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ARTICLE

Time and Space in the Middle Paleolithic: Spatial Structure and Occupation Dynamics of Seven Open-Air Sites

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The spatial structure of archeological sites can help reconstruct the settlement dynamics of hunter-gatherers by providing information on the number and length of occupations. This study seeks to access this information through a comparison of seven sites. These sites are open-air and were all excavated over large spatial areas, up to 2,000 m^2, and are therefore ideal for spatial analysis, which was done using two complementary methods, lithic refitting and density zones. Both methods were assessed statistically using confidence intervals. The statistically significant results from each site were then compiled to evaluate trends that occur across the seven sites. These results were used to assess the "spatial consistency" of each assemblage and, through that, the number and duration of occupations. This study demonstrates that spatial analysis can be a powerful tool in research on occupation dynamics and can help disentangle the many occupations that often make up an archeological assemblage.

Hunter-gatherer mobility is a popular subject among archeologists.[1–6] Its popularity can perhaps be partially attributed to a romantic impression of a mobile lifestyle in contrast to the concretely (and, some may argue, increasingly) sedentary life with which we are familiar. More importantly, however, the mobility of hunter-gatherers is such an intrinsic part of their livelihood that it is difficult to study any other part of their economy and culture without understanding the underlying physical movement.[7,8]

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Archeologists traditionally address mobility by sourcing raw materials,[3,4,9,10] assessing the degree of site provisioning with raw materials,[1,11–13] and determining the season(s) of occupation and occupation intensity through faunal analysis.[5,14,15] Each of these methods gives a slightly different perspective on the mobility of groups occupying a site and can provide some insight into the number and duration of occupations. However, differentiating between many short-term occupations and one long occupation, or any combination of the two variables, remains a major obstacle in the reconstruction of mobility and land use patterns.

The number of occupations, the size of the group, and the duration of the time spent at a site is not only salient to any discussion of hunter-gatherer mobility,[16] but also pertinent to our understanding of how resources were exploited. For example, how are we to make inferences about what behaviors occurred at a site and how strategies of resource procurement were organized if we do not know whether the analyzed assemblage derives from a single long-term occupation or many short occupations? Reconstructions of human mobility based on raw material proveniences also run into the same problem when we attempt to define territory or home-range size for an archeological assemblage.

This paper demonstrates that the spatial patterning of artifacts can be used to assess the temporal characteristics of an assemblage. The organization of artifacts and features relative to one another can indicate whether an assemblage was the result of a single or multiple occupations, as well as the relative duration of occupations. This is particularly the case when the sites are open-air and were excavated at very large scales, as was the case for the sites in this study. Because the duration of occupation and the number of occupations occur along a continuum, such a study should take place in a comparative format.

The sites included in this study range in occupation intensity, measured in artifact density and assemblage size, from sites located directly on raw-material sources to a low-density site on a floodplain. The two interrelated analyses used to determine the spatial structure of each site partition a site into density groups and refitting groups based on where they are located relative to the general distribution of materials, as well as to

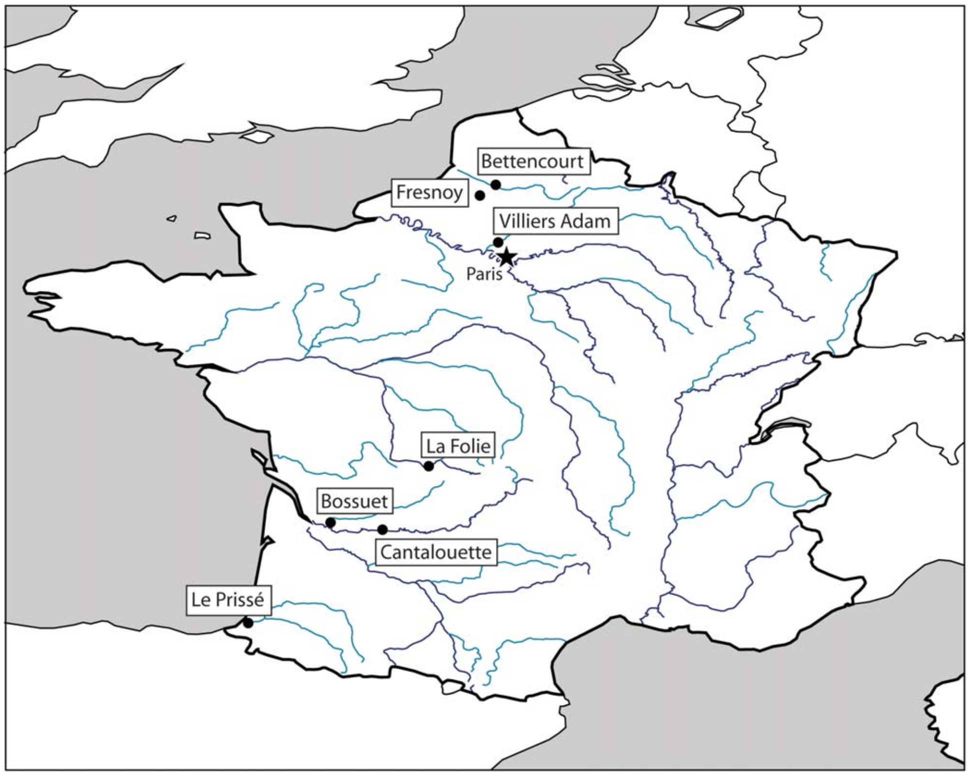

Figure 1. A map of France showing the location of all seven sites. (Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.)

pieces that belong to the same refitting set. These two analyses provide information about how the sites were organized, as well as how long they were occupied, and the relative number of occupations. In this paper, "occupation" refers to any period of time spent at a site, whether that time be minutes, hours, days, or months or, potentially, years. Therefore, "occupation" should not carry any connotations of "home" in the sense that a site was used as a living place; instead, "occupation" implies only that a space was occupied by the physical presence of at least one human at one point in time.

