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Rethinking Intrasite Spatial Analysis

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The spatial patterning of artifacts and features within archaeological sites is one of the primary forms of archaeological data. Because the sites that archaeologists locate and excavate are often places where people stayed for some time, intrasite spatial patterning frequently documents patterns in living spaces. For this reason, studies of site structure can provide information about how occupants organized and maintained their domestic spaces, and, in turn, how social units may have been organized. Other pieces of information potentially accessible to the archaeologist through intrasite spatial analysis include group size, the length and number of occupations, and the type and spatial configuration of activities performed on site (Fisher and Strickland 1991).

The organization of space is something that is an inherent part of life in modern societies, and mobile groups are no different (Gorecki 1991; Graham 1994; O'Connell 1987; Yellen 1977a). However, mobile peoples have different constraints on their spatial organization than do people living in a sedentary, built society. Hunter-gatherer and pastoralist camps or task-specific sites are often ephemeral, but living spaces can still be highly structured. The extent to which space is structured, and the structured form it takes, varies by site. Variation in site structure can be explained by a host of factors: environmental, social, or temporal. We do not have a good idea of how this variation was manifested in the past, however, because this type of research has long been stymied by problems relating to method, theory, and an understanding of what kind of information is accessible.

An interest in site structure and spatial patterning began in the 1970s and 1980s with the advent of New Archaeology. New Archaeology marked a shift from a focus on chronology and typology to one on reconstructing ancient behavior. Technological advances, such as radiocarbon dating, allowed archaeologists to turn their attention away from the minutiae of tracking archaeological "cultures" in time and space and toward large-scale questions regarding human behavior. Spurred by the promise of deciphering behavior within archaeological sites, many archaeologists began studying how modern groups organized their living spaces and how this might be translated to the archaeological record. These ethnoarchaeological studies generated a large corpus of information regarding the living spaces of extant hunter-gatherers. Much of this information was descriptive. Ethnoarchaeologists described the behaviors they observed—and the spatial patterning generated from such behavior. Often, the reports warned of behaviors that led to spatial patterns that could easily be misinterpreted (so-called "cautionary tales" [O'Connell 1995]). Most of the reports contained maps in which space was neatly demarcated (Binford 1978a; Kent 1984; O'Connell 1987; Yellen 1977a). These maps, and the information about behavior that they contained, inspired archaeologists to try to find similar spatial patterning within the archaeological record.

Although much of the ethnoarchaeological work was descriptive and did not propose general models for human behavior, many of the observations noted by ethnographers were repeated in several studies. For example, Spurling and Hayden (1984) noted that among Pintupi-speaking groups in the Australian Western Desert, disposal of debris was structured by shade and the comfort of those sitting or lying down. This meant that lithic knapping was conducted away from the sitting and sleeping areas, and larger objects were thrown many meters away. These observations were repeated in numerous additional studies (e.g., Bartram et al. 1991; Fisher and Strickland 1991; Yellen 1977a). Kent and Vierich (1989) found that the length of time the Basarwa and Bakgalagadi people of Botswana stayed at a site was an important factor in how much investment was placed into the structuring of space. More importantly, it was not only the length of time but the *anticipated* length of time that was a factor (Kent 1991a). This observation could confound the interpretation of archaeological sites. O'Connell (1987) described Alyawara site structure as being conditioned by several factors, including food storage, the season of occupation, household size, and the duration of time activity areas were utilized. He also cautioned that meaningful site structure is only apparent at very large scales (at least 300–400 m^2 and sometimes more than 1,000 m^2) and that this is a very serious problem for archaeologists who generally excavate significantly smaller areas.

A few ethnoarchaeological practitioners built on observations collected in the field and created models to help archaeologists interpret spatial patterning. Based on ethnographic work with the !Kung, hunter-gatherers living in the Kalahari Desert, Yellen (1977a) created the "ring model," which uses the area of a number of spatial units to predict group size and length of occupation. The !Kung organized their camps in a circle, with household units located around the circumference of the circle and a communal space in the middle. Yellen found that the size of this circle was a good predictor of group size. Many activities occur next to the individual households or within the communal space in the center. However, other activities occur outside the ring of households, such as pit roasting or skin drying. Shady areas next to trees or shrubs will also draw activities outside of the inner circle. This region, which Yellen terms the "outer ring," can be used to predict length of occupation. The longer the group stays at a site, the more this area is utilized. Based on these observations, Yellen created equations that archaeologists could potentially use to predict group size and occupation duration if they are able to collect amenable spatial data.

