Cambridge Archaeological Journal 11:2 (2001), 165–84

Interview with a Neanderthal: an Experimental Approach for Reconstructing Scraper Production Rules, and their Implications for Imposed Form in Middle Palaeolithic Tools

Michael S. Bisson

This article investigates the degree and nature of 'imposed form' in Middle Palaeolithic scrapers, the most common category of stone tool produced by Neanderthals. Novice flintknappers unfamiliar with Middle Palaeolithic tool forms were found to consistently employ two rules in manufacturing scrapers: the striking platform and any adjacent blunt edges were left intact to facilitate prehension, and the longest edge with the most acute spine-plane angle was retouched. Scrapers from three major Middle Palaeolithic sites adhered to these rules in over 90 per cent of cases, but significant divergence from these rules was found in a sample from Skhūl cave (Israel) level B1, associated with early anatomically modern Homo sapiens*. It is concluded that Middle Palaeolithic scraper manufacture was structured by the need to create a suitable working edge, and to locate that edge to maximize ease and comfort during manufacture and use. The overall shape of the resulting tools was thus not an expression of 'imposed form' in the conventional sense. The discovery of violations of these rules in the Skhūl B1 collection provides evidence of increased use of imposed form, as well as potentially significant behavioural differences between early anatomically modern* Homo sapiens *and contemporary Neanderthals.*

The relationship of Neanderthals to anatomically modern *Homo sapiens* continues to be one of the most active debates in palaeoanthropology (Stringer & Gamble 1993; Trinkaus & Shipman 1993; Mellars 1989; 1996; 1999; Wolpoff & Caspari 1997; d'Errico *et al.* 1998; Zilhão & d'Errico 1999). Disagreements not only exist over the evolutionary relationships of these two hominid sub-species, but also over the relative capabilities of their technologies, and their food and raw material procurement strategies. In addition, many scholars doubt the presence of complex language, personal adornment, ritual, and other evidence of symbolic behaviour among Neanderthals. Inherent in these debates is our assessment of the nature of Neanderthal cognition and the Neanderthal mind. Were they capable of the same mental processes and level of mental flexibility as are modern *Homo sapiens*? The majority opinion today is that they were not (Mithen 1996; Kuhn & Stiner 1998). Although there is no question of their successful adaptation to the rigorous environment of Pleistocene western Eurasia, with few exceptions (most notably Wolpoff & Caspari 1997, and d'Errico *et al.* 1998) Neanderthals are viewed as biologically and culturally inferior to the anatomically modern people that succeeded them.

Understanding the mental capabilities of early hominids is a particularly challenging task, since the luxury of direct observation is not available. In the early years of palaeoanthropology, this problem was resolved through assumptions conditioned by prevailing national and anthropological ideologies (Brace 1964; Hammond 1982). Reliance on assumption continued throughout most of the twentieth century for one simple reason: the archaeological record for the Middle Palaeolithic assemblages produced by Neanderthals is cryptic, containing little obvious evidence of complex cognition comparable to the more familiar look of the Upper Palaeolithic. This is particularly true of stone tools.

Stone tools are the most common and durable evidence of Middle Palaeolithic behaviour, but are also among the most enigmatic. They are, obviously, technological artefacts, produced by a set of mechanical processes beginning with raw material acquisition followed by its transformation into blanks and retouched implements, which may be discarded as-is, or undergo one or more episodes of rejuvenation. At the same time, we can safely presume that their production was deliberate and goal-directed in the sense that their makers created them to perform one or more tasks. Yet beyond these basic points, Middle Palaeolithic stone tools do not lend themselves to easy interpretation. No strong links can be drawn between form and function (Beyries 1987; Mellars 1996), at least when the Bordesian typology is used to describe form (Bisson 2000), and there is a broad consensus that 'style', when defined as patterning of choices between functionally equal alternatives, is not present in Middle Palaeolithic flake tool forms (Dibble 1987 and elsewhere; Mellars 1996).

These fundamental differences have led palaeoanthropologists to approach Middle Palaeolithic assemblages in three different ways. The first was chronotypological, where individual types or type frequencies were used to define cultures and culture chronologies (Bordes & Bourgon 1951; Bordes 1953). Although these taxonomies remain in place, this is no longer a primary research focus. The second is forensic analysis of use-wear and residues to determine function (Semenov 1964; Beyries 1987; Hardy 1999; Hardy & Kay 1999). This remains a promising line of research, but its labour-intensive nature combined with the problems of chemical and mechanical post-depositional surface modification, which are often intensified by the cryo-turbated nature of many Pleistocene sediments, have limited its applicability (Levi-Sala 1986). Most recently, the *chaîne opératoire* approach developed in France has been widely employed to both describe and understand the full range of behaviours affecting an artefact from raw material acquisition through to discard. This often includes an analysis and reconstruction of the artisans' technical knowledge and the 'concepts' of tool production (Pelegrin *et al.* 1988). Both of these more recent research orientations have proved dynamic and productive, whereas formal analysis has stagnated (see Bisson 2000 for an extended discussion of this topic). This article explores a novel way in which a non-traditional type of formal analysis, combined with a *chaîne opératoire* orientation that seeks to identify the behavioural patterns that underlay the production of a particular class of Middle Palaeolithic tools, may provide insights into the nature of the Neanderthal mind.

The *chaîne opératoire* method requires an understanding of the sequence of actions that form the 'behavioural chain' (Schiffer 1976), yet archaeologists cannot directly observe the behaviours that produced a lithic assemblage. Our data consist of formal, spatial and temporal attributes from which behaviour must be inferred. In this context, the key question is how, and to what extent, are the workings of the Neanderthal mind reflected in the forms of their lithic artefacts, and does this differ from the patterns produced by anatomically modern *Homo sapiens*?

Although formal analysis has a long history in palaeoanthropology, it has until recently been primarily concerned with the description and classification of artefacts. The assumptions that underlay classifications up to the 1960s were that even the most primitive tool forms were deliberate products reflecting real cognitive categories on the part of the makers. The most influential expression of this view *vis-à-vis* the Lower and Middle Palaeolithic was Bordesian typology and assemblage systematics (Bordes 1953; 1961), and even those who initially rejected Bordes' interpretations of inter-assemblage variability (Binford & Binford 1966; Binford 1973) implicitly accepted his belief that Middle Palaeolithic tool types were material expressions of mental templates (Dibble 1987; 1995a; Dibble & Rolland 1992; Clark 1993), exhibiting what has been referred to as 'imposed form' (Mellars 1989). The notion of imposed form assumes deliberate creation of a specific shape. In the archaeological record, that shape must occur frequently enough to be identifiable as a real behavioural pattern rather than a random combination of attributes. Imposed form is unambiguously present in the European Upper Palaeolithic, and is one reason why 'index fossil' tool types have been successfully used in culture-chronological systematics (but for a critique of this view see Clark 1997).

Middle (and Lower) Palaeolithic tools are generally considered to be different from those in the Upper Palaeolithic in some important respects. As has been frequently noted, Middle Palaeolithic artefacts are remarkably similar across space and over time, with little or no change in designs (Binford 1973; Jelinek 1976; 1988; Clark 1982; Mellars 1989; 1996; Dibble & Rolland 1992; Dibble 1991; Kuhn 1995). Kuhn & Stiner (1998) argue that this is because Middle Palaeolithic tools were made for generalized tasks such as working other materials and simple processing of foods that did not require standardized design or promote much change in tool forms over time. Subsistence technology was significantly simpler than that of later periods, and combined with the tendency of traits subject to functional constraints to be highly conservative, it is not surprising that this basic technology appears so uniform. Variability in tool forms does exist, and much of it is attributable to mechanical and raw material constraints acting on blank production technology (Dibble 1985; Kuhn 1992; 1995), and tool life-history, including the number and intensity of re-sharpening episodes (Dibble 1984 and elsewhere). The primary constraint on tool form is, of course, function (Binford 1973). Dibble (1987; 1995a) argues that the mental categories represented by Middle Palaeolithic stone tools are functional rather than formal, and this implies that it is the working edge (what Bordes (1961) called the 'effective part') of the tool that, along with blank production technique (Boëda 1988; Turq 1979; 1992; Dibble & Bar-Yosef 1995) is likely to convey the most behavioural information.

Although the influence on tool form of raw material, technology, function and tool life-history are now generally recognized, disagreement remains on the nature and extent of imposed form in the Middle Palaeolithic. Imposed symmetry and standardization, as exemplified by the shapes of handaxes, may extend back to the Lower Palaeolithic (Gowlett 1984; Wynn 1989), but the effects of raw material, technological and functional constraints on handaxe form are not fully understood. Innovative and promising techniques to investigate the complex determinants of handaxe form are currently under development, but not yet published (Nowell 1999). A complicating factor is that imposed form may not be equally manifested in all tool categories. Mellars (1996, 133–5) argues that it is absent in most tool types, notably the scrapers, but present in others such as handaxes, as well as in blank production strategies. Most of the recent North American authors cited above would attribute less to imposed form, and more to raw material, mechanical, and functional constraints (Dibble & Rolland 1992; Kuhn & Stiner 1998). This debate remains unresolved, in part because the concept of imposed form is incompletely developed. As modern humans, we have specific designs for our artefacts, designs which often carry social information. This tendency toward standardized artefact forms is further exaggerated by the fact that almost all material culture in the developed world is mass-produced. In contrast, Middle Palaeolithic tool forms are thought to have carried no social information (Kuhn & Stiner 1998, 156) and could be, and likely were, produced by any adult or juvenile member of the group, female or male, rather than by occupational specialists. In this simpler technology, raw-material and mechanical constraints, as well as the random flaking accidents inherent in a subtractive manufacturing process, would inject significant 'noise' into tool forms, even if they were intended to correspond to a mental template. Identification of imposed form has therefore proved difficult. To date, most efforts have sought evidence for imposed form in the standardization and symmetry thought to characterize heavily reduced tool categories such as handaxes, as discussed above.

It is with Middle Palaeolithic retouched flake tools that the question of imposed form has been most problematic. 'Points' would be the most likely class to exhibit imposed form, but analyses of Mousterian and retouched Levallois points show that length-width ratios and the degree of lateral convexity, as well as symmetry, are primarily determined by blank form (Mellars 1996), which is in turn dependant on raw-material characteristics and flaking technology. What Mousterian points do not exhibit is the formal homogeneity that characterizes Upper Palaeolithic and Neolithic projectiles. Indeed, the seeming uniformity of Mousterian points can be entirely explained by the characteristics of the blank forms produced by the prevailing traditional technology (i.e. either Levallois or non-Levallois), and the functional requirements of a suitable tip for piercing combined with a base-shape appropriate for hafting. This does not imply that conscious intent is not present in point production. It had to have been if they were intended for a particular task. Pointed and elongated flakes were consistently selected for blanks (Boëda 1988). These, however, were subject to the minimal retouch necessary to achieve the desired functional ends rather than being shaped to more rigid production standards.[1] The shapes of other diagnostic Middle Palaeolithic types such as backed knives were also strongly dependent on flake blank form (Monnier 1992; Mellars 1996), with appropriately shaped blanks again being selected for conversion to tools.