THE DATA SET

The sites used in this study were excavated as rescue or contract projects by *l'institut de recherches archéologiques préventives* (INRAP). All sites were excavated over large spatial extents and therefore are well suited for a study of spatial organization. Figure 1 provides a map of site locations within France; Tables 1 and 2 give basic site details. Two of the sites, La Doline de Cantalouette II and Champs de Bossuet, are located directly on raw material sources and, accordingly, boast assemblage sizes of more than 15,000 lithics. The other sites are located further from raw material sources, but all of them have high-quality flint sources within relatively close proximity. None of these sites contain preserved bone. La Folie, a small site located on a floodplain, is the only site to contain a preserved fire feature.

The general spatial structure of these sites presents a range of variation (Fig. 2). Cantalouette and Bossuet, the quarry sites, have uniformly dense accumulations. At Bossuet, lithic nodules were exploited within a partially filled paleo-channel on a terrace of the Isle River, northeast of Bordeaux.[17,18] Because the lithic nodules were exploited where they were found, the site follows the contours of the paleo-channel. La Doline de Cantalouette II is one of a series of several sites set atop the high-quality and prolific Bergeracois flint sources near the city of Bergerac.[19] Like Bossuet, the exploitation of flint at this site was concentrated within a depression in the landscape, this time within a doline.

Fresnoy, Bettencourt, and Villiers Adam are located in the loess belt of northern France.[20–23] All three sites are situated within paleosols on a northeastern facing slope. Fresnoy and Bettencourt contain dense patches of artifacts, but also areas of low and medium density. The deposits at Bettencourt are divided into three sectors by channels of erosion. Villiers Adam is a very large site that contains many small clusters, but has a low density over all.

Le Prissé de Bayonne and La Folie have the smallest assemblage sizes in the data set; both contain two principle clusters of high-density accumulations. La Folie, outside of Poitiers, is arguably the best preserved site in this sample, with evidence of a hearth, a nonpedogenic organic horizon (likely bedding), and postholes that may have been used for a windbreak (they enclose an area thought

TABLE 1. Basic Information on the Seven Sites

	Landscape Position	General Spatial Structure
Le Prissé	Plateau near the confluence of two major rivers	Two closely spaced clusters, large area of low density scatter
Bettencourt	Northeast facing gentle slope, forest soil within loess deposits	Three sectors separated by erosion, several very high density clusters
Bossuet	Paleo channel on river terrace	Extremely high density distribution, follows contours of the drainage
Cantalouette	Doline (sinkhole)	Extremely high density distribution with some more concentrated clusters
La Folie	Floodplain	Small site with two clusters connected by many refits. Evidence for windbreak and bedding (excellent preservation)
Fresnoy	Northeast facing moderate slope, forest soil within loess deposits	Large scatter over large area, refits connect the entire area
Villiers Adam	Northeast facing gentle slope, forest soil within loess deposits	Many small, distinct clusters over a large area

to be too large for a covered structure).[24–26] Le Prissé is located on a plateau outside of the city of Bayonne.[27] While this site has two distinct concentrations of material, like La Folie, the majority of the site's area is made up of very low-density scatter.

METHODS

The spatial analysis of these seven sites used two related approaches. Both analyses were done using Arc GIS® 10.0 and combine the spatial location of lithics and their techno-typological attributes. The first analysis, the density contour analysis, begins by constructing a density map of all coordinated artifacts (lithics greater than 2 cm).[28] A density map is a raster image with color shading values depending on the relative density of artifacts. The next step is to create contours for the density map in the same way that might be done for an elevation map (Fig. 3). The generated contours are used to isolate high-, medium-, and low-density areas. The artifacts are then organized into the three density groups based on where they are located. This analysis excluded the two quarry sites, Cantalouette and Bossuet, because they do not have technological data associated with each coordinated artifact. The data sets were simply too large; thus, the artifacts were segregated into technological categories and counted, rather than recording each individual artifact into the database.

The second analysis, the refitting location analysis, makes use of the extensive refitting data that was collected for these sites. The percent of the assemblage that was refitted is outlined in Table 2. It ranges from 38% at La Folie to just above 5% at Bossuet. The small assemblage size and low refit percentage (4%) at Villiers Adam make it unsuitable for this analysis. Like the density contour analysis, the refitted lithics are divided into three groups.[28] Each set of refitted pieces is analyzed separately: all lithics within one meter of each other are placed into refitting group 1, lithics within 2 meters of that group into group 2, and lithics more than 2 meters from group 1 into group 3 (Fig. 4). Group 1 is determined by locating the smallest area where the highest concentration of lithics occurs. This area most likely corresponds to the location where they were knapped.

