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From Activity Areas to Occupational Histories: New Methods to Document the Formation of Spatial Structure in Hunter-Gatherer Sites

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Abstract Over the past five decades, archaeologists have proposed a wide range of methods for the study of spatial organization within hunter-gatherer sites. Many of these methods sought to identify the spatial location of activities based on patterns of behavior observed in ethnographic contexts. While this resulted in productive observations at certain sites, many of these methods were tailored to specific situations and thus could not be applied to a wide range of sites. For example, open-air sites rarely contain preserved bone or features, such as hearths, which were central components to identifying characteristics of site structure. In addition, many of these methods often did not take into consideration the temporal dynamics of the occupation, *i.e.*, that many sites were formed through subsequent occupations of differing duration. This paper proposes the use of two related methods that assume many assemblages are the result of more than one occupation. The methods target the distribution of lithic artifacts, the most ubiquitously preserved of archaeological materials, and accounts for the potential that the final resting place of artifacts was the result of both intentional and unintentional movement by humans and a host of biological and geological processes. The main goal of this paper is to use an understanding of how these processes influenced the formation of site structure to estimate the relative number and duration of occupations for each site in the sample. These new methods will be presented and explained through the study of seven open-air Middle Paleolithic sites in France but are applicable to a wide range of hunter-gatherer sites.

Keywords Spatial analysis · Site structure · Hunter-gatherers · Lithic technology · Lithic refitting · Middle Paleolithic

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Introduction

The spatial organization of artifacts and features within archaeological sites has the potential to provide a great deal of information regarding type of occupation, length of stay, group structure, and the organization of the use of space. An emphasis on site spatial structure emerged along with processual archaeology in the late 1970s through the early 1990s and focused mainly on the use of space and the arrangement of activities (Binford 1998; Carr 1985, 1991; Dekin 1976; Grimm and Koetje 1992; Hietala and Marks 1981; Koetje 1994; Rigaud and Simek 1991; Simek 1987; Stapert 1989, 1990; Whallon 1973, 1984). The frequency of spatial analysis studies has decreased in recent years, partially due to disillusionment with the results from this earlier work, though research certainly continues (Adler *et al*. 2003; Aldeias *et al*. 2012; Bamforth *et al*. 2005; Folgado and Brenet 2010; Henry 1998, 2012; Merrill and Read 2010; Riel-Salvatore *et al*. 2013; Yvorra 2003). In most cases, recent analyses have matured and more clearly delineate what is and is not possible. This study follows this trend by focusing on both geologic and anthropogenic processes that can affect spatial structure.

The proliferation of spatial studies that arose in the 1970s and 1980s was accompanied by a surge in ethnoarchaeological research that mapped the spatial organization of activities and their associated debris at hunter-gatherer campsites (Binford 1978, 1983; Fisher and Strickland 1989; Gorecki 1988, 1991; O'Connell 1987; Yellen 1977). Some of these studies were used as cautionary tales warning archaeologists that patterning was ephemeral or at such a large scale that study was not feasible for the archaeological record (O'Connell 1987; Simms and Heath 1990). Others attempted to create models for spatial patterning that could be discerned at archaeological sites (Gamble 1991). Binford (1978), for example, used his observations of discard behavior at Nunamiut campsites to coin the phrases "drop zone" and "toss zone," which quickly became integrated into the literature. Archaeologists subsequently strove to recreate these maps of debris, and the spatial organization of behaviors that produced them, in archaeological contexts.

In an attempt to track behavior, many of these spatial studies focused on the location of "activity areas" and have been largely unsuccessful in that pursuit. The identification of activity areas assumes a context in which objects are organized in space based on particular tasks that are static in both time and space. In order for activity areas to be identified, the location of these tasks cannot move position and they must generate enough (non-perishable) waste material to be identified. This situation *may* arise in very particular cases, such as at remarkable sites like Pincevent (Leroi-Gourhan and Brézillion 1966) or Verberie (Audouze and Enloe 1997), both late Upper Paleolithic sites in the Paris basin, but countless ethnographic studies have shown that hunter-gatherer use of space is fluid and unconstrained. Activity areas may shift based on shade, on proximity to the fire, on comfort, and on social interactions (Fisher and Strickland 1989; Spurling and Hayden 1984; Yellen 1977). Furthermore, except in the case of butchering or other malodorous and/or messy endeavors, most of these activities occur in overlapping spatial contexts within a central area. Many of the studies do assume an overlapping of activities (*e.g.*, Merrill and Read 2010; Whallon 1984) and incorporate it into their methodology. However, these studies still accept that objects located near to each other were used together, which cannot always be assumed, particularly in the case of reoccupation. In a detailed study of the spatial distribution of refitting sets at the Epipaleolithic site of Meer, Cahen *et al.* (1979) reached this very conclusion, finding that tools used together were not necessarily abandoned together.

Ethnoarchaeological research succeeded in breathing life into the static and often incomprehensible archaeological record. It showed archaeologists that patterning of discard, rather than patterns of use (the archaeological context versus the systemic context, as Schiffer termed it), controls the archaeological record (Schiffer 1972, 1987). The distribution of discarded artifacts and manufacturing debris, along with subsequent modification of these discarded items through site use (*e.g.*, trampling), controls the spatial patterns that emerge upon excavation. However, archaeological spatial patterns proved to be more difficult to interpret than at an ethnographic site abandoned for a few weeks or even a few years. Not only are archaeological sites much more distant in time, but also they were potentially the result of many subsequent occupations (Wandsnider 1996). The most visible sites are those with the most debris, so our sample is likely biased towards sites occupied for longer periods of time, or with many reoccupations (Brooks 1998). The simple fact is that the archaeological record is much more complicated to interpret than the ethnographic record, particularly as we go back further in time. Thus, in most cases, the ethnographic record provides only rough guidelines, rather than specific models. And though most archaeologists understand that patterns of discard coupled with subsequent modification from post-depositional processes control the spatial patterning of archaeological sites, it is usually not explicitly integrated within their method and theory (Wandsnider 1996).

The effect of time on archaeological sites, as a result of both repeated human occupations and geologic processes, has recently gained more attention from intra-site spatial analysis studies (Bamforth *et al.* 2005; Galanidou 1999; Vaquero *et al.* 2012; Wandsnider 2008). These studies have shifted the focus away from activity areas and instead concentrate on the occupational histories of sites, which highlight the many processes that create spatial structure. Wandsnider (2008) used site features, such as hearth size and density, and the geomorphology of the land surface (whether the site was aggrading, deflating, or stable) to assess the occupation history of hunter-gatherer sites in the Wyoming Basin. In a spatial analysis of Level J at Abric Romani, Vaquero *et al.* (2012) used evidence from raw material provisioning and lithic refitting to argue that a mixture of many short-term visits and a few longer-term occupations explained the differential spatial patterning of lithics. In addition, they saw clear evidence for recycling, indicating that the spatial structure of earlier occupations was modified by later inhabitants. In a similar vein, the spatial structure of earlier occupations can dictate that of later occupations (Holdaway and Wandsnider 2006). For example, Bamforth *et al.* (2005) found repeated use of the same location as a trash dump over the course of many occupations at the Allen site. These studies highlight that geologic processes, as well as temporal dynamics of occupation periods, *e.g.*, how long a site was occupied and whether it was reoccupied, may play a much larger role in site structure formation than any individual activity.