Like Yellen, Binford (1978a, 1983) used ethnographic observations to forward a model of spatial use. Binford argued that much of the spatial organization exhibited within sites is linked to the mechanical positioning of human bodies. At a Nunamiut hunting stand, Binford noted that small items were dropped at the feet of those sitting around the fire, while larger items were thrown over their shoulder. He proposed the "toss and drop" model, which maps the position of people seated around a hearth and locations where items might be discarded. Toss zones would only occur around outdoor hearths, however, because people would not likely toss rubbish over their shoulders within their homes.

These ethnographic studies inspired a slew of attempts to find similar patterns in the archaeological record. Binford's toss and drop model formed the basis for Stapert's (1989, 1990) "ring and sector" method, which divided space around a hearth into rings and then sectors, like spokes on a wheel. The densities of artifacts in each ring were compared to identified toss and drop zones and seating positions. In addition, if the density of artifacts was unevenly distributed throughout the sectors, one could potentially identify the direction of the prevailing wind because people, and their associated debris, would be located away from the fire smoke. Stapert (1989) applied his method to a series of open-air Upper Paleolithic sites from Northern Europe, all with hearth-focused assemblages. The most famous of these was Pincevent, which was hypothesized by Leroi-Gorhan to contain numerous habitation structures. Based on his ring and sector method, Stapert determined that the hearths at Pincevent were exterior and not located within a structure as Leroi-Gorhan had theorized. He also noted that the distribution of artifacts around the hearths was oriented to avoid the smoke blown by prevailing westerly winds.

Stapert's ring and sector method was focused on hearth-centered activities. Other intrasite spatial techniques attempted to distinguish other types of activity areas. In many cases, practitioners strove to develop techniques that were more quantitative and therefore—in their view—more objective and replicable. Robert Whallon (1973a, 1973b, 1974, 1984) used a series of quantitative methods, such as dimensional analysis, nearest neighbor analysis, and unconstrained cluster analysis, to explore how best to objectively analyze how objects were distributed in space. After first ensuring that the distribution of objects was nonrandom, these methods indicated which artifacts were correlated with one another in space.

Another popular method was k-means analysis. K-means attempts to minimize the sum squared error (SSE) (Kintigh and Ammerman 1982). Each point is assigned to a cluster with a centroid. The distance between the point and the centroid is calculated for each point assigned to that cluster, and the squared distances of each point is the SSE. This process is iterative: first, all points are assigned to a single cluster, and then two clusters, and so forth until the maximum (assigned by the analyst) is reached. The analyst then plots the SSE against the number of clusters and tries to identify breaks or "knees" that indicate the most likely number of clusters (Grimm and Koetje 1992). Clusters identified through k-means tend to be circular in shape because it is based on measurement to a centroid.

K-means analysis has had variable success. Gregg and colleagues (1991) tested k-means by applying it to a map of a !Kung campsite published by Yellen (1977a). They found that k-means did a good job of breaking the campsite into groupings that matched the household activity zones that Yellen described. Most clusters corresponded to household units. One cluster combined two households, but these two families shared a significant proportion of their resources. Therefore, the technique could be viewed as successful for an ethnographic campsite without the numerous sources of noise inherent within the archaeological record.

In an archaeological context, Rigaud and Simek (1991) used k-means to identify potential activity areas at the Mousterian site of Grotte XV in the Dordogne region of France. The site was divided into clusters via k-means, but the contents of the clusters were repetitive, and meaningful information about behavior proved elusive. K-means is an effective way to demarcate space, but what these clusters mean behaviorally is a separate problem. In the example from Gregg and colleagues, k-means demarcated household units, so it was essentially repetitive artifact clusters that were spatially segregated. At Grotte XV, the contents of the clusters were similarly repetitive, but Rigaud and Simek had hoped to find each cluster representing a different activity. Household units were not a feasible explanation for the spatial patterning at Grotte XV because of the small spatial scale of the site.