Typological scrapers, flakes with one or more edges regularized (as opposed to notched or denticulated) by continuous, usually unifacial, retouch, were among the first Palaeolithic tools recognized by Boucher de Perthes (1847). From the time of de Mortillet (1883), they have been considered diagnostic of the Middle Palaeolithic because they are often the most frequent retouched pieces found in those assemblages. Scrapers therefore exert a strong influence on statistical comparisons of those collections (Dibble 1988). Although they are among the simplest of stone tools, one and a half centuries of research has failed to resolve the debate over their classification or the determinants of their variability. The starting point in any discussion on scrapers must be the *Typologie du Paléolithique ancien et moyen* by François Bordes (1961), which brought order to the analysis of Middle Palaeolithic stone tools. Bordes recognized 23 specific types of scrapers (including the 'limace') based on combinations of the type of retouch, the number of retouched edges, their form and position relative to each other and/or to the major technological landmarks of the blank; the striking platform, interior and exterior surfaces, and axis of flaking. Although Bordes' typology is almost universally employed today, it is not the only one that has been proposed. For example, Laplace (1964; 1968) advocated an 'analytical typology' based on blank form. Including names that have persisted in the literature from earlier classifications, approximately 60 scraper type names are currently found in the European literature (Brézillon 1968).

Certain assumptions about the nature and causes of variability are implicit in the established scraper typology. There is universal agreement that the need to create an edge at least minimally suitable for the intended use of the tool exerted a strong influence over scraper form (Bordes 1961; Mellars 1964; 1996; Dibble 1987; 1995a). Beyond that basic functional constraint, three additional factors have been invoked. Bordes' *Typologie* (1961) assumed types to reflect mental templates, forms imposed on blanks (including the selection of appropriately shaped blanks as a starting point) to match concepts in the minds of the tool makers. This assumption has been widely criticized in the past two decades.

As early as 1964, Mellars argued that the shape of the retouched edge was the most important attribute in understanding scraper variability, and that the overall shape of the tool was 'of little importance' (p. 231). In a similar interpretation, Dibble (1987; 1991) proposed that the mental categories represented by Middle Palaeolithic stone tools are functional rather than formal, and that in the case of scrapers, morphological variability is continuous rather than nodal, suggesting that imposed form creating discrete scraper types was not present. Scraper variability was instead attributed to a continuum of reduction of the original flake blank as the edge was used and rejuvenated, and further influenced by the availability and flaking characteristics of the lithic raw material (Dibble & Rolland 1992). An alternative model (Kuhn 1991; 1992; 1995) stating that the initial form of the blank was the primary determinant of scraper morphology also implied that imposed form was not present. It is now generally recognized that both reduction history and blank form are significant variables which are subject to complex interactions dependant upon the particular circumstances of each site (Dibble 1995a; Kuhn & Stiner 1998).

Defining imposed form on scrapers

The prevailing view that Middle Palaeolithic scrapers lack imposed form does not take into account what is perhaps the most important question: how would imposed form be manifested on such simple tools, and how can it be identified? It could, after all, be argued that imposed form is inherent in simple tools, and is only manifested in more complex types. For example, current definitions of imposed form appear to exclude these tools because they often lack extensive retouch.

> The suggestion, in essence, is that the majority (though by no means all) Upper Palaeolithic tools appear to reflect a much more obvious attempt to modify the shapes of the flakes or blade blanks in order to achieve some specific, sharply defined form. In other words, shaping of the tools usually involves removal of large areas of the original flake or blade blanks, so that the final form of the tool bears little if any direct relationship to the shape of the blank chosen. (Mellars 1996, 347)

Yet imposed form could potentially be present if, as Bordes assumed, hominids deliberately chose to position retouch in an arbitrary manner relative to flake landmarks. This type of patterning could therefore be imposed on tools without removal of large areas of the original blank, as is the case in Upper Palaeolithic end scrapers, where the retouched edge is positioned on the end of the blank and always intersects the axis of flaking at an angle of 90°. In order to identify imposed form, we must first determine the patterning, if any, that governed the manufacture of Middle Palaeolithic scrapers, what might be called their 'production rules'. In spite of the voluminous literature on Middle Palaeolithic lithic technology, the production rules of scrapers have received remarkably little attention when compared to the detailed reconstructions of decision-making processes found in *chaîne opératoire*-oriented studies of blank production (Boëda 1988; Turq 1979; 1992; Dibble & Bar-Yosef 1995), and in the process of edge rejuvenation (Dibble 1984 and elsewhere). This may have been the result of the assumption inherent in Bordes' typology that the retouched tool types were natural categories, but whatever the cause, little thought has been given to the interpretive potential of determining the initial decisions that were made in converting a flake into a scraper. It is only after we develop a comprehensive understanding of the determinants of scraper form that we can begin to unravel the complex meaning of both intra- and inter-assemblage variability identified by typological studies. In one sense, the question is not whether imposed form exists in the Middle Palaeolithic, but rather at what level — the edge or the tool — it operates and according to what rules was it applied? If it is found that the Mousterian scraper forms defined in the Bordesian typology are spontaneously generated by the contingencies of functional requirements, the mechanical properties of flaked stone, and the morphology of the blanks employed, then it can be argued that imposed form as defined by Mellars (1996) is not a characteristic of these typological categories. In consequence, analytical systems would need to be modified to accommodate these differences between Middle and Upper Palaeolithic technologies.

These questions have not been entirely ignored by previous research. It has long been recognized that retouch was usually situated on one of the longest flake edges (Bordes 1961). Mellars (1964; 1996) contends that this was done to maximize the length of the working edge, and to impose a regular, smooth form on that edge. In the most comprehensive discussion to date, Dibble notes that large (relative to other flakes in an assemblage) blanks were preferentially selected for scraper manufacture, and that two criteria influenced which edge was the first to be retouched. The most important was that retouch avoided steep or cortical edges because they are more difficult to flake. Other factors being equal, however, the longest edge will normally be retouched first, and its position relative to the standard flake landmarks (and thus its type in the Bordesian system) will be dependent on blank form, which is in turn dependent on blank production technology. These criteria continued to operate during rejuvenation, so that when a retouched edge became too steep, a second edge might be retouched, creating a double scraper which if further reduced, would become a convergent form (1991, 248–50). Another important factor is prehension. Turq (1979; 1992) is one of the few to attribute the specific positioning of retouch to accommodate the demands of manual prehension.

In order to test the relative importance of these influences, and to discover if any other factors affected the choice of which edge or edges were retouched, and in what order, a novel program of experimental replication followed by the analysis of actual prehistoric specimens was undertaken. The goal was to discover if there were specific rules that governed Middle Palaeolithic scraper manufacture, and if so, how these rules affected the formal characteristics of these tools.

Interviewing Neanderthals

Reflecting on my own experience in 30 years of replicating Middle Palaeolithic tools for pedagogical purposes, I realized that whenever I wanted to create one of Bordes' types, I would select an appropriately shaped blank if one were available. Thus the working hypothesis of this research is that blank form is the initial determinant of scraper form. The primary test implication of this hypothesis is that a strong correlation will exist between blank morphology and the position of the initial episode of retouch. The use of myself or other experienced flint-knappers to test this hypothesis experimentally was unsuitable because of the possibility that they would be unduly influenced by prior knowledge of the Bordes *Typologie*, and the relationships being investigated. What was needed was a set of experimental subjects who were unfamiliar with and thus not influenced by the Bordesian typological categories, and who had not internalized any particular lithic typological tradition that might provide an *a priori* structure for the shapes of tools they created. This latter point was critical. The goal of the experiment was to investigate the decision-making processes used to create simple flake tools in the absence of a cultural tradition that dictated overall shapes or the positioning of the retouch relative to flake landmarks such as the axis of flaking. In other words, we were attempting to create a situation in which imposed form was not inherently present. The subjects chosen were 12 university undergraduates with no prior knowledge of or experience in flint-knapping.

It could be argued that modern humans, with their propensity to name and categorize objects, can never adequately serve as analogues for Neanderthal behaviour if the latter did in fact differ significantly in their cognitive abilities. Although that is certainly true when behaviour is viewed as a whole, the partitioning of behaviour into a set of mechanical actions, divorced as much as is possible from an overriding cultural context, comes as close as we can to creating a situation analogous to the production of tools in a technological tradition where the final form of a tool is not dictated by a mental template. This was a primary concern in the methodology of the experiments, and the way the novices were allowed to train themselves in basic flake removal techniques. University undergraduates are clearly not Neanderthals, but under carefully controlled conditions, and in the absence of cultural constructs to structure their tool-making behaviour, they may perform some actions in the same way.

The experiments involved two sessions, with the first devoted to training. The subjects were shown flakes and cores, and taught to recognize the basics of flake morphology. These included the exterior and interior surfaces, striking platform, bulb of percussion, and how to distinguish a flaked surface from a cortical one. The only element of scraper morphology which they were told was that the flake blank was struck somewhere on the perimeter of the interior surface to remove flakes from the exterior surface. This was demonstrated using a tabular piece of stone, so that no cues were given as to the 'ideal' position of retouch *vis-à-vis* the platform or other flake attributes. Limited information was also given to them about the functions of scrapers. They were told the technical differences between scraping and planing actions, and that retouching was used to create a 'uniform' edge suitable for these tasks. The term 'uniform' was only defined to mean not serrated. No information was given as to the ideal edge shape (i.e. straight, convex or concave) or which edge angles (i.e. the angle of the intersection of the exterior and interior surfaces of the retouched edge) were optimum for these tasks. In fact, since we were concerned with the choices being made as to which edge was to be retouched, the utility of the edge after retouch was immaterial to the experiment. It was also assumed that these novices would not have developed the motor skills to execute their plans as cleanly as experienced knappers.

Using soft hammer billets, the students were then allowed between one and two hours of unsupervised practice, with the only instruction being that they should experiment by striking the flakes on edges of all forms and angles to 'see what works'. No instructions were given on how to hold the flake other than that the interior surface should be the one struck. To ensure that each individual constituted an independent trial, participants were not permitted to watch each other work or discuss the experiment among themselves. At the end of the practice session the students felt confident that they could shape an edge suitable for use and, although individual skill varied widely, observations of their test pieces indicated that they were all sufficiently competent to complete the experiment. The final stage of the practice session was a brief open-ended interview with each participant in which they were asked two questions: What have you discovered about retouching and what did you do to remove flakes successfully? These questions were deliberately vague in order to avoid influencing the responses, and the students were told that there were no necessarily right or wrong answers.

Because these first interviews were primarily about technological issues, the potential use of tools was rarely addressed. All 12 participants had discovered that 'thinner' edges, meaning those with the most acute spine-plane angles, were easier to shape than 'thicker' (more obtuse) edges, and that unless the blank itself was thin, an edge with a 90° spine-plane angle was very difficult to retouch. Five of the participants did note that holding the blank by the platform end or along a 'thick' edge was the most comfortable and made retouching easier.