Another major challenge is the simple fact that most hunter-gatherer sites only contain certain types of preserved materials and at most open-air sites—generally the best candidates for spatial analysis—stone is often the only material remaining. In this case, the bulk of the material represents one activity, stone tool manufacture, and stone tools used in other activities are left stranded from the accompanying refuse. The spatial organization in these contexts is therefore not structured by *activities* in the plural, but one activity primarily, and then a series of processes that serve to move this material away from the location where it was manufactured. The methods proposed in this paper aim to deconstruct these structuring components. Incorporated within these methods is an understanding that lithic artifacts were moved by many processes, not only intentional movement by humans but also unintentional anthropogenic movement and geologic and biogenic processes. Thus, this paper, like Bamforth *et al.* (2005) and Wandsnider (2008), aims to understand the occupational history of the sites in question, but with a focus on the spatial structure of one ubiquitous and robust class of data: lithic artifacts.

By limiting the spatial analysis to lithic artifacts, the methods presented here can be applied to many kinds of sites. Idiosyncratic spatial characteristics, such as structures or even hearths, are not considered. Many open-air sites, including those in this study, do not favor the preservation of organic remains and structures. Since these methods are designed to be comparative, these features are not discussed in this analysis. It is difficult to interpret results without comparing different kinds of sites that span a range of occupation durations, patterns of site reuse, and depositional histories. By using the same methods, one can directly compare sites not only within one's own sample, but within the published literature as well.

The proposed methods utilize the distribution of lithic artifacts within density zones and the spatial arrangement of lithic refitting sets. These methods are not necessarily completely new. Indeed, different iterations of what I call the "density contour analysis" have been used for years (*e.g.*, Alperson-Afil *et al.* 2009; Baales 2001; Enloe *et al.* 1994), but the way it is utilized here is different. Instead of comparing high-density areas to each other, as one might do in the pursuit of activity areas, the high-, medium-, and low-density areas are compared to one another in an effort to track artifact movement from the knapping location. The refitting sets are also broken into three groups, based on where they are located relative to one another. Neither of these methods employ complicated statistical or geospatial methods. Instead, it was the intention to create simple methods that could be easily interpreted and also easily applied to a variety of contexts.

Middle Paleolithic Sites Considered in the Study

The sites utilized in this study are located in France and were all excavated by INRAP (*l'institut national de recherches archéologiques préventives*) in advance of construction projects. All of the sites are open-air, and, except for a few teeth at Bettencourt, none of the sites have preserved bone. Only one site, La Folie, has a preserved fire feature. Therefore, lithic artifacts are the only artifact category used to assess spatial patterning. Most of the sites are found either to the north of Paris in the loess belt of northern Europe or in the southwest of France (Fig. 1). The sites have a range of artifact densities and assemblage sizes and are located in varying topographic positions on the landscape (Tables 1 and 2).

The three sites located in the north of France are Villiers Adam, Fresnoy-au-Val, and Bettencourt-Saint-Ouen (the latter two hereafter shortened to Fresnoy and Bettencourt). All three are found on a gentle northeast-facing slope in a dry, asymmetrical valley

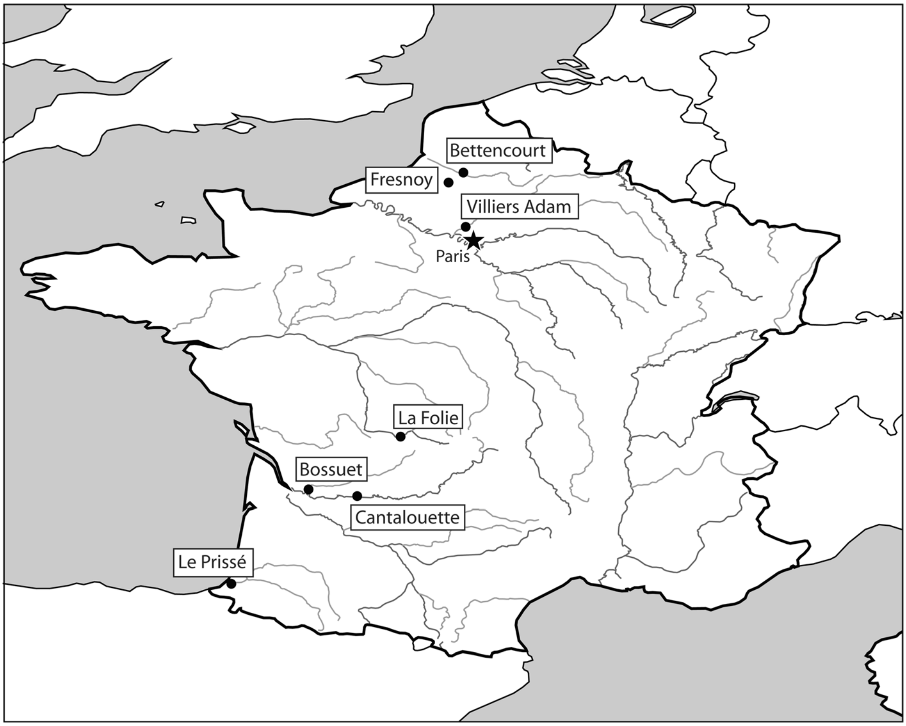

Fig. 1 The location of the seven sites in the study

Table 1 General site information

	Geographic context	On top of raw material source?	General spatial organization
Le Prissé	Plateau near the confluence of two major rivers	No	Two clusters closely spaced, large area of low-density scatter
Bettencourt	North facing gentle slope, forest soil in loess deposit	No	Three sectors separated by erosion, several very high-density clusters
Bossuet	Paleo channel on a river terrace	Yes	Extremely high-density distribution, follows contours of the drainage
Cantalouette	Doline (sinkhole)	Yes	Extremely high-density distribution with some more concentrated clusters
La Folie	Flood plain	No	Small site with two clusters connected by many refits. Evidence for windbreak and bedding (excellent preservation)
Fresnoy	Northeast facing moderate slope, forest soil in loess deposit	No	Large scatter over large area, refits connect the entire area
Villiers Adam	North facing gentle slope, forest soil in loess deposits	No	Many small, distinct clusters over a large area

Table 2 Site characteristics

	Area (m^2)	No. of lithics	No. of lithics in densest square	Percent of assemblage refit
Le Prissé	1075	870	66	20%
Bettencourt	915	5729	225	14%
Bossuet	228	15,797	527	5%
Cantalouette	282	15,404	443	10%
La Folie	207	1262	189	38%
Fresnoy	1143	4270	183	9%
Villiers Adam	1928	1619	108	4%

(Goval and Locht 2009; Locht 2001, 2002; Locht *et al.* 2003, 2008, 2010). This topographic position favored site preservation because winds originating from the southwest deposited loess on the slopes in which forest soils developed. All three sites are found within these forest soils. Villiers Adam is a very large site with a low artifact density punctuated by small, discrete concentrations of lithics. Fresnoy is a few hundred square meters smaller than Villiers Adam but also very large, and the layer included in this analysis, series 1, contains a much higher artifact count that is relatively evenly distributed over space. Bettencourt also contains several archaeological layers, but only the layer with the highest artifact count, N2b, was included in this study. This site was divided into three sectors by channels of erosion after occupation. Sector 3 is very dense with several concentrations of very high artifact density, sector 2 has one high density concentration, and sector 1 consists of a low-density scatter.

