

# Using spatial context to identify lithic selection behaviors

Amy E. Clark

Department of Anthropology, University of Oklahoma, 455 West Lindsey, Norman, OK 73019, USA

## ARTICLE INFO

### Keywords:

Lithic technology  
Spatial analysis  
Middle Paleolithic

## ABSTRACT

To differentiate between “tools” and “debris”, lithic analysts usually rely on the presence or absence of retouch, traces of use-wear, or extrapolation of the “desired end products” through the reconstruction of the *chaîne opératoire*. These methods usually fail to identify the full range of unretouched lithics utilized, especially at the assemblage scale. The spatial context of lithic pieces is often overlooked as an additional tool to identify tool selection. This paper presents the results of a study of seven open-air Middle Paleolithic sites in France, where lithic production and selection can be segregated in space. Two interrelated methods are utilized, one which relies on refitting data and the other which focuses on the differential spatial distribution of lithic artifacts. At these sites, the selected lithics identified using these methods match up well with what archaeologists have long thought to be “desired end products” but many of these sought pieces were also left with the manufacturing debris, indicating that lithics were produced in mass irrespective of immediate demand. The methods presented in this paper can therefore provide answers to many salient questions regarding lithic production and selection and are applicable to any context where lithic production has a strong spatial signature.

A major obstacle in lithic analysis is the difficulty of distinguishing between products and waste. Some pieces, such as points, were clearly knapped with the intent to be utilized. Flakes modified by retouch can also be easily identified as products. Unretouched flakes present a problem, however. We know from ethnographic accounts (MacCalman and Grobelaar, 1965; Masao, 1982; Miller Jr., 1979; White, 1967; White and Thomas, 1972) and use wear analysis (Keeley, 1980) that many were utilized as tools. Experimental work has also supported this conclusion (Crabtree and Davis, 1968). In lithic analysis the standard procedure is to divide the assemblage into tools and debitage (Andrejsky Jr., 2005). Tools are defined as those pieces that are modified after being knapped. Unmodified pieces, even large flakes, are often treated as waste in lithic analysis, even though most archaeologists acknowledge their tool potential. The result is that a whole subset of potential tools is missing from analyses and the conclusions drawn from them. This dilemma has not gone unrecognized in the literature (Dibble et al., 2017).

In some studies, the invisibility of utilized, but unretouched, flakes does not pose a problem. Retouched lithics provide an indication of the intensity of tool use. Tools used repeatedly, or for prolonged periods of time, generally have to be retouched in order to maintain a sharp edge (Frison, 1968, 2004). Thus, in some situations, such as in areas of raw material scarcity, retouch indexes might be high and the use of unretouched flakes negligible. Likewise, if the objective of the research is to compare the intensity of occupation over long periods of time, the

addition of unmodified flakes would not be necessary (Kuhn, 2004a; Kuhn and Clark, 2015; Riel-Salvatore and Barton, 2004). Nevertheless, unretouched lithics constitute a part of the lithic tool kit. In some places and time periods, they may have been the *entire* tool kit.

White (1967) describes tool selection among Highland New Guineans as simply the search for the most suitable material at hand, whether it be a flake, a core, or an amorphous chunk of stone material. All pieces of stone material were regarded in the same way. In this ethnographic example, flakes were never modified after having been knapped. But if we cannot use retouch as a marker, how can we separate tools from debitage? Which unmodified flakes were viewed as having utility and which were not? In some cases, these flakes may have been utilized, in other cases they may have been set aside, or cached, for future use. In both cases, however, these lithics were identified as having use-potential and selected from among the knapping debris. In a summary of the ethnographic literature of stone tool use, Holdaway and Douglass (2012 and citations therein) provide several examples of post-production lithic selection, where lithics were set aside for future use but only a small subset of this selected group were ultimately utilized. This selection process, however, is of utmost interest to archaeologists because it gives us an indication of which lithics were deemed to have use-potential and which were not. Of course, the determination of having use-potential is not always shared by all stone users, it can change from task to task, and in some cases the decision can be fairly arbitrary (Holdaway and Douglass, 2012). Lithics that were rejected by

E-mail address: [aeclark@ou.edu](mailto:aeclark@ou.edu).

<https://doi.org/10.1016/j.jasrep.2019.03.011>

Received 3 October 2018; Received in revised form 28 February 2019; Accepted 15 March 2019

Available online 02 April 2019

2352-409X/ © 2019 Elsevier Ltd. All rights reserved.

the knapper might be picked up and utilized by another individual and the knapper may later return to her debitage pile to scavenge any remaining pieces. The challenge, therefore, is how to identify this sometimes irregular behavior in the archaeological record.

Archaeologists have relied on two principle methods to identify selected, but unmodified, lithics in an archaeological assemblage. The first is by examining them for use-wear or residue (Dinnis et al., 2009; Hardy et al., 2008; Rios-Garaizar and Ortega Cordellat, 2014; Rots, 2013; Rots et al., 2011). Although this approach has been instrumental in proving that unretouched flakes were utilized, it is seldom suitable for assemblage-scale study, because it is labor intensive and often too time consuming to thoroughly investigate all lithic artifacts (Holdaway et al., 2014). Typically, only a small number of pieces can be fully analyzed, and those specimens thought to be the best candidates for use are selected by the archaeologist for analysis. This provides archaeologists with a larger sample of lithics exhibiting use wear and a correspondingly wider suite of behaviors represented. However, it is also a biased sample of utilized and unutilized artifacts.

Another perspective on potentially selected lithics comes from the *chaîne opératoire* approach (Boëda, 1995; Boëda et al., 1990; Bourguignon, 1997). Scholars, particularly in France, have defined a diverse suite of core reduction techniques, such as the Levallois, Discoid, or Quina methods, based on the characteristic procedures and presumed goals of lithic knapping sequences (Meignen et al., 2009). The inferred goal of such a reduction method might be Levallois flakes or pseudo-Levallois points. Although it is reasonable to assume that these pieces have a higher likelihood of being selected for use, we cannot know whether any one particular piece was chosen unless there is additional evidence for its use. Furthermore, what are typically considered to be byproducts in the reduction process have been found to exhibit use wear or retouch (Shimelmitz and Kuhn, 2017, 2013).

Analyses of lithic use-wear and reduction sequences produce information salient to many questions, but they cannot tell us – at the scale of the assemblage – which lithics were selected for use and which were simply discarded after production. In both types of analysis, information is sought within the lithic itself, rather than the context in which it was found. Holdaway and Douglass (2012:102) point out a fixation on the characteristics of lithics, rather than the systemic context, is the norm for most interpretations of lithic artifacts. This goes hand in hand with a persistent focus on the “end product” (as determined by the archaeologist) of lithic reduction, be it via a typological or *chaîne opératoire* approach, rather than the entire suite of debitage. Dibble et al. (2017) recently argued that, in fact, the desired end product in lithic manufacture is a “fallacy” and furthermore we are simply unable to identify selected pieces in the archaeological record. This leaves current lithic analysis in a tenuous position: an obsessive focus on one portion of the lithic assemblage that is not necessarily reflective of prehistoric tool use. However, if we turn our attention to the context of lithic artifacts, through the use of spatial analysis, we can better identify those artifacts that were selected from the debitage to be utilized or set aside, regardless of evidence of subsequent use (retouch or use wear). Spatial analysis can also provide a perspective on the production of lithic knapping by studying the location of lithic knapping, the associated debris pile, and the types of lithic pieces that were not selected but left with the manufacturing debris.