Thus, these analyses produce two sets of groups: the high-, medium-, and low-density groups determined by the density contour analysis and refitting groups 1, 2, and 3 determined by the refitting location analysis. Once the artifacts are divided into density and refitting groups, the proportion of technological categories was calculated for each group. This value was then subtracted from the breakdown of technological groups for the assemblage as a whole to assess whether categories were over- or under-represented in each group. For example, there were 60 total cores at Bayonne, 22 of them located in the low-density zone, which gives a

TABLE 2. Quantitative data for each site in the study[a]

	Le Prissé	Bettencourt	Bossuet	Cantalouette	La Folie	Fresnoy	Villiers Adam
Site density (lithics/m^2)	0.81	25.13	69.29	54.62	6.1	3.74	0.84
Site area (m^2)	1075	915	228	282	207	1143	1928
Total lithics	870	5729	15,797	15,404	1,262	4,270	1,619
Densest square (# lithics)	66	225	527	443	189	183	108
Refit percentage	20%	14%	5%	10%	38%	9%	4%

[a]The site size quoted here was calculated in ArcGIS and reflects the minimum area occupied by the cloud of coordinated artifacts.

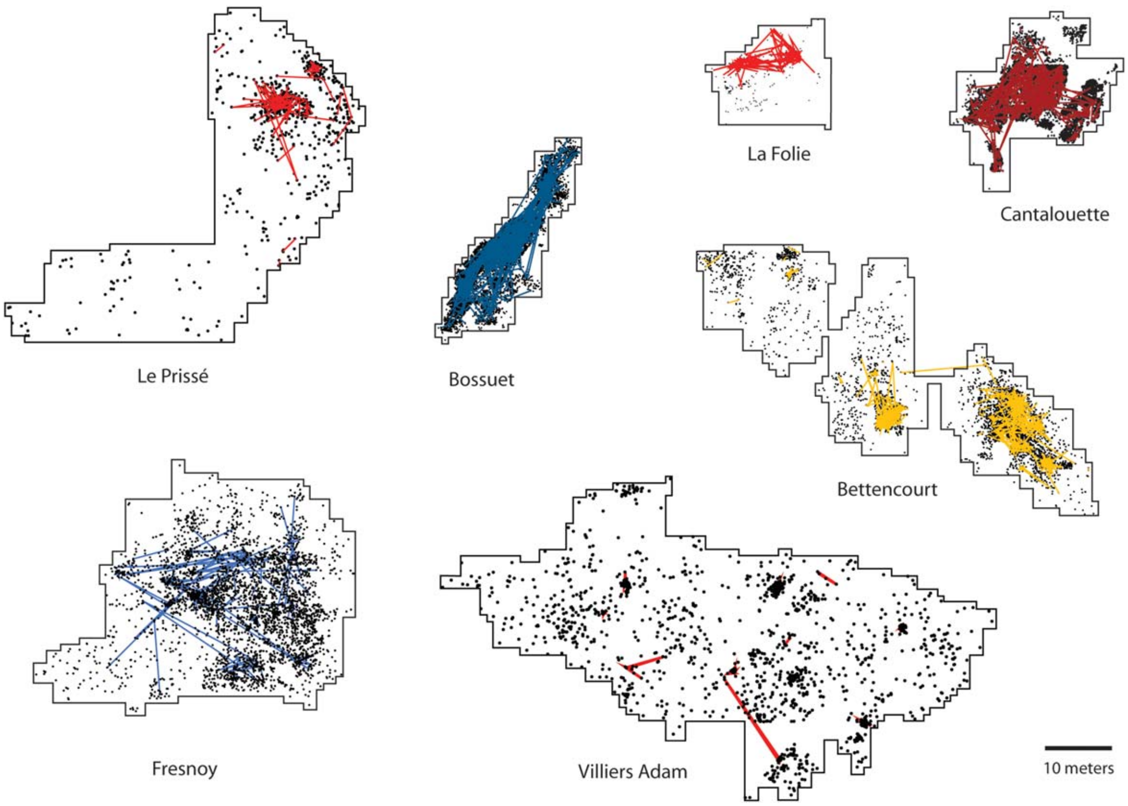

Figure 2. All seven sites included in this analysis displayed at the same scale. This image also provides a sense of the general site structure, including the refitting connections (colored lines). (Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.)

proportion of 0.37. In order to evaluate whether this number was statistically significant, 95% confidence intervals were established around the total lithics that fell into the high-, medium-, and low-density zones. The proportion of cores that were located within the low-density zones fell outside of this interval and was therefore deemed significant. This method was used for both the density and refitting groups.

The density contour analysis and refitting location analysis are simply ways of dividing coordinated lithics into groupings based on where they were mapped during excavation. The density contour analysis divides all lithics into zones based on whether the artifact was located within a low-, medium-, or high-density part of the site. The refitting location analysis, on the other hand, divides refitted lithics based on where they are located relative to other lithics within a given refitting set.

