once the group left the site), and such economization may also have played a role at le Moustier. Access to, or availability of, raw materials may have some influence over the decision to employ the technique as it produces blanks that, based on quantities of edges per raw material volume, are more raw material efficient.

The greater edge length to weight of all Levallois products and the significantly larger size of the Central flakes would have made these products the most logical choices for use as longer-lived ("curated") tools that would be carried with a group when they moved between major occupation sites. The Peripheral flakes would have been used as well, and were not simply waste flakes. The Levallois strategy would appear to have been an alternative choice to bifaces, which were likely tools designed for similar high mobility circumstances. Bifaces are, however, the more reliable of these two choices and their use may reflect consistently higher mobile adaptations (more residentially mobile groups), while the use of optimal flake blanks as mobile tool kits may reflect an adaptation that involved less frequent residential moves. Alternatively, using optimal flake blanks may reflect increased processing volumes.

Middle Palaeolithic people specifically chose to practice hardhammer reduction in order to produce flakes that were relatively sharp, but were also significantly flat and robust, unlike billet flakes, which are much sharper, but are too fragile and often have significant ventral curvature. Also, hardhammer reduction strategies fit well in highly mobile contexts in that the knapper is not required to make and carry about specialized knapping tools (e.g., wood or antler billets), and can likely count on having access to cobbles suitable for use as hammerstones at almost any location on the landscape.

The Levallois (*sensu strictu*) technique was recognized and used as a method for producing less robust hardhammer flakes (which are otherwise generally quite robust), but it is more easily and effectively applied to larger, more regular shaped raw material nodules. For such nodules the technique is more recognizable as the classic form and will result in more 'classic' Levallois flakes and thus a higher Levallois Index. However, when applied to smaller, more irregular raw material nodules, it tends to take on (or is intentionally modified into) more of a Disc or centripetal core form and can be modified to produce products that are slightly more robust and have greater average edge-angles. This describes the differences observed between Pech de l'Azé IV and le Moustier.

In all four study assemblages some form of single-surface core reduction was the predominant strategy. At Pech de l'Azé IV, this strategy was mainly used to produce *Eclats Débordants*, which would appear to be a task-specific tool form; likely used mainly for woodworking (Beyries and Boëda 1983). At le Moustier, classical preferential Levallois was the dominant reduction strategy, used under conditions of more restricted raw material access. At Combe Capelle Bas, where raw material was available on site, while single-surface core reduction was the most common strategy. However, it was carried out in less structured forms than at the other sites, Amorphous core reduction was quite common, and products recognizably associated with to single-surface reduction were far more rare than at the other sites. At Jiboui, almost 75% of cores were single surface, with both classic preferential and recurrent Levallois making up half of these. Recognizably Levallois products made up a very high proportion of the assemblage here.

These patterns might provide some indication of why we see a mix of reduction strategies within a site or even a single component. This variability could be seen to be the result of several different site-specific factors. At Pech de l'Azé IV, a dominant constraint faced by the knappers was the small size and irregular form of the available nodules. While the focus appears to have been on a type of Disc core reduction and the production of *Eclats Débordants*, raw material constraints may have prevented the effective reduction of some nodules in this manner. Some nodules just did not fracture as the knapper might have preferred. At Combe Capelle Bas there were no raw material restrictions and, while there was some attempt to employ some form(s) of single-surface core reduction, the knappers were not so motivated to follow any particular strategy as strictly as appears to have been the case at le Moustier and Jiboui. At these two sites the knappers seemed to have been more strictly constrained in their reduction behaviour and seemed to have spent more effort in following a specific reduction strategy, mainly *préferéntial* Levallois. We might surmise that at sites such as these, much of what appears to be variability in behavioural is actually the result of variability in individual reduction events; from variability in the quality, size and form of individual nodules to random knapping mistakes which result in flake products and cores which deviate from the typical. As the importance of technological constraints increases, more effort would be directed towards carrying out specific reduction strategies successfully and achieving the advantages that each one presented, and the resulting flakes and cores would tend to deviate less from some norm. This source of variability might explain much of that seen in the le Moustier assemblage. While constraints in raw material access and, perhaps, functional requirements at this site resulted in Levallois reduction being a logical choice, perhaps the constraints were not particularly heavy allowing some relaxation in the efforts put into the reduction process.