In this paper, I identify selected lithics by using spatial segregation of lithics and knapping debris, though the identification of high, medium, and low density areas and the spatial spread of refitting sets. The Middle Paleolithic sites that I utilize in this study are open air with raw materials nearby. High density areas where knapping occurred can be relatively easily identified. I assume that artifacts removed from the knapping debris and moved several meters away were either brought there to be utilized immediately or cached, and therefore can be considered to be “selected”. Mass movement of artifacts through geologic processes was ruled out but some movement from geologic processes and unintentional anthropogenic behavior is expected to be present. In

general, knapping usually takes place in one location, where a large amount of debris is created. Certain objects are selected and moved elsewhere. This pattern has been identified repeatedly through the analysis of refitted lithics (Bourguignon et al., 2008; Clark, 2015, 2017). By examining spatial disjunction between the lithic knapping locations and the locations of artifact abandonment, we can identify which lithics were selected presumably to be further utilized or cached and which were left with the manufacturing debris. Furthermore, we can gain an understanding of how the manufacturing process unfolded in time, because displacement of artifacts references longer temporal increments than does abandonment of artifacts in the place they were produced.

Two important conclusions can be made from these results. First, there is variability in the lithic pieces selected, but some kinds of pieces are chosen more often than others. These pieces tend to be those archaeologists consider to be products of the reduction sequence. Second, a large portion of knapped material was left in place after knapping. This discarded material forms dense piles and is the most distinctive spatial feature at open-air sites across France (Locht, 2011). These piles are not made up just of “waste” material, such as core maintenance flakes and cortical flakes, but of Levallois flakes and blades, which are often interpreted as desired end products. This pattern suggests that lithic blanks were not produced on a one-by-one basis as needed but, rather, that a large portion of a core was knapped at one time irrespective of immediate demand. These sites were all located close to, or even on top of, a raw material source. Conservation of raw materials was therefore not a concern, and production costs were low. This situation proved to be an ideal scenario in which to study the production and selection of lithic stone tools.

## 1. Distinguishing between selected and non-selected lithics at open-air Middle Paleolithic sites

The sites included in this study were excavated by INRAP (*Institut National de Recherches Archéologiques Préventives*) archaeologists prior to large scale construction projects. Because they were to be destroyed, or permanently covered, these sites were excavated over very large areas and, often, in their entirety. As such, they are well suited for intra-site spatial analysis. The individual site areas range from 207 to 1928 square meters<sup>1</sup> and assemblages vary from 870 to 15,797 specimens (Table 1). Within this variation, sites share certain structural features. They can be characterized as aggregates of one or more high-density piles, or *amas*, of lithic artifacts, grading into medium- and low-density zones between the piles and toward the extremities of the site (Fig. 1). At some of the sites, such as those situated very close to raw material sources, the number of *amas* is so great and they are so tightly packed that the site appears to be one high-density concentration. At other sites distinct concentrations of material are well separated in space. These characteristics are not unique to the sites included in this study; INRAP has excavated a large number of open-air sites in France and they typically share these basic features (Depaepe, 2007; Locht, 2011).

Three sites, Bettencourt-Saint-Ouen, Fresnoy-au-Val, and Villiers Adam, are located north of Paris in the loess belt of northern Europe (Fig. 2). These three sites consist of archaeological layers associated with forest soils on gentle northeast-facing slopes where eolian sediment was accumulating (Goval and Locht, 2009; Locht, 2001, 2002; Locht et al., 2003, 2008, 2010). Bettencourt and Fresnoy have multiple archaeological horizons associated with soils but I only included the horizon with the highest artifact count in this study. La Folie is located further south, outside the city of Poitiers, on the flood plain of the Clain River. It is a small, exceptionally well preserved site with a fire feature, a non-pedogenic organic horizon interpreted as bedding, and post holes

<sup>1</sup> Area was calculated by creating a polygon around the plotted lithics and therefore is an approximation of site area rather than excavation area.

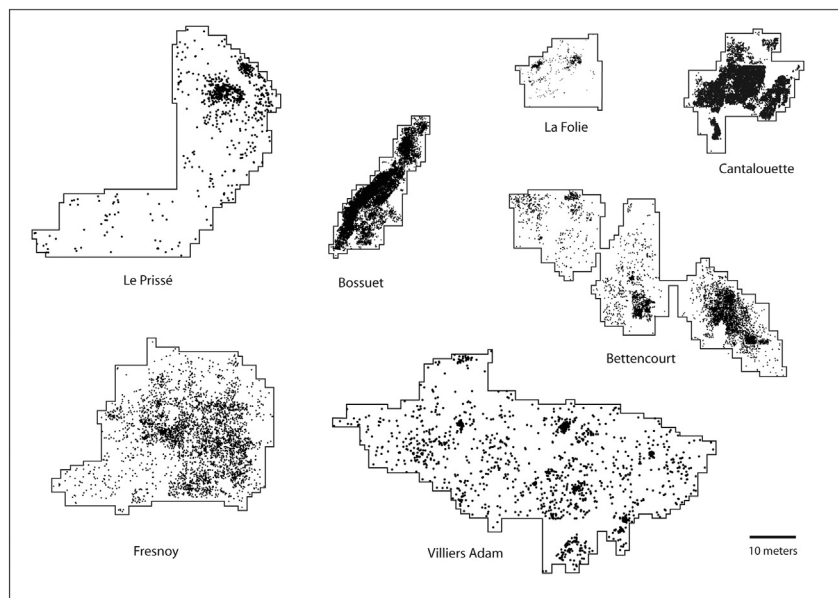
**Table 1**

The site area, total lithics, and percentage of the assemblage that was refit for all seven sites in the study. Note that the site area was calculated by creating a polygon around the plotted lithics and is therefore a minimum site boundary rather than the area excavated.

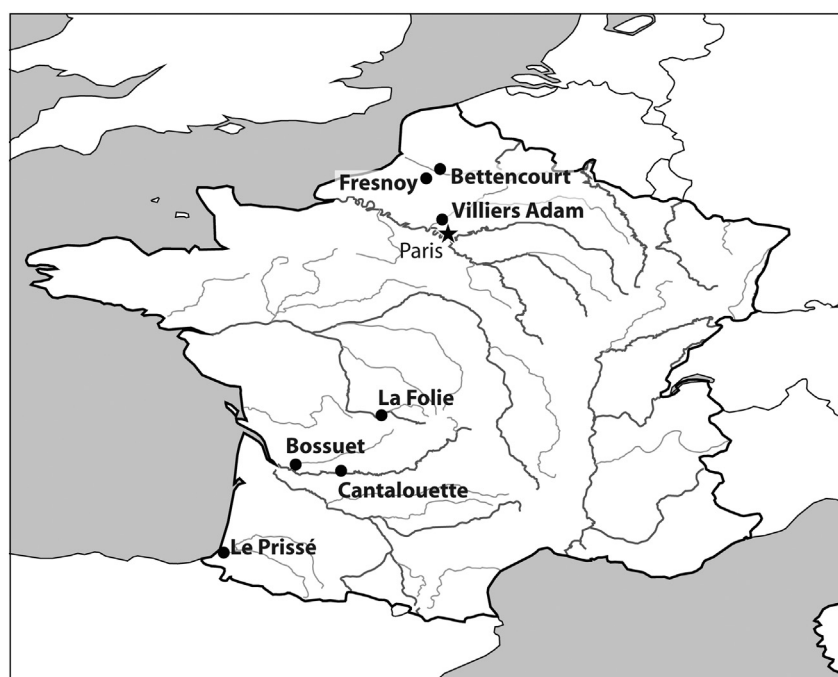
	Site Area (m <sup>2</sup> )	Total lithics	% refit
Bettencourt	915	5729	14
Bossuet	228	15,797	5
Cantalouette	282	15,404	10
La Folie	207	1262	38
Fresnoy	1143	4270	9
Le Prissé	1075	870	20
Villiers Adam	1928	1619	4

that may be the remains of a wind break (Bourguignon et al., 2002, 2006; Bourguignon, 2010). Champ de Bossuet, northeast of Bordeaux, and La Doline de Cantalouette (near Bergerac) are both located on sources of high quality (chert) raw material (Bourguignon et al., 2008, 2000). In the case of Bossuet, this material was located within a paleo channel on a terrace next to the Isle River and at Cantalouette, the material is found within and adjacent to a doline, or sink hole. Le Prissé de Bayonne is the southernmost site in the study and is situated on a plateau near the confluence of the Adour and Nive rivers, outside the city of Bayonne (Colonge et al., 2015; Deschamps et al., 2016).

