Intrasite Spatial Analysis of a Late Upper Paleolithic French Site Using Geographic Information Systems

by Dustin Keeler

Introduction

This paper is an analysis of site structure as it applies to social and behavioral organization within Paleolithic hunter-gather camp sites. A complete understanding of site structure requires the examination of high-definition sites that are very well preserved in terms of their spatial integrity. Magdalenian open-air sites within the Paris basin are some of best-preserved Paleolithic sites, due to particular depositional processes present at the sites, the light flooding of nearby rivers and gentle accumulation of silts and sand. The spatial structures of Magdalenian sites within the Paris basin are comparable to the spatial structures of many other Paleolithic sites and certain types of ethnographic hunter-gatherer sites. Verberie is one of the best examples of a high-definition site within the Paris Basin and therefore well suited for a spatial examination of site structure.

It has long been known that these sites were optimal resources for spatial analysis but there has always been the problem of choosing the most effective techniques in performing the spatial analysis. New techniques are continuously being developed, each of which add to the ability of accurately analyzing spatial data, but the most important advance in the recent past has been the development of new tools that can be used in spatial analysis. Geographic Information Systems are particularly well suited for the spatial analysis of Paleolithic sites since they are able to quickly and easily store and work with the large amount of spatial data that results from the excavations of Paleolithic sites[1]. New techniques of spatial analysis available through Geographic Information Systems allow for a much better understanding of spatial relationships then was previously possible.

Once the spatial data from these sites is analyzed another problem arises of how best to interpret the results. The results may be interpreted based on a variety of assumptions about the processes that produced the spatial pattern. A particular model of site structure may also order an interpretation of spatial data from hunter-gatherer sites. Finally, the assumptions made about Paleolithic hunter-gatherer camp sites as well the site structure models applied to them have changed dramatically over the past thirty years due to more and more advanced archaeological research and the incorporation of ethnoarchaeological observations.

The analysis that I will perform on the data from Verberie will utilize some of the most advanced techniques of spatial analysis available in Geographic Information Systems. The results of this analysis will then be interpreted using the most current models and assumptions of Paleolithic site structure in order to better understand Magdalenian behavioral and social organization at the site of Verberie.

[1] The spatial data from most Paleolithic excavations is very detailed since in many cases the exact location of every artifact is recorded and the number of artifacts found at just one Paleolithic site can be in the 100's of thousands.

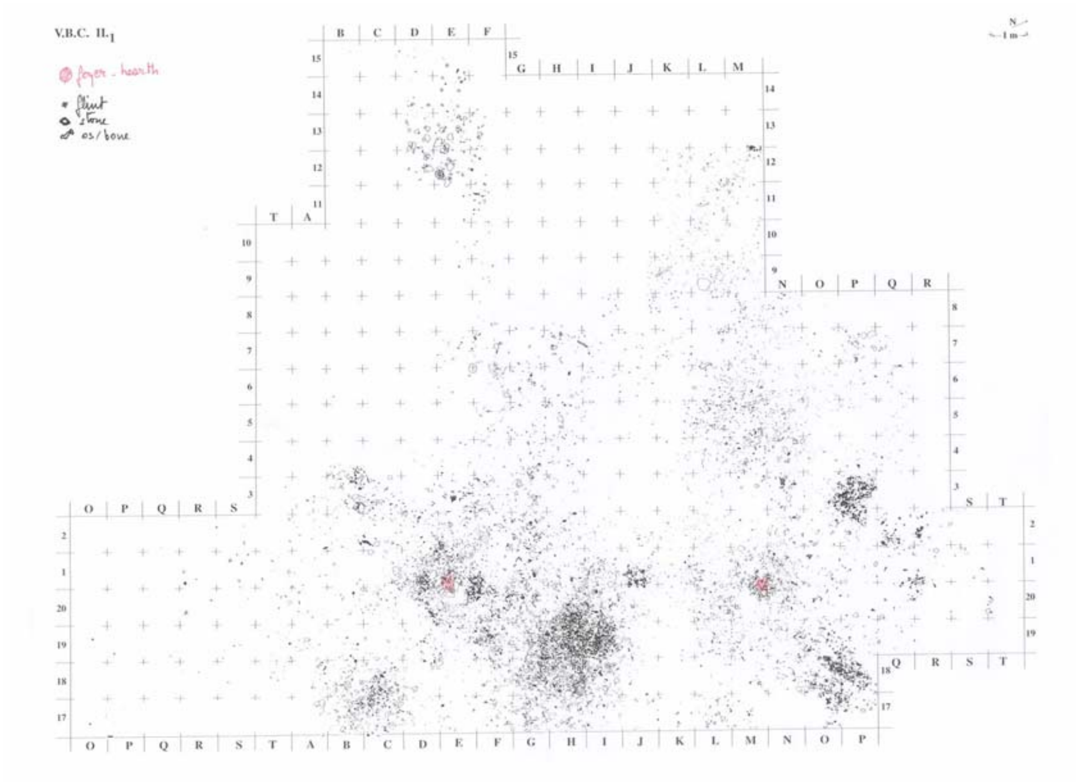

Figure 1. Verberie site map: Level II.1 .

Site

Verberie is a critically important site in that its unique qualities lend themselves to a high quality analysis. Among these unique qualities is the amount of unusually well preserved faunal remains at the site, the very clear spatial organization resulting from short seasonal occupations, the unpatinated lithics at the site that allow for a high quality microwear analysis, and simply the large variety of activities that were performed at the site, of which we are well informed due to the other unique qualities. The presence of all part of the reindeer is also unique for this type of site and implies the primary butchering took place there and that the settlement was very close to the kill location. This is unique since most other sites present a selection of parts related to transportation from kill sites further away.

Verberie is a stratified open air site located at the bottom of the Oise river valley. It was regularly covered by silts brought by floods. This resulted in the unusually good preservation of eight successive and highly spatially organized living floors with bones, flint, and hearths, making it is possible to identify activity areas such as flint workshops, butchering areas, and filleting areas, and offering great promise for the interpretation of past human behavior. The living floors belong to the late Magdalenian, which is dated during the most temperate phase of Bolling (13000-12500 BP) between two cold phases of the Dryas. It's lithic and bone industry is typical of the period. Verberie has been excavated for twenty-six years since the late 70's. Over the course of the excavation eight occupation levels have been identified. The data from one level, level II.1, has been the most extensively analyzed. The analysis of data from this layer includes lithic use-wear studies and refitting of both flint and bone. Both of these analyses have contributed to the interpretation of the spatial structure of the site, but no formal spatial analysis had as yet been performed on any of the data. The spatial interpretations have so far come just from visual inspection of the artifact distribution displayed on site maps.

One problem with Verberie is that it is difficult to distinguish between the several occupation layers, which are located directly on top of each other. Vertical spatial analysis techniques are used to understand the deposits in sites such as this (Koetje, 1991). Some statistical methods of this type have been used Verberie and we can be reasonably sure of layer distinctions at this point (Audouze and Enloe, 1997).

The first interpretation of spatial patterning at Verberie was based on the interpretation of Pincevent by Leroi-Gourhan. The interpretation was that of hearths within tents (Gamble, 1986). A latter interpretation of the spatial patterning was influenced by the work of Binford among the Nuniamut. In it the location of the tents were moved back farther away from the hearths to the empty areas near the hearths with the area directly around the hearth being interpreted as a drop zone (Audouze, 1988). The interpretation of areas not associated with the hearths was also influenced by the work of Binford (Audouze and Enloe, 1997). These areas located at the peripheries of artifact concentrations adjacent to the hearth were interpreted as areas of butchery since they were largely devoid of artifacts but surrounded by rejected bone. Use-wear analysis of blades found within these areas identified them as having been used to cut meat (Audouze and Enloe, 1997). This fit with Binford's model of the area of butchery that he observed among the Nuniamut (Audouze, 1988; Enloe, 2002).

Use-wear studies by Keeley and Symens involving the examination of the traces and polished wear on lithics under the microscope led to the determination of what activities were performed at the site and where they were performed (Audouze, 1994; Keeley, 1991; Symens, 1986). This was also used to interpret use and discard patterns in relation to the spatial distribution of artifacts (Symens, 19860. The main activities identified through use-wear analysis were the cutting of meat, bone working, and skin working. Data on the use of stone tools was used in the interpretation of spatial patterning through the identification of activity areas. In some cases it confirmed the previous interpretation of the spatial structure in that the areas thought to be locations of butchery contained tools with use wear caused by meat cutting (Enloe, 2002). In other cases they produced new insights into the location of activities such as bone and antler working, which was mainly performed around the hearth (Keeley, 1991:263-266), and even demonstrated some resharpening done by unskilled knappers, possibly children. A problem with the use of use-wear studies in the interpretation of spatial patterning is factors such discard of tools and the cleanup of sites (Keeley, 1991:258). An analysis that can determine the affects of these factors is the refitting studies.