The second session was the experiment itself. Each participant was given three flakes which had been photographed and had the spine-plane angles of all edges measured in advance. Each individual received blanks of different shapes, including at least one end-struck and one side-struck example. They were asked to retouch a single edge to make it uniform enough to either scrape dry hide or plane wood (spruce). Samples of those materials were provided for those who wished to try their tools. They were instructed to stop working on each specimen as soon as a usable tool edge was completed to their satisfaction. The two participants who interjected that a suitable working edge might already be present on a blank, were told to consider the edge dulled by use and requiring renewal. The flake blanks themselves were produced by the author using the discoid core technique, or were particularly large by-products of biface manufacture. These latter specimens were the morphological equivalent of first-order Levallois flakes, with the exception of having somewhat smaller platforms. The raw material was Flemming 'Chert' from northern Quebec, a fine-grained quartzite with flaking properties similar to European flint. The one difference was that the quartzite blocks did not have a chalky cortex, so that most cortical edges had similar flaking characteristics to non-cortical edges, and were just as sharp to hold. (The thick layer of de-silicified cortex on many flint nodules renders cortical edges both dull and difficult to flake.) To avoid cuing, participants were again isolated while working, and after the tools were complete, were interviewed to learn why they had placed the retouch as they had.

Of the 36 blanks employed, 21 were end-struck, 11 were side-struck, and 4 were blade-like. These were transformed into 19 side-scrapers (including one on the interior surface), 14 transverse scrapers, and 3 atypical end scrapers (Fig. 1). Seven of Bordes' types are represented (Table 1) including all of the single forms that are most common in real assemblages. Cross-tabulation of type by blank form and by the shape of the edge chosen to be retouched both showed statistically significant and strong associations of attribute sets. Put simply, the production of side-scrapers from end-struck blanks, and transverse scrapers from side-struck blanks was true in 30 of 36 cases.

These numbers clearly indicate the strong influence of blank morphology on the production of these scrapers, but it was the interviews with the participants, in which they were asked what they had done to each blank and why, which allowed us to refine our understanding of how the relationship between blank morphology and tool type is formed. As in the earlier interviews, the thinness of an edge was considered an important factor, but more often, functional considerations, namely the suitability of the edge as a scraping tool prior to retouching, were also considered. These combined factors were cited in 28 of 36 cases. This explains the observed relationship between end-struck blanks and side scrapers, where the acute edge angles were normally on the side of the flake, and between side-struck blanks and transverse scrapers, where the longest acute edge was almost always opposite the striking platform. However, a second factor, prehension, was considered equally important. Ease of manual prehension, during both manufacture and for the intended use of the tool, was

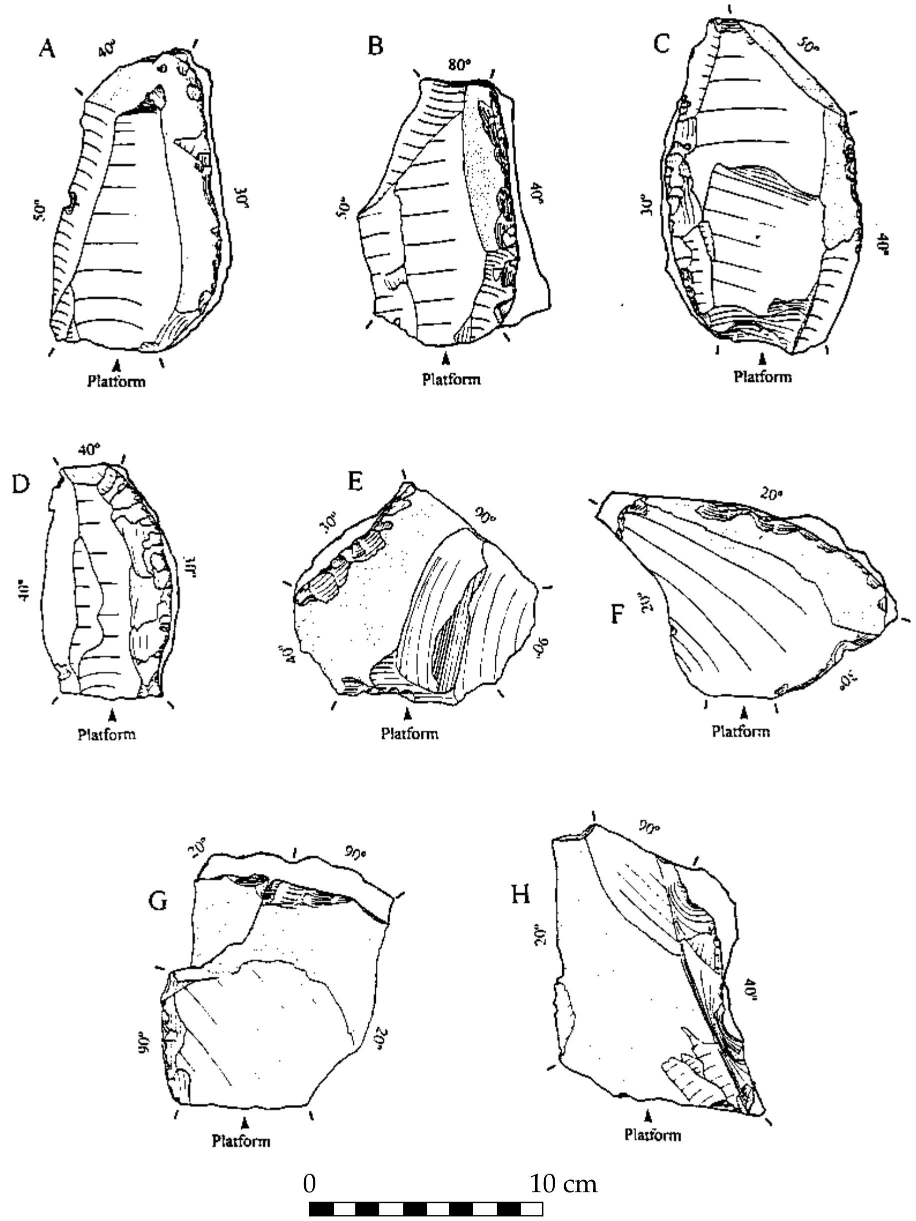

Figure 1. *Experimentally produced scrapers. The solid line indicates the original perimeter of the blank, and the original spine-plane angles are indicated for each edge. A to F are specimens where the edge with the most acute spine-plane angle was selected for retouch. G and H violate this rule. In both cases the students cited ease of prehension during anticipated use as the factor that determined which edge they retouched.*

cited more than any other factor (30 of 36 cases) as directly influencing the choice that was made of which edge of a blank would be retouched.

Combining the interview data with what the students actually did to the blanks, two rules were identified that governed the initial retouch episode in scraper manufacture:

1. The striking platform and any adjacent edges with spine-plane angles approximating 90° are left intact to serve as a hand-hold. (This rule was followed in all 36 cases.)
2. The longest uniform edge with the most acute spine-plane angle will be retouched first. (This rule was followed in 32 of 36 cases.)

In the experimental collection 88.9 per cent corresponded to both rules, which predicted scraper form at a higher rate than either general blank form (77.8 per cent) or the shape of the edge prior to retouch (83.3 per cent). This increased success was gained by the explicit recognition of attributes related to prehension as a significant variable.

Scraper production rules in the Middle Palaeolithic

Can these rules be seen to have operated in the past? To investigate this, a detailed analysis of 285 Middle Palaeolithic scrapers from the Garrod and Ami collections housed in the Redpath Museum, McGill University, was conducted. Four samples from some of the best-known early Middle Palaeolithic and Mousterian sites were chosen, covering a broad chronological range in both Western Europe and the Middle East. These were:

A) a Mousterian of Acheulian Tradition collection from Le Moustier, probably dating to between 40–55,000 BP (Valladas *et al*. 1986.) (*n* = 20);
B) a collection from Combe-Capelle Bas, originally interpreted to be Quina Mousterian but recently recognized by Dibble & Lenoir (1995) to be a Typical Mousterian with a high frequency of denticulates and notches. This material is of uncertain age, but probably predates the onset of the last glaciation at *c*. 70,000 BP (*n* = 67);
C) an early Middle Palaeolithic collection from layers Ea-Ed at Tabun, Israel. This is characterized as the Acheulo-Yabrudian variant of the Mugharan tradition (Jelinek 1982), and ESR dates place its age between 154,000 and 213,000 BP (Schwarcz *et al*. 1988.) (*n* = 152);
D) two collections from layers B1 and B2 at Skhūl cave, Israel. These are Tabun C-type Mousterian, with average ESR ages between 81,000 and 101,000 BP (Schwarcz *et al*. 1988.) (B1 *n* = 31; B2 *n* = 15).

The use of museum collections derived from early excavations is potentially problematic if the original excavator selected specimens in a manner that created an unrepresentative sample. This would be a significant problem if these collections were compared using Bordes' full list of tool types. For example, the typological composition of the collections made by Garrod from Tabun and Skhūl were biased by her failure to recognize many denticulates and notches (Jelinek 1975). The collections employed here, however, consist of all available examples of only one tool class, the scrapers, which because they are identifiable by easily recognized retouch, were well represented in all these collections. Although we were unable to cross-check the Le Moustier sample, subsequent first-hand inspections of more recently excavated scraper samples from the entire Tabun sequence (see below), as well

Table 1. *Percentages of Bordes' scraper types in the experimental and archaeological samples. Unrepresented types are omitted from the table. Exp. = Experimental tools; L.M. = Le Moustier; C.C. = Combe-Capelle Bas; T.E. = Tabun Ea-Ed; S.B1 = Skhūl B1; S.B2 = Skhūl B2.*

				Sites (%)			
Type	**Code**	**Exp.**	**L.M.**	**C.C.**	**T.E.**	**S.B1**	**S.B2**
Limace	8	5.0	1.5	2.0			
Straight side	9	13.9	25.0	6.0	19.1	25.8	20.0
Convex side	10	33.3	30.0	44.8	25.7	35.5	33.3
Concave side	11	2.8	5.0	1.3	6.5		
Double straight	12	4.6	3.2				
Dbl. straight-convex	13	5.0	3.0	3.3	9.7	13.3	
Double convex	15	1.5	1.3	6.5			
Dbl. convex-concave	17	6.5					
Straight convergent	18	0.7	6.7				
Convex convergent	19	3.0	4.6				
Déjeté	21	3.0	9.2				
Straight transverse	22	16.7	1.5	11.2	3.2	6.7	
Convex transverse	23	22.2	20.0	31.3	13.2	3.2	6.7
Concave transverse	24	1.5					
Interior surface	25	2.8	2.6	6.7			
Thinned back	27	0.7					
Bifacial scraper	28	1.5	0.7	6.7			
Typical endscraper	30	5.0					
Atypical endscraper	31	5.5	5.0	1.5			
	n =	36.0	20.0	67.0	152.0	31.0	15.0

as a study of detailed descriptions and photographs of a representative sample of scrapers from Combe-Capelle Bas published on a CD-ROM (Dibble & McPherron 1996) showed that the collections in the Redpath Museum were not biased in favour of unusual forms or atypical patterns of retouch.