All seven sites are characterized by lithics derived from well-organized *chaînes opératoires* (Table 2). The three sites in the north of France, Fresnoy, Bettencourt, Villiers Adam, contain points, Levallois



**Fig. 1.** The spatial distribution of lithic artifacts (black dots) at the seven sites included in this study presented at the same scale.



**Fig. 2.** A map of France displaying the location of the sites included in this study.

**Table 2**  
The dominant *chaîne(s) opératoire(s)* and products at the sites in the study.

	Dominant <i>chaîne(s) opératoire(s)</i>	Main products as determined by the <i>chaîne opératoire</i>
Bettencourt	Levallois Unipolar	Flakes Blades Points
Bossuet	Discoid	Pseudo-Levallois points
Cantalouette	Preferential Levallois Unipolar	Levallois flakes Naturally backed flakes
La Folie	Levallois	Levallois flakes
Fresnoy	Levallois	Levallois flakes Blades Points
Le Prissé	Discoid	Pseudo-Levallois points
Villiers Adam	Levallois	Levallois flakes Blades Points

flakes, and blades manufactured by several *chaînes opératoires*. The most dominant is the Levallois method, represented by several production modes (preferential, recurrent unipolar, centripetal) but there is also a convergent unipolar method for producing points, and the turning method for producing blades (Locht et al., 2010). La Folie is dominated by the Levallois method oriented toward the production of flakes (Bourguignon et al., 2006). This is also the case for Cantalouette, in addition to a unipolar method, which produced backed pieces (Bourguignon et al., 2008). Champs de Bossuet and Le Prissé are the only two sites that are not well represented by the Levallois method; these two sites contain artifacts primarily produced through the Discoid method (Bourguignon et al., 2000; Colonge et al., 2015).

These sites are ideal locations to differentiate between selected and non-selected lithic artifacts. Like many open-air Middle Paleolithic sites in France, the sites studied here were primary locations for lithic production. Raw material sources were located nearby (and sometimes right underneath) the site and lithic knapping was a major activity at these locations. Importantly, however, activities other than lithic production also took place at these sites. Many lithic artifacts were picked up and moved across the site, likely for use in another activity. Use wear analysis further indicates that many artifacts were used in tasks such as woodworking, butchering, and hide working. This pattern holds true even for the sites located on raw material sources, such as Cantalouette and Bossuet. Therefore, many lithics were selected to be used on site and were deposited there, although many others were likely exported to be used off-site. Finally, because so much lithic production occurred in an unconstrained area, we can more easily separate knapping locations from non-knapping locations. This is in contrast to many cave and rockshelter sites where re-occupation and low rates of sediment deposition mean that artifacts are jumbled together and locations of lithic production are difficult to identify. Open-air sites in contrast were often re-occupied less intensively and evidence for individual short-term events such as knapping episodes tend to be better preserved.

## 2. Intra-site spatial analysis methods

The spatial structure of these sites was evaluated by using two complementary methods (Clark, 2015, 2016, 2017). The first uses data from lithic refitting and assigns each artifact from a refitting set to a group based on where it is located relative to the other specimens in the set. A refitting set is made up of two or more lithics that refit together, and therefore came from the same raw material nodule. Lithic refitting sets are commonly spatially organized in a repetitive pattern. Most pieces are located within 1 m of each other, a smaller number are found in adjacent areas, and very few pieces are located at a greater distance from the main cluster. This pattern is documented by measuring

distances using ArcGIS. Each refitting set is measured separately. Measuring begins with the lithics that are located closest together. All lithics located within 1 m of one another, and are most tightly clustered together, are assigned to refitting group 1; refitted artifacts located within two meters of group 1 are placed in refitting group 2; and specimens more than two meters away from group 1 are placed in refitting group 3. All refitted lithics are assigned to one of the three refitting groups for each refitting set. The lithics assigned to refitting group 1, which are those found concentrated together, are most likely to correspond to the knapping location and left where they were knapped. Lithics in groups 2 and 3 were likely moved away from their knapping location.

The second method uses the spatial distribution of all lithic material. Like the first method, the lithics are assigned to three groups based on where they are located. The majority of artifacts in any site cannot be (or were not) refitted to other specimens. This method was developed to track which lithic technological categories are found in the lithic piles, or high density areas, and which are located in the medium and low density areas that surround them, irrespective of whether they can be refit. First a density map is created in ArcGIS. A density map is a raster image that depicts changes in artifact density with changes in color. High, medium, and low density areas are delimited by creating contours from the density map and then selecting two contours that best track the visible spatial structure. Finally, lithics are assigned to a density group based on where they occur within the site.

All lithics in the study sample were analyzed by INRAP archaeologists (or by me) and assigned to standardized technological and typological categories. I further grouped the determinations made by INRAP archaeologists into simplified categories such as “core maintenance flakes” and “debris”. I then examined the composition of the density and refitting groups. I compared the representation of technological categories in each spatial group to the assemblage as a whole, using standard criteria for statistical significance (95% confidence intervals,  $\alpha = 0.05$ ).

## 3. The selection of lithics

Lithic selection – either by the knapper or another individual – can be identified by examining the pieces moved away from the knapping piles. Geologic processes have a role in this movement, but the dominant processes at the sites in question are related to human action, particularly for those lithic pieces moved the longest distances (Clark, 2017). Some pieces were also moved by humans accidentally through trampling or other actions. This type of movement would most likely have moved individual specimens shorter distances. For this reason, I concentrate on lithics located in the low-density areas and in refitting group 3, which were moved more than two meters from the location of knapping. These groups can be compared with the high-density group and refitting group 1, which should display the inverse of the patterns found in the low-density group and refitting group 3. Because I will be referring to these two sets of groups repeatedly, I will call refitting group 1 and the high density group the “clumped” groups and refitting group 3 and the low density group the “dispersed” groups. Table 3 displays the predictions for lithic categories we might expect to see in the clumped groups and the dispersed groups if these zones correspond with knapping debris and selected lithics respectively. Table 4 lists the results of the analysis by showing lithic categories that are over-represented or under-represented at each site in these two sets of groups. A site is listed when it achieved a statistically significant result for that lithic category. A site is listed twice if it achieved significance for both analyses in the set.

I predicted that the clumped groups (refitting group 1 and the high-density group) would be overrepresented in core maintenance flakes and debris (Table 3). This was indeed the case. In fact, debris was one of the lithic categories to achieve statistical significance consistently at most sites. Most of the significant results for debris came from the

**Table 3**

The predicted results by technological category. The “clumped groups” are refitting group 1 and the high density group. The “dispersed groups” are refitting group 1 and the low density group.

	Overrepresented: Clumped groups	Underrepresented: Dispersed groups	Underrepresented: Clumped groups	Overrepresented: Dispersed groups
Debris	✓	✓		
Core maintenance flake	✓	✓		
Cortical flake	✓	✓		
Partially cortical flake	✓	✓		
Débordant flake	✓	✓		
Naturally backed flake	✓	✓		
Core	✓	✓		
Tested nodule	✓	✓		
Retouched tool			✓	✓
Non-cortical flake			✓	✓
Levallois flake			✓	✓
Blade			✓	✓

density contour analysis where debris was found to be overrepresented in the high-density group at four of the seven sites and underrepresented in the low-density group at five of the seven sites. The two sites that did not show statistical significance for debris were Cantalouette and Bossuet, the two sites on top of raw material sources where the spatial patterning was particularly convoluted. The refitting analysis produced fewer significant results for debris because this category of lithics is smaller and therefore more difficult to refit. Core maintenance flakes follow the pattern of debris and are overrepresented at three sites in the clumped groups and underrepresented at three sites in the dispersed sites. Some discrepancy occurs at the site of Bettencourt where the two analyses disagreed with one another. Core maintenance flakes achieved significant results in the refitting analysis for overrepresentation in the clumped groups and underrepresentation in the dispersed groups while the density contour analysis displayed the

opposite pattern. It is difficult to explain why this contrasting pattern occurred, but it may have been through site reuse (see [Clark, 2016](#) for a longer discussion). The refitting analysis, which has considerably less noise than the density contour analysis, follows the predicted pattern of core maintenance flakes associated with the reduction debris.