La Folie, located outside of Poitiers, is a small, low-density site that contains a fire feature, a non-pedogenic organic horizon that likely represents a type of bedding or mat, and post-holes that may have formed a windbreak (Bourguignon *et al.* 2002, 2006; Bourguignon 2010). The site is situated on the flood plain of the Clain River and was covered by low-energy flood deposits relatively soon after being abandoned, which explains its remarkable preservation. Further south are two high-density sites positioned directly on sources of raw material. Champs de Bossuet (hereafter shortened to Bossuet), located northeast of Bordeaux, is situated within a paleo channel on a terrace of the Isle River (Bourguignon *et al.* 2000). The site's occupants were exploiting chert cobbles found within this paleo channel, which accounts for its remarkably high density. The contours of the site closely follow the paleo channel. La Doline de Cantalouette II (hereafter, Cantalouette) is located in Bergerac, atop the high-quality raw material known as *bergeraquois* (Bourguignon *et al.* 2008). Like Bossuet, Cantalouette is located within a depression in the landscape, in this case a sinkhole, which yields an extremely high artifact density. Finally, Le Prissé de Bayonne (hereafter, Le Prissé) is located on a plateau outside the city of Bayonne and contains two relatively diffuse clusters of lithics with the remaining part of the site made up of a low-density scatter (Colonge *et al.* 2015; Deschamps *et al.* 2016).

Figure 2 presents all seven of the sites at the same scale. This figure displays not only the differences in size but also the basic spatial structure of each site in question. Some sites are made up of distinct spatial clusters of material such as Le Prissé, Villiers Adam, and La Folie. Other sites, such as Bettencourt and Fresnoy, have clear clustering, but the clusters are larger and less discrete. Finally, the two sites situated atop raw material sources, Cantalouette and Bossuet, are extremely dense with both artifacts and refitting lines; as a result, spatial clustering is not readily apparent. These sites are also made up of clusters, but the clustering is so dense and overlapping that spatial structuring is difficult to discern. The mechanisms of spatial clustering and the centrifugal spread of the material from these clusters outward to other parts of the site will be explored in the following sections.

How Do Artifacts Move Within Sites?

There are a myriad of processes that structure the ultimate position of artifacts within an archaeological site. Before embarking on a detailed account of the spatial analyses performed in this study, I will briefly go through some of these processes from the perspective of lithic artifacts, as this is the main focus of this paper. Later, after the methods and initial results have been explained, I will return to these processes as they apply to the sites in this analysis.

Abandonment at the Location of Manufacture

This category contains the debris from core reduction or tool shaping. These lithics can range from very small flakes and core trimming elements to Levallois flakes or blades that were simply never picked up and utilized. Experiments have shown that most of the debris from flint knapping is located within 1 m of the knapper (Newcomer and Sieveking 1980). Schiffer would term this debris primary refuse (Schiffer 1972).

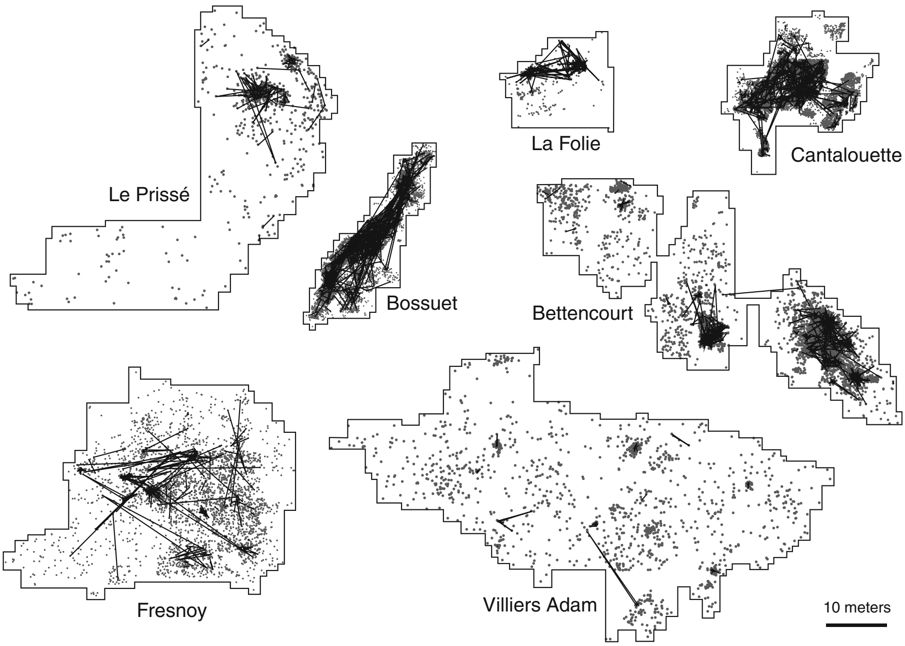

Fig. 2 Site map for each site at the same scale. *Black dots* are the location of lithic artifacts, and *lines* are the refitting connections

Abandonment at the Location of Use

These are lithics that are abandoned after being utilized in a task. They are left in the general proximity of where a task occurred. In general, they were moved some distance from where they were knapped (or imported to the site already made) and abandoned at that location through intentional human action. Lithics abandoned after use would likely be retouched or shaped or show some sign of use. Like the previous category, these lithics also would be considered primary refuse.

Abandonment Through Site Maintenance/Cleaning

Artifacts in this category were intentionally moved through site cleaning. For example, they could be lithics swept aside to clear a space. These tend to be larger items because they are easier to identify and would be less likely to get lost in the sediment (Binford 1978; Schiffer 1987; Simms and Heath 1990). One would expect manufacturing debris, such as cortical flakes or core maintenance flakes, to be moved through this behavior. Often, refuse from successive episodes of cleaning would be deposited in the same location, creating a refuse pile (Bamforth *et al.* 2005). Schiffer terms this secondary refuse (Schiffer 1972).

Movement Through Unintentional Human Action

Lithics could also be moved by human action that has nothing to do with the characteristics of any individual lithic object. This could include behaviors such as trampling or accidentally kicking items (Gifford-Gonzalez *et al.* 1985; Wilk and Schiffer 1979). One would expect that this kind of movement would increase with occupation duration or intensity and would not preferentially affect any one artifact class.

Movement Through Geological Processes

There are a host of geological processes that would move artifacts within archaeological sites. These include water runoff, solifluction, shrinking and swelling from clayey sediments, and biogenic activity from plants or animals (Enloe 2006; Schiffer 1983). The degree to which a site's spatial structure was disturbed by geological processes can be studied by looking for evidence of size sorting, the orientation of elongated objects, or the proximity of lithics from the same core (Isaac 1967).

Method 1: Refitting Location Analysis

All archaeological analyses must find a way to divide the assemblage into analytical units (Newell and Dekin 1978). Often in studies of intra-site spatial analysis, groups are formed based on which artifacts are found within close proximity of one another. The distinction between these groups, however, is often arbitrary and ignores the element of *time* that is essential to understanding site *formation*. Formation, after all, is a process that occurs over a certain period of time. In other words, we can be sure that two objects excavated next to one another occupy the same space, but did they occupy the same time? One of the only ways to isolate the passing of time within an otherwise static archaeological horizon is through refitting data. Prior to knapping, refitted lithics were located at a single point in space *and* time (*i.e.*, within the nodule), but subsequently, a knapping event occurred and the lithics were separated. Some of these lithics were moved to another location within the site, or off the site. Refitting sets unify lithic pieces that are often found at some distance from one another upon excavation, but were once at a single location. Therefore, dividing the assemblage based on refitting sets crosscuts forms of spatial analysis that seek to unify artifacts based on spatial proximity.