CENTRIFUGAL MOVEMENT AND THE FORMATION OF SITE STRUCTURE

The two methods presented are essentially mapping the formation of site structure through centrifugal movement of lithic artifacts. The underlying concept here is that the spatial structure of lithic artifacts within archeological sites is primarily formed by the introduction of lithic raw materials, the knapping of these materials at one or several discrete spatial locations, and the subsequent centrifugal movement of these artifacts to other locations of the site through human or geologic agents. By tracking the relative number of times this process occurred (that is, the number of times raw materials were introduced to a site and then reduced), the extent to which the artifacts were then redistributed, and how these events are configured relative to one another, we can begin to disentangle the temporal factors that controlled site structure formation.

The density contour analysis maps the location of artifacts within concentric rings of artifact density. The areas highest in density are most likely where the majority of core reduction occurred; the medium- and low-density areas roughly coincide with areas where lithics were moved at some point after they were knapped. Knapping events, of course, may have taken place in the medium- and low-density areas and some lithics may have been moved from the low- and medium-density areas into the high-density areas. However, these are exceptions to this idealized model. This model will be tested by looking at whether the high-density areas largely consist of core reduction debris.

There will also be a certain number of lithics that were not knapped on site but were transported to the site from some other location. These lithics, however, are not numerous

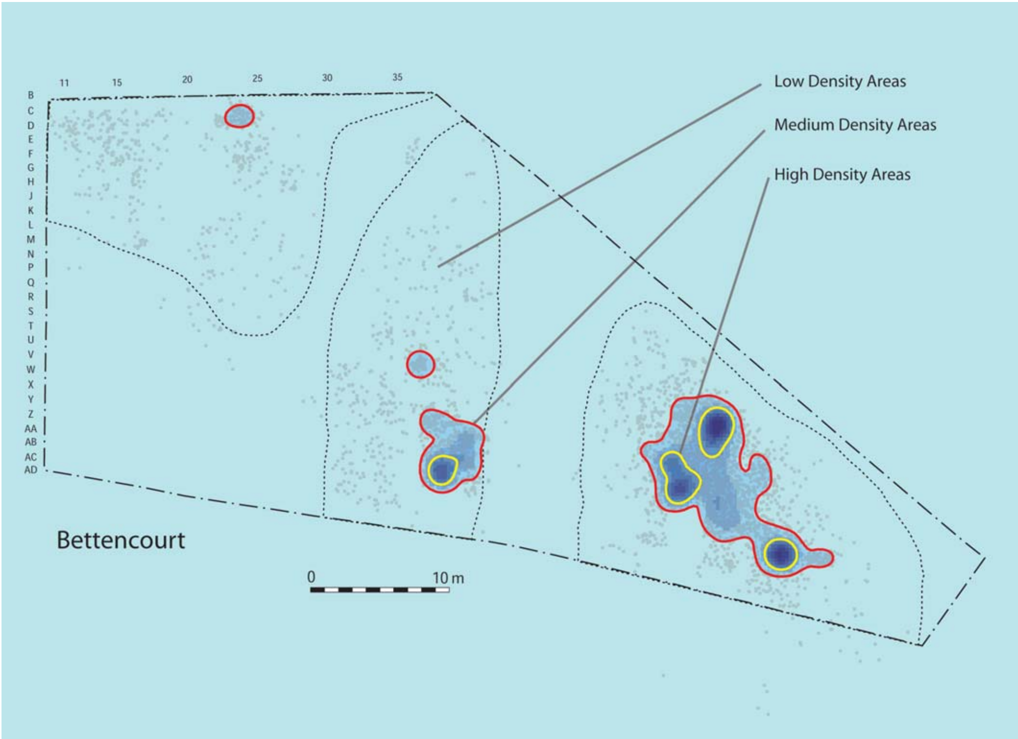

Figure 3. An example of how spatial groups are divided in the density contour analysis. This figure displays the density map from Bettencourt overlain by contours chosen to delimit the low-, medium-, and high-density zones. Artifacts found within each of these zones are then assigned to the corresponding group. (Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.)

enough to contribute significantly to the overall site structure. They can be expected to occur in higher proportions in low-density areas because there they will not be overwhelmed by reduction debris.

The refitting location analysis also tracks the location of artifacts based on the extent of their spatial spread from where they were knapped. This analysis, however, differs from the density contour analysis in that here there is a concrete, rather than implied, indication of artifact movement. This is because at one point in time each artifact in a refitting group was located at the same point in space (that is, within the core, before knapping). The location of refitting group 1 may not always correspond with the location of knapping for every refitting set, but we can expect the two to co-occur in the majority of cases.

Both analyses track the centrifugal movement of artifacts within the site and, therefore, the formation of the site structure as a whole. The density contour analysis documents movement by locating artifacts within high-, medium-, and low-density zones of the site. The refitting location analysis, however, documents the movement of individual reduction events. Once these analyses are performed at each site, we can begin to deconstruct the site structure formation and, through that, the temporal dynamics of occupations.