Cortical flakes and partially cortical flakes also tend to be overrepresented in the clumped groups and underrepresented in the dispersed groups. However, at Bettencourt and Fresnoy the two analyses once again display conflicting results. Like with core maintenance flakes, the results from the refitting analysis support the predicted pattern of cortical and partially cortical flakes spatially associated with the reduction debris. These flakes do tend to be larger, however, so some selection of these lithic types would not be surprising. Débordant flakes and naturally backed flakes do not display many significant results. They are found to be underrepresented only at Le Prissé in the

**Table 4**

The results by technological category. Sites in italicized font display results from the refitting analysis while those in normal font are from the density contour analysis. The raw data used to build this table can be found in the supplementary material.

	Overrepresented: Clumped groups	Underrepresented: Dispersed groups	Underrepresented: Clumped groups	Overrepresented: Dispersed groups
Debris	Bettencourt La Folie Fresnoy <i>Le Prissé</i> Villiers Adam	Bettencourt La Folie Fresnoy <i>Le Prissé</i> Villiers Adam		
Core maintenance flake	<i>Bossuet</i> <i>Bettencourt</i> Fresnoy	<i>Bossuet</i> <i>Bettencourt</i> Villiers Adam	Bettencourt	Bettencourt
Cortical flake	<i>Bettencourt</i> Villiers Adam	<i>Bettencourt</i> Villiers Adam	Bettencourt	Bettencourt Fresnoy
Partially cortical flake	La Folie <i>Fresnoy</i>	<i>Fresnoy</i> <i>Le Prissé</i>	Fresnoy	Fresnoy
Débordant flake			Le Prissé	
Naturally backed flake			Le Prissé	
Core			Bettencourt <i>Bettencourt</i> Cantalouette Villiers Adam	Bettencourt Fresnoy <i>Le Prissé</i> Villiers Adam
Tested nodule	<i>Le Prissé</i>		Villiers Adam	Villiers Adam
Retouched tool	<i>Bettencourt</i> <i>Fresnoy</i>		La Folie <i>La Folie</i> <i>Le Prissé</i> Villiers Adam	La Folie <i>La Folie</i> <i>Le Prissé</i> Villiers Adam
Non-cortical flake			Bettencourt <i>Bettencourt</i> Fresnoy Villiers Adam	<i>Bettencourt</i> Villiers Adam
Levallois flake			<i>Bettencourt</i> Fresnoy Villiers Adam	Fresnoy
Blade		Bettencourt	Fresnoy Villiers Adam	Fresnoy

clumped groups. This suggests that they may have been selected to be utilized at this site. While débordant flakes are often thought to be a type of core maintenance flake since they remove part of the platform, they also have a similar morphology as naturally backed flakes, which have sometimes been hypothesized to be a desired end product. Indeed, at Cantalouette, naturally backed flakes are the proposed product of the unipolar *chaîne opératoire* (Bourguignon et al., 2008). No significant results were found for this artifact category at Cantalouette, but there are few significant results at this site in general.

In Table 3, I predicted cores and tested nodules would stay with the knapping debris. Surprisingly, this did not prove to be the case. Cores were consistently found to be underrepresented in the clumped groups and overrepresented in the dispersed groups. They were not discarded with their associated reduction debris but were selected and moved to low density areas. There are several possible explanations for this behavior, but it is likely that they were set aside for use as tools or cores (Clark, 2017). Tested nodules display the same pattern except that they are overrepresented in refitting group 1 (a clumped group) at Le Prissé.

Cores displayed one of the strongest patterns of overrepresentation in the dispersed groups and underrepresentation in the clumped groups, suggesting that they were among the selected pieces. As we would expect, retouched tools also followed this pattern, although the refitting analysis at Bettencourt and Fresnoy did not agree. Non-cortical flakes also display a pattern consistent with having been selected for use. Levallois flakes and blades were also found to be overrepresented in the dispersed groups and underrepresented in the clumped groups, although there are fewer sites with significant results for these categories. It should be noted that not all sites contained these two categories (see Table 2). This analysis confirms that these pieces were indeed important to Middle Paleolithic foragers.

This method of identifying selected lithics works at these sites because the knapping process can be tracked spatially. One can see where lithic knapping occurred and the centrifugal movement of pieces from that location, whether through accidental movement, geologic activity, or lithic selection. By concentrating on longer distance movements, I can focus more exclusively on intentional selection. These sites are ideal because they are open air, and thus are not confined spatially, and because raw material sources are located nearby. Not all sites in the sample were well suited for this study, however; Cantalouette and Bossuet were mainly workshop sites and were so dense and jumbled that they did not provide many significant results.

If the knapping process can be spatially identified, as in many of the sites used in this study, selected pieces can be distinguished from non-selected material. It is an objective basis of determining selected artifacts, in that we do not need to speculate on the intention of the knapper, rather we can simply see which pieces were picked up and moved away from the knapping location. This method is based on the assumption that the occupants on the sites intended to move the lithics, but this assumption is safer than assuming what people wanted based on what they retouched or how they reduced their cores. The tool selection may have been done by the person who did the knapping or by another individual who needed a blank or other piece of stone. The reasoning behind this analysis is similar to that presented by Turq et al. (2013). Turq and colleagues argued that pieces moved from one site to another must have been utilized, or were intended to be utilized, even if many of these pieces are unretouched. Determinations based on long-distance movement are more robust than the results presented here, given that the artifacts they describe were moved many kilometers between sites while those in this study were moved only a few meters. Nonetheless, artifacts moved within sites do have a much higher probability of having been selected for future use than those left with manufacturing debris. Furthermore, given that every archaeological assemblage is the time average of a suite of behaviors, patterns must be examined by focusing on the average trend of behaviors, rather than attempting to interpret individual actions (Bailey, 2007; Binford, 1981; Holdaway and Wandsnider, 2006; Premo, 2014).

#### 4. Dense concentrations of non-selected lithics

Just as important as determining which artifacts were selected for use is the determination of which artifacts were abandoned after knapping and never utilized. This information can tell us which lithics were passed over when an implement or core was sought and, also, it can tell us about how the manufacturing process unfolded in time. The timing of core reduction, whether the core was reduced all at once or in a piecemeal fashion over the course of several sessions, can indicate whether lithics were knapped with a specific task in mind or produced *en masse* to give an array of sharp edges to choose from. A knowledge of the cadence of lithic knapping also provides a unique glimpse into the goals, or intention, of the stone knapper and the importance he or she placed on various parts of the *chaîne opératoire*. For example, if the core was prepped at one location and then reduced in short episodes at many other locations, we could conclude that each lithic artifact removed after the core was prepared was a target. On the other hand, if the core was prepared and completely reduced in one location this would suggest less emphasis was placed on any one removal. In reality, the spatial and temporal signature of core reduction may not be so clear cut and other factors may complicate our ability to make determinations regarding knapping goals, such as multiple individuals knapping the same core.

The spatial organization of lithic artifacts can give a unique glimpse into the cadence of lithic manufacture. Through lithic refitting and artifact density, the location of lithic manufacture can be identified and those lithics located elsewhere can be inferred as having been moved. Movement in space generally corresponds with intervals in time (though intervals in time can occur without movement in space), and we can gain a perspective on the timing of lithic manufacture that is not available from other approaches.