While the specific form in which this strategy was employed at each site seems to be tied to both functional (task-specific) constraints (especially at le Moustier and Pech de l'Azé IV) and site-specific raw material constraints (especially at Combe Capelle Bas), the choice to use the general single-surface reduction strategy would appear to be the most important behaviour to be addressed here. While the classic Levallois approach might produce a limited number of flakes of above average size, and these may present significant advantages under certain conditions (high processing volumes associated with butchering activities and restricted access to raw materials requiring longer-lived tools), Levallois products as a whole (Central and Peripheral flakes) present a notable advantage in the total length of usable edge that can be produced relative to raw material volumes (length of usable edge per gram: Amorphous Core products = 2.85; *Eclats Débordants* = 4.40; Central Levallois flakes – 5.70; and Peripheral Levallois products = 5.30 -- see Table 9.12), and retouch and usewear show that these were used. However, this reduction approach tends to require significantly more care and skill to carry out effectively. Therefore, unless specific task constraints or constraints on raw material availability dictate, the advantages presented by classic Levallois might not be that attractive. Amorphous core reduction tends to produce a range of products that, while generally smaller than Central Levallois flakes, have a greater mean size than Levallois products collectively (see Table 9.20). Furthermore, other reduction approaches, like *Eclats Débordants* production, can be effectively applied to smaller, more irregular nodules and still produce, with significant consistency, quasi-standardized blanks, which, based on their form are particularly suitable for certain tasks.

There are some obvious correlations here between the characteristics specific to the products of the different approaches used at the sites and blank selection criteria followed at the sites. However, the use of some form of single-surface core reduction at all the sites suggest that there is a common, underlying advantage of such strategies. Rather than just the potential to produce a variety of products (e.g., classic Central flakes, Peripheral flakes, *Eclats Débordants)*, this advantage revolves around how it exploits the flake-production potential of a nodule of raw material. I would suggest that classic, *préferential* Levallois reduction, as with all single-surface core reduction strategies, in large part represents the formation and exploitation of the largest reduction surface possible in a subspherical nodule, and so allows the maximization of size of all (or most) of the flakes produced and the amount of usable cutting edge per quantity of raw material reduced. Such strategies represent the most efficient manner to maximize flake size, relative to the size of the core, and reduce the degree of potential variability using just hardhammer reduction. Classic Levallois Central flake production presents the further advantage of reduced robusticity, sharper edges, and an even increased advantage quantity of usable edges per raw material volume. Logically, this strategy is best suited for circumstances mobility.

Thus, while *Hypotheses #2* (that is, different forms of single-surface core reduction may provide task-specific products) may best explain the advantages of individual forms of single-surface core reduction, and some products (particularly Central Levallois flakes) represent more maintainable tools (*Hypothesis #3*), single-surface core approaches as a whole represent a strategy that can be modified to deal with the specific, circumstantial constraints encountered at different times and places because, in part, they more effectively exploit a volume of raw material, which may reflect a response in line with advantages in raw material economization (as proposed in *Hypothesis #4*).

Appendix A

<u>Photographic Plates</u>

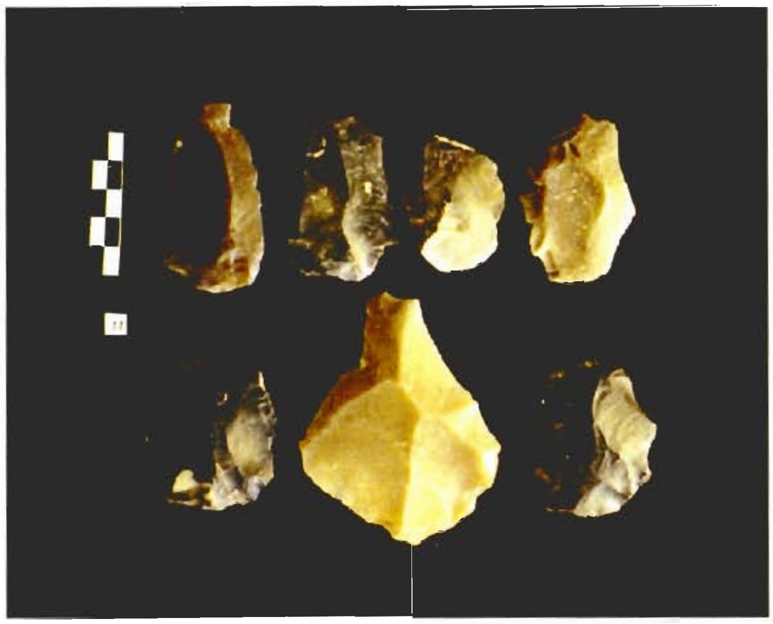

Plate 1 Examples of Central Levallois flakes (le Moustier, level G).
(photographer D. Sandgathe)