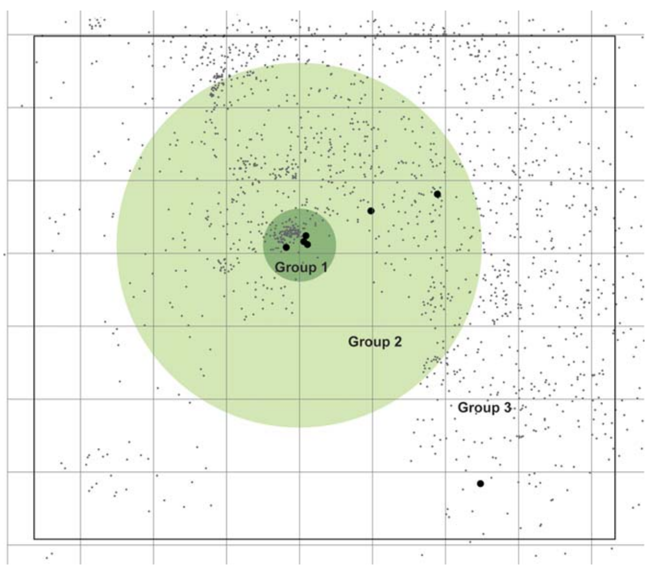

Figure 4. An example of how refitted lithics are divided into groups. This figure shows the spatial location of artifacts from refitting set 12 from Bettencourt. Three lithics tightly clustered together fall into group 1, two more slightly farther away are in group 2, and a final lithic some meters from the others falls into group 3. The grid is in square meters. (Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.)

TABLE 3. Significant Values for Both Analyses Indicating Whether an Artifact Category Was Over- or Underrepresented[a]

	Refitting Group 1	High Density	Refitting Group 2	Medium Density	Refitting Group 3	Low Density
Cortical Flake	↑	↑**↓**	**↓**	↑	**↓**	↑↑**↓**
Partially Cortical Flake	↑↑	**↓**			**↓**	**↓**↑
Naturally Backed Flake	**↓**					
Maintenance Flake	↑↑	↑**↓**			**↓↓**	**↓**↑
Débordant Flake	**↓**↑		**↓**	**↓**		
Debris	↑↑	↑↑↑	**↓**	**↓**	**↓**	**↓↓↓↓**
Non-Cortical Flake	**↓**	**↓↓↓**		↑↑↑	↑	↑
Levallois Flake	**↓**	**↓↓**	↑	**↓**		↑
Blade		**↓↓**		↑		**↓**↑
Nodule	↑	**↓**				↑
Core	**↓↓**	**↓↓**		**↓**		↑↑↑↑
Tool	↓↑↑	**↓↓**↓	**↓**		↑	↑↑↑
Biface/Cleaver		**↓**		**↓**		↑

[a]Significant values for both analyses indicating whether an artifact category was over or underrepresented. A upwards facing arrow indicates overrepresentation while a bolded downwards facing arrow indicates underrepresentation. The number of arrows corresponds to the number of significant results per site (for example, partially cortical flakes are overrepresented in refitting group 1 at two of the sites in the analysis).

RESULTS: REFITTING LOCATION ANALYSIS AND DENSITY CONTOUR ANALYSIS

The number of statistically significant results for the two analyses is shown in Table 3. This table breaks the significant results down by technological category and whether they were over or underrepresented. Both analyses are placed together in a single table to facilitate comparison. In theory, results from the high-density group should be similar to results from refitting group 1, as should results from the medium-density group and refitting group 2 and results from the low-density group and refitting group 3. The alignment in results between these two analyses may vary by site because differing site use may yield different patterns, but the results from equivalent groups should be more or less similar within any particular site.

The high-density area and refitting group 1 are both assumed to be locations where the majority of core reduction occurred, so the artifacts there should reflect this behavior. Artifacts found in refitting group 2 and the medium-density group would have moved, by a variety of processes, a short distance from where they were knapped. Artifacts found in refitting group 3 and low-density areas were moved a longer distance from where they were knapped. Much of this "movement" is, of course, assumed rather than proved, but this is the general model that most artifacts should follow. Whether these assumptions are correct will be tested, to an extent, by which artifacts are over and underrepresented in each group.

The categories of debris and cores yield the strongest patterns. Debris are overrepresented in the first group of both analyses and underrepresented in the third. The debris category is made up of small flakes (<3 cm), shatter, and split pieces; therefore, an overrepresentation of these pieces in refitting group 1 and the high-density group support the assumption that these areas can be linked with knapping events. Although there are some examples of knapping events occurring in medium-density zones, determined by the location of refitting sets, most artifacts located in the medium- and low- density areas were moved to their location after being knapped in the high-density area or off site.

In contrast to debris, cores are overrepresented in the low-density group but underrepresented in the high-density group and refitting group 1. The location of cores likely reflects their conspicuous nature, which renders them more mobile than other technological types. They are large objects that receive a great deal of attention from the knapper and, likely, other group members as well (such as children). They could have been moved for future knapping or for other uses. In addition, their rounded geometry and generally larger sizes makes them more susceptible to movement by site reuse or other surface disturbances.

Flakes, blades, and Levallois flakes were also overrepresented in refitting group 3 and the low- density group, but underrepresented in refitting group 1 and the high-density group. Bifaces and cleavers were present only at the site of Le Prissé, but they also followed this pattern in the density contour analysis. In addition, retouched tools were strongly overrepresented in the low-density group and underrepresented in the high density group, although the results of the refitting analysis (specifically, group 1) were mixed, showing more variability. Cortical flakes, partially cortical flakes, and maintenance flakes displayed a pattern that was generally the inverse of these "planned" pieces, but their results were mixed.