Lithic refitting was performed on all seven sites in the analysis. The refitting analysis produced refitting sets, *i.e.*, a group of lithics that refit together, which is the basis of the analytical procedure presented here. The sites included in the refitting location analysis have refitting rates that range from 4% at Villiers Adam to 38% at La Folie (Table 2). These data are therefore a sample and do not represent the assemblage as a whole. However, I have compared the rates of representation of various artifact classes within the refitting assemblage to the total assemblage and the rates were comparable (Clark 2015). The only artifact category that is severely underrepresented in the refitting assemblage is debris because these pieces are often very small and irregular and are therefore difficult to refit. The bias inherent in the refitted sample is also mitigated by the concurrent use of the complementary method presented in the next section, which incorporates the distribution of all lithic pieces.

The objective of this study is to track the movement of lithic artifacts and, through this cumulative movement, site formation, and time (Clark 2015, 2016). To do this, I must document the movement of these objects from where they were knapped to the location of abandonment. This is done at the scale of individual refitting sets, each of which represents a knapping episode (or several episodes if a core was set down and picked up again). Each refitting set is made up of lithics that were once part of the same nodule. These pieces were most likely knapped in one location, and some or all pieces were subsequently moved to other locations. For the sites in this study, the refitting sets are often spatially organized in a repetitive pattern (Bourguignon *et al.* 2008). The largest number of lithics are clustered together, a few are located a meter or two apart, and one or two are located at a greater distance. I tracked this spatial pattern by dividing the refitting sets into three groups based on their spatial relationship. All lithics found within 1 m of one another are considered "group 1," lithics located within 2 m from the edge of "group 1" are considered "group 2," and lithics found more than 2 m away from group 1 are considered "group 3" (Fig. 3). In some rare cases, a refitting set had two separate clusters of lithics, both of which could potentially be considered group 1. In this case, group 1 was identified either as the cluster with the highest number of lithics within 1 m of each other, or, if the number of lithics were the same, then the tightest cluster. One meter was chosen as the diameter for group 1 because experimentation has shown this to be the area in which most of the debris from knapping falls (Newcomer and Sieveking 1980). The distinction between groups 2 and 3 was determined by analyzing the histograms of refit distances for each site in the study (Clark 2015). The histograms had the greatest number of refit distances below 1 m, then there was a fall off, and a long tail began around approximately 3 m.

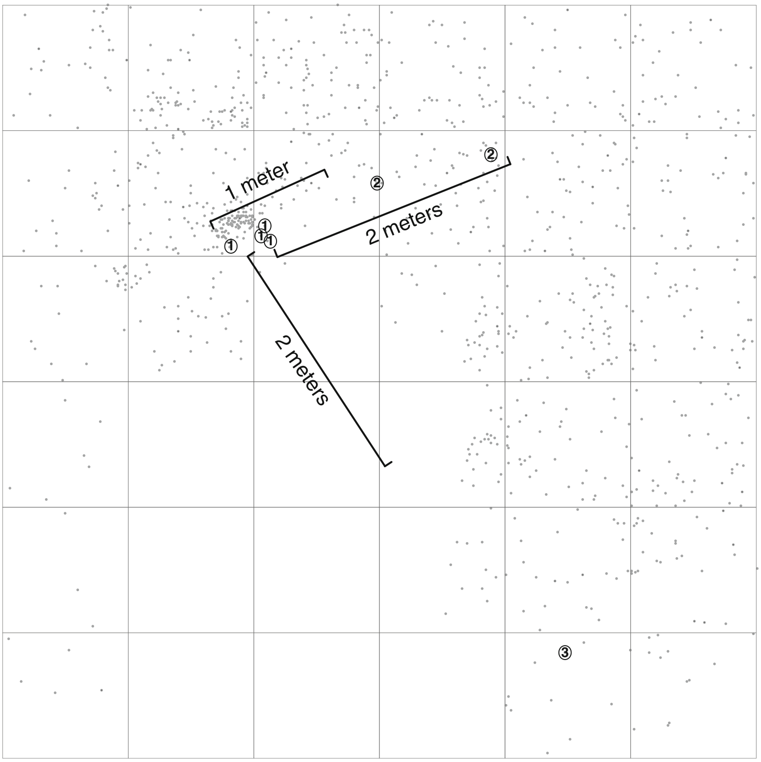

Fig. 3 An example of how refitting groups are determined for the refitting location analysis. The *circled numbers* displayed here each represent the location of a lithic from a single refitting set at Bettencourt (refitting set 12). As members of the same refitting set, all seven lithics refit together. *Circles* with a "1" are lithics that fall within 1 m of each other and are therefore in refitting group 1, *circles* with a "2" are lithics that are located within 2 m of the edge of group 1 and are therefore in group 2, and the *circle* with a "3" is a lithic located more than 2 m away from group 1 and is therefore in group 3. These measurements are performed for each individual refitting set, and thus, every lithic is assigned to a refitting group

Once each refitting set is divided into the three groups, the percentages of lithics that fall into each refitting group are compared between sites. This can indicate the extent of the processes that moved lithics outward from their location of knapping. In addition, the relative proportion of each technological class by refitting group can be compared.[1] The statistical significance of these results was determined by calculating the confidence intervals of the proportions of the artifact class within a given refitting group at 95%. If this interval did not overlap with the confidence interval of the proportion of the total assemblage in that refitting group at 95%, the result was considered significant.

There are a number of processes, both anthropogenic and geologic, that would move lithics away from where they were knapped. Some of these processes might have directionality, such as movement through fluvial processes, but in general, lithics could potentially move from where they were knapped in any direction. In theory, the longer and more repeatedly a site is occupied, the greater the degree of outward movement, or

[1] Villiers Adam was excluded from this part of the refitting location analysis because its low refit percentage (4%), coupled with a small lithic assemblage, made the sample size of technological classes too small.

centrifugal dispersion. The longer and more often the site is occupied, the more likely lithics are going to be either intentionally picked up from the knapping piles and utilized or unintentionally kicked around through site reuse. This process is documented at the scale of the individual nodule through the refitting location analysis.

Method 2: Density Contour Analysis

The refitting location analysis provides a significant amount of information about individual reduction events that make up archaeological assemblages and, through that, the passage of time. Its representation of time, however, can also be misleading. The sample of refitted lithics is likely biased towards reduction events that occurred later in the site's occupation. This is because the more time that passes, the more likely it is that potential refitting sets will acquire holes in their sequence from the movement of lithics off-site. Lithics knapped earlier in the occupation are thus considerably more difficult, or even impossible, to refit. The refitting contour analysis must therefore be complemented by a spatial analysis that takes into account all of the lithics found at the site.