For each scraper, observations were made on 24 variables including Bordes type (Table 1), the relationship of the retouched edge to the position of the striking platform, and also to the thickest or dullest edge. Platform modification made after the blank was produced was noted, as were any unmodified edges of the flake that would indicate its original form. It was found that through a careful inspection of the orientation of dorsal scars, whether a flake was originally side-struck or end-struck could be reliably determined in a large majority of cases. In most cases it was also possible to estimate the shape of the cross-section of the blank prior to retouch, the only exceptions being intensively reduced specimens. In many cases, overlapping of retouch scars permitted reconstruction of the sequence with which retouching occurred, as earlier flake removals were truncated by later ones. Metrical attributes including flake length and thickness, platform area, and angles of the retouched edge as well as spine-plane angles both adjacent to and opposite the retouched edge were also measured. The original spine-plane angle of the retouched edge was estimated in those cases where the dorsal scars of the blank were not entirely removed along the retouched edge. An overall assessment of the correspondence of the tool to the two experimentally-derived rules was also recorded.

Following this initial analysis, an additional sample of 57 scrapers from Layer D at Tabun that was excavated by Jelinek and housed at the University Arizona was added to the study. This strongly blade-based assemblage is characterized as Early Mousterian (Jelinek 1982) and has an ESR date ranging from 122,000 to 166,000 BP (Schwarcz *et al*. 1988).[2]

The results of these studies demonstrated a remarkable similarity between the location and sequence of retouch that created the Middle Palaeolithic scrapers and the experimentally-derived rules generated by the novice flintworkers reacting solely to blank morphology rather than concepts of ideal tool forms (Table 2). For the two European Mousterian sites and the early Middle Palaeolithic of Tabun, both rules were followed in from 75 and 82.1 per cent of cases. This is below the 88.9 per cent of the experiment, but these collections are not equivalent. The experiment recreated only the first retouch episode, and thus does not include any scraper forms with multiple or renewed retouched edges. The archaeological samples included multiple-edged forms such as double, convergent and déjeté scrapers, and variable percentages of specimens with heavily renewed edges. In addition, some of the archaeological specimens were made on distal flake blank fragments, and so their adherence to Rule 1 could not be determined. By deleting those specimens where adherence to both rules could not be observed for either technical reasons or because of intense reduction, it was found that actual adherence to both rules exceeded 90 per cent at all three sites. Figure 2 illustrates specimens that adhered to both of these rules.

Table 2. *Frequency of adherence of the archaeological collections to the scraper production rules. The 'actual' percentages were computed by eliminating specimens where adherence to or violation of the rules could not be determined.*

	Adherence to rules (Per cent)							
Adherence	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Actual**
Experiment (*n* = 36)	88.9	11.1						88.9
Le Moustier (*n* = 20)	75.0	5.0			10.0	5.0	5.0	93.8 (16)
Combe-Capelle (*n* = 67)	82.1	3.0	7.5		1.5	4.5	1.5	90.6 (61)
Tabun Ea-d (*n* = 152)	77.6		5.3		5.9	7.9	3.3	90.1 (131)
Skhūl B1 (*n* = 31)	45.2	22.6	29.0	3.2				45.2 (31)
Skhūl B2 (*n* = 15)	80.0	6.7			6.7	6.7		92.3 (13)

1. Follows both rules.
2. Follows Rule 1 (platform conserved). Violates Rule 2 (longest most acute edge not retouched first or most intensively).
3. Follows Rule 2. Violates Rule 1 (platform removed or modified).
4. Violates both rules.
5. Follows rule 1. Rule 2 not observable because specimen is too reduced.
6. Follows Rule 2. Rule 1 not observable because specimen is made on a distal flake fragment.
7. Intense retouch on all edges makes both rules unobservable.

Certain technical violations of the rules are particularly important in showing the validity of the rules themselves. Figure 3 shows a transverse scraper across the proximal end of a side-struck blank. Since the platform has been entirely removed, it is in violation of Rule 1. The blank itself, however, was a 'core tablet', a form of overstruck flake in which the distal end, and in this case the sides as well, happened to be thicker than the platform end. Although

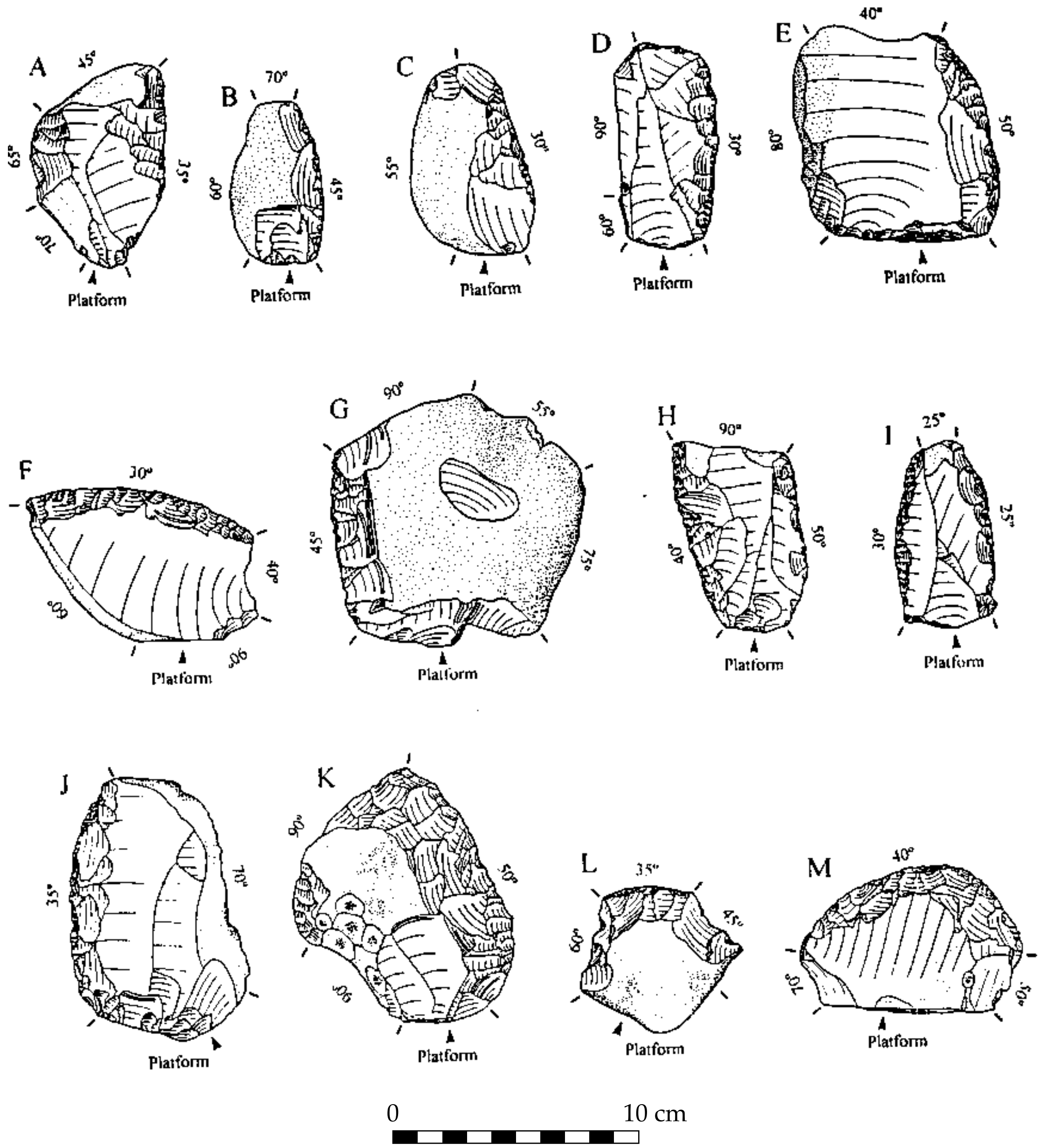

Figure 2. *Scrapers from Tabun, Combe-Capelle Bas and Le Moustier. Spine-plane angles are indicated for each edge. All scrapers except E adhere to both scraper production rules. On E, an edge with a higher spine-plane angle was retouched. On double scrapers (H & I), the edge with the most acute spine-plane angle has the most extensive retouch. Transverse scrapers F and L were created on side-struck blanks, whereas M was probably created by multiple edge renewals of an end-struck blank. (A–C, E, F, H and L — Tabun Layer E; D, G, J, K and M: Combe-Capelle Bas; I: Le Moustier. Garrod and Ami Collections, Redpath Museum.)*

a technical violation, this specimen exemplifies the overriding pattern that the thickest and dullest edge will be retained as a hand-hold, while the longest and thinnest edge will be retouched.

It is important to note that adherence to the rules does not require all end-struck blanks to form side scrapers, and all side-struck blanks to form transverse scrapers. The spine-plane angle of the edge chosen for retouching is as critical as its length. Nevertheless, in cases where flake blanks have normal terminations, the longest acute edges occur on the sides of most end-struck blanks and across the end of most side-struck blanks.

Table 3. *Cross-tabulation of scraper type by blank form (Pearson Chi-Square) and blank form frequencies.*

Sample	Chi square	df	Significance	*n*
Experimental tools	32.957	12	.00098	36
Le Moustier	45.667	28	.01886	20
Combe-Capelle Bas	92.044	33	.00000	67
Tabun Layer Ea-d	157.321	42	.00000	152
Skhūl Layer B1	29.221	16	.02249	31
Skhūl Layer B2	45.000	21	.00173	15

	End struck	Side struck	Triang.	Blade	*n*	(% Levallois)
Experiment	58.3	30.6	11.1	36		
Le Moustier	67.7	11.1	11.1	11.1	18	(21.1)
Combe-Capelle Bas	69.2	29.2	1.6		65	(4.6)
Tabun Ea-d	68.9	27.1	2.3	1.6	129	(2.3)
Skhūl B1	80.6	12.9	6.5		31	(74.1)
Skhūl B2	71.4	21.5	7.1		14	(66.7)

Edge-renewal effects

Dibble (1984; 1987) has experimentally demonstrated that repeated edge-renewal can transform side into transverse scrapers, and double scrapers into convergent and déjeté forms. Examples F, L and M (Fig. 2) illustrate transverse scrapers, either on side-struck blanks in which retouch intensity did not effect the final form (F, L), or on an end-struck blank in which sequential renewal preserving the striking platform and dullest edge as a hand-hold eventually created a transverse scraper in the manner described by Dibble (M). Figure 4 illustrates a convergent and déjeté scraper in which the original blank form cannot be inferred. The frequency with which this process occurs has been the subject of debate (Kuhn 1992; Mellars 1996). In this study, special attention was paid to reconstructing the reduction histories of each transverse, convergent, déjeté and limace scraper. The same pattern was not found in each of these types. Intense retouch that obliterated the original blank form is present on all five limaces in the Le Moustier, Combe-Capelle Bas and Tabun samples, suggesting that repeated edge-renewal was responsible for this form. Had the makers intended to create these limaces, appropriately shaped blanks requiring less retouch could certainly have been selected. Nine of eleven convergent scrapers were also associated with intense retouch. Only seven of seventeen déjeté scrapers could be attributed to retouch intensity, and only one out of three (21 of 63) transverse scrapers could be confidently attributed to retouch intensity rather than blank form. Although reduction histories clearly did effect the typological composition of these assemblages, blank form was clearly the more important variable.