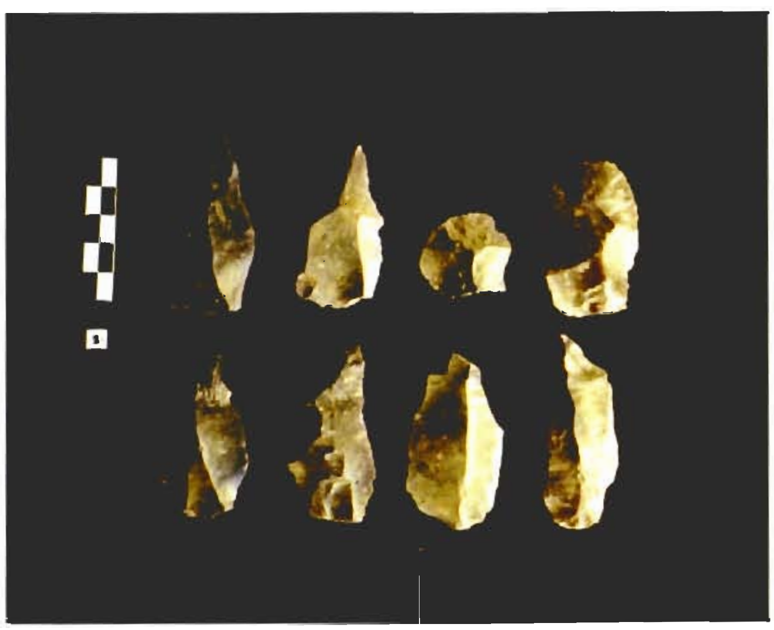

Plate 2 Examples of Central Levallois flakes (le Moustier, level G).
(photographer D. Sandgathe)

Plate 3 Examples of Central Levallois flakes (Combe Capelle Bas, level I1D).
(photo courtesy le Musée National de Préhistoire des Eyzies, France – photographer Phillip Jugie)

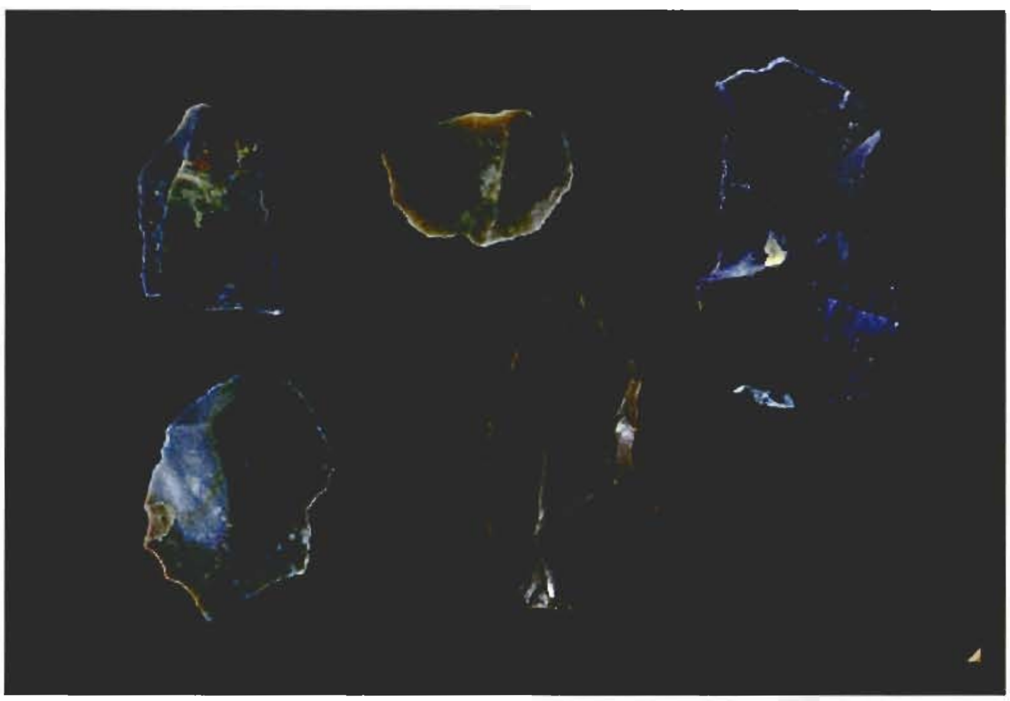

Plate 4 Examples of Central Levallois flakes (Combe Capelle Bas, level I1D).
(photo courtesy le Musée National de Préhistoire des Eyzies, France – photographer Phillip Jugie)