Ethnographic studies demonstrated that the effort to identify separate clusters corresponding to individual activities was misdirected (Binford 1983; O'Connell 1987). Different activities are not necessarily spatially segregated; in fact, they almost always overlap. A similar problematic assumption at the base of many early spatial analysis studies is that objects found within close proximity to one another were used together. This assumption is at the heart of Whallon's methods. For example, he used the dimensional analysis of variance to study the covariation of lithics and bones at a preceramic site in Oaxaca, Mexico (1973a). Lithics that covaried with faunal remains were thought to have been utilized in the butchering of those animals. Galanidou (1997a, 1997b) used another method

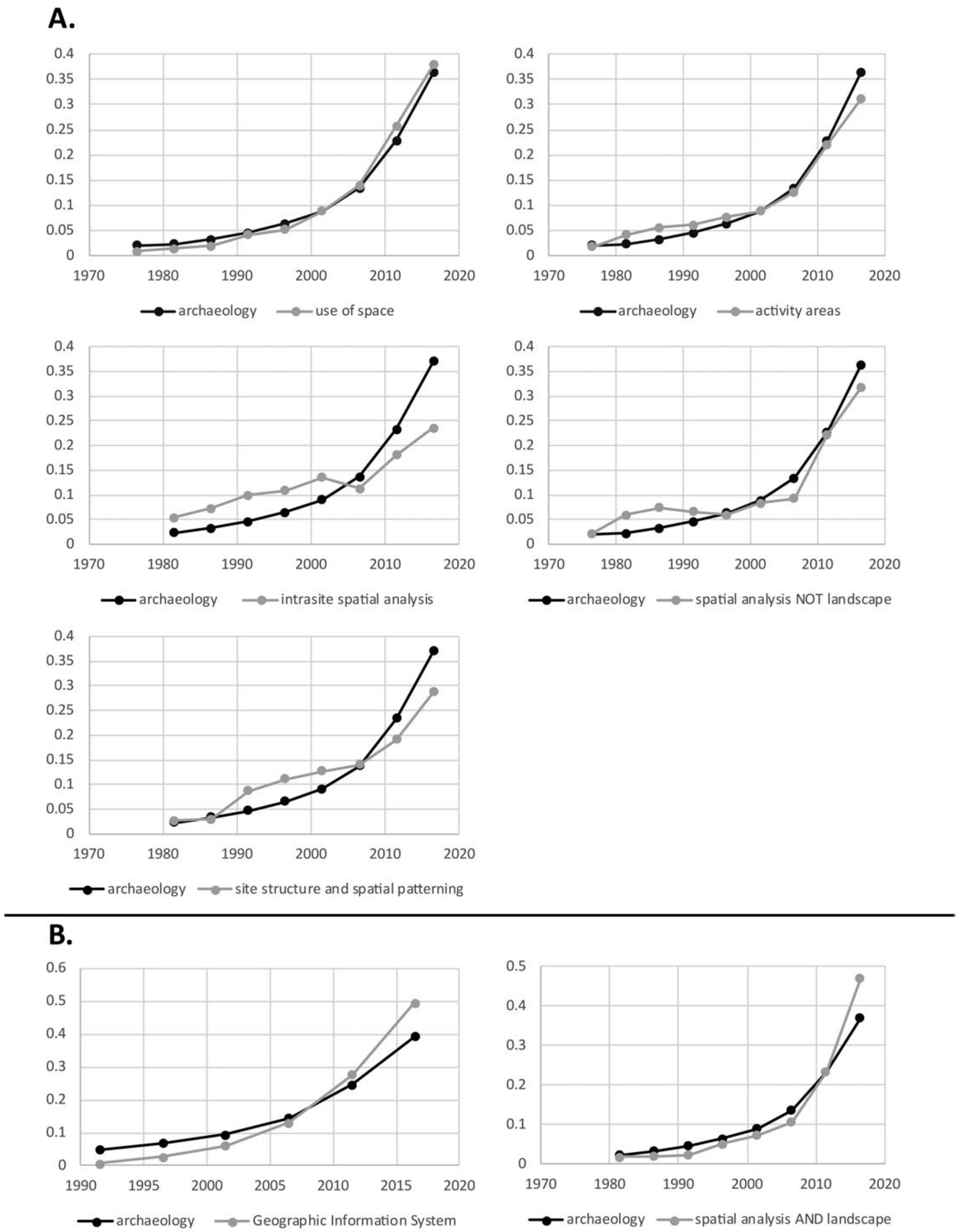

FIGURE 1.1. The proportion of publications by year for the field of archaeology as a whole compared with various keywords, those associated with intrasite spatial analysis (*A*), and those associated with GIS or landscape-based spatial analysis (*B*). All patterns were found to be significantly different from the field as a whole according to a chi-squared test ($p < .05$).

developed by Whallon called the unconstrained cluster analysis to study the spatial structure at two Upper Paleolithic rockshelter sites in Greece. At the site of Klithi, Galanidou found that backed bladelets, burnt debris, and hearths were strongly associated with one another. This could suggest that retooling of composite pieces took place around the fire. In this case, unconstrained cluster analysis did successfully identify an activity area. Hearth-side activity areas are often the most robust spatial patterning at a site, and studying the adjacent materials can prove fruitful.