The sites in the study are characterized by dense concentrations of lithic material surrounded by large areas with a low density of lithic artifacts. As discussed above, the high-density areas mark areas of lithic knapping, evidenced by the overrepresentation of debris, core maintenance flakes, and cortical flakes. At most sites, over one third of the lithics were located within high density areas as defined by the Density Contour Analysis, though they usually make up less than 10% of a site's area (Table 5). This suggests that these dense concentrations were the result of the reduction of more than one core. In order to test this, I examined the association of refitting sets with high density areas from two sites, Bettencourt and La Folie. I chose these sites because they represent opposing ends of the artifact density continuum. I counted each refitting set that included one core and that had more than 50% of the refitted pieces located within a high density area. This was to ensure that the core reduction took place within the high density areas, and that the pieces were not simply brought there. I included only refitting sets with cores so that fragmented reduction sequences were not counted twice. This would represent a minimum estimate of the number of cores reduced per high density area, as I was only counting

**Table 5**

The percentage of lithics in the high density area and refitting group 1 (both hypothesized to be equivalent to knapping locations) and the percentage of the site's area that is high in density.

	Percent of assemblage located in high density area	Percent of site's area that is high density	Percent of refitted assemblage that is in refitting group 1
Bettencourt	34%	2%	58%
Fresnoy	42%	9%	51%
Le Prissé	49%	3%	51%
La Folie	78%	4%	69%
Villers Adam	26%	2%	81%
Bossuet	42%	13%	55%
Cantalouette	20%	5%	77%

pieces that were refit and those sets which included a core. At Betten-court, there were four high density areas. They had between five and fourteen minimum cores reduced there (5, 6, 9, and 14 for the four high density areas). La Folie had two high density areas, one that contained six minimum core reductions, and the other with seven. La Folie has one of the lowest artifact counts in this study and still contains a minimum of six core reductions per high density area. This reinforces the conclusion that core reduction was concentrated in these discrete spatial areas. Other activities likely took place in the low-density areas, away from knapping debris. Most lithics located in the high-density areas were likely never picked up after having been knapped. Most pieces that were further utilized were moved away from the knapping area.

The amount of knapping debris left in place can be further illustrated by considering the entire data set of refitted artifacts. Over 50% of the refitted material at all seven sites is in refitting group 1, which are pieces located within 1 m of one another (Table 4). This is a powerful finding for several reasons. First, the refitting analysis offers a more precise assessment of knapping location than the density contour analysis because it traces knapping debris from a single core. Second, the definition of “refitting group 1” is the same at each site (i.e. all lithics within 1 m of each other) so that they are more directly comparable. In contrast, high-density zones are established independently at each site based on the distribution of lithics. Third, the category of “debris”, which includes all pieces smaller than 3 cm and “mistakes” such as split pieces, is underrepresented in the refitted assemblage and therefore the pieces included are more likely to be good candidates for use as tools. Finally, the refitted pieces likely represented knapping episodes that occurred later in the site's occupation because there were fewer holes in the refitting sequence from pieces moved off-site. Over time, it is more and more likely that a given artifact will be picked up and carried away, making it more and more unlikely that the reduction sequence can be refitted. Therefore, the refitting data might reflect the production and selection from fewer, more recent occupations and therefore were less impacted by trampling, recycling, and other processes of reoccupation that tend to distort the spatial patterning of previous activities. Of course, the more occupations occur at a site, the more lithics there are, and the harder it is to refit in general.

The sites with the highest percentage of artifacts in refitting group 1 are Cantalouette, Villiers Adam, and La Folie. Cantalouette is a workshop located on a raw material source: many cores were reduced and only a few pieces moved away and utilized. The lithics at Villiers Adam are concentrated in a number of small high-density zones spread out over a huge area. This may represent repeated occupations that are separated in space (Clark, 2016). Therefore, lithics may have been less likely to have been scavenged during later occupations. The same is the case for La Folie, which might be the only site in the study to represent a single occupation. The high percentage of artifacts in refitting group 1 suggests that after each knapping episode, a large part of the knapping debris and products was left unutilized in a high-density concentration and as time went on, lithic users selected lithics little by little. The lithics could have been selected during the same occupation as the core reduction, or they could have been picked up during a subsequent occupation (“post production selection” as described by Holdaway and Douglass, 2012).

An important point to emphasize is that the high-density zones and refitting group 1 do not contain only technological categories thought of as knapping debris. Many of the artifacts located in the high-density areas are considered “end products” by many lithic analysts. These include Levallois flakes, blades, and non-cortical flakes. At many sites, these categories are underrepresented in high-density areas, demonstrating that they were preferentially picked up and moved away. Still, many other pieces remain very close to where they were knapped. One could argue that these pieces were selected but utilized within the high-density refuse piles and discarded there. This is certainly possible, but in most cases one would assume that activities would take place in areas

clear of sharp debris, especially in open air contexts where space is unconstrained by stone walls. Furthermore, the refitting analysis indicates that most lithics are tightly clustered within a meter of one another. This spatial patterning is therefore more likely the production of primary core reduction since lithic experiments have shown that most lithic debris is concentrated within about 1 m of the knapper (Barton and Bergman, 1982; Newcomer and Sieveking, 1980).

Because most knapping products are left in place, it can be inferred that many cores were reduced all at once even though most products were not immediately needed. The need for a flake may have instigated a knapping episode but the knapping session did not necessarily end once the required flake was produced. Instead, knapping episodes often continued until a large number of products had been removed from the core. Furthermore, this process did not occur only once. A second core was reduced, producing another set of products, *before* all products from the previous episode were utilized. This occurred again and again until a large pile of lithic debris was created. This scenario is supported by the high number of minimum cores per high density area and by the contents of these concentrations, which includes not only knapping debris, but large non-cortical flakes, blades, and Levallois flakes. Most lithic artifacts were therefore not deliberately manufactured for a specific purpose, but were created in large numbers and left in place to be selected – or not – in the future.

This approach to core reduction does not indicate that the knapper was attempting to conserve time, energy, or raw material. None of these pressures would have been at work at these sites, however, because they are all located close to raw material sources. Very little time and energy was required to acquire the raw material, and raw materials were obviously in such an abundance that conservation was not necessary. Nevertheless, formalized and highly organized *chaînes opératoires* were utilized that have been proven to optimize raw material use (Brantingham and Kuhn, 2001; Eren et al., 2008; Eren and Lycett, 2012). Since economic pressures were not a factor, cultural norms likely explain why these core reduction methods were utilized.

What, therefore, was driving core reduction at these sites? It could have been effort to knap certain “ideal” pieces, and perhaps the best ones were removed from the site altogether. At the sites themselves, however, we often see similar pieces selected for use as those left behind with the reduction debris. Of course, this analysis was based on technological categories and not other attributes, such as edge length or flake size, that may have driven selection and were not evaluated here. One could hypothesize that it was a way to provision the location with a sizable store of knapped flakes, even if there were many raw materials nearby (Kuhn, 1995, 2004b). There was little economic pressure against such excessive flint knapping. Each visit to the site may have prompted another round of core reduction to ensure the freshest edges, even if many suitable pieces already remained. Nevertheless, whatever prompted the prodigious knapping, many of these sites became attractive locales on the landscape. The knapped material would have attracted reoccupation as a raw material source in and of itself (Camilli and Ebert, 1992; Haas et al., 2015).

## 5. Conclusions

This study utilized the spatial positioning of lithic artifacts to determine which pieces were selected and removed from the lithic debris and which were left where they were knapped. Two interrelated methods were employed. One utilized the spatial spread of lithic refitting sets and the other utilized the variable spatial density of artifacts to determine which pieces were selected or not selected at the site. The general trend is that lithic categories traditionally considered to be end products, such as Levallois flakes, non-cortical flakes, and tools, as well as cores, were selected to be utilized at a higher rate than other categories. At the same time, there is variability in the pieces that were selected, including “non-optimal” pieces such as cortical or maintenance flakes. In addition, the high density areas contain many

“optimal” lithics that were left with the knapping debris.