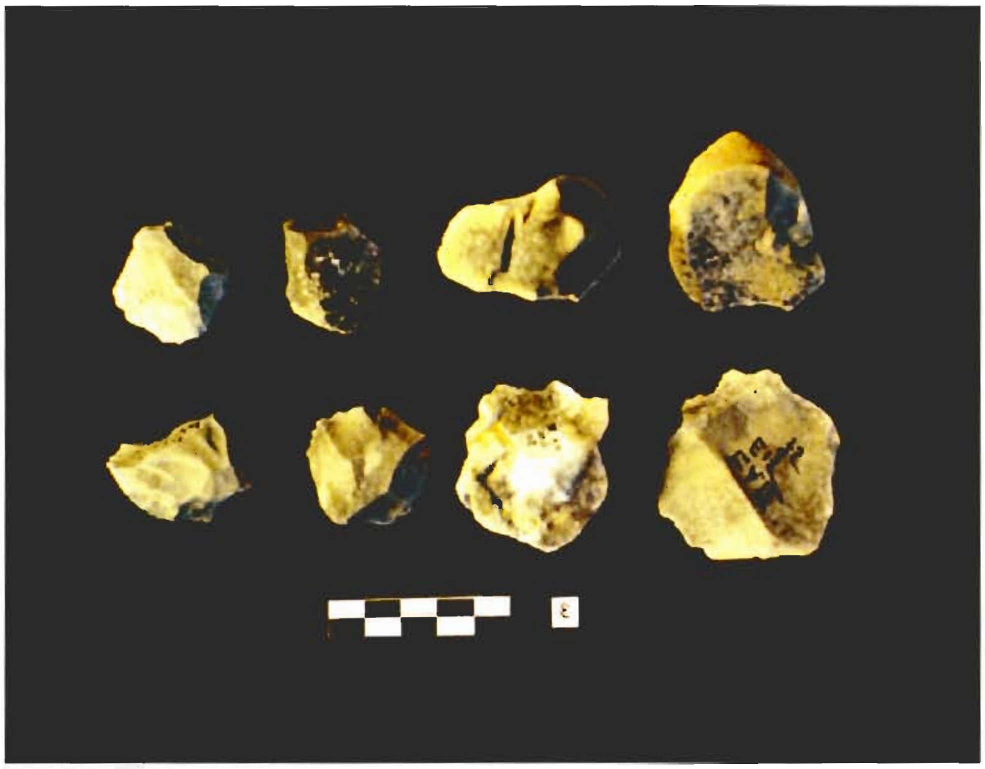

Plate 5 Examples of various small cores typical of Pech de l'Azé IV, Level F3.
(photographer D. Sandgathe)

Plate 6 Examples of various small cores typical of Pech de l'Azé IV, Level F3.
(photographer D. Sandgathe)

Plate 7 Examples of a single-surface core (le Moustier, level G).
(photographer D. Sandgathe)

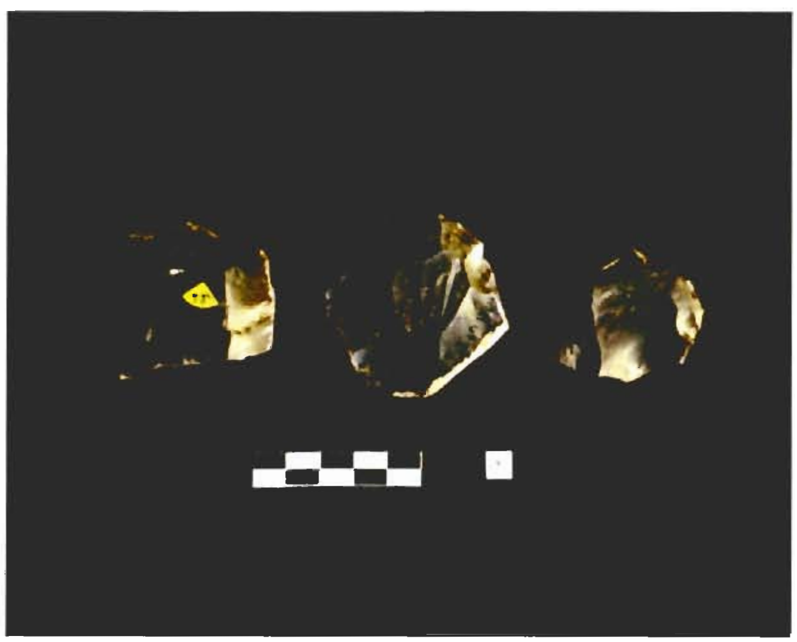

Plate 8 Examples of single-surface cores from which éclats débordants were produced (le Moustier, level G).
(photographer D. Sandgathe)