The results of the lithic refitting studies have mainly been used to identify the various stratigraphic layers of the site, which are directly on top of each other, making them hard to distinguish, but they have also been used in the identification of flint knapping activity areas at the site that are mainly located around the hearths (Audouze and Enloe, 1997). It is also possible to distinguish trough the refitting of flint blocks between very good knappers, regular ones, and unskilled ones, the later corresponding to children who have not yet mastered motor habits. A more complete lithic refitting study is currently being done for all the layer of the site. Jim Enloe has done a refitting study of the faunal material, which has implications on the interpretation of social organization at Verberie, in that it may indicate food sharing and communal eating among the occupants of the site (2002). There are different patterns of faunal refitting in sites in the Paris Basin. In some sites such as Pincevent the refits are mostly between households while at Verberie, the refits are between a central area to the households. This may indicate different patterns of food sharing, food sharing within nuclear or extended families at Pincevent and more communal food sharing at Verberie. One of the major questions concerning Verberie is weather it was occupied by a task group of hunters or one or more families (Enloe, 2002). The spatial structure of the site is largely dependant on which of these types of groups inhabited the site therefore the spatial analysis will be used to answer this question. Since the social conditions existing at the site will play a major role in our proposed study we will include these results in our spatial analysis.

Data

The data used in this spatial analysis of occupation floors comes from level II.1 of Verberie. This is the first level excavated at the site from the late 70's into the 80's. The exact locations of every single artifact found were recorded during excavation. Additional attribute data includes information on the artifacts, including form, size, and use-wear.

The data available is in a variety of forms. The pure locational data for all of the artifacts made up one tables that included over 26,000 entries. It includes all the tools as well as non-tool data such as bone and stone and all the flakes of all materials. Another table consisted of tool locations and their attributes, consisting of the coordinate data, the type of tool, the material of the lithic, the function of the tool, and the material it was used on (from use-wear studies). The third table was in the form of quadrats, consisting of artifact counts within a 10cm grid. The information provided by this data set is from the area around the south hearth, excluding the main dump.

Analysis

For a site like Verberie multiple levels of analysis are required, ranging from fairly global to very fine-grained. The first step of the spatial analysis will be the identification of spatial clusters at multiple levels of resolution. This study will use kernel density estimation as an analytical technique that has the ability to emphasize either local structure or overall patterns.

More specifically Kernel density estimation is a method by which the smoothed value at any point is estimated. The estimated value is calculated by using a weighted average based on the values of all other points. The kernel is a probability function that calculates the weights at each point. The bandwidth is the width of the area from which the points are taken to calculate the estimated weight at the each point. This is more or less the equivalent of the "bin" width in a histogram. Changing the value of the bandwidth, which can be set to reflect different scales of interest, can control the degree of smoothing. The result is spatially smooth estimate of the intensity of events over a study area (Bailey, 1994:27).

Kernel density estimates are preferable to other spatial cluster analysis for they reveals pattern more clearly, produces smoother surfaces and allows tuning of the density through changing the bandwidth (Wheatley and Gillings, 2002:186). It can be used to examine structure at different levels of resolution and this study will be concerned with identifying the highly local surface that reflects smaller clusters of points equating to the activity areas as well as broader surfaces that reflect larger clusters representing social units. The specific merits of kernel density estimates are that they represent the real structure of clusters through contouring, rather that the spherical clusters produced by k-means cluster analysis. They can aide in the determination of the number of clusters through the examination of contours at different levels of inclusion as a means of looking for structure at different scales of spatial resolution (Baxter, Beardah, and Wright, 1997). An application of kernel density estimates by Baxter, Beardah, and Wright on the data from the Mask site studied by Binford showed that this type of analysis identifies structure in the distribution of materials more clearly than other methods (1997).

Kernel density estimates will be performed on individual areas of the surface to identify higher resolutions of the clustering in areas that are underrepresented when looking at the entire surface, which is dominated by the dump and hearth locations. The results that will be obtained through kernel density analysis will be compared to the results of other analysis that will be performed on the same data such as unconstrained clustering. Preliminary use of kernel density estimate analysis of the data from level II.1 has shown that clusters defined by this method are more representative of the actual spatial distribution than other methods of cluster analysis.

Whallon's unconstrained clustering is a well known approach that is a framework for analysis rather than a sequence of rigid methods. The approach consists of creating smoothed density contours over an area from the distribution patterns of separate artifact types. The density of each type is then determined at each data point from the smoothed density contours. The vector of densities is then converted to a vector of relative densities by summing the elements of the vector and dividing each of the elements by the sum for that vector. Cluster analysis is then performed to combine data points into groups that tend to be homogeneous with respect to the vectors of relative densities. Finally, one plots the data points belonging to each group on the floor and inspecting them for spatial integrity or interpretable spatial patterning. This description is informative of the structure and patterning inherent in the data and can be informative of the processes and activities that formed the observed spatial distributions (Whallon, 1984).

The analysis using GIS began using the quadrat data for the area around the south hearth to create nearest neighbor smooth contour maps for each of the major artifact classes. Those include flint, bone, rock, esquille flint, esquille bone, and esquille rock. The esquille artifacts are those artifacts under 1 cm in size. They are distinguished from the larger artifacts because they are much more likely to have been subject to bioturbation, which consisted mainly of movement by worms. They are also put into separate classes because they can identify locations where specific activities were performed more than larger artifacts, which were more likely to have moved by the occupants of the site.

The density map of the flint (figure 2) shows a very high concentration around the hearth. The flint in this area is much more widely distributed than this map actually displays, but the areas away from the hearth are underrepresented because the density of artifacts around the hearth is so much higher relative to the densities away from the hearth. That is one of the problems with density maps of this type, if the density is too high in one area other areas may be underrepresented. Nonetheless, this map is useful in displaying the clusters around the hearth, the importance of which will be discussed in the interpretation section.

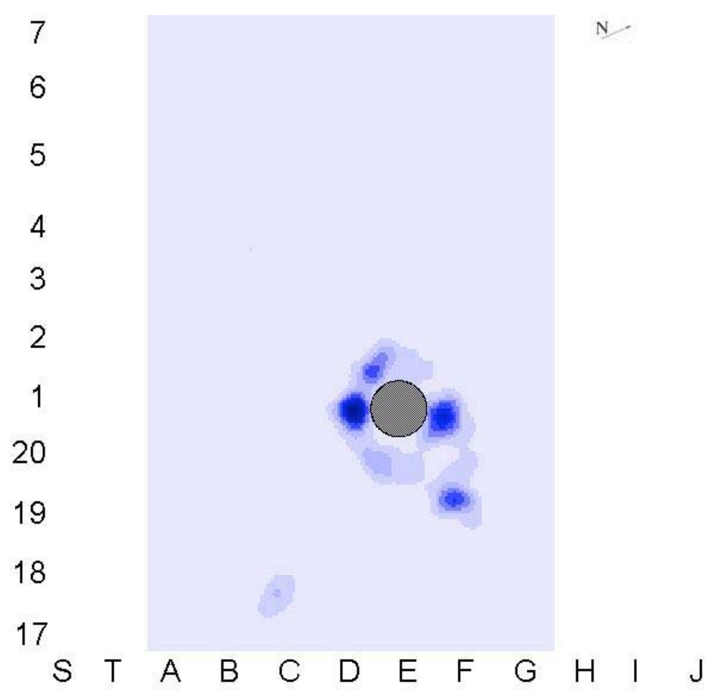

Figure 2. Density map of flint around hearth 1.

The density map for the bone around hearth 1 (figure 3) more accurately displays the widespread distribution of the artifact type throughout the entire are. It not only shows a high concentration around the hearth but also in adjacent areas each of which is accurately represented because no one density cluster is too high relative to the other clusters.

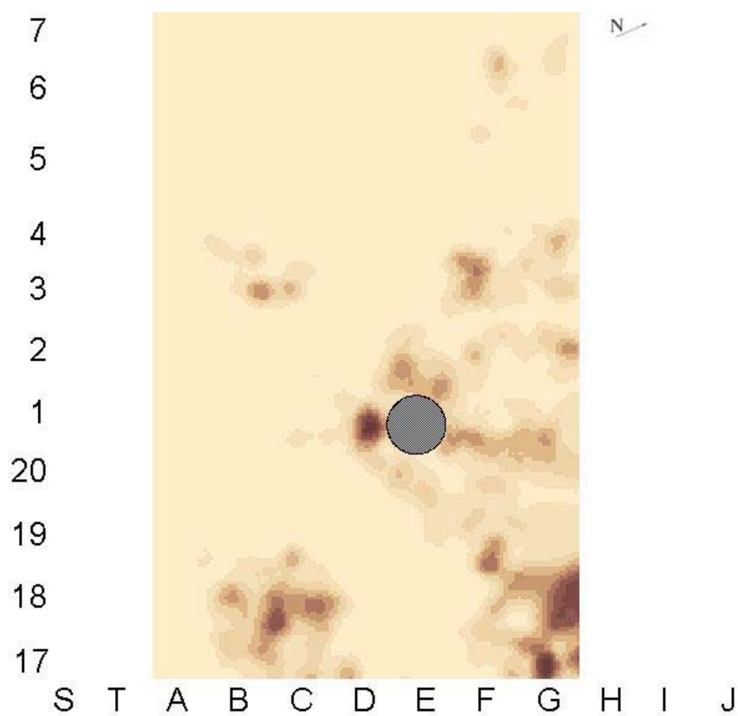

Figure 3. Density map of bone around hearth 1.