The density contour analysis, like the refitting location analysis, divides the lithics into three groups that roughly reflect the movement of lithics from their location of knapping to position of abandonment. This was done by using ArcGIS to create a density map of the distribution of all point-plotted lithics (Fig. 4). A density map is a raster image that depicts artifact density by using

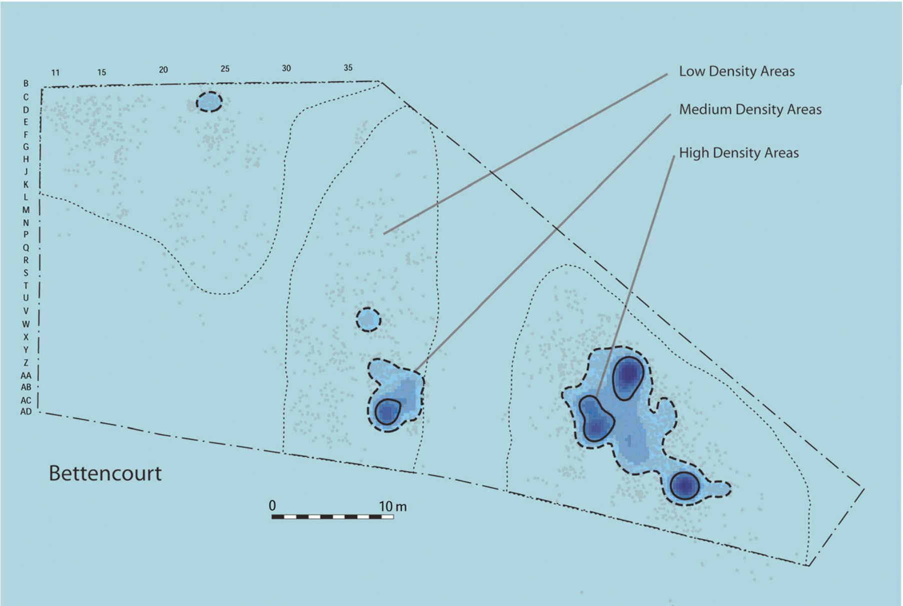

Fig. 4 An example of the density contour analysis for Bettencourt, including the density map and the two contour lines that delimit density areas. The *solid line* delimits the high- and the medium-density areas, and the *dotted line* delimits the medium- and low-density areas

different shades of color. In order to separate lithics into discrete density groups, contours are created based on this raster image, in the same way that is done for an elevation map. Two contours were selected: one that delimits the high- from medium-density areas and another that delimits the medium- from low-density areas. The selection of these two contours is subjective but employs the use of visual techniques, such as the spacing of contour lines, to infer where changes in density are greatest, and then uses this information to capture visible spatial patterning. After the site is divided into density areas, all artifacts are assigned to a density group based on where they are located. In a manner analogous to the refitting location analysis, the contents of each group are analyzed proportionally by technological category and the overrepresentation or underrepresentation of particular artifact classes are assessed for statistical significance by using confidence intervals.

The results from this analysis, along with the refitting location analysis, will determine what processes led to the formation of site structure. Were the high-density areas created through in situ core reduction, or were they the result of continuous dumping? And what processes led to the formation of the medium- and low-density areas? The proportions of each lithic category in the density groups will help determine the type and extent of each of the formation processes.

Results

Refitting Location Analysis

All refitting sets were analyzed in the manner described above, and the results are displayed in Table 3. At all sites, at least half of the refitted lithics fall into group 1. The high percentages in this group indicate that a large proportion of lithics are abandoned where they were knapped. The sites with the highest number of lithics in this group are Cantalouette (77%) and Villiers Adam (81%). Cantalouette is situated directly atop a high-quality chert source, and Villiers Adam has a unique spatial structure of many small concentrated lithic piles and a very low density scatter between them. The percentage of lithics in group 2 ranges from 13% at Villiers Adam (Cantalouette is just behind with 14%) to 31% at Bettencourt. Finally, group 3 comprises 6% of the refitted lithics at Villiers Adam to 22% of the refitted lithics at Fresnoy and Le Prissé. These lithics all follow a pattern of centrifugal movement from the location where they were knapped. The extent of this movement varies by site. Villiers Adam has arguably the lowest degree of centrifugal movement, while Fresnoy, Bossuet, and Le Prissé have the highest.

A clearer view of this movement can be provided by the lithic classes that are found in each refitting group. Table 4 displays the artifact classes that are significantly overrepresentation or underrepresented in each refitting group, as was determined by confidence intervals. The number of arrows corresponds to the number of sites with statistically significant results. The table indicates that lithic pieces associated with primary reduction, such as cortical flakes, partially cortical flakes, maintenance flakes,

Table 3 The percentage of refitted lithics in the three refitting groups by site

	Group 1	Group 2	Group 3
Le Prissé	51%	26%	22%
Bettencourt	58%	31%	9%
Bossuet	55%	28%	17%
Cantalouette	77%	14%	8%
Fresnoy	51%	27%	22%
La Folie	69%	19%	8%
Villiers Adam	81%	13%	6%

and debris, tend to be overrepresented in group 1. Other pieces, such as non-cortical flakes, Levallois flakes, and naturally backed flakes, are underrepresented in group 1. Formal tools display mixed results.[2] Along with debris, they are perhaps the most difficult artifact class to refit, however, because they are modified after being knapped and therefore have fewer and smaller surfaces that could potentially refit with other lithics within the knapping sequence. Therefore, there is a considerable bias against heavily modified tools. Cores also display a somewhat surprising result and are found to be underrepresented in group 1 at two sites. They were therefore not discarded with their own reduction debris. Group 1 displays the most robust results when the results are divided by artifact classes because groups 2 and 3 have much smaller sample sizes. A detailed analysis of what these results mean for each artifact class is beyond the scope of this paper. However, these results support the assumption that group 1 was formed through primary core reduction and artifact classes moved away from this central area tend to be "preferential pieces" such as non-cortical and Levallois flakes.

Density Contour Analysis

The results from the density contour analysis support those from the refitting location analysis. This analysis, however, provides a higher number of statistically significant results due to larger sample sizes (Table 5). This means that results from certain artifact categories are clearer. In particular, debris show a very clear signal here, but were difficult to refit and therefore have only a moderate number of statistically significant results in the refitting location analysis. They are significantly overrepresented in the high-density parts of the site and underrepresented in the low- and medium-density areas in four out of five sites included in the analysis. Cortical flakes, débordant flakes, and maintenance flakes have a mixed signal and vary by site. However, the pattern exhibited by "preferential pieces," *i.e.*, non-cortical flakes, blades, Levallois flakes, and tools, are particularly robust. All statistically significant results show the underrepresentation of these artifact categories in the high-density group. Like in the refitting location analysis, cores also were located away from the high-density areas, a pattern that is nearly as robust as that exhibited by debris.

[2] In this paper, I use the term "tools" to refer to retouched and modified pieces. Where shaped pieces occur, they are included within the "biface/cleaver" category.

Table 4 Results of the refitting location analysis

	Group 1	Group 2	Group 3
Cortical flake	↑	↓	↓
Partially cortical flake	↑↑		↓
Naturally backed flake	↓		
Maintenance flake	↑↑		↓↓
Débordant flake	↑↓	↓	
Debris	↑↑	↓	↓
Non-cortical flake	↓		↑
Levallois flake	↓	↑	
Nodule	↑		
Core	↓↓		
Tool	↓↑↑	↓	↑

Significant values determined by confidence intervals indicating overrepresentation or underrepresentation of each artifact class by refitting group. The number of arrows equals the number of sites that produced significant results (six total sites, Villiers Adam was excluded from this analysis)

How Did Artifacts Move Within These Middle Paleolithic Sites?

The two methods presented here document the processes of site structure formation through the knapping of lithics and their subsequent movement to other parts of the site through a variety of anthropogenic and non-anthropogenic processes. In order to assess what specific processes moved these lithics to their final resting position, I will revisit the categories presented earlier.