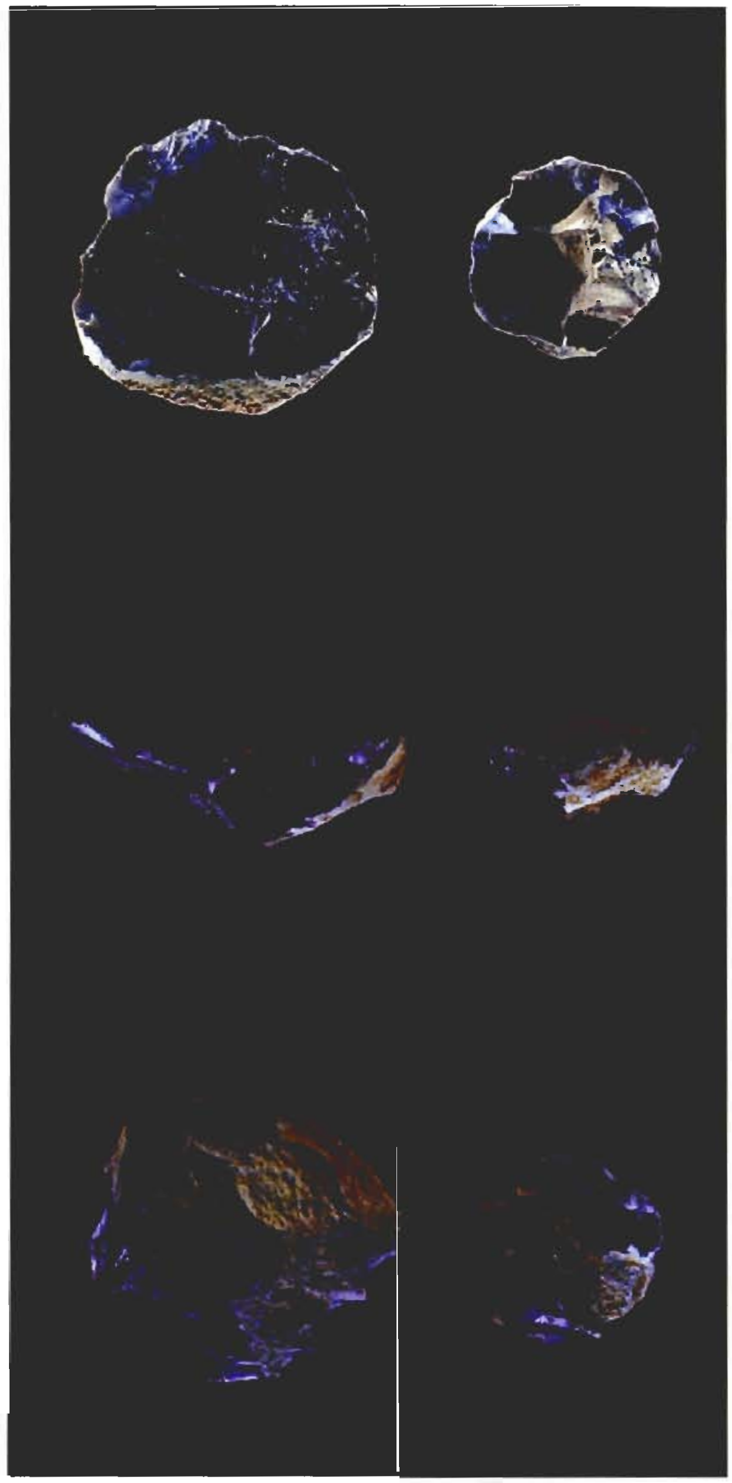

Plate 9 Three views of two single-surface cores (Combe Capelle Bas, level I1D).

(photo courtesy le Musée National de Préhistoire des Eyzies, France – photographer Phillip Jugie)

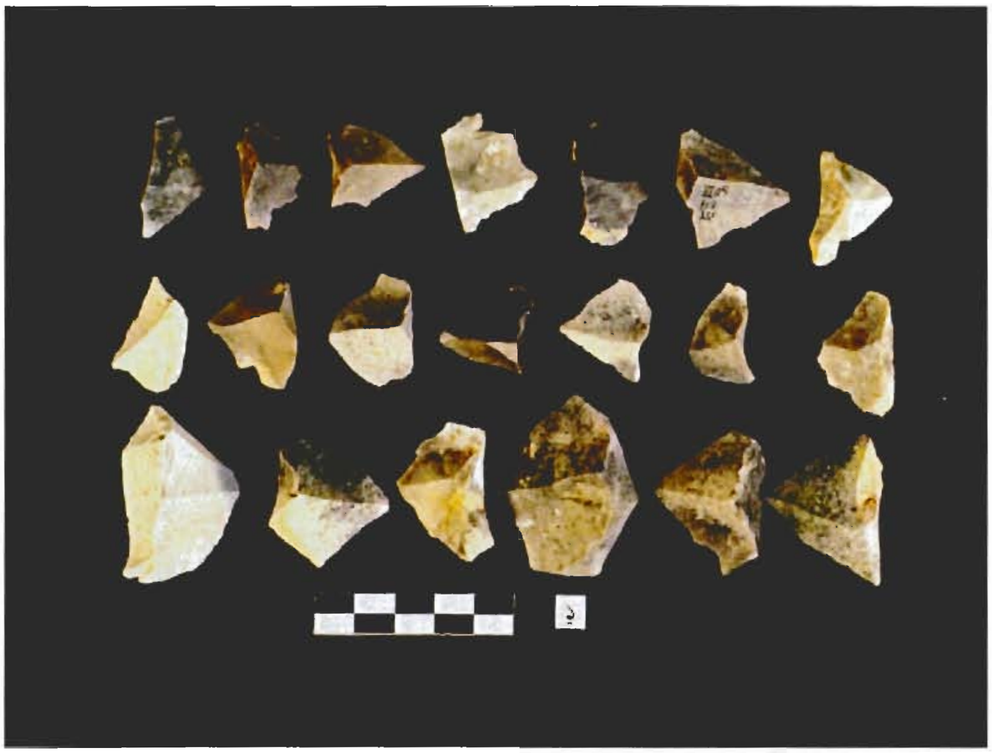

Plate 10 Examples of éclats débordants (Pech de l'Azé IV, level F3).
(photographer D. Sandgathe)