Statistical tests support this conclusion. In this hypothesis, a statistically significant association of blank form and tool type is expected. Cross-tabulation of Bordes' type by blank form for the experimental assemblage plus both European Mousterian sites and Tabun layer E (Table 3) yielded chi-square scores with significance levels that are all below 2 per cent, allowing us confidently to reject the hypothesis of no association between the variables. Cross-tabulation of type by retouch intensity was also statistically significant, but substantially less

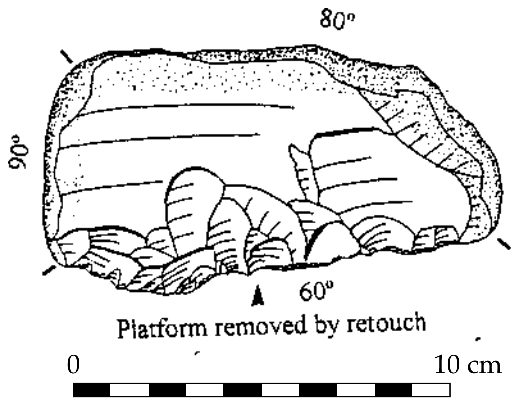

Figure 3. *Scraper from Combe-Capelle Bas. The blank was an overstruck flake in which the platform was the thinnest and most acute edge. (Ami Collection, Redpath Museum.)*

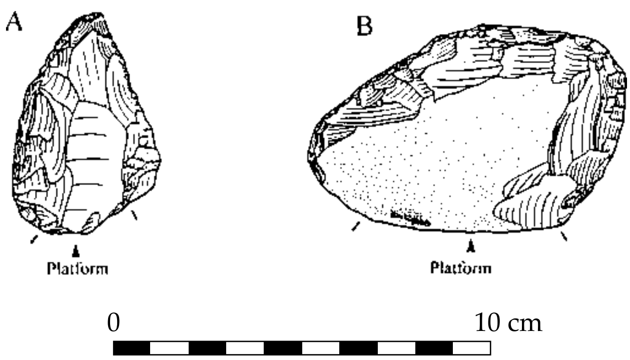

Figure 4. *Intensively retouched scrapers in which adherence to Rule 2 could not be determined. (Tabun Layer E, Garrod Collection, Redpath Museum.)*

strong. Including specimens from all assemblages, type by retouch intensity generated lambda symmetric and tau (type dependent) scores of .08133 and .13068 respectively, both weak associations. The same statistics for type by blank form were .29795 and .49348 which, given the number of cases, indicates a moderate to strong association.

These results do not negate Dibble's fundamental observations. Instead, the model of scraper production proposed here provides a more refined model of the interaction of blank form with the processes of morphological change through re-sharpening. The logical extension of the two primary rules of scraper manufacture is that renewal or re-sharpening episodes will continue these patterns until the implement is exhausted. Additional retouched edges may be added if the angle of the initial retouched edge becomes more obtuse. In this way, we can predict that in double or convergent scrapers the edge that has the most acute initial spine-plane angle (i.e. the edge angle prior to retouch) will show the most intense retouch as defined by Dibble (1987). Thus, blank morphology does determine where a flake is first retouched, but from that point on, the reduction sequences identified by Dibble begin to take effect in a manner predictable by the crucial variables identified here: edge length and uniformity, and edge spine-plane angle.

Tabun Layer D

All of the assemblages described above were dominated by flake blanks. A follow-up study of a sample from Tabun Layer D (Levels 61–66 in the Jelinek excavations) was conducted to see if the Middle Palaeolithic scraper production rules were followed with different blank morphologies (Table 4). In this sample (*n* = 57), well-executed prismatic blades, created by both single-platform and Levallois techniques, constitute 49.1 per cent of the blanks retouched into typological scrapers. Determining the order in which retouch was applied to these scrapers was made easier by the fact that retouch intensity was low, i.e. the scars were less invasive than in the other assemblages in this study. In many cases only a single episode of retouch is repre-

Table 4. *Tabun Layer D, frequency of Bordesian scraper types, blank forms and correspondence to the rules of scraper production. (Jelinek Collection, University of Arizona.)*

Tabun Layer D Type	Code	%	*n*
Straight side	9	17.5	10
Convex side	10	36.8	21
Concave side	11	8.8	5
Double straight	12	8.8	5
Dbl. straight-convex	13	3.5	2
Double convex	15	7.0	4
Double concave	16	1.8	1
Dbl. convex-concave	17	1.8	1
Convex convergent	19	7.0	4
Straight transverse	22	3.5	2
Convex transverse	23	1.8	1
Miscellaneous	62	1.8	1
			57
Blade blanks	49.12% (28)		
Flake blanks	50.88% (29)		
Correspond to both rules	92.98% (53)		
Violates Rule 2	7.02% (4)		

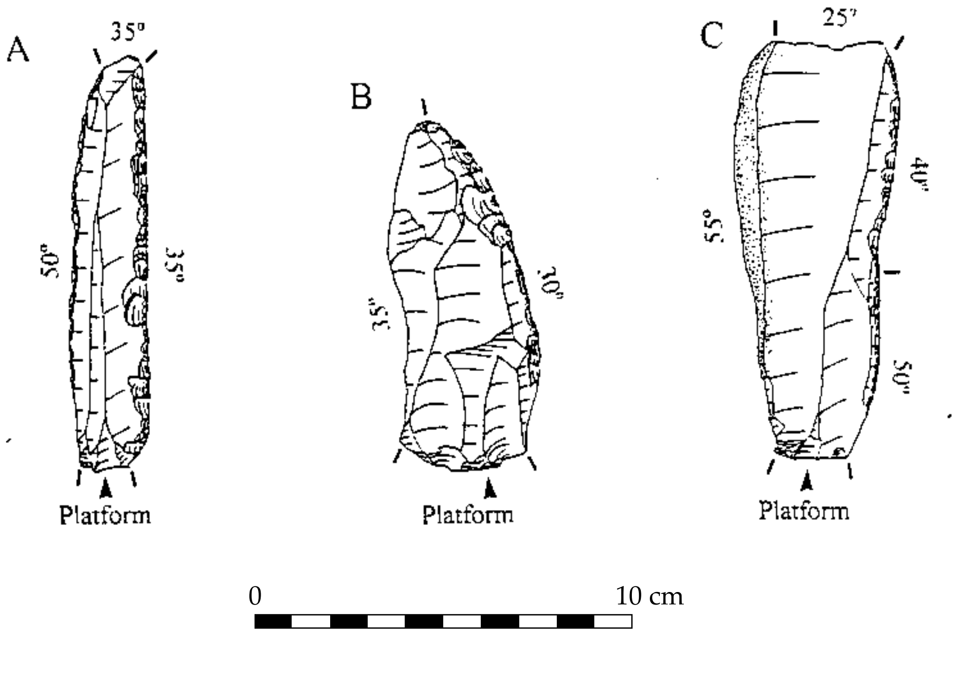

Figure 5. *Scraper retouch on blades from Tabun Layer D. In the double scraper (A), the most intense retouch is on the edge with the most acute spine-plane angle. (Garrod Collection, Redpath Museum.)*

sented. This suggests that fewer episodes of edge-rejuvenation and re-sharpening took place in comparison to the Layer E sample. The retouched edges of both the blade and the flake blanks were often quite sharp, suggesting that many of these specimens were used as knives rather than scrapers in the strict sense. No specimens from the Layer D sample were so heavily reworked that their adherence to, or violation of, the rules could not be inferred.

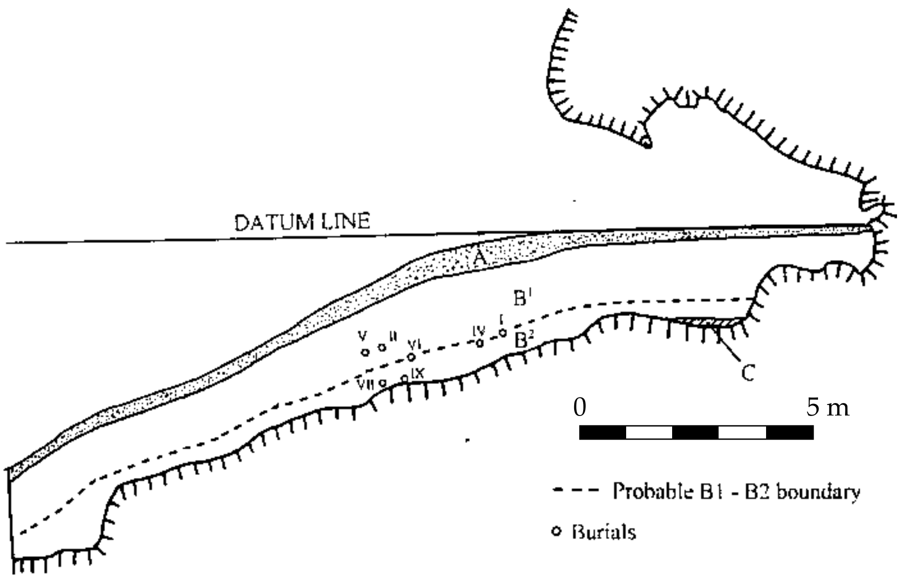

Figure 6. *Longitudinal profile of Skhūl cave, Israel. The position of the B1–B2 boundary given here is an approximation because its precise position is not included in the published sections. (After Garrod & Bate 1937, pl. L.)*

Although employing dramatically different blanks, adherence to the rules in the Tabun Layer D sample is extremely high (92.98 per cent). For both blade and flake blanks, platforms were never removed, and the most acute edge was not the one retouched on only 4 specimens (7.02 per cent), with no difference in the proportion of these violations between blank types. Not only was retouch positioned on the longest and most acute edge of the blank, but these distinctions were very finely drawn, since the lateral edges of the blade blanks were symmetrical and often had only slight differences in spine-plane angle. There is no evidence of modification of the platform (or distal end) to facilitate hafting, although it is theoretically possible that hafting was employed. Although a more efficient technique of blank production, in terms of raw-material utilization and the ratio of usable tool edge to volume of stone was being employed, these blade blanks were being treated in exactly the same way as the less uniform flake blanks that dominate the other assemblages.