SPATIAL CONSISTENCY AND ITS USE IN DETERMINING THE NUMBER AND DURATION OF OCCUPATIONS

The results produced by the two analyses can be used to evaluate the spatial consistency of each site in the study. Spatial consistency simply refers to the clarity of spatial patterning at the site in question: Can patterns be identified and do these patterns agree with each other? The spatial consistency of a site can first be evaluated by the number of statistically significant results from the spatial analyses. A high number of significant values indicates that the spatial patterns resulting from site use were clear and not jumbled through site reuse or prolonged occupation. The clarity of spatial patterning can also be evaluated by whether the two analyses agreed with each other for each of the three levels of spatial groupings. For example, were cortical flakes overrepresented in

TABLE 4. The Total Number of Significant Results (Counting Both Analyses) for the Seven Sites[a]

	Total results subjected to significance test	Total significant results	Significant results/ total possible	Disagreements
Le Prissé	75	14	.19	0
Bettencourt	72	23	.32	4
Bossuet	36	2	.06	0
Cantalouette	36	1	.03	0
La Folie	72	7	.10	0
Fresnoy	72	20	.28	2
Villiers Adam	36	18	.50	0

[a]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 (that is, 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. The final column displays the number of times the results of the two analyses contradict each other.

the high-density group but underrepresented in refitting group 1 (considering only statistically significant patterns)? If so, this would count as a disagreement. A disagreement between the two analyses might indicate that there is discordance in spatial patterning at the site.

Table 4 presents the number of statistically significant results, as well as the number of disagreements between analyses for each site in this study. This table can be used to evaluate spatial consistency. The first column presents the number of statistically significant results found at each site; the second presents the number of categories that were submitted to the statistical test; and the third column displays a ratio of these two values. A ratio is important because not all sites were subjected to both analyses. Furthermore, Le Prissé is the only site to contain the category "biface/cleaver." The final column of Table 4 displays the number of times these two analyses disagree with each other at any particular site. This occurred, for example, at Bettencourt, where cortical flakes were found to be significantly overrepresented in refitting group 1 but significantly underrepresented in the high-density group.

Spatial consistency can give insights into the number and duration of occupations. Agreement between the two analyses and a high number of statistically significant results may indicate that a site was occupied for a short time and not reoccupied. The inverse, however, could be related to the jumbling and disorder of artifacts that might occur when sites were occupied on numerous occasions and for longer times. These results can be complimented by other site characteristics found in Table 2.

Bossuet and Cantalouette, the two sites located directly on raw material sources, have very few significant results. These sites likely experienced many short occupations that left the sites with fragmented and inconsistent spatial structures. These two sites were located on top of high-quality raw material sources, so not only were they nodes on the landscape that attracted multiple occupations, but lithic debris accumulated at a much faster rate than at other sites. This is shown by their extremely high artifact counts, which were spread over a fairly small area, making their densities very high and evenly distributed (Table 2).

La Folie and Le Prissé, the sites with the smallest assemblage sizes, have a medium number of significant results. Le Prissé had a very low sitewide artifact density. Artifacts were mainly concentrated in two clusters in the northeast portion of the site. These clusters were not particularly dense, however; the densest square contained only 66 lithics. The remaining portion of the site, which amounted to quite a large area, was made up of a very low-density scatter. This scatter could have been partially the result of a "background scatter" of material, suggesting a continued human presence on the landscape.[16,29,30] The density contour analysis captures the signal from the background scatter from the low-density group, which can be expected to disproportionally represent lithics left during short-term visits to the site. Indeed, Le Prissé has a particularly high number of statistically significant results showing that retouched tools, as well as bifaces and cleavers, are overrepresented in the low-density area. These lithics likely represent discarded elements of a mobile toolkit.[31]

In contrast to Le Prissé, the site area of La Folie was very small; it was located on a floodplain and therefore was covered too quickly to accumulate a background scatter. La Folie also had a much more concentrated density than did Le Prissé. Both sites have low overall artifact counts, but La Folie contained 189 lithics in its densest square, a number nearly three times as high as that at Le Prissé. The concentrations of lithics at La Folie were covered more quickly that than those at Le Prissé, and thus not subjected to as many processes that may have caused their diffusion. However, La Folie had a higher overall artifact count and thus was also likely occupied for a longer time Le Prissé. Discounting the background scatter found at Le Prissé, the two sites likely had only one occupation. Both sites had a medium number of statistically significant results, a number that was difficult to achieve, given their smaller assemblage sizes. In addition, both sites have high refitting percentages, which indicate well-ordered assemblages that had not been reorganized through long-term or multiple occupations.