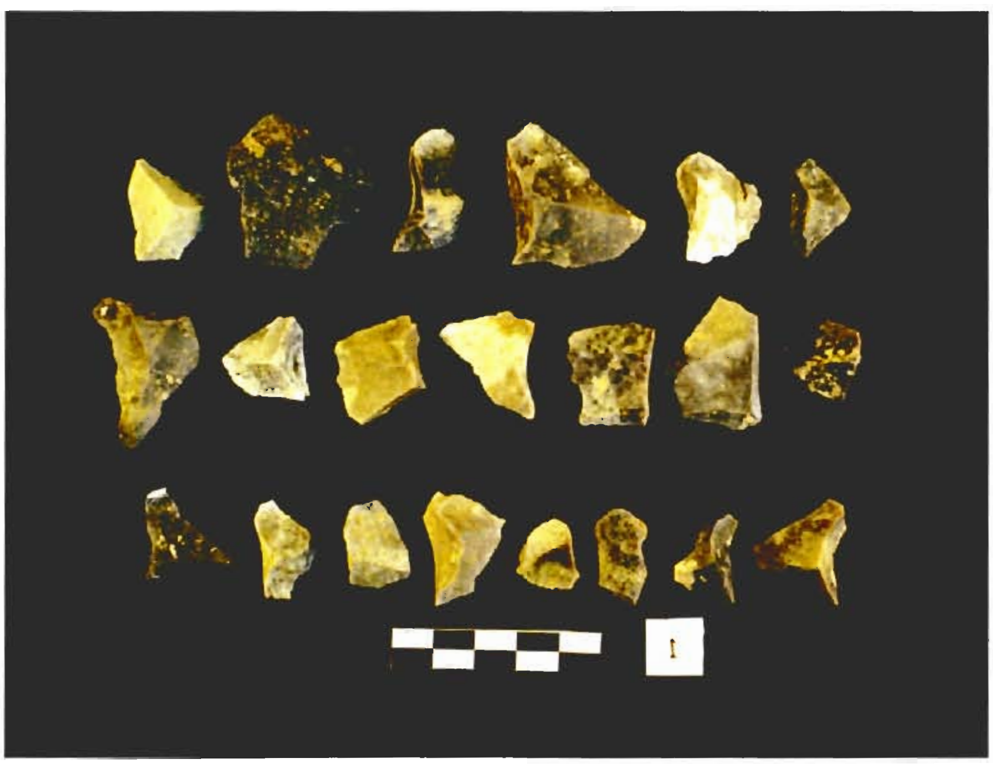

Plate 11 Examples of éclats débordants (Pech de l'Azé IV, level F3).
(photographer D. Sandgathe)