The methods proposed in the early days of intrasite spatial analysis have had variable success. While the numerous ethnographic studies were inspirational, the archaeological record was frequently resistant to interpretation. In some cases, meaningful behavioral patterns were established, but more often, the assumptions on which the methods were built proved to be problematic. I discuss critiques of many of these assumptions later, but first I will present data about how interest in this research topic has changed over time.

Patterns through Time

In order to understand how interest in intrasite spatial analysis has changed, I tracked the number of publications with keywords linked to site spatial patterning over the past few decades. In this effort, I used a website called Dimensions (https://www.dimensions.ai/). This website searches for publications (journal articles and book chapters) with a specified keyword(s) or phrase. It also enables a researcher to specify the field of research, in this case "archaeology," to help filter unrelated publications. It then tallies the numbers by year. Because the field has been growing rapidly for the last 40 years, the number of publications for each keyword increased over time. In order to control for this growth, I aggregated the years into five-year increments and then calculated the percentage of the total represented by each interval. I did the same for the total number of archaeology papers published in that time frame. I plotted these two sets of percentages against one another to visualize whether the proportion of intrasite spatial analysis publications matched publications in the field as a whole, whether they were over- or underrepresented, and how this changed over time. I then performed a chi-squared test to evaluate whether the patterns were significant.

I chose keywords (or phrases) based on words commonly utilized in intrasite spatial analysis publications. In these queries, I was also able to employ "AND" and "NOT," which helped me narrow down the listed publications. Most obviously, I chose the phrase "intrasite spatial analysis." I also searched for "site structure AND spatial patterning," "spatial analysis NOT landscape," "activity areas," and "use of space" (Figure 1.1A). In these search terms, I tried to capture only intrasite spatial analysis and not spatial analysis at the landscape scale. However, I also was interested in how the landscape-scale spatial analysis might compare with intrasite spatial analysis, especially with the advent of geographic information systems (GIS). With this goal in mind, I searched for "geographic information systems" and "spatial analysis AND landscape" (Figure 1.1B).

The results are telling. All keywords linked to intrasite spatial analysis were overrepresented compared to the field in the 1980s and 1990s, but sometime during the early 2000s (around 2005), the pattern shifted and intrasite spatial analysis publications became underrepresented. This pattern is most clearly expressed in the search terms "site structure AND spatial patterning," "intrasite spatial analysis," and "spatial analysis NOT landscape." Search terms associated with landscape scale spatial analysis more closely tracked the field as a whole, but the overall pattern was the inverse of the intrasite scale. Publications were underrepresented in the 1980s, 1990s, and early 2000s, but by 2010, when GIS use had become widespread, publications for spatial analysis at the landscape scale were overrepresented compared to the field.

This study indicates that interest in intrasite spatial analysis peaked in the 1980s and 1990s, but since then, interest has decreased considerably. Moreover, intrasite studies did not appear to gain a marked benefit from the advent of GIS, as was the case for landscape-scale studies. In the following sections, I propose an explanation for these trends. In my view, the enthusiasm for intrasite spatial analysis in the 1980s and 1990s was linked to optimism, spurred by ethnoarchaeology, surrounding the potential information about ancient human behavior that could be obtained through the study of site structure and artifact distributions. Ethnoarchaeologists saw firsthand how certain behaviors created spatial patterning in nonperishable materials that could potentially be identified in the archaeological record. Moreover, much of this patterning was replicated at a variety of sites and even observed cross-culturally. Yet the archaeological record is simply much more complicated to interpret than the ethnographic record. Patterning left at the ethnographic time scale must compete against a variety of postdepositional processes as well as the compression of many, many years of site use into a single archaeological deposit. When intrasite spatial analysis failed to advance our understanding of ancient human behavior, researchers became disenchanted and turned elsewhere.