There are several important conclusions to be drawn from this study. First, contrary to what Dibble et al. (2017) argue in a recent paper, selected artifacts can be identified and many of those pieces are what archaeologists have long thought to be “end products”. Levallois flakes and non-cortical flakes were found to have been selected more often than pieces traditionally considered to be manufacturing debris. Therefore, to a certain extent, the desired end products of the stone knapper does line up with the selected piece of the stone user, given that these pieces were often found to have been selected according to the results of this study. But, many of the same pieces were left in place with the other lithic debris indicating that these lithics were not manufactured with a specific task in mind but produced in high numbers for unspecified future use. The idea of a “desired end product” was therefore much more fluid than what Dibble et al. claimed most archaeologists believed.

This study also demonstrated that spatial analysis can give some indication of how lithic reduction unfolded in time. From the vast amount of spatially concentrated debris, it is clear that a significant portion of each core was reduced during one knapping session, producing a large number of potential blanks without a particular task in mind. This does not mean that discarded cores were not picked up and knapped by other individuals, simply that a large amount number of flakes were produced during each knapping session. Many of the discarded lithics were not selected by the knapper, but by other individuals and sometimes significant amounts of time may have elapsed between production and selection. The post-production selection of material, usually by someone other than the knapper, is well-documented in the ethnographic literature (Holdaway and Douglass, 2012). In addition, not only were a large number of flakes produced during each knapping episode, but a systemic and well-thought-out *chaîne opératoire* was adhered to. This is contrary to many ethnographic accounts that describe a “smash and grab” model where a flake was knapped quickly and without predetermination, and then utilized (Sillitoe and Hardy, 2003; White, 1967; White and Thomas, 1972). But although Levallois flakes, blades, and non-cortical flakes were produced through efficient and well-organized core reduction strategies, it does not mean each piece was utilized. These highly systematic *chaînes opératoires* were utilized even though there was no economic impetus to do so.

These sites were located not far from raw material sources and, once a core is prepared, it does not require a lot of extra time to simply continue knapping until the core was significantly reduced. Most ethnographic examples show a large amount of rejected lithics compared to a small number of selected pieces (Holdaway and Douglass, 2012; MacCalman and Grobelaar, 1965; Miller Jr., 1979). In a paper describing two OvaTjimba groups in what is now Namibia, MacCalman and Grobelaar (1965) recount how one informant knapped twenty lithics, selected four for use, and only used two. The amount of debris represented at these Middle Paleolithic sites would have required quite a number of such episodes. New nodules were opened even though many suitable blanks remained, perhaps because “fresh” edges were desired in order to ensure the sharpest edges. Because these sites were located so close to raw material sources, these may have been good locations for individuals to practice their knapping skills. Whatever the explanation, it is clear that knapping products heavily exceeded existing needs.

In most studies, intra-site spatial analysis is used to identify activity areas (Adler et al., 2003; Alpersen-Afil et al., 2009; Folgado and Brenet, 2010; Simek, 1987), evaluate the use of space (Hayden, 2012; Pettitt, 1997; Riel-Salvatore et al., 2013), or to understand occupation dynamics and geologic processes (Enloe, 2006; Vaquero et al., 2012; Wandsnider, 2008). In these studies, lithic technology is used to inform spatial patterning. The location of tools indicates a wood or animal processing area. Tool types found in proximity are inferred to be a part of the same tool kit (Merrill and Read, 2010). Refitted lithics in

different stratigraphic units can indicate post-depositional mixing. Fewer studies, however, have used the spatial positioning of lithic artifacts to provide information about the lithics themselves. An exception is Cahen et al.'s (1979) influential article that uses the spatial location of refitted lithics to show how lithics were utilized and modified. Here, I focus specifically on lithic production and selection by determining which lithics were picked up and moved from the knapping location and which were left behind. I have established that the spatial arrangement of lithics follows an identifiable pattern. Lithics are knapped in one location, producing a pile of debris, and then pieces are chosen from this debris pile to be utilized. We can exploit this predictable pattern to distinguish “selected” pieces from “unselected” pieces. These methods of spatial analysis could therefore be applied to many different archaeological sites containing lithic knapping debris, as long as the spatial patterning of core reduction can be identified.

## Acknowledgements

I am deeply grateful to Laurence Bourguignon, Jean-Luc Loch, and David Colonge for providing me with the data for this research. I would like to thank everyone at the Institut National de Recherches Archéologiques Préventives Center in Campagne, Dordogne, France (most especially Laurence Bourguignon) for hosting me during my doctoral and post-doctoral research. Funding was provided by a Chateaubriand doctoral fellowship and a Fyssen Foundation post-doctoral grant. I would also like to thank the two anonymous reviewers who offered helpful comments that improved the quality of this manuscript.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jasrep.2019.03.011>.

## References

- Adler, D.S., Prindiville, T.J., Conard, N.J., 2003. Patterns of spatial organization and land use during the Eemian Interglacial in the Rhineland: new data from Wallertheim, Germany. In: *Eurasian Prehistory*. vol. 1. pp. 25–78.
- Alpersen-Afil, N., Sharon, G., Kislev, M., Melamed, Y., Zohar, I., Ashkenazi, S., Rabinovich, R., Biton, R., Werker, E., Hartman, G., Feibel, C., Goren-Inbar, N., 2009. Spatial organization of hominin activities at Geshar Benot Ya'aqov, Israel. *Science* 326, 1677–1680. <https://doi.org/10.1126/science.1180695>.
- Andrefsky Jr., W., 2005. *Lithics: Macroscopic Approaches to Analysis*, 2nd ed. Cambridge University Press, Cambridge.
- Bailey, G., 2007. Time perspectives, palimpsests and the archaeology of time. *J. Anthropol. Archaeol.* 26, 198–223. <https://doi.org/10.1016/j.jaa.2006.08.002>.
- Barton, R.N.E., Bergman, C.A., 1982. Hunters at Hengistbury: some evidence from experimental archaeology hunters at Hengistbury: some evidence from experimental archaeology. *World Archaeol.* 14, 237–248.
- Binford, L.R., 1981. Behavioral archaeology and the “Pompeii Premise”. *J. Anthropol. Res.* 37, 195–208. <https://doi.org/10.3109/00952990.2011.643980>.
- Boëda, E., 1995. Levallois: A volumetric construction, methods, a technique. In: Dibble, H.L., Bar-Yosef, O. (Eds.), *The Definition and Interpretation of Levallois Technology*. Prehistory Press, Madison, WI, pp. 41–68.
- Boëda, E., Geneste, J.-M., Meignen, L., 1990. Identification de chaînes opératoires lithiques du Paléolithique ancien et moyen. *Paléo* 2, 43–80. <https://doi.org/10.3406/pal.1990.988>.
- Bourguignon, L., 1997. *Le Moustérien de type Quina: Nouvelle définition d'une entité technique*, T.2. Université de Paris X.
- Bourguignon, L., 2010. Le Campement Moustérien de La Folie (Vienne). In: *Préhistoire Entre Vienne et Charente: Hommes et Sociétés Du Paléolithique*. Ministère de la Culture et de la Communication, Paris, pp. 169–174.
- Bourguignon, L., Ortega, I., Lenoble, A., Brenet, M., Astruc, L., 2000. *Le gisement moustérien de Champs de Bossuet*. (Bordeaux).
- Bourguignon, L., Sellami, F., Deloze, V., Sellier-Segard, N., Beyries, S., Emery-Barbier, A., 2002. L'Habitat Moustérien de “La Folie” (Poitiers, Vienne): Synthèse des Premiers Résultats. *Paléo* 14, 29–48.
- Bourguignon, L., Vieilleveigne, E., Guibert, P., Bechtel, F., Beyries, S., Deloze, V., Lahaye, C., Sellami, F., 2006. Compléments d'Informations Chronologiques sur le Campement Moustérien de Tradition Acheuléenne du Gisement de la Folie (Poitiers, Vienne). *Paléo* 18, 37–44.
- Bourguignon, L., Blaser, F., Rios, J., Pradet, L., Sellami, F., Guibert, P., 2008. L'occupation moustérienne de la Doline de Cantalouette II (Cressy, Dordogne): spécificités technologiques et économiques, premiers résultats d'une analyse intégrée. In: Jaubert, J., Bordes, J.-G., Ortega, I. (Eds.), *Les Sociétés Du Paléolithique Dans Un Grand Sud-Ouest de La France: Nouveaux Gisements, Nouveaux Résultats, Nouvelles Méthodes*.