Table 5 Results of the density contour analysis

	High density	Medium density	Low density
Cortical flake	↑↓	↑	↑↑↓
Partially cortical flake	↓		↑↓
Maintenance flake	↑↓		↑↓
Débordant flake		↓	
Debris	↑↑↑	↓	↓↓↓↓
Non-cortical flake	↓↓↓	↑↑↑	↑
Levallois flake	↓↓	↓	↑
Blade	↓↓	↑	↑↓
Nodule	↓		↑
Core	↓↓	↓	↑↑↑↑
Tool	↓↓↓		↑↑↑
Biface/cleaver	↓	↓	↑

Significant values determined by confidence intervals indicating overrepresentation or underrepresentation of each artifact class by density group. The number of arrows equals the number of sites that produced significant results (five total sites, Bossuet, and Cantalouette were excluded from this analysis)

Movement through Geological Processes

I begin with geological processes because it is difficult to assess cultural movement without first understanding the role non-anthropogenic processes played. One common method of assessing the movement of artifacts through geologic processes is analyzing the orientation of elongated objects by using fabric analysis (Dibble *et al*. 1997; Enloe 2006; Lenoble and Bertran 2004). Unfortunately, this type of data (*i.e.*, two coordinates on elongated objects or excavation notes describing dip and strike) were not collected for the sites in this study. Some might suggest using the refit data for these purposes, but this idea was rejected because there are many cultural processes that would also create preferential directionality in the orientation of refit connections. This includes the geometry of the site (such as at an elongated site like Champs de Bossuet) or when there are two primary lithic concentrations with many refits between them (such as at La Folie).

While fabric analysis could not be used in this case, we do have other useful data. Fluvial processes would also lead to the size sorting of artifacts, resulting in the preferential removal of smaller flakes (Dibble *et al*. 1997; Isaac 1967; Schiffer 1983). One way to assess size sorting based on results generated from these analyses is to examine whether or not the small lithics (in this case, the category "debris" which includes all point-plotted pieces smaller than 3 cm in size) were found within the high-density zones or were scattered evenly throughout the site. Given that the high-density zones are assumed to be the refuse of in situ knapping (an assumption that will be addressed more fully later), small lithics should be concentrated in this area. Sheet wash or other fluvial processes may have moved them and either washed them away completely or dispersed them more evenly throughout the site. Of the five sites analyzed using the density contour analysis, only one site (Le Prissé) does not achieve statistical significance for debris either overrepresented in the high-density areas or underrepresented in the low-density areas (Table 6). These results indicate that Le Prissé could have been subject to fluvial processes that left high-density concentrations of material but removed the smaller-sized lithics. Unfortunately, because Cantalouette and Bossuet could not be analyzed using the density contour analysis, an assessment of size sorting could not be performed at these sites.

Another method of assessing the degree to which these sites may have been affected by geological processes is to simply look at the overall spatial patterning of artifacts, particularly with regards to the refitted lithics. Discrete concentrations of lithics, as opposed to an even spread, would suggest an anthropogenic origin for the spatial patterning. To assess the degree of spatial clustering, I calculated a Gini index, a

Table 6 The results for the category "debris" from the density contour analysis broken down by site

	High density	Medium density	Low density
Le Prissé			
Bettencourt	↑		↓
La Folie			↓
Fresnoy	↑		↓
Villiers Adam	↑	↓	↓

measure of evenness, for each site in the analysis (Clark 2015; Lorenz 1905) (Table 7). The most common application of this index is to measure the distribution of wealth in a population, but it has significant untapped potential as a general measure of evenness. In this case, I used the index to measure the "inequality" in the number of lithics in each meter square. The higher the index, the more unequal the distribution of lithics. La Folie, Bettencourt, and Fresnoy had particularly high values. Cantalouette and Bossuet had lower values, likely because their distributions of lithics were so dense. Le Prissé and Villiers Adam generated the lowest values, but this was likely affected by their very large areas of low-density lithics. It could, of course, also suggest that these sites were subjected to a higher level of post-depositional processes. This is particularly the case for Le Prissé where other lines of evidence (*i.e.*, the distribution of debris) suggested potential disturbance via fluvial processes. As a contrast, I also included a second archaeological layer from Le Prissé where excavators found robust evidence to suggest that the lithics had been redistributed though fluvial processes. The Gini index for this layer was much lower than the other sites, indicating that even if some redistribution had taken place for the sites in this study, it was likely at a low level (for example, a low-energy sheet wash sufficient to redistribute some small pieces but leave the majority of lithics in place).

In addition to the general patterning of lithics, the patterning of the refitted lithics can also provide some evidence for disturbance by geological activity. If many lithics from the same core are concentrated in a small area, this would indicate that the positioning of the lithics had been subject to only minimal disturbance from post-depositional processes (Isaac 1967). Every site in this study had greater than 50% of its refitted lithics located less than 1 m from one another (refitting group 1, Table 3). Villiers Adam, Cantalouette, and La Folie had particularly high percentages of refitted lithics found within 1 m of each other, suggesting that these sites were minimally impacted by post-depositional processes. Of course, lithics were moved away by humans, too, as I will address in the sections below.

Lastly, one can turn to the distribution of particular artifact classes to assess whether or not artifacts were positioned through anthropogenic or geological processes. A differential distribution of certain artifact types would suggest that humans were the cause of their position of deposition (Dibble *et al.* 1997). Both the density contour

Table 7 The Gini index for each site in the study

La Folie	0.77
Bettencourt	0.69
Fresnoy	0.65
Bossuet	0.59
Cantalouette	0.58
Le Prissé PM1	0.56
Villiers Adam	0.48
Le Prissé PM2	0.32

The higher the index, the more uneven the distribution of artifacts. Le Prissé PM1 is the layer included in this study, while Le Prissé PM2 is another layer from the same site where excavators reported a high degree of spatial reorganization due to fluvial processes analysis and the refitting location analysis indicate that pieces sought after, such as Levallois flakes, tools, non-cortical flakes, and blades, were often significantly over-represented in the low-density parts of the site or more than 3 m away from associated reduction debris. These patterns have an anthropogenic origin. This varies between sites, and sites with lower numbers of statistically significant results might indicate higher levels of disturbance through geologic processes. This will be discussed further below.

The data presented above indicate that the spatial patterning of artifacts within these sites were not subjected to major reorganizing through geological processes and that the general patterning of artifacts can be attributed to anthropogenic behaviors. Some sites, such as Le Prissé, could have experienced low-intensity washing, which led to the removal of smaller lithics, and perhaps the "spreading out" of lithic clusters. The general spatial patterning observed, however, was primarily the result of human behavior. This is not to say that small-distance random movements, such as from burrowing animals or the expanding and contracting of sediments, did not play a role. Indeed, the methods presented here expect and assume such processes to have played a part in small- and medium-distance artifact movement at these sites.

Abandonment at the Location of Manufacture

One of the most dominant patterns to emerge from these analyses is the large amount of knapped material that is left in place. The refitting location analysis shows this trend most clearly. At all sites in the analysis, more than 50% of the refitted material was located within 1 m of lithics from the same refitting set. Furthermore, these pieces are predominantly made up of cortical flakes, core maintenance flakes, and debris, pieces that are associated with primary core reduction. This pattern holds within the refitting location analysis and, also, the high-density zones of the density contour analysis. In addition, refitted lithics are concentrated within the high-density zones for the four sites subjected to both analyses. At Bettencourt and Fresnoy, around 50% of refitted lithics are located within the high-density zones, whereas at Le Prissé and La Folie, the number is higher than 70%. This supports the evidence from the technological categories that the high-density zones were formed through in situ knapping.