Skhūl Layer B

The Middle and Late Mousterian in the Levantine coastal region has been seen as homogeneous, and no significant typological differences have been observed between assemblages associated with Neanderthals and early anatomically modern *Homo sapiens* (Bar-Yosef 1994). Indeed, this has always been a puzzle to those who assumed that there should be observable behavioural differences between the two hominids. Skhūl cave layer B exemplifies this paradox. It contained multiple burials of robust anatomically modern *Homo sapiens*, associated with a Tabun C type Mousterian that in nearby Tabun cave is associated with a typical Neanderthal. Initial inspection of the Skhūl sample in the Redpath Museum confirmed that there was little difference between the scraper type frequencies and prevalence of Levallois technique in Skhūl layer B and published accounts of other contemporary Mousterian assemblages.

Skhūl was excavated by T.D. McCown (1937), who identified three strata: A) a thin layer of recent soil mixed with a few Middle Palaeolithic artefacts; B) a layer from two to almost three metres in thickness containing Middle Palaeolithic tools and human remains; and C) a thin horizon of earlier deposits adhering to small pockets in the bedrock floor of the terrace. The artefacts were analyzed by Garrod & Bate (1937), who arbitrarily divided layer B into upper (B1) and lower (B2) horizons, with the boundary two metres below surface (Fig. 6). The sole factor differentiating these horizons was that in B1, artefacts were heavily patinated, and in B2 they were not.[3] There was 'no essential difference' observed between the industries (1937, 110). The samples available to us (31 scrapers from B1, 15 from B2) seem to indicate that from a typological perspective, this is correct. In both, side scrapers are the most common forms. Double scrapers are more common in B1, and transverse more common in B2, but these may be the vagaries of relatively small samples.

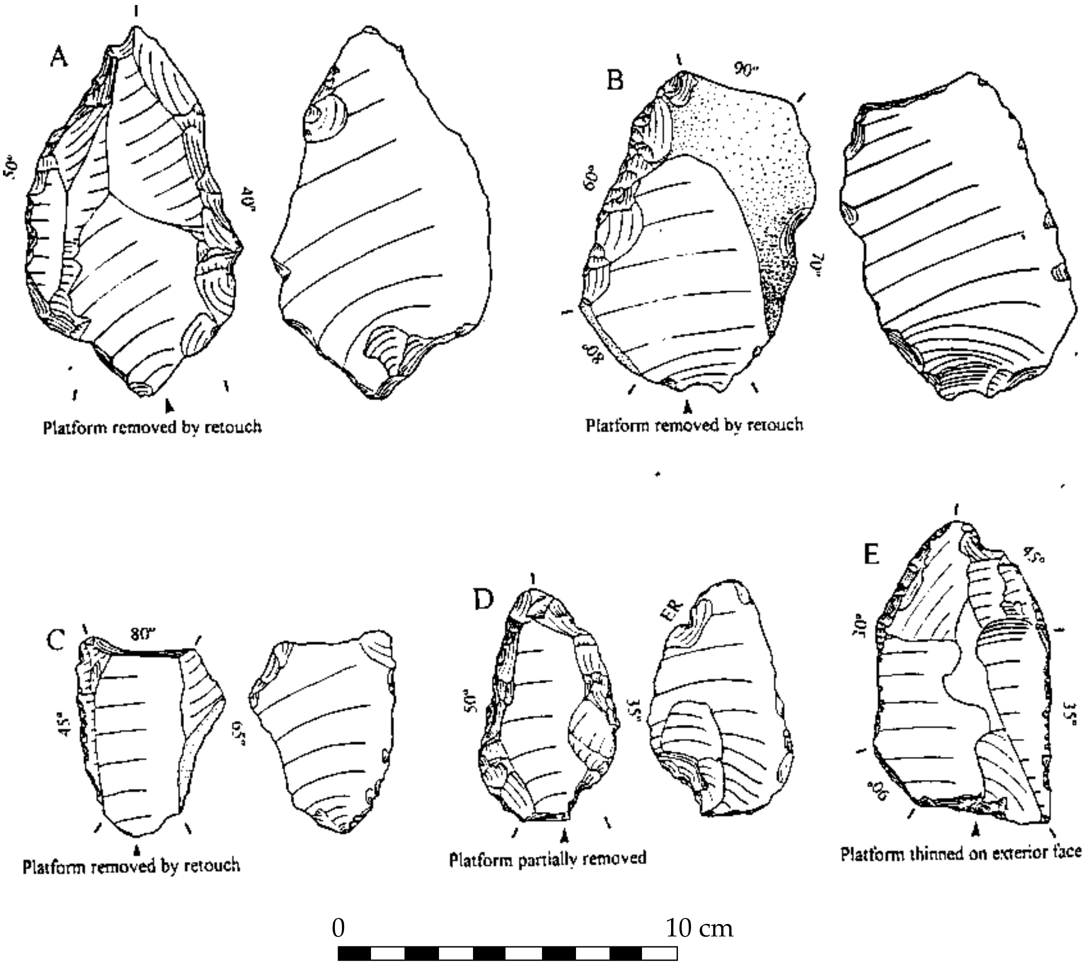

Figure 7. *Scrapers from Skhūl Level B1 showing total or partial platform removal. Platform totally removed by inverse retouch (A–C). Platform partially removed creating a shoulder (D). Platform thinned on the exterior surface (E). Specimen A, a double scraper, also violates Rule 2 because the most intense retouch is not on the edge with the most acute spine-plane angle (ER = excavation retouch). (Garrod Collection, Redpath Museum.)*

When the Skhūl specimens were subject to more detailed analysis, dramatic differences between B1 and B2 became apparent, and B1 was found to differ from all the other assemblages as well. Whereas the B2 scrapers followed the rules 80 per cent of the time in the strict sense, and 92.3 per cent of the time when heavily reduced and fragmentary specimens were deleted, only 45.2 per cent adhered to the rules in B1. Both rules were routinely violated in B1. The longest and most acute edge was not retouched first or most intensively on 22.6 per cent of cases, the platform was modified or removed on 29 per cent of cases, and in one case (the only one of the 285 in the study) both rules were violated.

Platform modifications included thinning to produce a wedge shape, and unifacial or bifacial trimming producing a stem or point (Fig. 7). Although not all modified platforms were suitable, at least six specimens did appear to be designed for hafting. Two methods of hafting seem to be indicated. The wedge-shaped platform modifications suggest the use of split shafts, and some form of socket was probably used with the pointed butts. The specimens are too patinated for microscopic traces of hafting to be identified, but if these are hafting modifications, they imply that the tools were being used in a more efficient manner.

The specimens where retouch was positioned on edges not predicted by Rule 2 were also important (Fig. 8). This implies that blank form, manual prehension and function were no longer the sole determinants of scraper form, and that in at least a few cases, the blank was being shaped into a form that was being consciously imposed on the tool. If

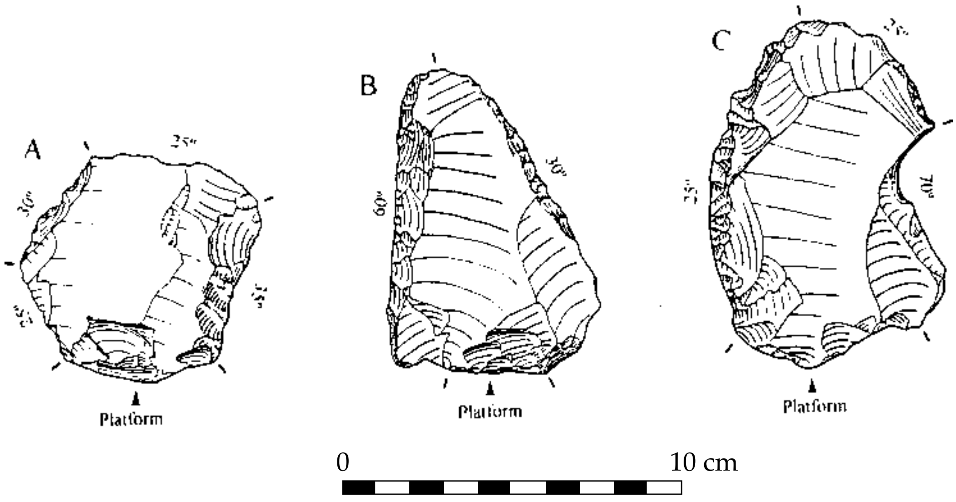

Figure 8. *Scrapers from Skhūl B1. A and B violate Rule 2 but show no platform modification. Specimen C adheres to both rules. (Garrod Collection, Redpath Museum.)*

true, this illustrates the operation of different cognitive processes in the production of these tools and is evidence for the beginning of the development of true mental templates for scrapers.

An important issue is whether or not the Skhūl sample analyzed here is representative. Garrod distributed parts of her Skhūl collection to a number of universities and museums, inhibiting study of the entire assemblage. It is theoretically possible that specimens with unusual platform modifications and positions of retouch were somehow concentrated in this collection. As a cross-check, all of the artefacts discovered by Jelinek during an investigation of the waste-dump from McCown's excavations were inspected. These included 62 retouched tools and a sample of 77 unretouched whole flakes. These artefacts derived from all layers at Skhūl, but given the nature of the site, the great majority must have come from layer B. As expected, a majority of the retouched specimens were denticulates and notches (n = 32), the categories most frequently discarded by Garrod. Among the 24 scrapers, adherence to the rules could be determined on all but one specimen. If attributed to layers B1 or B2 based on patination, 10 specimens derive from B1. Five of these exhibit violations of one or both rules. Only one of the 13 specimens lacking patination and thus attributed to B2 violates the rules. These data show that the Redpath collection does accurately reflect a significant difference between these layers in how scrapers were produced and modified.

Who made the B1 tools? Skhūl is famous for its specimens of early anatomically modern *Homo sapiens*. Both Garrod & Bate (1937) and McCown (1937) described them as coming from layer B, but failed to attribute each individual to a specific subdivision of that layer. The two published sections of Skhūl are highly confusing because in some cases the same burial is shown at different depths in the longitudinal and transverse profiles (Garrod & Bate 1937, pl. L). None of the burials were intersected by the transects along which these profiles were drawn, and their positions were projected on to them. The longitudinal profile (Fig. 9) seems to indicate that at least four of the burials were within B2. Published measurements (McCown 1937, 97–105) show that three of the four most intact burials, including those which exemplify the anatomically modern characteristics of this population, are all definitely within B1 when that unit is defined as anything less than two metres below surface (Skhūl I, –1.8 m.; Skhūl IV, –1.25 m.; Skhūl V, –1.25 m.). McCown was of the opinion that these three might be somewhat later than the others. None of the other burials is more than 35 cm below the B1–B2 boundary, and from the crouched position of the skeletons and orientation of the bones, he inferred that they were interred in shallow pits. In order to bury a human body, a pit would need to be at least 30 cm in depth. With the exception of Skhūl III (–2.35 m) and Skhūl IX (–2.15 m), both of which were found close to bedrock and, significantly, are described as having the most robust skeletal characteristics of this sample, it is clear that most, if not all, of the Skhūl hominids are derived from B1, and were thus responsible for the unusual characteristics of its scrapers.