Villiers Adam has the highest ratio of statistically significant results (50% of the total results subjected to the significance test). It is also distinct from the other sites because of its very large area and low artifact density. Although it is larger than all of the other sites in the study by nearly 800 m^2, it contained only 1,619 lithics. The high number of significant results indicates clear spatial patterning, but this was likely the result of multiple short-term occupations that

TABLE 5. The disagreements in statistically significant results between spatial analyses

Bettencourt	Cortical Flake	Density Contour Analysis	High Density	Under
		Refitting Location Analysis	Refitting Group 1	Over
Bettencourt	Maintenance Flake	Density Contour Analysis	High Density	Under
		Refitting Location Analysis	Refitting Group 1	Over
Fresnoy	Partially Cortical Flake	Density Contour Analysis	High Density	Under
		Refitting Location Analysis	Refitting Group 1	Over
Bettencourt	Cortical Flake	Density Contour Analysis	Low Density	Over
		Refitting Location Analysis	Refitting Group 3	Under
Bettencourt	Maintenance Flake	Density Contour Analysis	Low Density	Over
		Refitting Location Analysis	Refitting Group 3	Under
Fresnoy	Partially Cortical Flake	Density Contour Analysis	Low Density	Over
		Refitting Location Analysis	Refitting Group 3	Under

were spatially distinct. Subsequent occupations did not occur on top of abandoned debris but, instead, were spatially segregated so that the site is made up of a number of distinct clusters, all of which display spatial consistency. This means that sample sizes were able to become large enough to obtain significance, but patterns were not jumbled during reoccupation. It is likely that each of these occupations was relatively short; the densest square at Villiers Adam contains 108 lithic pieces, about halfway between the numbers at Le Prissé and La Folie.

One might question why these clusters were produced through reoccupation when they could have been produced by the occupation of one large group. Large group size could be one explanation for the observed spatial patterning at the site. However, with only 4% of the assemblage part of a refit, the site does not reflect interconnectivity. Furthermore, most of these refits occur at small scales within rather than between clusters. This does not exclude the possibility of a large group, but it merely makes spatially distinct reoccupations a more parsimonious explanation.

Bettencourt and Fresnoy also have high numbers of statistically significant results, but they are also the only two sites that exhibit disagreements among these results. This indicates that these sites have some consistency in their spatial organization, but discordance in the spatial patterning. In order to understand what this discordance means, we must consider what each analysis is tracking. The density contour analysis tracks the distribution of all lithics across the entire site. The refitting location analysis, however, tracks only the location of lithics that have been refitted. The refitted lithics are likely biased toward reduction events that occurred later in time during the site's occupation; earlier reduction events are more likely to have holes in their sequence from lithics discarded off-site. Therefore, the results of the density contour analysis display patterns that document the entire occupation span, while the refitting location analysis is skewed toward representation of events occurring later.

At Bettencourt and Fresnoy, lithic classes were systematically moved around the site, but the patterns found for the overall distribution of artifacts (tracked by the density contour analysis) did not always match the pattern found for the events occurring later in the site's occupation (tracked by the refitting location analysis). Examining the data presented in Table 5, the results of the refitting location analysis always follow the dominant results from other sites in the study; that is, although cortical flakes are overrepresented in the first group and underrepresented in the third, the density contour analysis found the opposite results.

The refitting location analysis reveals patterns consistent with other sites in the study because they have been less obscured by long occupation. The density contour analysis indicates that Fresnoy and Bettencourt were occupied long enough for a significant amount of centrifugal dispersion to occur. In other words, as the site was occupied for a longer period of time, the lithics knapped at the beginning of the occupation were more likely than others to be moved away from their knapping location to other parts of the site. This movement was likely the result of both intentional action through selection of lithics for use and, perhaps more importantly, unintentional movement through site reuse. This differential representation of time explains the discordance in the results. It also indicates that Fresnoy and Bettencourt had much longer occupations than did the other sites in the study. This conclusion is supported by other lines of evidence, as shown in Table 2. Compared to the other sites, Bettencourt has a very high artifact density, the highest without being situated atop a raw material source. In addition, its density is quite concentrated, with its densest square containing 225 lithics. At Fresnoy, the artifact density was lower over a larger area. The densest square contained only 183 artifacts, a value just slightly lower than the densest square found at La Folie. Fresnoy is situated on a slightly steeper slope than other sites, however, which might have contributed to a less concentrated distribution of material. However, its total artifact count is still high, with 4,270 pieces. Bettencourt was therefore occupied for a longer period than was Fresnoy. It has a higher artifact count, a higher ratio of statistically significant results, and also more disagreements between the two analyses.

It can be concluded from these analyses that Cantalouette and Bossuet had many reoccupations, all located on top of one another, in areas where abundant raw materials could be found. This resulted in inconsistent spatial patterning and few statistically significant results from the two spatial analyses. Villiers Adam also had numerous reoccupations but, because raw materials were not being exploited in place (though likely imported from close by), the successive occupations were separated in space. Thus, spatial patterning was not obscured through reuse and the site exhibited a strong spatial consistency. Le Prissé has the smallest lithic assemblage in the dataset and a ratio of statistically significant results that falls in the middle. This site therefore likely had a relatively short principal occupation, but with a background scatter suggesting repeated human presence on the land surface, which likely was exposed for a longer time than other sites in the dataset. La Folie has a lower ratio of statistically significant results than Le Prissé and a higher assemblage size, with a much denser concentration of lithics. Therefore, La Folie was likely occupied for a longer time. Finally, Fresnoy and Bettencourt had higher ratios of statistically significant results but, as noted, there were disagreements between the two analyses. This indicates that the sites were occupied long enough that the centrifugal dispersion of knapping events created a pattern that was at odds with more recent reduction events, revealed through the refitting location analysis. These more recent events followed patterning exhibited at other sites in the dataset. Given its high density and largest number of disagreements between analyses, Bettencourt was likely occupied for the longest time.