Abandonment at the Location of Use

As was mentioned earlier in reference to geological processes, these analyses indicate that certain pieces were systematically moved away from their associated core reduction debris, in particular Levallois flakes, non-cortical flakes, blades, and tools. These pieces were moved to low-density zones likely to be used there, where all associated organic refuse is now missing.

Abandonment Through Site Maintenance/Cleaning

There is no evidence for systematic site maintenance through cleaning or other activities. None of the concentrations of material, for example, consist of larger objects that would have been dumped. In addition, refitted lithics are concentrated within the high-density zones, which indicates that in situ knapping took place there. This was found not to be the case at the Allen Site, a Paleoindian site in Nebraska, where Bamforth *et al*. (2005) found no lithic refits within dense accumulations of knapping refuse. They concluded that these were likely trash piles accumulated through many subsequent occupations.

Likely some scale of "cleaning" did occur at the sites in this study, such as pushing sharp or bulky objects aside before sitting, but no patterned behavior is evident from the spatial distribution of lithics. The only pattern that could potentially be seen as site "maintenance" is the movement of cores to the low-density areas. Of the five sites in the density contour analysis, four displayed an overrepresentation of cores in the low-density areas (La Folie is the exception). There are many potential explanations for why cores may be overrepresented in these areas. If we consider that the high-density zones, made up as they were by piles of sharp and bulky debris, were not the focal points of the occupation, but rather at the peripheries, then these cores may have been removed and set aside for future use in order to distinguish them from the discarded material ("placed" items as Binford [1978] described them). This hypothesis would need to be explored further by comparing the cores and assessing whether or not cores were exhausted when discarded. I do not have the data to address this question. At one site, Le Prissé, where I have the mass of each core, the cores from the low-density areas are indeed larger than those in the high-density areas (178 versus 131 g) but standard deviations for both groups are very high and this question certainly requires more exploration.

Movement Through Unintentional Human Action

Finally, we must consider the movement of lithics though unintentional human action. I am particularly interested in this type of artifact movement because I believe that the extent of such movement can give us a clue about how long, or how repeatedly, a site was occupied. Many of the statistically significant results can be interpreted as intentional anthropogenic movement because, in general, geologic, biogenic, or accidental anthropogenic movement would not preferentially select Levallois flakes or retouched pieces for transport. However, there are many cases in which statistical significance was not achieved. This was possibly the result of site reuse or post-depositional disturbance that randomized the distribution of lithic classes. Therefore, the number of statistically significant results at any particular site can be used as a proxy for how "intact" the spatial patterning can be considered (Table 8). An intact site would result not only from minimal levels of post-depositional disturbance but also from shorter periods of occupation, as well as fewer occupations altogether. For example, Bossuet and Cantalouette had by far the fewest number of statistically significant results, even when considering that they were only included in one of the two analyses. Given that these sites were situated on top of high-quality raw material sources, it makes sense that they were revisited on many occasions and thus their spatial patterning is more difficult to distinguish. Villiers Adam, on the other hand, has a very high number of statistically significant results, especially considering that the site was only included in the density contour analysis. Half of the statistical tests were found to be significant. This site consists of a number of small concentrated lithic clusters, likely representing a number of short-term occupations that do not overlap, and therefore, the spatial patterning is particularly clear.

Table 8 The total number of significant results (counting both analyses) for the seven sites

	[1]No. of results subjected to significance test	No. of significant results	Significant results/total possible
Le Prissé	75	14	0.19
Bettencourt	72	23	0.32
Bossuet	36	2	0.06
Cantalouette	36	1	0.03
La Folie	72	7	0.10
Fresnoy	72	20	0.28
Villiers Adam	36	18	0.50

The total possible results are different for each site because both analyses were not performed on all sites and not all sites had the same artifact categories (*i.e.*, Le Prissé is the only site to include the category "biface/cleaver"). For this reason, the third column contains a ratio of the significant results and the total possible results

Refitting group 2 is an interesting place to look for unintentional anthropogenic types of movement. These artifacts were moved less than 3 m from where they were knapped. Some of this movement could have resulted from intentional use of the artifacts in an area adjacent to the knapping location. A large part of this group also could have resulted from post-depositional disturbances and especially unintentional movement through site reuse (*i.e.*, kicking and trampling). Experimental work has shown that trampling can move lithics as far as 85 cm to 2 m, depending on the study (Gifford-Gonzalez *et al.* 1985; Nielsen 1991; Villa and Courtin 1983). Therefore, trampling could have played a large role in the formation of group 2. Indeed, this group has a particularly low number of statistically significant results, even though its sample sizes were larger than refitting group 3. Bettencourt, Bossuet, Fresnoy, and Le Prissé all have high percentages of artifacts that fall into refitting group 2, potentially implying that these sites were either subjected to longer occupations or had a greater degree of post-depositional disturbance (Table 3). Recalling the earlier discussion of movement by geologic processes, this piece of information could be indicative of fluvial activity at Le Prissé. Bossuet could equally be a candidate for post-depositional disturbance, given its low number of statistically significant results and topographic location within a paleo channel. Bettencourt and Fresnoy, however, are good candidates for an argument for longer-duration occupations.

Assessing the Number and Duration of Occupations in a Comparative Format

The methods presented here allowed for a careful consideration of the processes that could potentially move lithics within Middle Paleolithic sites. We can use this information to go further by uniting the information these two analyses yielded about site structure formation with other lines of evidence included in Table 1 in order to interpret the occupation dynamics of these sites in a comparative format. Figure 5 is a conceptual

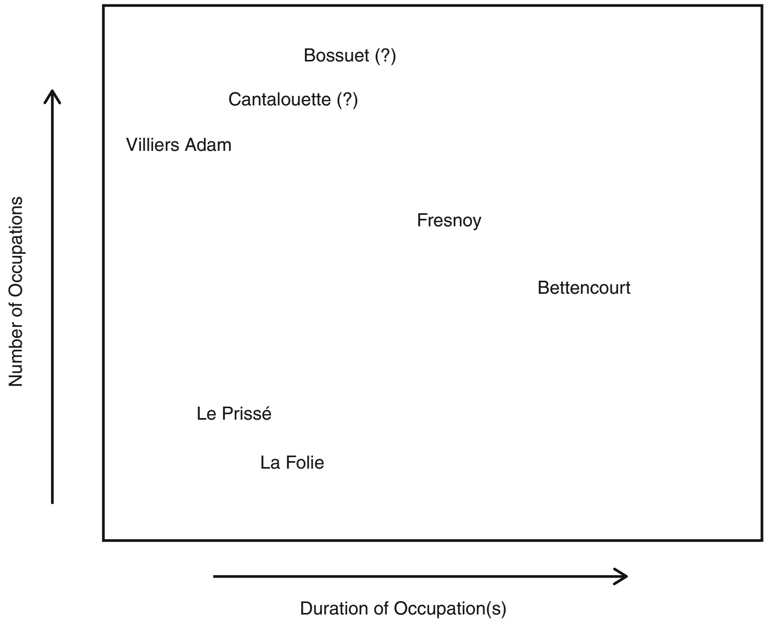

Fig. 5 A conceptional tool used to compare the sites along two continua: the duration of occupation on the *x-axis* and the number of occupations on the *y-axis*. The sites were placed in their location based on results from the two methods presented here and supported with other lines of evidence explained in the text