The density map of esquille flint (figure 4) looks much the same as the density map of flint. The difference is that the esquille flint density map actually does accurately represent the distribution of the artifact within the area. Esquille flint is highly concentrated around the hearth and is not found in any significant amount further away from it.

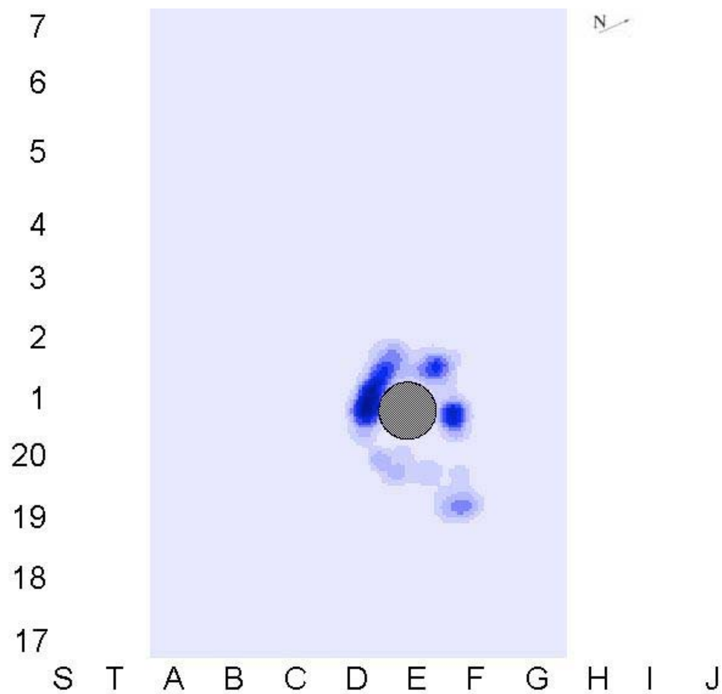

Figure 4. Density map of esquille flint around hearth 1.

The density map of esquille bone (figure 5) is also an accurate representation of the distribution of the artifact type but it displays a very different distribution than that of the bone. This is important for the interpretation of activity locations and will be further discussed in the next section.

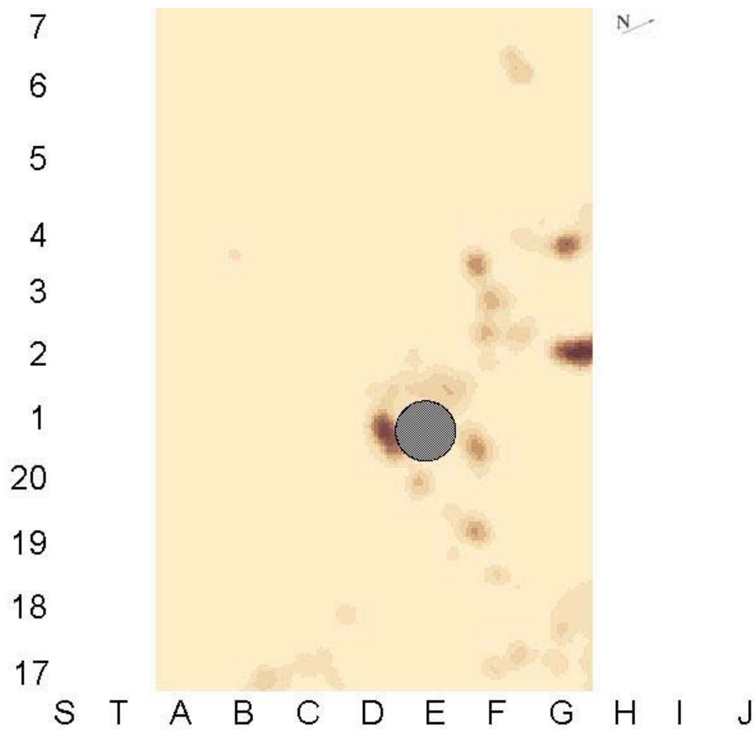

Figure 5. Density map of esquille bone around hearth 1.

For the next step of the analysis I performed unconstrained cluster analysis using the quadrat data for the area around the first hearth. I used a method similar to Whallon's, only I used the relative densities of the three major artifact classes, rock, flint and bone, within one meter squares. I performed a cluster analysis on these squares using a hierarchical clustering method within the SPSS statistical program which grouped the squares into classes based on the relative density of artifact types within them. The results of this analysis can be displayed graphically by numbering the squares based on their designated class (figure 6).

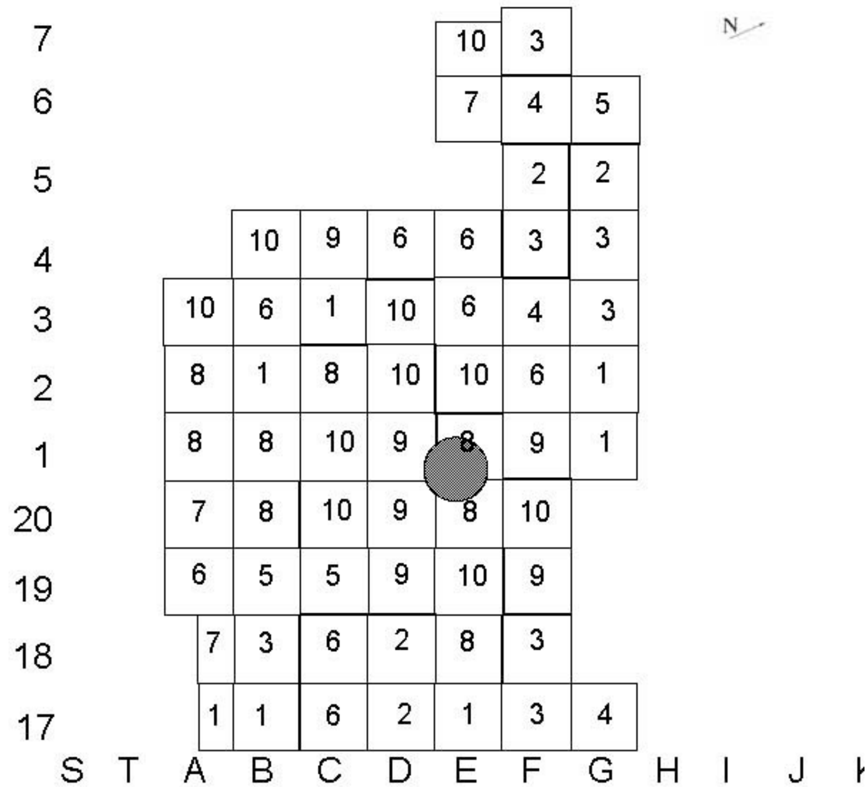

Figure 6. Unconstrained clustering around hearth 1.

Table 1. Cluster descriptions

cluster 1- low percentage of rock, higher percentage of flint, and a very high percentage of bone
cluster 2- low percentages of rock and flint, high percentage of bone
cluster 3- very low percentage of rock, higher percentage of flint, very high percentage of bone
cluster 4- very low percentages of rock and flint, very high percentage of bone
cluster 5- low percentage of flint, higher percentage of rock, very high percentage of bone
cluster 6- low percentage of rock, even percentages of flint and bone
cluster 7- similar percentages for all three types
cluster 8- low percentage of rock and bone, high percentage of flint
cluster 9- very low percentage of Rock and bone, very high percentage flint
cluster 10-very low percentage of rock, higher percentage of bone, very high percentage of flint

This unconstrained clustering analysis achieved the purpose that was originally intended by Whallon, that is the identification of clusters that are not spatially constrained and that are not dependant on the absolute density of artifacts, as pure locational clusters are (Whallon, 1984). The unconstrained clustering can be used to make inferences about the relationship between various classes of artifacts and can identify similarities between unconnected areas within a site. It may also be used in comparison with the density maps to further define the locational clusters.

The next step of the analysis involved the creation of kernel density estimates using the point artifact location data for all the material in level II.1. I experimented by using different bandwidths to determine which would most accurately display the artifact cluster. Because of the large amount of artifacts, over 26,000, it was necessary to use a very small bandwidth. Kernel density maps were created for all artifact classes combined as well as the individual artifact classes. The kernel density maps more accurately display the variation of densities within the clusters while the kernel density contour maps more accurately display the boundaries of clusters.

The results of this pure locational clustering technique are more useful compared to results that could be achieved using other techniques such as K-means clustering. Like K-means clustering, kernel density estimates can identify clusters at multiple levels of resolution[2] but kernel density estimates do not require the number of clusters to be determined before hand as K-means clustering does. For this reason the number of

[2] Only the kernel density estimates of the optimal resolution are displayed here. The optimal resolution was decided on based on experimentation through the creation of maps at multiple levels of resolution. The optimal resolution chosen was the one that most accurately displayed the size of clusters previously identified though examination of the site map.

clusters identified using kernel density estimates is probably much closer to the number of actual clusters.

