Using spatial context to identify lithic selection behaviors

Amy E. Clark

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

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.

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- Spatial analysis
- Middle Paleolithic

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 Grobbelaar, 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 (Craibtree and Davis, 1968). In lithic analysis the standard procedure is to divide the assemblage into tools and debitage (Andrefsky 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 it in some cases the decision can be fairly arbitrary (Holdaway and Douglass, 2012). Lithics that were rejected by
the knapper might be picked up and utilized by another individual and
the knapper may later return to her debitage pile to scavenge any re-
mainning 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 archae-
ologists with a larger sample of lithics exhibiting use wear and a cor-
aditionally 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, Dis-
coid, or Quina methods, based on the caracteristic 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 in-
formation 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, in-
formation 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 con-
text, is the norm for most interpretations of lithic artifacts. This goes
hand in hand with a persistent focus on the “end product” (as de-
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 prod-
uct 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 util-
ized or set aside, regardless of evidence of subsequent use (retouch
or use wear). Spatial analysis can also provide a perspective on the pro-
duction 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 con-
sidered 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 ar-
chaeologists 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 irre-
versible 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 si-
tuation 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 Preventives) 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 meters1 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, oramas, 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 ty-
pically share these basic features (Deapaee, 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 sedi-
ment was accumulating (Geval 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

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

<table>
<thead>
<tr>
<th>Site</th>
<th>Site Area (m²)</th>
<th>Total lithics</th>
<th>% refit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bettencourt</td>
<td>915</td>
<td>5729</td>
<td>14</td>
</tr>
<tr>
<td>Bossuet</td>
<td>228</td>
<td>15,797</td>
<td>5</td>
</tr>
<tr>
<td>Cantalouette</td>
<td>282</td>
<td>15,404</td>
<td>10</td>
</tr>
<tr>
<td>La Folie</td>
<td>207</td>
<td>1262</td>
<td>38</td>
</tr>
<tr>
<td>Fresnoy</td>
<td>1143</td>
<td>4270</td>
<td>9</td>
</tr>
<tr>
<td>Le Prissé</td>
<td>1075</td>
<td>870</td>
<td>20</td>
</tr>
<tr>
<td>Villiers Adam</td>
<td>1928</td>
<td>1619</td>
<td>4</td>
</tr>
</tbody>
</table>

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.
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 blades
(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 pro-
duction. 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 pro-
duction 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
ture 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, so much lithic production
occurred in an unconstrained area, we can more easily se-
parate 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 to-
gether 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 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
site 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
Table 2
The dominant chaîne(s) opératoire(s) and products at the sites in the study.

<table>
<thead>
<tr>
<th>Site</th>
<th>Dominant chaîne(s) opératoire(s)</th>
<th>Main products as determined by the chaîne opératoire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bettencourt</td>
<td>Levallois</td>
<td>Flakes</td>
</tr>
<tr>
<td></td>
<td>Unipolar</td>
<td>Blades</td>
</tr>
<tr>
<td></td>
<td>Points</td>
<td></td>
</tr>
<tr>
<td>Bossuet</td>
<td>Discoid</td>
<td>Pseudo-Levallois points</td>
</tr>
<tr>
<td>Cantalouette</td>
<td>Preferential Levallois</td>
<td>Levallois flakes</td>
</tr>
<tr>
<td></td>
<td>Unipolar</td>
<td>Naturally backed flakes</td>
</tr>
<tr>
<td>La Folie</td>
<td>Levallois</td>
<td>Levallois flakes</td>
</tr>
<tr>
<td>Fresnay</td>
<td>Levallois</td>
<td>Levallois flakes</td>
</tr>
<tr>
<td></td>
<td>Blades</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Points</td>
<td></td>
</tr>
<tr>
<td>Le Prissé</td>
<td>Discoid</td>
<td>Pseudo-Levallois points</td>
</tr>
<tr>
<td>Villiers Adam</td>
<td>Levallois</td>
<td>Levallois flakes</td>
</tr>
<tr>
<td></td>
<td>Blades</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Points</td>
<td></td>
</tr>
</tbody>
</table>