- Mémoire XLVII de la Société préhistorique française, Bordeaux. pp. 133–150.
- Brantingham, P.J., Kuhn, S.L., 2001. Constraints on Levallois core technology: a mathematical model. *J. Archaeol. Sci.* 28, 747–761. <https://doi.org/10.1006/jasc.2000.0594>.
- Cahen, D., Keeley, L.H., Van Noten, F.L., 1979. Stone tools, toolkits, and human behavior in prehistory. *Curr. Anthropol.* 20, 661–683. <https://doi.org/10.1086/202371>.
- Camilli, E.L., Ebert, J.L., 1992. Artifact refuse and recycling in continuous surface distributions and implications for interpreting land-use patterns. In: Rossignol, J., Wandsnider, L. (Eds.), *Space, Time, and Archaeological Landscapes*. Plenum Press, New York, pp. 113–136.
- Clark, A.E., 2015. Spatial Structure and the Temporality of Assemblage Formation: A Comparative Study of Seven Open Air Middle Paleolithic Sites in France. The University of Arizona.
- Clark, A.E., 2016. Time and space in the middle paleolithic: spatial structure and occupation dynamics of seven open-air sites. *Evol. Anthropol. Issues, News, Rev.* 25, 153–163. <https://doi.org/10.1002/evan.21486>.
- Clark, A.E., 2017. From activity areas to occupational histories: new methods to document the formation of spatial structure in hunter-gatherer sites. *J. Archaeol. Method Theory* 24, 1300–1325. <https://doi.org/10.1007/s10816-017-9313-7>.
- Colonge, D., Claud, E., Deschamps, M., Fourloubey, C., Hernandez, M., Sellami, F., Anderson, L., Busseuil, N., Debenham, N., Garon, H., O'Farrell, M., 2015. Preliminary results from new Palaeolithic open-air sites near Bayonne (south-western France). *Quat. Int.* 364, 109–125. <https://doi.org/10.1016/j.quaint.2014.12.007>.
- Crabtree, D.E., Davis, E.L., 1968. Experimental manufacture of wooden implements with tools of flaked stone. *Science* 159, 426–428.
- Depaepe, P., 2007. Le Paléolithique moyen de la vallée de la Vanne (Yonne, France): matières premières, industries lithiques et occupations humaines. Société préhistorique française, Mémoire 41, Paris.
- Deschamps, M., Clark, A., Claud, E., Colonge, D., Hernandez, M., 2016. Approche technoeconomique et fonctionnelle des occupations de plein air du Paléolithique moyen récent autour de Bayonne (Pyrénées-Atlantiques). *Bull. Soc. Préhistorique Fr.* 113, 659–689.
- Dibble, H.L., Holdaway, S.J., Lin, S.C., Braun, D.R., Douglass, M.J., Iovita, R., McPherron, S.P., Olszewski, D.I., Sandgathe, D., 2017. Major fallacies surrounding stone artifacts and assemblages. *J. Archaeol. Method Theory* 24, 813–851. <https://doi.org/10.1007/s10816-016-9297-8>.
- Dinnis, R., Pawlik, A., Gaillard, C., 2009. Bladelet cores as weapon tips? Hafting residue identification and micro-wear analysis of three carinated burins from the late Aurignacian of Les Vachons, France. *J. Archaeol. Sci.* 36, 1922–1934. <https://doi.org/10.1016/j.jas.2009.04.020>.
- Enloe, J.G., 2006. Geological processes and site structure: assessing integrity at a Late Paleolithic open-air site in Northern France. *Geoarchaeology* 21, 523–540.
- Eren, M.I., Lycett, S.J., 2012. Why Levallois? A morphometric comparison of experimental “preferential” Levallois flakes versus debitage flakes. *PLoS One* 7, 1–10. <https://doi.org/10.1371/journal.pone.0029273>.
- Eren, M.I., Greenspan, A., Sampson, C.G., 2008. Are Upper Paleolithic blade cores more productive than Middle Paleolithic discoidal cores? A replication experiment. *J. Hum. Evol.* 55, 952–961. <https://doi.org/10.1016/j.jhevol.2008.07.009>.
- Folgado, M., Brenet, M., 2010. Economie de débitage et organisation de l'espace technique sur le site du Paléolithique moyen de plein-air de La Mouline (Dordogne, France). In: Conard, N.J., Delagnes, A. (Eds.), *Settlement Dynamics of the Middle Paleolithic and Middle Stone Age*. vol. III. Kerns Verlag, pp. 427–454.
- Frison, G.C., 1968. A functional analysis of certain chipped stone tools. *Am. Antiq.* 33, 149–155.
- Frison, G.C., 2004. *Survival by Hunting: Prehistoric Human Predators and Animal Prey*. University of California Press, Berkeley.
- Goval, É., Locht, J.-L., 2009. Remontages, systèmes techniques et répartitions spatiales dans l'analyse du site weichselien ancien de Fresnoy-au-Val (Somme, France). *Bull. Soc. Préhistorique Fr.* 106, 653–678.
- Haas, W.R., Klink, C.J., Maggard, G.J., Aldenderfer, M.S., 2015. Settlement-size Scaling Among Prehistoric Hunter-gatherer Settlement Systems in the New World. pp. 1–25. <https://doi.org/10.1371/journal.pone.0140127>.
- Hardy, B.L., Bolus, M., Conard, N.J., 2008. Hammer or crescent wrench? Stone-tool form and function in the Aurignacian of southwest Germany. *J. Hum. Evol.* 54, 648–662. <https://doi.org/10.1016/j.jhevol.2007.10.003>.
- Hayden, B., 2012. Neandertal social structure? *Oxf. J. Archaeol.* 31, 1–26. <https://doi.org/10.1111/j.1468-0092.2011.00376.x>.
- Holdaway, S., Douglass, M., 2012. A twenty-first century archaeology of stone artifacts. *J. Archaeol. Method Theory* 19, 101–131. <https://doi.org/10.1007/s10816-011-9103-6>.
- Holdaway, S.J., Wandsnider, L., 2006. Temporal scales and archaeological landscapes from the Eastern Desert of Australia and Intermontane North America. In: Lock, G., Molyneux, B. (Eds.), *Confronting Scale in Archaeology: Issues of Theory and Practice*. Kluwer Plenum Press, New York, pp. 183–202. [https://doi.org/10.1007/0-387-32773-8\\_13](https://doi.org/10.1007/0-387-32773-8_13).
- Holdaway, S., Douglass, M., Philipps, R., 2014. Flake selection, assemblage variability, and technological organization. In: Shott, M.J. (Ed.), *Works in Stone: Contemporary Perspectives in Lithic Analysis*. University of Utah Press, Salt Lake City, pp. 46–62.
- Keeley, L.H., 1980. *Experimental Determination of Stone Tool Uses*. The University of Chicago Press, Chicago.
- Kuhn, S.L., 1995. *Mousterian Lithic Technology*. Princeton University Press, Princeton, NJ.
- Kuhn, S.L., 2004a. Middle Paleolithic assemblage formation at Riparo Mochi, in: *Processual Archaeology: Exploring Analytical Strategies, Frames of Reference, and Cultural Process*.
- Kuhn, S.L., 2004b. Upper Paleolithic raw material economies at Üçagizli cave, Turkey. *J. Anthropol. Archaeol.* 23, 431–448. <https://doi.org/10.1016/j.jaa.2004.09.001>.