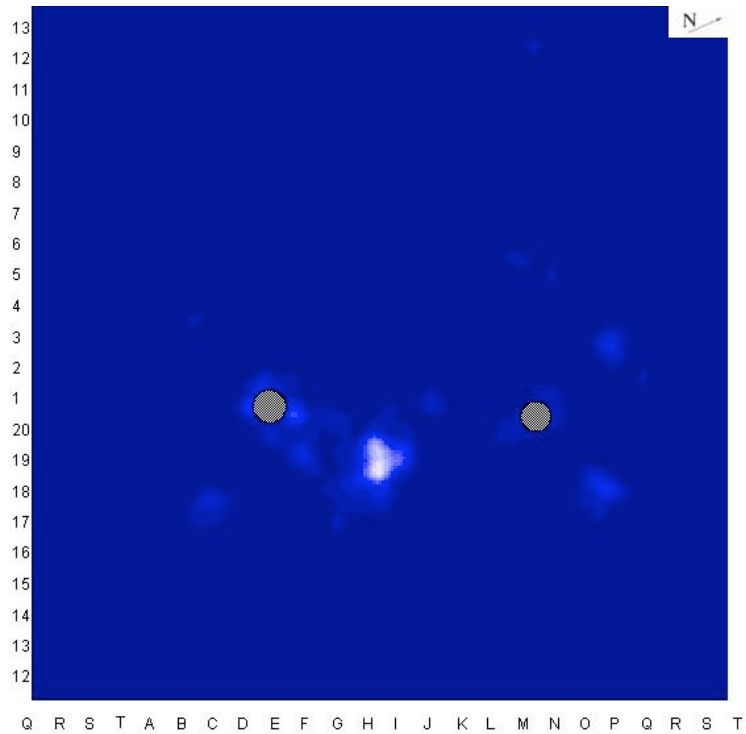

Figure 7. Kernel density map of all artifacts in level II.1.

The kernel density map of all the artifacts (figure 7) does not accurately show the extent of the distribution since certain areas have such a high density and cause other areas to be underrepresented. More accurate displays of the distribution however will be seen with the kernel density maps of the individual artifact classes. The kernel density contour map (figure 8) accurately displays the main clusters, which will be discussed in the interpretation section.

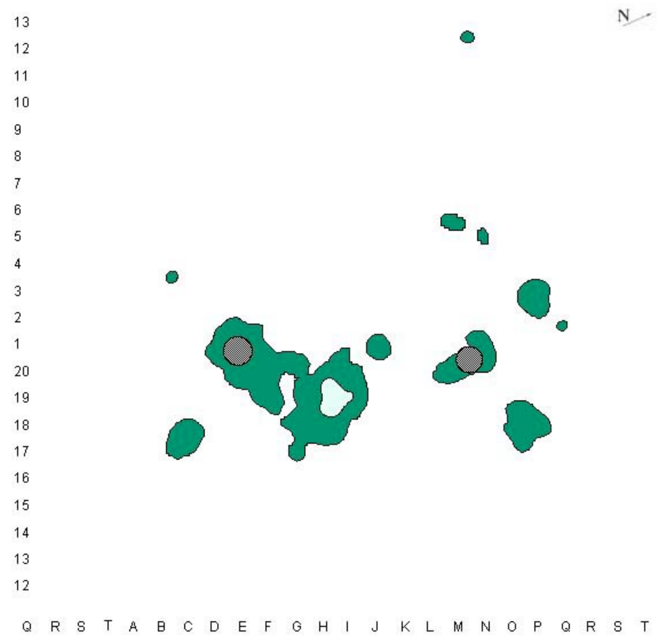

Figure 8. Contours of kernel density estimates for all artifacts in level II.1.

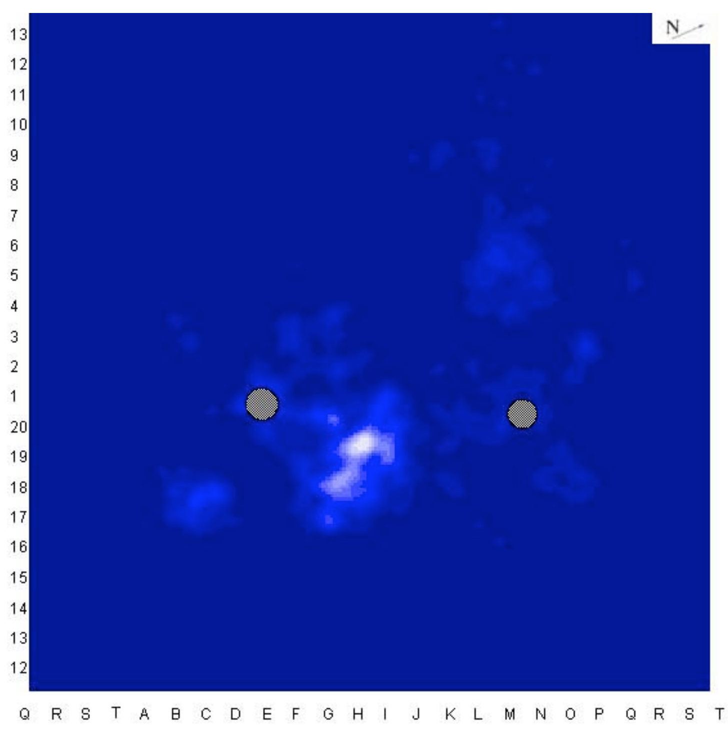

Figure 9. Kernel density map of all bone in level II.1.

The kernel density map of bone (figure 9) best displays the true extent of the distribution of artifacts since the densities of bone do not vary to such a large extent over the occupation area and because bone appears in relatively high densities where other artifact types do not. The main clusters also appear in the kernel contour map (figure 10) though the delimitation between them is harder to distinguish.

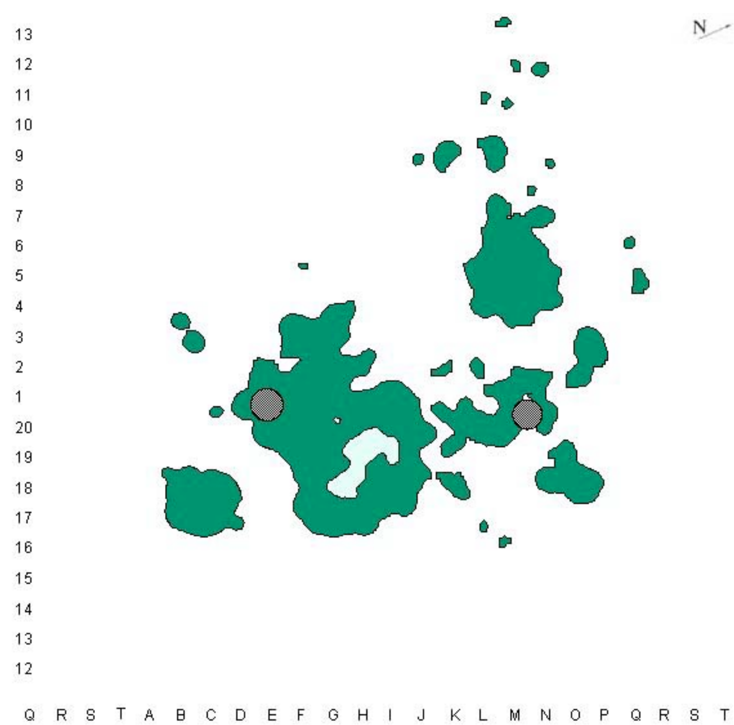

Figure 10. Contours of kernel density estimates for all bone in level II.1.

The kernel density map of rock (figure 11) shows that this artifact class only appears in a significant amount in a few discreet locations. This map is used to identify the exact locations of the hearths, which are not displayed in by symbols in this map since two of the cluster locations more accurately show where they are.

The rock kernel contour map (figure 12) displays the least number of main clusters of all the artifact types, but the shapes of the main clusters that are displayed are different than those displayed in the maps of other artifact classes. This is important for the interpretation and will be further discussed later.

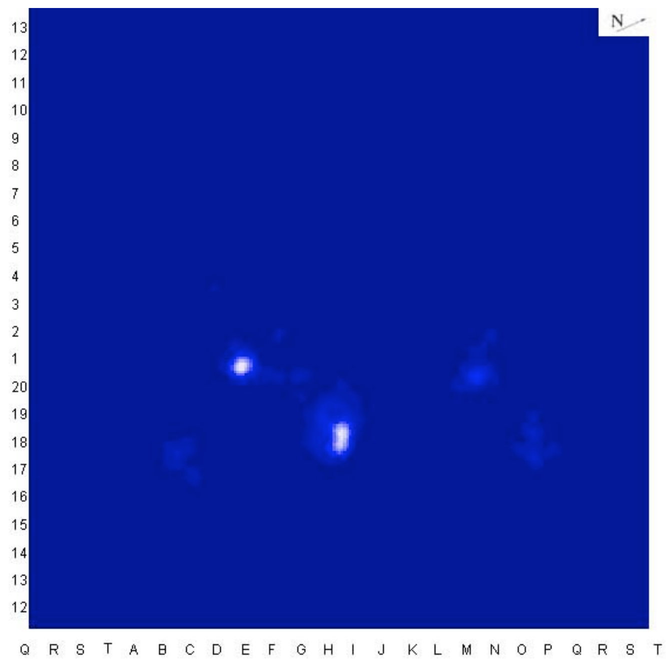

Figure11. Kernel density map of all rock in level II.1.