tool that I created to help with this task. This figure joins two continua, one for occupation length and the other for occupation number. I placed Le Prissé and La Folie in the lower end of both continua. Both of these assemblages are low in artifact count and had a medium number of statistically significant results from the two analyses. Based on Le Prissé's geographic context (a plateau, see Table 1) and the higher number of lithics in refitting group 2, we can surmise that this site was exposed on the landscape for a longer period of time, making it more susceptible to repeated occupation and also post-depositional disturbances. La Folie, on the other hand, was located on a floodplain and had exceptional preservation, indicating that it was formed during single occupation and suffered only minimal post-depositional disturbance. In addition, La Folie's densest square meter contained a much higher number of lithics than Le Prissé's, and thus, the site was likely occupied for a longer period of time. Villiers Adam was also placed to the right side of the figure because the evidence suggests that it was formed through a series of short-duration occupations. It had a very high number of statistically significant results and a low percentage of refitted lithics in group 2 of the refitting analysis, demonstrating that it was not subjected to a great deal of trampling caused by longer-duration occupations. The site's area is very large, however, and its structure is made up of many small concentrations of lithics, suggesting that it was likely reoccupied, but not in the same exact location.

Fresnoy and Bettencourt were placed towards the center of the two continua. Both sites have a fairly high percentage of refitted lithics in refitting group 2, suggesting that they may have experienced higher levels of trampling (*i.e.*, prolonged site use) or post-depositional disturbances. Both sites also have a high number of statistically significant results, indicating that their spatial structure is fairly "intact." Their assemblage sites are also quite large, and they have a relatively high number of lithics in their densest square (particularly Bettencourt). Together, this evidence suggests that these sites may have been occupied for longer periods of time and had fewer numbers of reoccupations. Spatial patterning would have been reinforced through longer-duration occupations, resulting in clearer patterns of centrifugal dispersion, but the longer occupations also led to a greater amount of trampling evidenced in refitting group 2. I have placed Bettencourt to the lower right of Fresnoy, to indicate that these arguments are stronger for that site.

Bossuet and Cantalouette are much more difficult to place on the two continua. These two sites are located on top of raw material sources, and thus, measures used to determine time spent at the site are skewed. Because the raw materials are located within the site itself, there is no cost associated with transport. Nodules do not need to be carried and so they can be knapped in place and abandoned without much effort. The relationship of artifact number to time is thus much different than at the other sites in the study, and therefore, it is difficult to place them within the same comparative continua. However, we can surmise that the sites were subject to a high number of occupations, supported by the very low number of statistically significant results and the obvious attraction of the locale. But I do not take it for granted that *all* occupations were very short. There are many refits that span the site, suggesting that lithics were moved to be used in on-site activities. If these sites were only used as short-duration (*i.e.*, hours, not days) provisioning sites, one would expect refitting sets to be confined to small areas, with missing holes in the reduction sequence corresponding to lithics removed from the site. While this does characterize some of the refitting sets, it is not the only pattern exhibited. In addition, Bossuet has a high percentage of lithics in refitting group 2, which could be linked to prolonged occupations, but it is difficult to determine whether it is the result of post-depositional disturbances or site reuse.

It is clear from the above discussion that the major factor that differentiates site structure, certainly for the sites in this study but likely for all Middle Paleolithic sites, is not intentional structuring of space by the occupants. Rather, it is structured by a series of knapping events and a myriad of processes that moved this material centrifugally from where it was knapped. The number of these knapping events, their configuration relative to one another, and the extent of dispersion are structured by access to raw materials and the number and duration of occupations. Access to raw materials was a primary factor structuring space for the two sites located directly on top of raw material sources, but all of the sites were located in raw material-rich environments. The number of times a site was visited, and the length it was occupied, was therefore the main structuring agent conditioning how many raw material nodules were reduced at the site and how spread out the reduction products became. Number of site occupants is also a crucial part of this equation, but the given data set does not provide any information to contradict the current assumption that Middle Paleolithic groups were small. This question will have to be addressed by comparing sites where larger group sizes are well established so that we can better understand what signatures a larger group might leave on site structure.

Conclusions

This study demonstrates that in the Middle Paleolithic the spatial patterning of lithic artifacts is very repetitive and is largely structured by flint knapping. This observation conflicts with many prior interpretations that attempted to discern activity areas reflecting diverse and discrete tasks. Most of the lithics knapped were left in place and were not utilized. These dense concentrations of knapping debris form the most visible and defining characteristic of the spatial organization. The density of these concentrations grows with the number of knapped nodules and, presumably, the duration of occupation. The number of high-density concentrations could reflect either the number of occupations or the number of knappers. Because so much of the spatial structure is defined by knapping, one could be tempted to label these occupations "workshops." If they are, nearly every open-air Middle Paleolithic site in France should be considered a "workshop." Dense concentrations of material, or *amas*, are the main structuring agent at open-air sites all over France (Depaepe 2007; Hérisson 2012; Locht 2011).

The methods presented here aim to establish an understanding of the formation of site spatial structure through a comparative format. The more we understand about how spatial structure forms, the more we will be able to disentangle the anthropogenic processes from the geologic/biogenic processes and the intentional from the unintentional. These methods approach the distribution of lithic pieces from a simple and straightforward perspective. There are certainly spatial patterns that these methods cannot detect, particularly at exceptional sites where a closer adherence to ethnographic models could be possible. Yet, one of the main obstacles in archaeological research is a lack of comparative methods. From the onset, comparison was the goal of this study. It arose from the need to compare a site like La Folie to sites like Cantalouette and Bossuet. With its exceptional preservation and readily apparent spatial structure, La Folie is an obvious candidate for spatial analysis. Cantalouette and Bossuet, however, are dense concentrations of debris within depressions on the landscape. Most would not attempt spatial analysis in these circumstances. Alone, these sites may not yield particularly interesting information. In contrast, an exceptional site like La Folie would just be another anecdote of what is possible. Taken together, however, robust patterns begin to emerge. And though this particular study focused on the Middle Paleolithic of France, these methods are applicable to hunter-gatherer sites from a wide range of time periods and contexts. Direct comparisons over time and space may prove to be enlightening. For example, is refuse from knapping the main structuring agent in sites from other regions and time periods like it is in French Middle Paleolithic sites?

Spatial analysis is important for learning whether or not humans structured space, and if so, which humans, in what places, and how it was done. Before addressing these questions, however, we need to understand how that structure was formed. What structural components were made by humans through intentional actions? Which ones were accidental through prolonged or repeated site use? And which were the result of geological processes or non-human organisms? By understanding the formation of site structure, we will gain information that is equally important as the questions proposed above. Through the very exercise of breaking down spatial structure formation, we will gain an understanding of the occupation dynamics. A determination of the number and duration of occupations within a single archaeological assemblage is a critical piece of information that consistently stymies archaeologists of mobile peoples. As Wandsnider (1996, p. 322) correctly points out, we will never achieve the chronological resolution to address questions related to occupation dynamics directly. Occupation dynamics are one of the central mechanisms that influence the spatial structure of hunter-gatherer sites (Svoboda *et al*. 2011) and, therefore, spatial analysis is perhaps our most powerful tool to disentangle the temporal dynamics that make up each archaeological assemblage.

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