- Kuhn, S.L., Clark, A.E., 2015. Artifact densities and assemblage formation: evidence from Tabun Cave. *J. Anthropol. Archaeol.* 38, 8–16. <https://doi.org/10.1016/j.jaa.2014.09.002>.
- Locht, J.-L., 2001. Modalités d'implantation et Fonctionnement Interne des Sites. L'Apport de Trois Gisements de Plein Air de La Phase Récente du Paléolithique Moyen dans le Nord de la France (Bettencourt-Saint-Ouen, Villiers-Adam et Beauvais). In: Conard, N.J. (Ed.), *Settlement Dynamics of the Middle Paleolithic and Middle Stone Age*. Kerns Verlag, Tübingen, pp. 261–394.
- Locht, J.-L., 2002. Bettencourt-Saint-Ouen (Somme): Cinq occupations paléolithiques au début de la dernière glaciation. (Paris).
- Locht, J.-L., 2011. Fonctionnement des habitats de plein air en Ile-de-France. In: *Les Dossiers d'Archéologie*. vol. 345. pp. 62–67.
- Locht, J.-L., Antoine, P., Bahain, J., Dwirila, G., Raymond, P., Limondin-Lozouet, N., Gauthier, A., Debenham, N., Frechen, M., Rousseau, D.D., Hatté, C., Haesaerts, P., Metsdag, H., 2003. Le gisement paléolithique moyen et les séquences pléistocènes de Villiers-Adam (Val-d'Oise): chronostratigraphie, environnement et implantations humaines. *Gall. Préhistoire* 45, 1–111. <https://doi.org/10.3406/galip.2003.2036>.
- Locht, J.-L., Deschodt, L., Antoine, P., Goval, E., Sellier, N., Coutard, S., Debenham, N., Coudenneau, A., Caspar, J.-P., 2008. Le Gisement Paléolithique Moyen de Fresnoy-au-Val (Somme, France).
- Locht, J.-L., Goval, É., Antoine, P., 2010. Reconstructing Middle Palaeolithic hominid behaviour during OIS 5 in northern France. In: Conard, N.J., Delagnes, A. (Eds.), *Settlement Dynamics of the Middle Paleolithic and Middle Stone Age*. vol. III. Kerns Verlag, Tübingen, pp. 329–356.
- MacCalman, H.R., Grobelaar, B.J., 1965. Preliminary report of two stone-working Ovattimba groups in the Northern Kookoveld of South West Africa. *Cimbebasia* 13, 1–39.
- Masao, F.T., 1982. On possible use of unshaped flakes: an ethno-historical approach from Central Tanzania. *Ethnos* 47, 262–270. <https://doi.org/10.1080/00141844.1982.9981244>.
- Meignen, L., Delagnes, A., Bourguignon, L., 2009. Patterns of lithic material procurement and transformation during the Middle Paleolithic in Western Europe. In: *Lithic Materials and Paleolithic Societies*. Wiley-Blackwell, West Sussex, UK, pp. 15–24.
- Merrill, M., Read, D., 2010. A new method using graph and lattice theory to discover spatially cohesive sets of artifacts and areas of organized activity in archaeological sites. *Am. Antiq.* 75, 419–451. <https://doi.org/10.7183/0002-7316.75.3.419>.
- Miller Jr., T.O., 1979. *Stonework of the Xetá Indians of Brazil*. In: Hayden, B. (Ed.), *Lithic Use-Wear Analysis*. Academic Press, New York, pp. 401–407.
- Newcomer, M.H., Sieveking, G.D.G., 1980. Experimental flake scatter-patterns: a new interpretative technique. *J. F. Archaeol.* 7, 345–352. <https://doi.org/10.1179/009346980791505392>.
- Pettitt, P.B., 1997. High resolution Neanderthals? Interpreting middle palaeolithic intrasite spatial data. *World Archaeol.* 29, 208–224.
- Premo, L.S., 2014. Cultural transmission and diversity in time-averaged assemblages. *Curr. Anthropol.* 55, 105–114. <https://doi.org/10.1086/674873>.
- Riel-Salvatore, J., Barton, C.M., 2004. Late Pleistocene technology, economic behavior, and land-use dynamics in southern Italy. *Am. Antiq.* 69, 257–274.
- Riel-Salvatore, J., Ludeke, I.C., Negrino, F., Holt, B.M., 2013. A spatial analysis of the late mousterian levels of Riparo Bombrini (Balzi Rossi, Italy). *Can. J. Archaeol.* 92, 70–92.
- Rios-Garaizar, J., Ortega Cordellat, L., 2014. Flint workshop or habitat? Technological and functional approaches towards the interpretation of site function in Bergerac Region Early Aurignacian. In: Marreiros, J., Bicho, N., Gibaja, J.F. (Eds.), *International Conference on Use-Wear Analysis: Use-wear 2012*. Cambridge Scholars Publishing, Newcastle-upon-Tyne, United Kingdom, pp. 162–172.
- Rots, V., 2013. Insights into early Middle Palaeolithic tool use and hafting in Western Europe. The functional analysis of level IIa of the early Middle Palaeolithic site of Biache-Saint-Vaast (France). *J. Archaeol. Sci.* 40, 497–506. <https://doi.org/10.1016/j.jas.2012.06.042>.
- Rots, V., Van Peer, P., Vermeersch, P.M., 2011. Aspects of tool production, use, and hafting in Palaeolithic assemblages from Northeast Africa. *J. Hum. Evol.* 60, 637–664. <https://doi.org/10.1016/j.jhevol.2011.01.001>.
- Shimelmitz, R., Kuhn, S.L., 2013. Early Mousterian Levallois Technology in Unit IX of Tabun Cave. *PaleoAnthropology* 1–27. <https://doi.org/10.4207/PA.2013.ART77>.
- Shimelmitz, R., Kuhn, S.L., 2017. The toolkit in the core: there is more to Levallois production than predetermination. *Quat. Int.* 464, 81–91. <https://doi.org/10.1016/j.quaint.2017.08.011>.
- Sillitoe, P., Hardy, K., 2003. Living lithics: ethnoarchaeology in highland Papua New Guinea. *Antiquity* 77, 555–566. <https://doi.org/10.1017/S0003598X00092619>.
- Simek, J.F., 1987. Spatial order and behavioural change in the French Paleolithic. *Antiquity* 61, 25–40.
- Turq, A., Roebroeks, W., Bourguignon, L., Faivre, J.-P., 2013. The fragmented character of Middle Paleolithic stone tool technology. *J. Hum. Evol.* 65, 641–655. <https://doi.org/10.1016/j.jhevol.2013.07.014>.
- Vaquero, M., Chacón, M.G., García-Antón, M.D., Gómez de Soler, B., Martínez, K., Cuartero, F., 2012. Time and space in the formation of lithic assemblages: the example of Abric Romaní Level J. *Quat. Int.* 247, 162–181. <https://doi.org/10.1016/j.quaint.2010.12.015>.
- Wandsnider, L., 2008. Time-averaged deposits and multitemporal processes in the Wyoming Basin, Intermontane North America: a preliminary consideration of land tenure in terms of occupation frequency and integration. In: Holdaway, S.J., Wandsnider, L. (Eds.), *Time in Archaeology: Time Perspectivism Revisited*. University of Utah Press, Salt Lake City, USA, pp. 61–93.
- White, J.P., 1967. Ethno-archaeology in New Guinea: two examples. *Mankind* 6, 409–414.
- White, J.P., Thomas, D.H., 1972. What mean these stones? Ethno-taxonomic models and archaeological interpretations in the New Guinea highlands. In: Clarke, D. (Ed.), *Models in Archaeology*. Methuen, London, pp. 275–308.