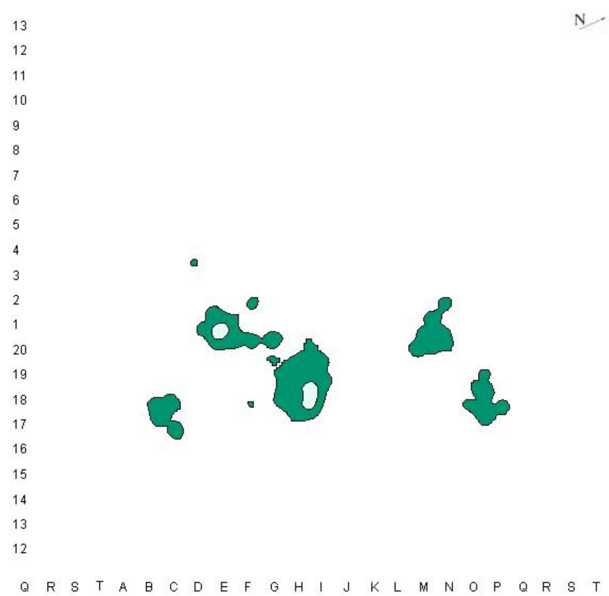

Figure 12. Contours of kernel density estimates for all rock in level II.1.

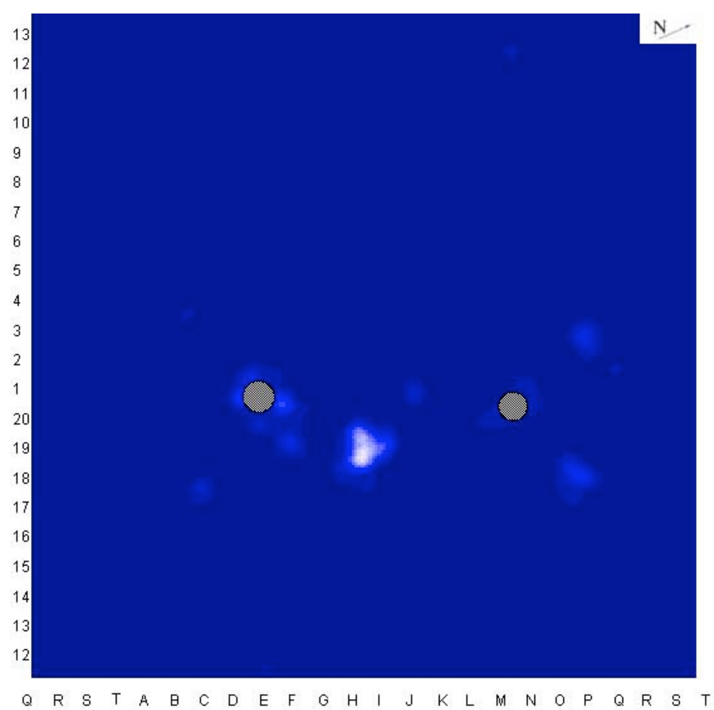

Figure 13. Kernel density map of all flint in level II.1.

The kernel density map of flint (figure13) is very similar to maps of all artifacts and rock since it is less widely distributed than bone and the densities in the main clusters are much higher than in other areas. The kernel contour map (figure 14) again displays the main clusters which are similar in shape to contours of all artifacts since flint is by far the most numerous artifact.

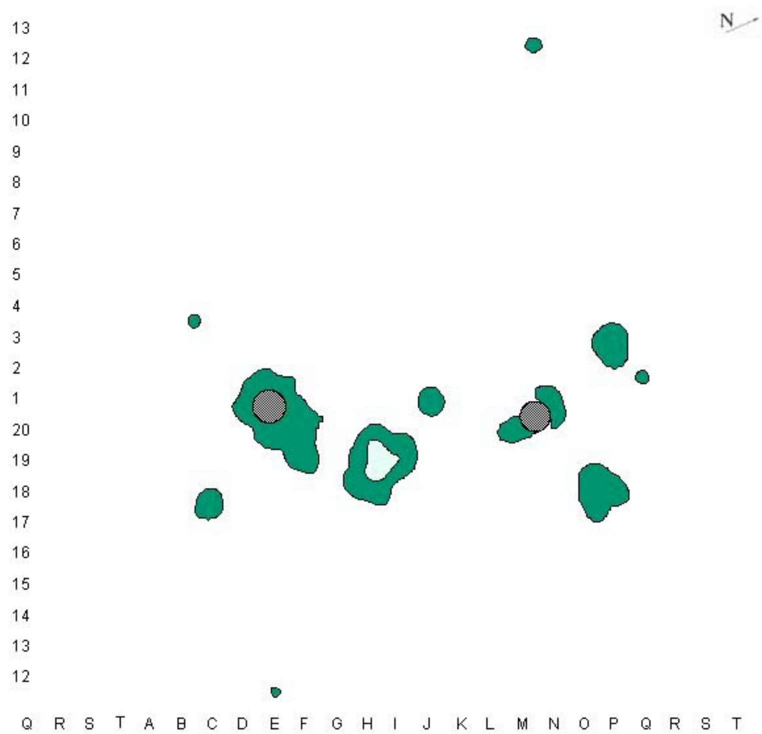

Figure 14. Contours of kernel density estimates for all flint in level II.1.

The advantage of using kernel density estimates over other techniques is demonstrated in the results obtained in this analysis. The shape of the clusters identified through this method more accurately displays the actual shape of the clusters which are displayed as simple circles in K-means cluster analysis. The level of resolution that can be obtained is probably the greatest advantage of this technique. This is best demonstrated by the highly localized maps of the area around the south hearth, which show very clear clusters as well as the variation in densities within the clusters.

The final step of the analysis within GIS involved the creation of kernel density maps for each of tool types. Only the most significant tool types are displayed. These distributions are primarily useful in determining activity area and discard patterns. Although the same technique of kernel density estimates is used, the data used to obtain these results varies significantly in that the number of tools is considerably less than the number of artifacts within the classes displayed in the above results. In consequence the results of the kernel density estimates for the tools types vary significantly from the kernel density estimates for the material classes. Firstly, the bandwidth used to obtain these results needed to be much higher since there were far fewer data points. Secondly, the delimitation of the clusters identified in these results are less clearly defined. Finally and related to this last point, there is much less variation within the clusters displayed in these results.

Burins are one of the most important tools types since they are one of the most numerous tools found at the site and were used in one of the primary activities performed at the site. The kernel density map of the burins (Figure 15) displays the concentration of this tool type in a few locations. The importance of this distribution will be discussed in the following section. The burin spalls, or chutes de burin as they are called in French, are the byproducts of burin manufacture. It is not surprising then that the distribution of burin spalls (Figure 16) is similar to that of the burins. The relationship between these distributions will be discussed further in the nest section.

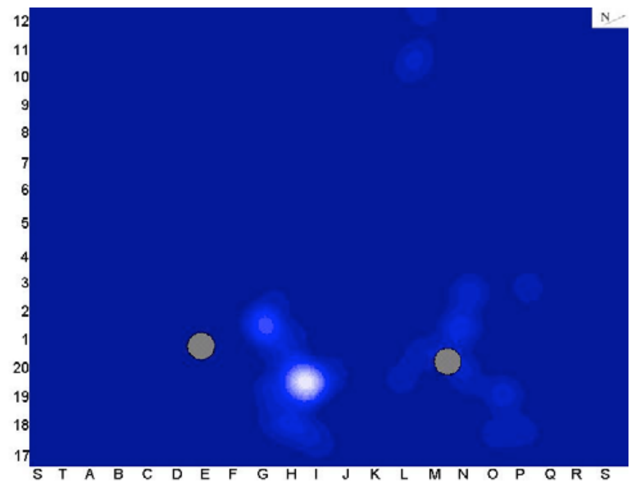

Figure 15. Kernel density map of burins.

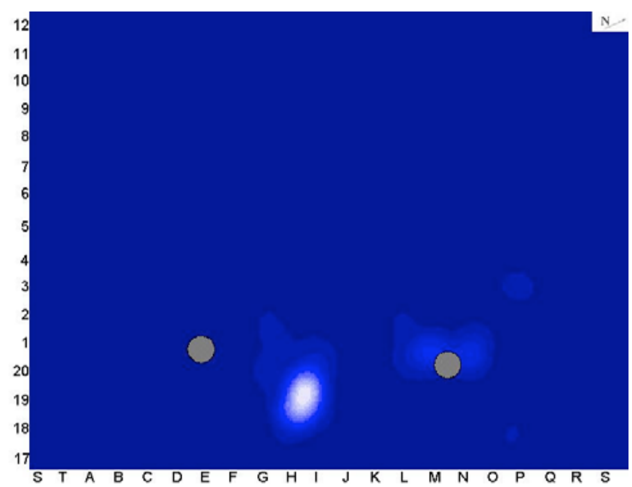

Figure 16. Kernel density map of chutes de burins.

Just as the burin distribution does, the distribution of typical scrapers (Figure 17), or grattoirs typique, and backed bladelets (Figure 18), or lamelles a dos, gives us information about a specific activity as well as discard practices.