Discussion

This, and much of the preceding research over the past two decades, has demonstrated that the morphology of Middle Palaeolithic scrapers is generated by functional contingencies, including intended use and the mode of prehension, the mechanical properties of stone, the initial form of the blank, and the degree to which the tool has been re-sharpened. Scraper types, in the Bordesian sense, are thus analytical constructs rather than natural categories (Bisson 2000). This implies that scraper manufacture is fundamentally expedient in nature, and that the behavioural significance of the tools themselves lies more in function than in form. Yet the identification of the rules that underlay scraper production in an assemblage can yield important behavioural information that differs from that provided by *chaîne opératoire* analyses of blank production. For example, unlike points (Shea 1988), evidence for the hafting of scrapers in the Middle Palaeolithic is relatively rare and in some cases subject to debate.[4] The production rules identified here imply manual prehension. Statistically significant violations of Rule 1 may provide the best possible evidence for hafting in circumstances where taphonomic processes have destroyed all traces of mastic and rendered microwear analysis unreliable. 'Style' in these tools may still be manifested in the choice of blank production strategies, but may also be identified if systematic violations of the two rules are found, since those violations would constitute evidence of imposed form.

The question of whether or not other categories of Middle Palaeolithic stone tools exhibit imposed form is neither confirmed nor denied by these data. As discussed above, handaxes and points may exhibit imposed form, although their characteristics may be structured by functional requirements and available raw materials. The lack of 'style' in Middle Palaeolithic material culture as a whole (Kuhn & Stiner 1998) suggests that functional and raw material constraints had a strong influence on all tool forms. The rules of scraper manufacture identified here are expressions of patterns of tool manufacture conditioned by a balance of two contingencies; the need to create a working edge suitable for the task or tasks to be performed, and the need to situate that edge on the blank in a manner consistent with the greatest ease and comfort during both manufacture and use. Thus this tool-making strategy may seem expedient, but it is not random or unstructured. It is just differently structured from the strategies employed in the Upper Palaeolithic. Moreover, these results do not demonstrate that Neanderthals were incapable of creating tools with imposed form, as the evidence of the Châtelperronian attests (d'Errico *et al.* 1998; Mellars 1999). They do, however, suggest that the use of imposed form on Neanderthal tools is restricted in area and very late in the temporal sequence.

The discovery that scrapers from Skhūl B1, associated with early anatomically modern *Homo sapiens*, deviate significantly from these rules, and that these deviations appear to be a consequence of different modes of prehension including the development of split-shaft and socketed hafting, may help differentiate these hominids behaviourally from the contemporary Neanderthals. It may provide evidence of a more sophisticated technological repertoire that has previously been obscured by comparisons of tool type frequencies and blank production techniques. These data are also in accord with the observations of Trinkaus that the reduced muscularity of the Skhūl population indicates '. . . a major improvement in the mechanics of the habitual use of technology among those early modern humans relative to their co-Middle Palaeolithic late archaic humans' (Trinkaus 1992, 290).

Stone tools resembling those of the Middle Palaeolithic, and apparently lacking imposed form, have sometimes been identified in the material cultures of ethnographically-recorded modern hunter-gatherers. These similarities are a product of similar functions and do not take into account the definition of imposed form employed here. For example, Gould *et al.* (1971) compared a set of adzes from the Western Desert of Australia to a small sample of scrapers from the Mousterian site of La Quina (France). The similarities they found (edge angles, thickness, the presence of hinge and step-fractured retouch, and patterns of use-wear) were attributed by them to similarities in function, and do not address the typological characteristics of the Mousterian specimens. The adzes that they illustrate (Gould *et al.* 1971, 159, fig. 8), as well as specimens illustrated by Allchin (1966, 158), do in fact show a pattern in which a steep edge is deliberately created along a wide front opposite the striking platform, which is imbedded in mastic to attach it to a wooden haft. This differs from the Mousterian pattern identified here, in which the longest, most acute edge will be retouched first, no matter what its position relative to the platform. In addition, other Australian aboriginal stone tool categories, such as points and backed elements (Allchin 1957) show clear evidence of imposed form. Even in the cases of the simplest stone technologies created by cognitively complex modern humans, more imposed form is evident than is found in any Mousterian assemblage.

The absence of imposed form on most Middle Palaeolithic scrapers can inform us about the thought processes of Neanderthals, at least when they were making the most common and possibly most important part of their technological repertoire. It tells us that they were trying to create an edge suitable for one or more tasks, and that instead of making an implement with a pre-conceived overall form, they were simply reacting to the three-dimensional properties of the blank. Their goal was to produce a tool that could be both hand-held and have the longest possible effective edge. These mechanical and raw-material constraints combined with tool life-histories are sufficient to explain tool variability. Culture, in the modern sense, had nothing to do with it. In addition, there appears to be little or no change over time, no gradual awakening of a sense of imposed form, in these data. The same production rules were applied equally to all blank types and were found in Tabun Layer E and at Le Moustier, which dates *c.* 170,000 years later.

The Middle Palaeolithic scraper production rules stand in sharp contrast to those employed to make scrapers in the Upper Palaeolithic, where the placement of retouch at the end of the blade invariably violates Rule 2. This difference is particularly striking in the case of Tabun Layer D, where nearly half of the scrapers were made on blades, yet the Middle Palaeolithic rules were adhered to in *c.* 93 per cent of cases, and not a single end scraper was found in the sample. Indeed, in the Upper Palaeolithic, hafting modifications are common and the rule for the placement of retouch is reversed. The effective edge is created at the end of the blade, seemingly in recognition of the mechanical advantage to be gained by using the length of the blade (often magnified by its combination with a handle) to increase leverage. No such evidence of innovation and flexibility in the use of raw materials combined with standardization of tool forms is evident in the Middle Palaeolithic. This lack of the flexibility that characterizes modern 'cognitive fluidity' as discussed by Mithen (1996) is reflected in the strict adherence by Middle Palaeolithic hominids to scraper production rules structured entirely by mechanical and functional constraints. It is a concept of material culture production that is largely alien to modern humans.

Notes

1. The situation as regards points is clouded by ambiguity in the Bordesian typology. Distinguishing Mousterian points from convergent scrapers was left to the judgement of archaeologists, resulting in dramatic differences in the identification of these types (Debénath & Dibble 1994; Dibble 1995b). Convergent scrapers are strongly correlated with high reduction intensity (Dibble 1987), whereas it is argued here that true Mousterian points will exhibit intense retouch only if it was necessary to achieve the desired functional characteristics.
2. Since blades are common in Tabun Layer D, many of the specimens included in this analysis are technically 'retouched blades' rather than 'scrapers' in the Bordesian sense. Only specimens with abrupt retouch (i.e. backed knives) were excluded. Retouch on the blades in this sample created a relatively sharp working edge, and was not simply a casual form of blunting.
3. The artefact sample from Skhūl presents problems because of the nature of the excavations. The 'hardened earth' and 'very hard breccia' that made up Layer B were so solid that they were excavated with heavy picks (McCown 1937, 94–5). No reference section was left with which to check the original excavators' observations. Attributions of artefacts to particular subdivisions of Layer B may therefore be problematic. We have no option but to accept the attributions made by the excavators. The Skhūl artefacts donated to McGill University were assigned to B1 or B2 by Garrod herself.
4 Use-wear linked to hafting in European Mousterian assemblages has been reported by Anderson-Gerfaud (1990) and Beyries (1987), but this evidence is limited and may have been skewed by post-depositional surface modifications (Levi-Sala 1986). Mastic and other residue employed in hafting scrapers has only been recovered in the Middle East (Boëda *et al.* 1996) and Eastern Europe (Hardy & Kay 1999).

Acknowledgements

I am indebted to Arthur J. Jelinek for his encouragement of my study of the Middle Palaeolithic, and for permission and assistance in my studies of the Tabun and Skhūl collections at the University of Arizona. Thanks also go to the Redpath Museum, McGill University for unimpeded access to their collections, and to Steven Kuhn, Steven Mithen and April Nowell, who provided advice and encouragement on early drafts of this article. I am also grateful to the anonymous reviewers for the *Cambridge Archaeological Journal*, who made many helpful suggestions for improving this article. Most of all, I wish to thank my 'Neanderthals', Lee Barsaqui, Genevieve Bertrand, Ayse

Boray, Robin Canuel, France Goguen, Tim Hodgson, Liliana Ibarra, Camilia Ibrahim, Jason Lerch, Julien Riel-Salvatore, and Flora Spiegel, for their enthusiastic participation in this project, and Kris Kovarovic, who both analyzed and drew many of the tools. Any errors or omissions are solely the responsibility of the author.

Michael S. Bisson
Department of Anthropology
Stephen Leacock Building
McGill University
855 Sherbrooke Street West
Montréal
Quebec
Canada
H3A 2T7
Email: mbisso8@po-box.mcgill.ca

References

Allchin, B., 1957. Australian stone industries: past and present. *Journal of the Royal Anthropological Institute* 87, 115–36.

Allchin, B., 1966. *The Stone-Tipped Arrow*. New York (NY): Barnes & Noble.

Anderson-Gerfaud, P., 1990. Aspects of behavior in the Middle Paleolithic: functional analysis of stone tools from southwest France, in *The Emergence of Modern Humans: an Archaeological Perspective*, ed. P. Mellars. Edinburgh: Edinburgh University Press, 389–418.

Audouze, F., 1999. New advances in French prehistory. *Antiquity* 73, 167–75.

Bar-Yosef, O., 1994. The contributions of Southwest Asia to the study of the origins of modern humans, in *Origins of Anatomically Modern Humans*, eds. M. Nitecki & D. Nitecki. New York (NY): Plenum Press, 23–66.

Beyries, S., 1987. *Variabilité de l'Industrie Lithique au Moustérien: approche fonctionelle sur quelques gisements Française*. (British Archaeological Reports International Series 328.) Oxford: BAR.

Binford, L., 1972. Models and paradigms in Paleolithic archaeology, in *Models in Archaeology*, ed. D. Clarke. London: Methuen, 109–66.

Binford, L., 1973. Interassemblage variability — the Mousterian and the 'functional' argument, in *The Explanation of Culture Change*, ed. C. Renfrew. London: Duckworth, 227–54.

Binford, L. & S. Binford, 1966. A preliminary analysis of functional variety in the Mousterian of Levallois facies. *American Anthropologist* 68(2.2), 238–95.

Bisson, M.S., 2000. Nineteenth century tools for twenty-first century archaeology? Why the Middle Paleolithic typology of François Bordes must be replaced. *Journal of Archaeological Method and Theory* 7(1), 1–48.

Boëda, E., 1988. Le concept Levallois et évaluation de son champ d'application, in *L'Homme de Neanderthal*, vol. 4: *La Technique*, ed. M. Otte. Liège: University of Liège, 13–26.