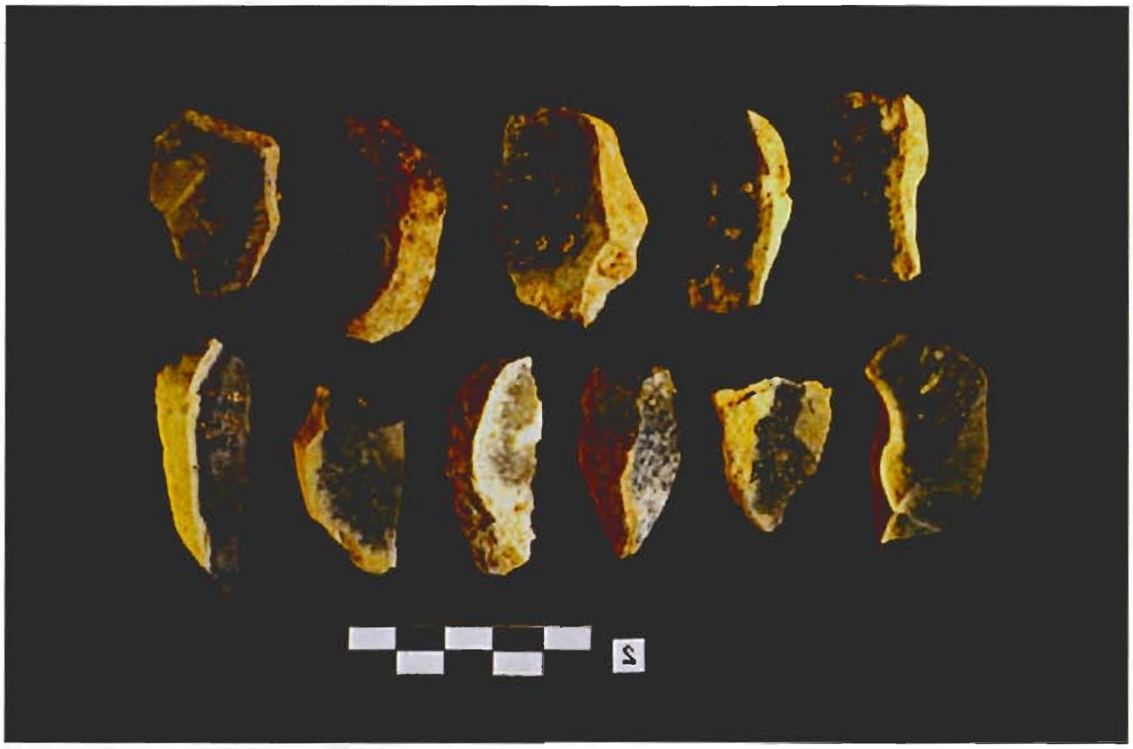

Plate 12 Examples of naturally-backed flakes (Pech de l'Azé IV, level F3).
(photographer D. Sandgathe)

Plate 13 Example of Levallois point that has had a flake removed from the bulb (Pech de l'Azé IV, level F3).
(photographer D. Sandgathe)

Plate 14 Example of scraper (retouched around almost all margins) that has had a flake removed from the bulb (Pech de l'Azé IV, level F3).
(photographer D. Sandgathe)

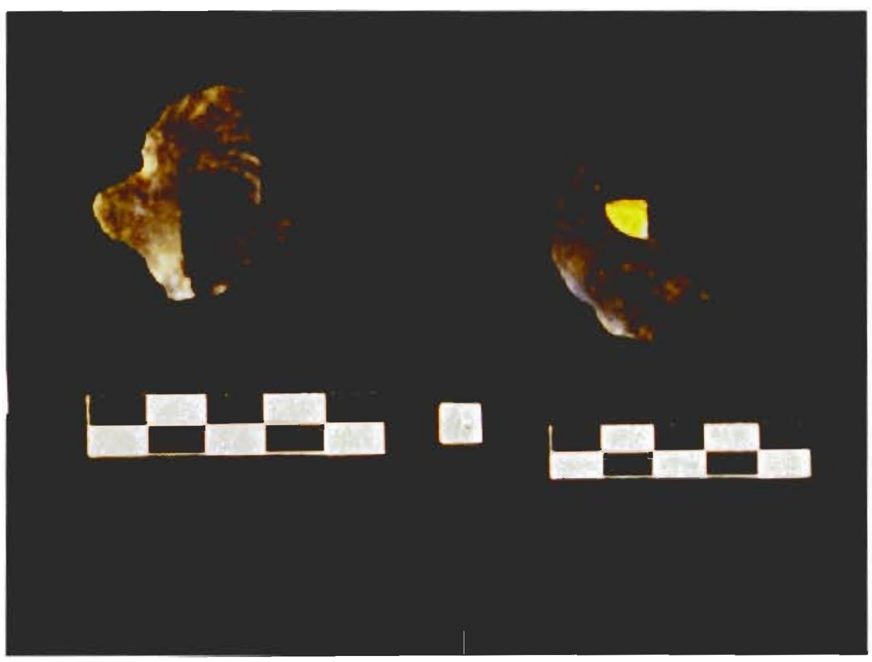

Plate 15 Example of scraper (retouched around almost all margins) that has had a flake removed from the bulb (Pech de l'Azé IV, level F3).

(photographer D. Sandgathe)

Plate 16 Example of macroscopic usewear (edge polish) along flake margin (Combe Capelle Bas, level I1D - @ 10X magnification).
(photo courtesy le Musée National de Préhistoire des Eyzies, France – photographer Phillip Jugie)

Plate 17 Example of macroscopic usewear (contiguous, patterned microchipping) along flake margin (Combe Capelle Bas, level I1D - @ 10X magnification).
(photo courtesy le Musée National de Préhistoire des Eyzies, France – photographer Phillip Jugie)

Plate 18 Example of macroscopic usewear (contiguous, patterned microchipping) along flake margin (Combe Capelle Bas, level I1D - @ 10X magnification).
(photo courtesy le Musée National de Préhistoire des Eyzies, France – photographer Phillip Jugie)

Plate 19 Example of macroscopic usewear (contiguous, patterned microchipping) along flake margin (Combe Capelle Bas, level I1D - @ 10X magnification).
(photo courtesy le Musée National de Préhistoire des Eyzies, France – photographer Phillip Jugie)