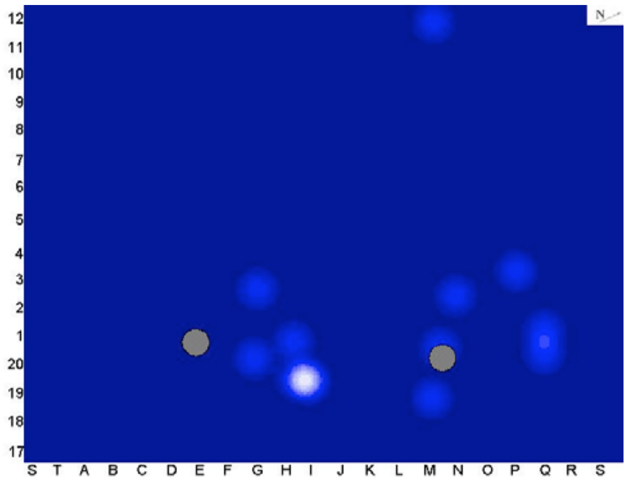

Figure 17. Kernel density map of grattoirs typique.

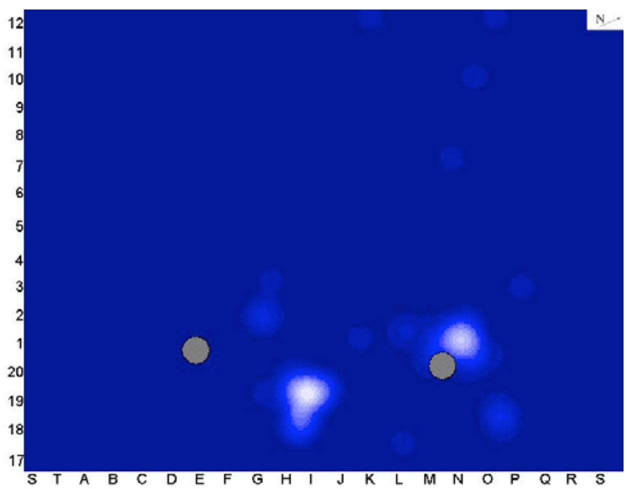

Figure 18. Kernel density map of lamelles a dos.

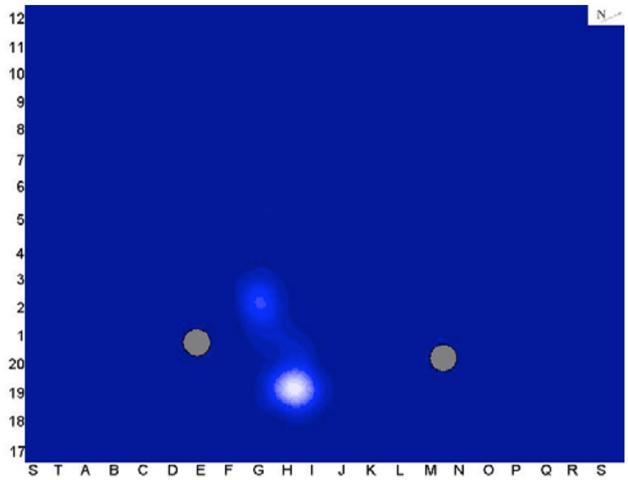

Figure 19. Kernel density map of lames.

The distributions of blank blades (Figure 19), or lames, and cores (Figure 20), or nucleuses primarily give us information about lithic manufacture and discard. Blades may also give information about other activities based on the use-wear discovered on them. This will be further discussed in the next section.

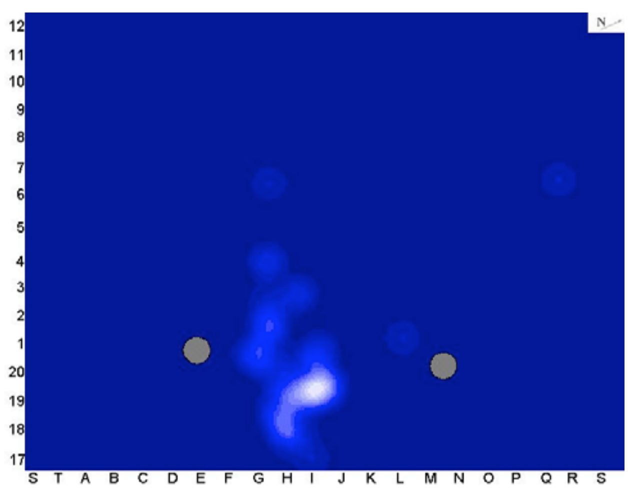

Figure 20. Kernel density maps of nucleuses.

Micropercoires, points de bec/percoirs, and bec/percoirs are all related in the activities in which they were used to perform, but the distributions of each (Figures 21,22, and 23) vary significantly. The distributions of these tool types give use the best information about the operational sequence of activities performed at the site and the discard practices related to manufacture activities.

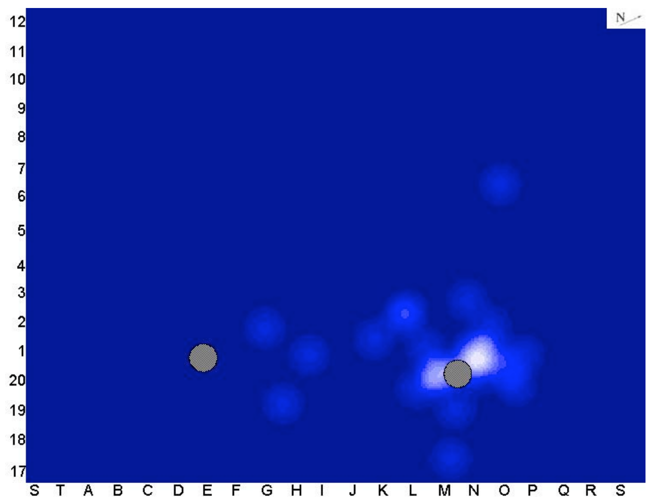

Figure 21. Kernel density map of micropercoirs.

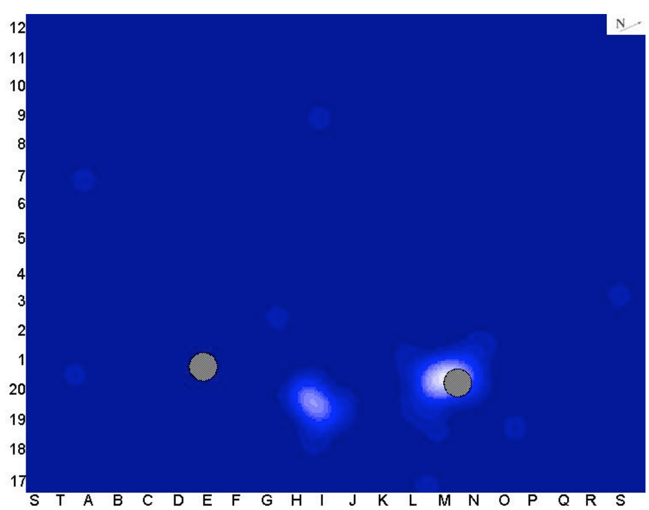

Figure 22. Kernel density map of point de bec/percoirs.

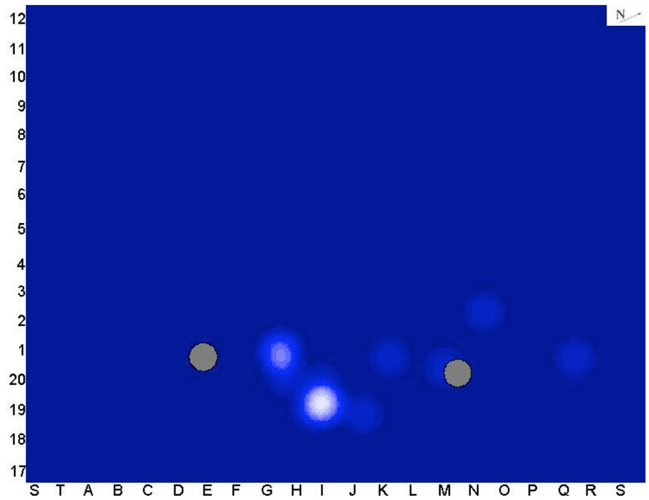

Figure 23. Kernel density map of bec/percoirs.

Interpretation and Discussion

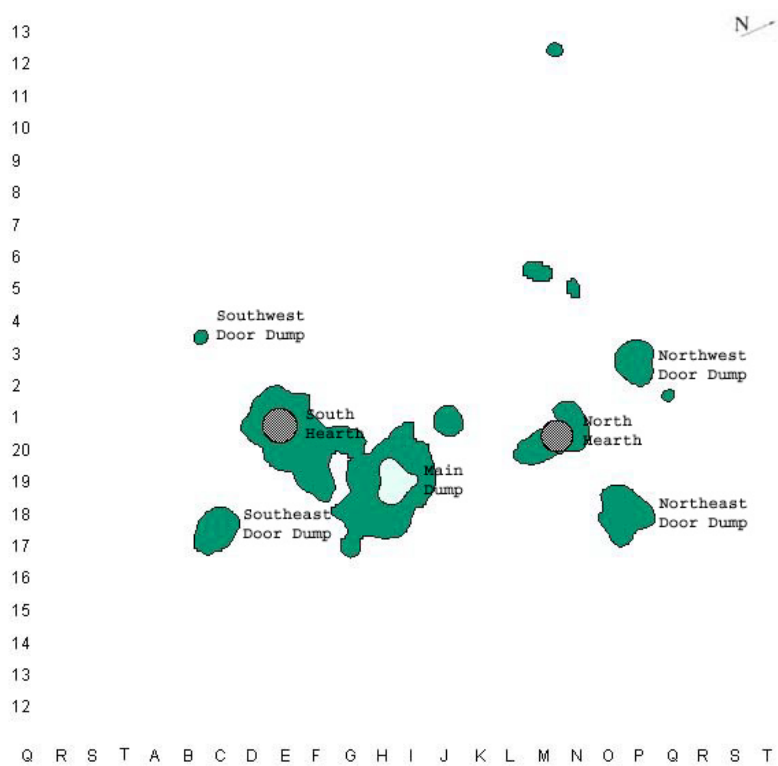

Figure 24. Kernel density contour map of all artifacts with main clusters labeled.