THE DIFFICULTIES OF DIFFERENTIATING BETWEEN OCCUPATION NUMBER AND DURATION

The methods presented here do not completely solve the problem of differentiating between many short-term occupations and one or several long-term occupations. They do, however, provide some additional lines of inquiry that can be used along with other indicators. In particular, breaking down site formation through centrifugal dispersion of reduction events can be a powerful tool for conceptualizing the effect of time on the spatial structure of archeological sites.

One confounding factor that makes this exercise so difficult is the different degrees of access to raw materials, which can distort the relationship of artifact quantity to time. For example, a site located close to a source of raw materials could accumulate a large quantity of lithic materials in a relatively short time. At sites located farther away from raw materials, the cost of transporting raw materials would result in a much slower rate of accumulation of lithic materials. In addition, much of the initial stages of core reduction may have taken place closer to the raw material source, reducing even further the amount of lithic debris discarded at the site under study. However, the sites discussed here are all relatively close to high-quality raw materials. The only major difference is whether or not they were physically located on top of the source.

A major disadvantage of this dataset is the lack of evidence from faunal remains. Faunal analysis can help determine whether an occupation was repeated seasonally or across many seasons.[14,15,32] However, many sites do not have preservation of faunal remains. Moreover, many that do are caves or rockshelters, which yield assemblages that are arguably even more difficult to disentangle (but see work at Abric Romaní[33–36]).

The duration and number of occupations directly influence the size and density of an archeological assemblage. However, an equally important variable in this puzzle is group size. This factor was mentioned earlier in reference to Villiers Adam. The spatially segregated concentrations of debris at Villiers Adam could potentially be the result of a larger group rather than the product of reoccupations. However, small group size is the more parsimonious explanation, particularly because it is supported by the majority of other studies.[37–39] It is a question that deserves further attention, however, and will most likely be accessed by comparing sites from a population that we know display a range of group sizes.

CONCLUSIONS

The spatial analysis presented here shows that a repeated pattern of spatial organization is found among the Neanderthal sites in this dataset. The factors that control this spatial organization are repeated events of core reduction followed by the centrifugal dispersion of lithics from this initial location. The centrifugal dispersion of lithics is caused by several agents. First, humans select lithics to be used elsewhere on the site, usually “preferential” pieces such as noncortical flakes, blades, or retouched pieces. Second, centrifugal dispersion can result from nonhuman agents, usually when a site is uncovered on the landscape. Such agents include fluvial or colluvial processes, bioturbation, or use of the land surface by nonhumans. Finally, prolonged site use causes centrifugal dispersion through accidental movement by humans or through cleaning and other behaviors. However, structuring of space through systematic cleaning or partitioning of activities was not found to be a major component of the spatial organization of lithics for sites in this dataset. It should be pointed out, however, that La Folie does have evidence of a structure, as well as bedding. Therefore, a certain cultural organization of space could be evidenced through other materials, but the spatial organization of lithics at La Folie followed the same rules that applied at other sites in the dataset.

The rules of centrifugal dispersion and site structure formation are closely tied to the impact of time on an archeological assemblage. Therefore, the spatial structure of lithics can be used to disentangle the elements of time (that is, the number and duration of occupations) on a lithic assemblage. This is vital if we are to understand the mobility and landscape use of hunter-gatherers in the past This is especially true for the study of populations of hunter-gatherers who are removed from us by tens of thousands of years of geologic processes and modification of the landscape by humans and other organisms.

This study used the spatial organization of lithics to address two of the factors that control the size and density of an archeological assemblage. A third factor, access to raw materials, occurred primarily on two scales: raw materials were either located within sites or within easy access. The final major factor, group size, was found to be more or less consistent among the sites in this dataset, though this factor must be addressed more rigorously in the future. However, if we are to accept the results of this study at face value, the major access of variation in terms of the size and density of Middle Paleolithic archeological assemblages is the number and duration of occupations. This indicates that certain locations were used repeatedly for different lengths of time. Numerous studies have found that Neanderthal population densities were low[40–42]; recent genetic work supports these findings. Genetic sequencing of a female Neanderthal from Siberia shows that her parents were half-siblings and that many of her recent ancestors were the product of inbreeding.[43] This suggests a long tradition of small group sizes. If population sizes were low, we cannot assume that the repeated use of specific locations was simply a random result of having many hominid groups on the landscape. Rather, it is reasonable to assume that many of these locations were used by the same group as a part of their seasonal rounds. This suggests that Neanderthals had a complex system of land use in which certain prime locations were used repeatedly and others were used for more prolonged occupation.

This conclusion is not a major revelation. Archeologists have known for some time that Neanderthals likely had a complex system of mobility and resource exploitation. However, using the methods presented here, we can identify features of the landscape that led to prolonged occupation versus repeated ones, then combine this with information about territory and home range sizes to achieve a more nuanced view of the specifics of these systems of land use.

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