Appendix B

Statistical Tables

The Chi-Square Distribution

Confidence	50%	80%	90%	95%	98%	99%	99.9%
	0.5	0.8	0.9	0.95	0.98	0.99	0.999
Significance	50%	20%	10%	5%	2%	1%	0.1%
	0.5	0.2	0.1	0.05	0.02	0.01	0.001
Degrees of Freedom							
1	.455	1.64	2.71	3.84	5.41	6.64	10.83
2	1.39	3.22	4.61	5.99	7.82	9.21	13.82
3	2.37	4.64	6.25	7.82	9.84	11.34	16.27
4	3.36	5.99	7.78	9.49	11.67	13.28	18.47
5	4.35	7.29	9.24	11.07	13.39	15.09	20.52
6	5.35	8.56	10.65	12.59	15.03	16.81	22.46
7	6.35	9.80	12.02	14.07	16.62	18.48	24.32
8	7.34	11.03	13.36	15.51	18.17	20.09	26.13
9	8.34	12.24	14.68	16.92	19.68	21.67	27.88
10	9.34	13.44	15.99	18.31	21.16	23.21	29.59
11	10.34	14.63	17.28	19.68	22.62	24.73	31.26
12	11.34	15.81	18.55	21.03	24.05	26.22	32.91
13	12.34	16.99	19.81	22.36	25.47	27.69	34.53
14	13.34	18.15	21.06	23.69	26.87	29.14	36.12
15	14.34	19.31	22.31	25.00	28.26	30.58	37.70
16	15.34	20.47	23.54	26.30	29.63	32.00	39.25
17	16.34	21.62	24.77	27.59	31.00	33.41	40.79
18	17.34	22.76	25.99	28.87	32.35	34.81	42.31
19	18.34	23.90	27.20	30.14	33.69	36.19	43.82
20	19.34	25.04	28.41	31.41	35.02	37.57	45.32
21	20.34	26.17	29.62	32.67	36.34	38.93	46.80
22	21.34	27.30	30.81	33.92	37.66	40.29	48.27
23	22.34	28.43	32.01	35.17	38.97	41.64	49.73
24	23.34	29.55	33.20	36.42	40.27	42.98	51.18
25	24.34	30.68	34.38	37.65	41.57	44.31	52.62
26	25.34	31.80	35.56	38.89	42.86	45.64	54.05
27	26.34	32.91	36.74	40.11	44.14	46.96	55.48
28	27.34	34.03	37.92	41.34	45.42	48.28	56.89
29	28.34	35.14	39.09	42.56	46.69	49.59	58.30
30	29.34	36.25	40.26	43.77	47.96	50.89	59.70

Student's *t* Distribution

Confidence	50% 0.5	80% 0.8	90% 0.9	95% 0.95	98% 0.98	99% 0.99	99.5% 0.995	99.9% 0.999
Significance	50% 0.5	20% 0.2	10% 0.1	5% 0.05	2% 0.02	1% 0.01	0.5% 0.005	0.1% 0.001
Degrees of Freedom								
1	1.00	3.08	6.31	12.71	31.82	63.64	127.32	636.62
2	0.82	1.89	2.92	4.30	6.97	9.93	14.09	31.60
3	0.77	1.64	2.35	3.18	4.54	5.84	7.45	12.92
4	0.74	1.53	2.13	2.78	3.75	4.60	5.60	8.61
5	0.73	1.48	2.02	2.57	3.37	4.03	4.77	6.87
6	0.72	1.44	1.94	2.45	3.14	3.71	4.32	5.96
7	0.71	1.42	1.90	2.37	3.00	3.50	4.02	5.41
8	0.70	1.40	1.86	2.31	2.90	3.36	3.83	5.04
9	0.70	1.38	1.83	2.26	2.82	3.25	3.69	4.78
10	0.70	1.37	1.81	2.23	2.76	3.17	3.58	4.54
11	0.70	1.36	1.80	2.20	2.72	3.11	3.50	4.44
12	0.69	1.36	1.78	2.18	2.68	3.06	3.43	4.32
13	0.69	1.35	1.77	2.16	2.65	3.01	3.37	4.22
14	0.69	1.35	1.76	2.15	2.62	2.98	3.33	4.14
15	0.69	1.34	1.75	2.13	2.60	2.95	3.29	4.07
16	0.69	1.34	1.75	2.12	2.58	2.92	3.25	4.02
17	0.69	1.33	1.74	2.11	2.57	2.90	3.22	3.97
18	0.69	1.33	1.73	2.10	2.55	2.88	3.20	3.92
19	0.69	1.33	1.73	2.09	2.54	2.86	3.17	3.88
20	0.69	1.33	1.73	2.09	2.53	2.85	3.15	3.85
21	0.69	1.32	1.72	2.08	2.52	2.83	3.14	3.82
22	0.69	1.32	1.72	2.07	2.51	2.82	3.12	3.79
23	0.69	1.32	1.71	2.07	2.50	2.81	3.10	3.77
24	0.69	1.32	1.71	2.06	2.49	2.80	3.09	3.75
25	0.68	1.32	1.71	2.06	2.49	2.79	3.08	3.73
30	0.68	1.31	1.70	2.04	2.46	2.75	3.03	3.65
40	0.68	1.30	1.68	2.02	2.42	2.70	2.97	3.55
60	0.68	1.30	1.67	2.00	2.39	2.66	2.92	3.46
120	0.68	1.30	1.66	1.98	2.36	2.62	2.86	3.37
∞	0.67	1.30	1.65	1.96	2.33	2.58	2.81	3.29

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