The interpretation of the results from the spatial analysis within GIS build on previous interpretations of the site structure of the site that come from both Paleolithic and ethnographic Hunter-gatherer site models. Figure 24 displays the division of level II.1 that will be used to structure the discussion and interpretation of Verberie's occupation surface in relation to various site models. As I said before, the previous interpretation of Verberie has been influenced by both Leroi Gourhan's site model of Pincevent and Binford's observations among the Nuniamut. The resulting model interprets the empty areas that are slightly removed from the hearths as tent locations. Other largely empty locations that are more removed from the hearths and which contain specific faunal materials[3], are interpreted as areas of butchery. The drop zones around the hearths and the dumps, including the main dump and the dumps that are thought to have been on either side of the tent doors, are also identified in the previous interpretation of this occupation level. Figure 24 has been labeled with what I named the north and south hearths, the main dump, and the northeast, northwest, southeast, and southwest door dumps. The area of butchery, designated in the current of model of Verberie, is located just northwest of the main dump. The tents that are hypothesized to have been used by the occupants of the site are thought to have been located in the empty areas to the south of the south hearth and to the north of the north hearth.

The results of the kernel density estimates and the unconstrained clustering show where and how strongly each of the material and tool types cluster. The relationship

[3] These faunal materials have been shown ethnographically to be associated with butchering activities. They include vertebrae and phalanges.

among the densities of the various material classes can also be determined. From these results the behavioral causes of the distributions can be inferred.

Basic observations

The density map for all of the data shows strong clustering around the south hearth and main dump and weaker clustering in the southeast door dump, in the two north door dumps, and around the north hearth. Rock is concentrated on the hearths, main dump and two east door dumps. From this density map we inferred the locations of the two hearths, which are represented as grey circles in all other maps. These correspond with the actual location of the hearths based upon independent criteria. Bone is widely dispersed (more than rock or flint) but clustered mainly in the main dump, in the southeast door dump and to a lesser degree in the north door dumps. There is also a cluster to the west of the north hearth and to the north of the south hearth. Bone is clustered to a lesser degree around the hearths. Flint is mainly clustered around the south hearth and in the main dump. It is clustered to a lesser degree in the southeast door dump, in the two north door dumps and around the north hearth.

The density maps of just the area around the south hearth reflect what is shown in the larger kernel density maps they also display high-resolution of the clustering. Flint is clustered around the hearth and to a lesser degree in the east door dump. Bone is clustered around the hearth, in the east door dump, to the north of the hearth, and in the area near where the main dump would be (to the east of the hearth). Esquille flint is clustered in the same way as flint. However, there is an additional cluster to the north adjacent to the hearth that does not cluster in the door dump. Esquille bone is clustered in a similar way to bone except it is clustered more to the north of the hearth and less in the area near the main dump to the east. The unconstrained clustering results for this area around the hearth give more information about the composition of the clusters displayed in the density maps. Clusters dominated by flint, clusters 8, 9, and 10, concentrate around hearth and are also present to the south. Clusters dominated by bone, clusters 1-5, are found on the peripheries mainly to the north and east of the hearth. Clusters with similar percentages of bone and flint, cluster 6 and 7, are found mainly to west and south of the hearth.

The kernel density maps of the tools display the locational clusters that can be compared to the distributions of the material types. Nucleuses are clustered in the main dump and to the north of the south hearth. Bec/percoirs are clustered in the main dump and to a lesser degree around the north hearth. Burins are clustered in the main dump and around the north hearth. Typical scrapers are clustered in the main dump and around the north hearth. Lamelles a dos are clustered in the main dump and around the north hearth. Lames are clustered in the main dump and to the north of the south hearth. Micro-percoirs cluster around the north hearth. Pointes de bec/percoir cluster around the north hearth and in the main dump. Burin spalls appear to cluster in the main dump and around the north hearth.

Comparisons of the various results

When comparing the material type distributions we see that bone is much more widely dispersed than either rock or flint, clustering wherever flint and rock cluster as well as in locations where neither clusters. Bone has the most complicated pattern of distribution. It clusters not only around the hearth and dumps but also in unique areas of the surface. This is seen in the maps of the entire surface as well as in the higher resolution maps of the area around the south hearth.

The density maps show that the clusters of flint are much smaller than those of bone and restricted mainly to the dumps and around the hearths, but the unconstrained clustering shows that at least in the cluster around the south hearth flint is the most numerous material type. Rock seems to follow the clustering pattern of flint, appearing mainly in the hearth and dump locations but in none of these locations is it more numerous than flint or bone. While all the materials cluster around the hearths and in the dumps there is significant differences in the densities between the material types within these areas.

Comparing the distribution of the tools with the distributions of the material types we see that the tools cluster, as do the materials, in the main dump. Many of the tool types also appear to cluster around the north hearth. The only ones that don't are the nucleuses and lames, which unlike the other tools, cluster closer to the south hearth. None of the tool types only show up at one place. They all appear in the main dump but they are also located in areas unassociated with any dumps. The strong presence of tools in the main dump is not surprising since every material type appears there in high densities. However it is interesting that many of the tool types are strongly clustered around the north hearth where there are relatively low densities of material types.

Activity specific inferences

We can infer the location of flint knapping activities from the distribution of flint that is not associated with the dumping areas and from the location of nucleuses and lames. The highest concentration of flint outside of the dumps is around the south hearth so we can infer that this was a flint knapping activity area. Individual clusters of flint around the south hearth can be identified as separate locations of flint-knapping. It may be that there was also a flint knapping area north of the south hearth, as indicated by the nucleuses and lames located there, but the concentrations there may also simply be the result of discard practices.

From the bone distributions outside of the dumps we can infer the locations of butchering, consumption, and bone-working activities. The distribution of bone around the south hearth is probably the result of consumption and possibly bone-working activities while the clusters north of the south hearth and west of the north hearth are probably the result of butchering activities that took place in the empty area between them. The distribution of bone around the north hearth is correlated primarily with clusters of tools such as burins and percoirs. Thus, it can be inferred that bone-working activities were performed around this hearth.

The interpretation of the tool distributions is a bit more complicated than the interpretation of simple artifact type distributions since it must take into account the process of manufacture, use and discard. The distribution of the tool types should give information about all three of these, but primarily discard since it was the last step of the process. First, the distributions of cores and blades will be most informative about manufacture and discard practices. Blades taken from the cores were retouched to make various tool types, after which the cores and unused blades were probably discarded. For this reason cores and blades are primarily concentrated in the main dump and areas nearby. There may have been manufacture activity in the main dump and the area to the north, this is probably the case since the main dump could also act as a catchment area for unused lithic material that would be readily available to the inhabitants of the site throughout most of the occupation, that is after refuse began accumulating in the area. It is known from use-wear studies that unretouched blades were also used in the activity of cutting meat. Some of these blades were found in the area that they were most likely used for this activity, in the area above the main dump, which has previously been identified as a butchering area based on the distribution of certain types of bones there.

The distribution of more specialized tools such as burins inform primarily about manufacture activities in addition to discard practices. The burin spalls identify the locations of manufacture of the burins themselves since the process of making the burins involved the removing of burin spalls from one edge of a blade. Burin spalls are concentrated around the north area, presumably the area where burins were manufactured, and in the main dump, another area where burins may have been manufactured or the area where refuse from the manufacture of burins was deposited. The burins themselves are also concentrated around the north hearth but across a wider area. This is most likely the area where the burins were used in bone working activities. This is supported by the presence of bone refuse in the same area. The other concentration of burins is in the main dump, where most of the burins were probably discarded after use. Backed bladelets and typical scrapers are also concentrated around the north hearth and in the main dump. As with the burins, these are probably the areas of manufacture/use and discard respectively. These tools were of course used in different activities than the burins though. Scrapers were primarily used to process hides while backed bladelets were hafted onto darts that were used in hunting with spear throwers.

Percoirs and micropercoirs were used in the same bone-working activity as burins but they each have unique distributions. The percoir points are produced from the manufacture of percoirs as the burin spalls come from the manufacture of burins. The distribution of the points is similar to the spalls, concentrating around the north hearth, where the percoirs were most likely manufactured, and in the main dump. The reason that the points and spalls concentrate so heavily around the north hearth is because they are relatively small and less likely to be affected by clean-up activities than the larger artifacts, such as burins and percoirs. The distribution of the percoirs is very different however, concentrating almost exclusively in the main dump and only minimally around the north hearth. Since it can be inferred that the percoirs were used in the bone-working activities that occurred around the north hearth, it must be assumed that nearly all of them were discarded after use, into the main dump. The distribution of micropercoirs is completely opposite to that of percoirs. Micropercoirs concentrate almost exclusively around the north hearth and only minimally in the main dump. Since micropercoirs were probably used in finer bone-working that represented the final part of the bone-working process it can be assumed that most of them were left in place after use since to area was no longer going to be used for bone-working or any other activities.