Boëda, E., 1995. Levallois: a volumetric construction, methods, a technique, in Dibble & Bar-Yosef (eds.), 93–116.

Boëda, E., J. Connan, D. Dessort, S. Muhesen, N. Mercier, H. Valladas & N. Tisnérat, 1996. Bitumen as a hafting material on Middle Paleolithic artifacts. *Nature* 380, 336–8.

Bordes, F., 1953. Essai de classification des industries moustériennes. *Bulletin de la Société Préhistorique Française* 50, 457–66.

Bordes, F., 1961. *Typologie du Paléolithique Ancien et Moyen*. (Publications de l'Institut de Préhistoire de l'Université de Bordeaux, Mémoire 1.) Bordeaux: Delmas.

Bordes, F. & M. Bourgon, 1951. Le complexe mousterien: Mousterien, Levalloisian et Tayacien. *L'Anthropologie* 55, 1–23.

Boucher de Perthes, J., 1847. *Antiquités celtiques et antédiluviennes. Mémoire sur l'industrie primitive et les arts à leur origine*, vol. 1. Paris: Treuttel & Wurtz.

Brace, C.L., 1964. The fate of the classic Neanderthals. *Current Anthropology* 5, 3–43.

Brézillon, M., 1968. *La dénomination des objets de pierre taillée: matériaux pour un vocabulaire des préhistoriens de langue Française*. (Gallia Préhistoire Supplément 4.) Paris: Centre National de la Recherche Scientifique.

Chabai, V.P. & K. Monigal (eds.), 1999. *The Paleolithic of the Crimea II*. Liège: University of Liège.

Clark, G., 1993. Paradigms in science and archaeology. *Journal of Archaeological Research* 1, 203–34.

Clark, G., 1997. Through a glass darkly: conceptual issues in modern human origins research, in *Conceptual Issues in Modern Human Origins Research*, eds. G.A. Clark & C.M. Willermet. New York (NY): Aldine de Gruyter, 60–76.

Clark, J.D., 1982. The cultures of the Middle Paleolithic/Middle Stone Age, in *Cambridge History of Africa*, vol. 1, ed. J.D. Clark. Cambridge: Cambridge University Press, 284–341.

Debénath, A. & H. Dibble, 1994. *Handbook of Paleolithic Archaeology*, vol. 1: *The Lower and Middle Paleolithic of Europe*. Philadelphia (PA): University of Pennsylvania Museum Press.

de Mortillet, G., 1883. *Le Préhistorique: Antiquité de l'Homme*. Paris: Reinwald.

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

Dibble, H., 1984. Interpreting typological variation of Middle Paleolithic scrapers: function, style, or sequence of reduction. *Journal of Field Archaeology* 11, 431–6.

Dibble, H., 1985. Raw material variability in Levallois flake manufacture. *Current Anthropology* 26(3), 391–93.

Dibble, H., 1987. The interpretation of Middle Paleolithic scraper morphology. *American Antiquity* 52, 109–17.

Dibble, H., 1988. Typological aspects of reduction and

intensity of utilization of lithic resources in the French Mousterian, in Dibble & Montet-White (eds.), 181–94.
Dibble, H., 1991. Mousterian assemblage variability on an interregional scale. *Journal of Anthropological Research* 47, 239–57.
Dibble, H., 1995a. Middle Paleolithic scraper reduction: background, clarification, and a review of the evidence to date. *Journal of Archaeological Method and Theory* 2(4), 299–368.
Dibble, H., 1995b. Biache Saint-Vaast, Level IIA: a comparison of analytical approaches, in Dibble & Bar-Yosef (eds.), 93–116.
Dibble, H. & O. Bar-Yosef (eds.), 1995. *The Definition and Interpretation of Levallois Technology*. Madison (WI): Prehistory Press.
Dibble, H. & M. Lenoir (eds.), 1995. *The Middle Paleolithic Site of Combe-Capelle Bas (France)*. Philadelphia (PA): University of Pennsylvania Museum Press.
Dibble, H. & S. McPherron, 1996. *The Middle Paleolithic Site of Combe-Capelle Bas (France)*. CD-ROM. Philadelphia (PA): University of Pennsylvania Museum.
Dibble, H. & P. Mellars (eds.), 1992. *The Middle Paleolithic: Adaptation, Behavior and Variability*. Philadelphia (PA): University of Pennsylvania Museum Press.
Dibble, H. & A. Montet-White (eds.), 1998. *Upper Pleistocene Prehistory of Western Eurasia*. Philadelphia (PA): University of Pennsylvania Press.
Dibble, H. & N. Rolland, 1992. On assemblage variability in the Middle Paleolithic of western Europe: history, perspectives and a new synthesis, in Dibble & Mellars (eds.), 1–28.
Garrod, D.A.E., & D.M. Bate (eds.), 1937. *The Stone Age of Mount Carmel*, vol. 1. Oxford: Clarendon Press.
Gould, R.A., D.A. Koster & A.H.L. Sontz, 1971. The lithic assemblage of the western desert of Australia. *American Antiquity* 36(2), 149–69.
Gowlett, J.A.J., 1984. Mental abilities of early Man: a look at some hard evidence, in *Human Evolution and Community Ecology*, ed. R. Foley. London: Academic Press, 167–92.
Hammond, M., 1982. The expulsion of the Neanderthals from human ancestry: Marcelin Boule and the social context of scientific research. *Social Studies in Science* 12, 1–36.
Hardy, B.L., 1999. Microscopic residue analysis of stone tools from the Middle Paleolithic site of Starosele, in Chabai & Monigal (eds.), 179–96.
Hardy, B.L. & M. Kay, 1999. Stone tool function at Starosele: combining residue and use-wear evidence, in Chabai & Monigal (eds.), 197–209.
Jelinek, A., 1975. A preliminary report on some Lower and Middle Paleolithic industries from the Tabun cave, Mount Carmel (Israel), in *Problems in Prehistory: North Africa and the Levant*, eds. F. Wendorf & A. Marks. Dallas (TX): Southern Methodist University Press, 297–316.
Jelinek, A., 1976. Form, function, and style in lithic analysis, in *Cultural Change and Continuity: Essays in Honor of James Bennett Griffin*, ed. C. Cleland. New York (NY): Academic Press, 19–33.
Jelinek, A., 1982. The Tabun Cave and Paleolithic man in the Levant. *Science* 216, 1369–75.
Jelinek, A., 1988. Technology, typology, and culture in the Middle Paleolithic, in Dibble & Montet-White (eds.), 199–212.
Kuhn, S., 1991. Unpacking lithic reduction: lithic raw material economy in the Mousterian of West-Central Italy. *Journal of Anthropological Archaeology* 10, 76–106.
Kuhn, S., 1992. Blank form and reduction as determinants of Mousterian scraper morphology. *American Antiquity* 57, 115–28.
Kuhn, S., 1995. *Mousterian Lithic Technology*. Princeton (NJ): Princeton University Press.
Kuhn, S. & M. Stiner, 1998. Middle Paleolithic 'creativity' reflections on an oxymoron?, in *Creativity in Human Evolution and Prehistory*, ed. S. Mithen. New York (NY): Routledge, 143–64.
Laplace, G., 1964. Essai de typologie systématique. *Annali Università di Ferrara n.s.* 15, 1–86.
Laplace, G., 1968. Récherches de typologie analytique. *Origini* 2, 7–64.
Levi-Sala, I., 1986. Use wear and post-depositional surface modification: a word of caution. *Journal of Archaeological Science* 13(3), 229–44.
McCown, T.D., 1937 Mugharet Es-Skhūl: description and excavations, in Garrod & Bate (eds.), 91–107.
Mellars, P.A., 1964. The Middle Paleolithic surface artifacts at Kokkinopilos. *Proceedings of the Prehistoric Society* 30, 229–44.
Mellars, P.A., 1989. Technological changes across the Middle–Upper Paleolithic transition: technological, social, and cognitive perspectives, in *The Human Revolution: Behavioral and Biological Perspectives on the Origins of Modern Humans*, eds. P. Mellars & C. Stringer. Princeton (NJ): Princeton University Press, 338–65.
Mellars, P.A., 1996. *The Neanderthal Legacy*. Princeton (NJ): University Press.
Mellars, P.A., 1999. The Neanderthal problem continued. *Current Anthropology* 40(3), 341–50.
Mithen, S., 1996. *The Prehistory of the Mind*. London: Thames & Hudson.
Monnier, G., 1992. Form, Function and Typology: a Case Study of Mousterian of Acheulian Tradition Backed Knives. Unpublished Masters dissertation, University of Cambridge.
Nowell, A., 1999. Symmetry and Standardization in Lithic Artifacts. Paper read at the Society for American Archaeology annual meetings, Chicago 1999.
Pelegrin, J., C. Karlin & P. Bodu, 1988. Chaînes opératoires: un outil pour le préhistorien, in *Technologie Préhistorique*, ed. J. Tixier. Paris: C.N.R.S., 55–62.
Schiffer, M.B., 1976. *Behavioral Archaeology*. New York (NY): Academic Press.
Schwarcz, H.P., W.M. Buhay, R. Grün, H. Valladas & E. Tchernov, 1988. ESR dates for the hominid burial site of Qafzeh in Israel. *Journal of Human Evolution* 17, 733–37.

Semenov, S., 1964. *Prehistoric Technology*. New York (NY): Barnes & Noble.
Shea, J.J., 1988. Spear points from the Middle Paleolithic of the Levant. *Journal of Field Archaeology* 15, 441–50.
Stringer, C.B. & C. Gamble, 1993. *In Search of the Neanderthals: Solving the Puzzle of Human Origins*. London: Thames & Hudson.
Trinkaus, E., 1992. Morphological contrasts between the Near Eastern Qafzeh-Skhūl and late archaic human samples: grounds for a behavioral difference?, in *Evolution and Dispersal of Modern Humans in Asia*, eds. T. Akazawa, K. Aoki & T. Kimura. Tokyo: Hokusen-Sha, 277–94.
Trinkaus, E. & P. Shipman, 1993. *The Neanderthals: Changing the Image of Mankind*. New York (NY): Alfred A Knopf.
Turq, A., 1979. L'évolution du Moustérien de type Quina au Roc de Marsal et en Périgord. Unpublished Thesis, l'École des Hautes Etudes en Sciences Sociales, Bordeaux.
Turq, A., 1992. Raw material and technological studies of the Quina Mousterian in Perigord, in Dibble & Mellars (eds.), 75–86.
Valladas, H., J-M. Geneste, J-L. Joron & J-P. Chadelle, 1986. Thermoluminescence dating of Le Moustier (Dordogne, France). *Nature* 322, 452–4.
Wolpoff, M. & R. Caspari, 1997. *Race and Human Evolution*. New York (NY): Simon and Schuster.
Wynn, T., 1989. *The Evolution of Spatial Competence*. Urbana (IL): University of Illinois Press.
Zilhão, J. & F. d'Errico, 1999. Reply to Mellars. *Current Anthropology* 40(3), 355–64.