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 spe-
cimens 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 cor-
respond 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 mate-
rial. 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 devel-
oped 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 archae-
ologists (or by me) and assigned to standardized technological and ty-
opological categories. I further grouped the determinations made by
INRAP archaeologists into simplified categories such as “core main-
tenance flake” and “debris”. I then examined the composition of the
density and refitting groups. I compared the representation of techno-
logical categories in each spatial group to the assemblage as a whole,
using standard criteria for statistical significance (95% confidence in-
tervals, 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 domi-
nant 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
trumpling 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 underrepresented 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 flake
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
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 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.

<table>
<thead>
<tr>
<th>Overrepresented: Clumped groups</th>
<th>Underrepresented: Dispensed groups</th>
<th>Underrepresented: Clumped groups</th>
<th>Overrepresented: Dispensed groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debris</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Core maintenance flake</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Cortical flake</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Partially cortical flake</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Débordant flake</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Naturally backed flake</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Core</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Tested nodule</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Retouched tool</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Non-cortical flake</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Levallois flake</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Blade</td>
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</table>

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.

<table>
<thead>
<tr>
<th>Overrepresented: Clumped groups</th>
<th>Underrepresented: Dispensed groups</th>
<th>Underrepresented: Clumped groups</th>
<th>Overrepresented: Dispensed groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debris</td>
<td>Bettencourt</td>
<td>Bettencourt</td>
<td>Bettencourt</td>
</tr>
<tr>
<td>La Folie</td>
<td>Fresnoy</td>
<td>Villiers Adam</td>
<td>Villiers Adam</td>
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<tr>
<td>Le Prissé</td>
<td>Villiers Adam</td>
<td>Bettencourt</td>
<td>Le Prissé</td>
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<td>Bosquet</td>
<td>Villiers Adam</td>
<td>Le Prissé</td>
<td>Fresnoy</td>
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<td>Core maintenance flake</td>
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<tr>
<td>Bosquet</td>
<td>Villiers Adam</td>
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<td>Villiers Adam</td>
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<td>Core</td>
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<tr>
<td>Le Prissé</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partially cortical flake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Le Prissé</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-cortical flake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Le Prissé</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Levallois flake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blade</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1018
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>
<thead>
<tr>
<th>Site</th>
<th>Percent of assemblage located in high density area</th>
<th>Percent of site's area that is high density</th>
<th>Percent of refitted assemblage that is in refitting group 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bettencourt</td>
<td>34%</td>
<td>2%</td>
<td>58%</td>
</tr>
<tr>
<td>Fresnoy</td>
<td>42%</td>
<td>9%</td>
<td>51%</td>
</tr>
<tr>
<td>Le Prissé</td>
<td>49%</td>
<td>3%</td>
<td>51%</td>
</tr>
<tr>
<td>La Folie</td>
<td>78%</td>
<td>4%</td>
<td>69%</td>
</tr>
<tr>
<td>Villiers Adam</td>
<td>26%</td>
<td>2%</td>
<td>81%</td>
</tr>
<tr>
<td>Bossuet</td>
<td>42%</td>
<td>13%</td>
<td>55%</td>
</tr>
<tr>
<td>Cantalouette</td>
<td>26%</td>
<td>5%</td>
<td>77%</td>
</tr>
</tbody>
</table>
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 Lyckett, 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 prodigous 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-ideal” 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 predetermined, and then utilized (Stilltote and White, 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 every 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 Grobbelaar, 1965; Miller Jr., 1979). In a paper describing two OvaTjimba groups in what is now Namibia, MacCalman and Grobbelaar (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; Polgardo 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; Vaqueri 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 Cahn 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.

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Appendix A. Supplementary data

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