The location of the structures can be inferred from the locations of dumps associated with the two hearths and the empty areas next to them. We can infer that there was one structure south of and facing the south hearth and one structure north of and facing the north hearth. The areas where the tents were located would have been clean, with refuse being distributed on either side of the doors. The refuse that accumulated in these door dumps most likely came from hearth activities, such as consumption and the manufacture of flint and bone objects, or from activities within the tents themselves if any refuse producing activities occurred within them.

Interpretation of site structure

The initial interpretation of Verberie's site structure, that of tent areas near hearths surrounded by activity areas and separate from additional activity areas (i.e. butchering areas), is confirmed by the results of this analysis. This initial interpretation of course came from the ethnographic observations of Binford and the site model developed by Leroi-Gourhan of the site of Pincevent. The tent area and hearth activity area model based on the model of Pincevent is clearly represented in the results of this analysis by the door dump clusters adjacent to largely empty areas near material concentrations around the hearths, which are displayed in the density maps of various material types. The specialized activity area model based on the ethnographic observations of Binford is also clearly represented in the results of this analysis. The density map of bone specifically clearly displays a large empty area surrounded by bone concentrations to the west of the north hearth that corresponds to a specialized butchering area[4].

It is now possible with the results of this analysis to apply another site model to this occupational level of Verberie. Like Binford's model, the hunter-gather site model developed by John Yellen was based on ethnographic observations (Yellen, 1977). Though the observations were of a very different ethnographic group, that of the !Kung bushmen in Africa. Yellen's model divides a site into separate but similar domestic areas, a community area, and specialized activity areas. The individual domestic areas of a site

[4] Tools used in butchery found within this area also support the designation of this space as a specialized butchering area.

are occupied by separate domestic groups equaling a either a nuclear family or another type of minimal group[5]. According to Yellen's model individual domestic areas and specialized activity areas within a site are utilized exclusively by a single domestic unit while the community area can be used by all domestic units within the site.

It is possible to recognize these various types of activity areas at Verberie using the results of this analysis. Two separate but similar domestic areas can be distinguished in the density maps of the material types. They appear in fact to be mirror images of each other when viewing the kernel density estimate maps of flint, rock and all the materials combined. Included in these individual domestic areas is a hearth, an activity area surrounding the hearth, an empty area corresponding to a tent location, and two door dumps adjacent to the empty area. The community area, while described as another empty space in Yellen's model, can be identified by the main dump area between the two domestic areas at Verberie. The community area this site is the location where refuse from both domestic areas accumulated[6]. There is only one specialized activity area at the site and that is the butchering area already discussed above. This is a relatively large area that may have been split between the two domestic groups, as fitting with Yellen's model of exclusive utilization of specialized activity areas. The lack of distinction of two specialized activity areas for two domestic groups does not hamper the application of Yellen's model to this site since it is possible for two specialized activity areas to exist adjacent to each other during the occupation of the site while not showing up in the archaeological record distinguishable individual areas, simply because the nature of

[5] Other examples can be a group of unmarried men or a group of widowed women.
[6] This is supported by the refitting of artifacts between the individual domestic areas and the main dump area. The exclusive utilization of these domestic areas is also supported by the lack of artifact refits between the two domestic areas.

specialized butchery activity that produced large empty space rather than a clear delimitation of material distribution. Yellen's model of site structure can therefore be applied effectively to this site in accord with site models that have previously been applied to the site.

Further discussion

The interpretation of this site is not as simple as the mere application of the above models since other consideration need to be taken into account. The duration of occupation for one may also be interpreted by looking at the differences between subsite areas. If different subsite areas are found to be similar in both composition and density than they are more likely to have been the remains of individual occupations (Sullivan III, 1992). Specifically, duration of occupation can be interpreted by looking at the relationships between micro and macro-refuse (Simms and Heath, 1990). One thing that needs to be taken into account when considering this however is that the site may have been occupied by more than one individual group or nuclear family at the same time, thereby producing similar subsite areas that are contemporaneous. Yellen's model of distinct domestic groups may still be applied to this site once this is taken into account, but it is also important to recognize that the similar subsite areas that appear at the site of Verberie may be the result of individual, non-contemporaneous occupations. The successive stages of a single occupation may also account for the variability in subsite areas. The kinds and intensity of activities vary between the successive stages of an occupation and this can strongly affect the spatial distribution of artifacts at a site (Stevenson, 1985). Taking this into account, it is important to recognize that while still being a result of a single occupation, the individual subsite areas may have been occupied by a single domestic groups, only at different stages of the occupation.

Larger issues of social and economic organization may also be interpreted from the spatial distribution of activity areas at certain types of habitation sites (Hayden, 1997). Verberie may be identified as specific type of site based on its size, spatial structure, and also the types and styles of artifacts found at it (Conkey, 1980). Weather Verberie is a type of site that will allow this type of interpretation will depend on further investigation and comparison with other sites, both Paleolithic and ethnographic. If Verberie is found to represent a household than issues such as household practice and domestic relations may be pursued. These may include craft specialization, gender division and other social conditions (Hendon, 1996). While it is not possible to make accurate conclusions about these larger issues with the results currently available, it is very likely the further analysis, spatial as well use-wear and refitting, will allow for more diverse interpretations from the site of Verberie.

REFERENCES

Audouze, Françoise. 1988. Des modèles et des faits: les modèles de A. Leroi-Gourhan et de L. Binford confrontés aux résultats récents. *BSPF* 84 :343-352.

Audouze, Françoise. 1994. Verberie. in *Environnements et habitats magdaléniens dans le centre du Bassin parisien*. Taborin, Y. ed. MSH: Paris. 167-172.

Audouze, Françoise, and J.G. Enloe. 1997. High resolution at Verberie: Limits and interpretations. *World Archaeology* 29(2): 195-207.

Bailey, T.C. 1994. A Review of Statistical Spatial Analysis in Geographic Information Systems. In *Spatial Analysis and GIS*. edited by S. Fotheringham and P. Rogerson 11-44. London: Taylor & Francis.

Baxter, M.J., Beardah, C.C., and R.V.S Wright 1997. Some Archaeological Applications of Kernel Density Estimates. *Journal of Archaeological Science* 24:347-354.

Conkey, Margaret W. 1980. The Identification of Prehistoric Hunter-Gatherer Aggregation Sites: The Case of Altamira. *Current Anthropology* 11(5):609-630.

Enloe, James G. 2002. *Food Sharing Past and Present: Archaeological Evidence for Economic and Social Interactions*. Paper presented at Symposium "Patterns of Food Consumption, Health and demography among Hunters Past and Present-the Last 10,000 Years" at the 9th International Conference on Hunting and Gathering Socities. September 9-13, 2002, Edinburgh, Scotland.

Gamble, Clive. 1986. *The Paleolithic Settlement of Europe*. Cambridge: Cambridge University Press.

Hayden, Brian 1997. Observations on the Prehistoric Social and Economic Structure of the North American Plateau. *World Archaeology* 29(2): 242-261.

Hendon, Julia A. 1996. Archaeological Approaches to the Organization of Domestic Labor: Household Practice and Domestic Relations. *Annual Review of Anthropology* 25: 45-61.

Kelley, Lawrence H. 1991. Tool Use and Spatial Patterning: Complications and Solution. In *The Interpretation of Archaeological Spatial Patterning*, edited by Ellen M. Kroll and T. Douglas Price. 257-268. New York: Plenum.

Koetje, Todd A. 1991. Simulated Archaeological Levels and the Analysis of Le Flageolet II, the Dordogne, France. *Journal of Field Archaeology* 18(2). 187-198

Simms, Steven R., and Kathleen M. Heath. 1990. Site Structure of the Orbit Inn: An Application of Ethnoarchaeology. *American Antiquity* 55(4): 797-813.

Stevenson, Marc G. 1985. The Formation of Artifact Assemblages at Workshop/Habitation Sites: Models from Peace Point in Northern Alberta. *American Antiquity* 50(1): 63-81.

Sullivan III, Alan P. 1992. Investigating the Archaeological Consequences of Short-Duration Occupations. *American Antiquity* 57(1): 99-115.

Symens, Nicole. 1986. A Functional Analysis of Selected Stone Artifacts from the Magdalenian Site at Verberie, France. *Journal of Field Archaeology* 13: 213-222.

Yellen, John E. 1977. Archaeological Approaches to the Present: Models for Reconstructing the Past. New York: Academic Press.

Whallon, Robert. 1984. Unconstrained Cluster Analysis. In *Intrasite Spatial Analysis in Archaeology*. edited by H. Hietala. 112-123. Cambridge: Cambridge University Press.

Wheatly, David, and Mark Gillings. 2002. *Spatial Technology and Archaeology: The Archaeological Application of GIS*. New York: Taylor & Francis.