Why the Slump? Criticisms of Intrasite Spatial Analysis

Many of the analyses published in the 1980s and 1990s sought to isolate the location of certain behaviors (i.e., where activities were performed) or to use spatial proximity to draw conclusions about how artifacts were used (Carr 1984; Rigaud and Simek 1991; Whallon 1973b). Unfortunately, the assumptions underlying many of these studies were flawed. Although ethnoarchaeology inspired many of these studies, it also demonstrated that the relationship between the location of discarded artifacts and the systemic context, as Schiffer (1972) would call it, is complex. As he emphasized (1983, 1987), the location of artifacts within the archaeological record is more about discard behavior than how or where the objects were used by the site's occupants. In other words, the spatial distribution of artifacts says a lot more about cleaning behavior and site maintenance than it does about where activities were performed at the site. Therefore, the main problem with many of these early studies was not only that they were underlain by faulty assumptions, but they were asking the wrong questions.

Before embarking on an analysis of site structure or artifact distribution, we must first understand what kind of behavior or processes this patterning is really documenting. This, of course, was one of the main critiques raised by New Archaeology and Behavioral Archaeology and was the subject of much debate (Ascher 1968; Binford 1981a; Schiffer 1985). Despite their disagreements, both Binford and Schiffer urged archaeologists to consider all processes—both anthropogenic and geologic—that lead to the formation of an archaeological deposit. But Binford, at least, was quite optimistic that if archaeologists engage these processes in their method and theory, they ultimately would be able to reconstruct past behavior. That optimism permeated early intrasite spatial analysis studies, even if many of the important points made by Schiffer and Binford were not fully internalized.

One repercussion of basing much of our method and theory on ethnoarchaeological studies was that ample consideration was given to the specific behaviors that led to artifact discard, but behaviors and geologic processes that can alter the spatial positioning of artifacts already discarded were often ignored. The ethnographic sites documented had not been subjected to hundreds or thousands of years of burial, nor were they collapsing decades (or more) of site use into one archaeological horizon. Harold Dibble and colleagues (1997) argued that too many archaeologists were approaching the spatial arrangement of artifacts at face value and were not adequately testing the effect of geologic processes. They advocated evaluating the degree to which sites were disturbed through geological processes by implementing several tests, such as the orientation of elongated lithics and bones, the degree to which artifacts exhibit breakage or abrasion, and whether all artifact sizes are represented. Through a combination of tests, one can determine the level of site disturbance and whether a study of the spatial arrangement would yield results that are behaviorally meaningful—or simply geologically meaningful.

Geological processes are not the only sources of postdepositional alteration in the spatial patterning of archaeological sites. Animals play a major role in horizontal and vertical displacement of artifacts and in obscuring features by digging into the archaeological deposits or simply using the site's land surface. Spatial patterning is also affected by human behavior after an artifact is discarded. Trampling can move artifacts both vertically and horizontally (Carrer, this volume; Gifford-Gonzalez et al. 1985; McBrearty et al. 1998). Artifacts may be picked up and used again, or children might alter the spatial patterning of objects through play (Mackie et al. 2015). The effects of these processes will increase with duration and number of occupations; the longer people are at a site, the more likely they will move items around through accidental movement, trampling, or child's play.

The spatial positioning of materials within an archaeological site is therefore a mixture of a much more complicated assortment of behaviors and processes than early studies accounted for. Furthermore, the information that early practitioners were really interested in—what activities were taking place at the site and what artifacts were used together—plays a maddeningly small role in the organization of site structure, at least once a site has been buried, or exposed, for several thousands of years. This left spatial analysis studies in a quandary. The information sought was inaccessible, and many practitioners lost interest and turned to other aspects of the archaeological record to address their questions.

Many of the starkest criticisms of intrasite spatial analysis occurred in the mid to late 1990s. Dibble and colleagues published their critique detailing a lack of investigation into alteration from geologic processes in 1997. The harshest critique of intrasite spatial analysis and its link to ethnoarchaeology was published by O'Connell in 1995. O'Connell argued that many ethnoarchaeological studies failed to contribute in a meaningful way to the interpretation of the archaeological record. By fixating too closely on variation exhibited in the ethnographic record, we were ignoring the fact that a good part of the archaeological record might not be represented in that variation. In other words, the range of behaviors exhibited by extant hunter-gatherers, living in the few isolated parts of the globe that had not been fully incorporated into globalized market economy, were not representative of hunter-gatherer groups living in the past. Pointing out cautionary tales or simply describing how these groups might be represented in the archaeological record does little to advance archaeological knowledge. O'Connell argued that if ethnoarchaeology were going to play a productive role in archaeological interpretation, it needed to incorporate a general theory of behavior. He illustrated this point by contrasting the influence ethnoarchaeology has had in site structure studies (intrasite spatial analysis) and faunal analysis. The difference between the two was that faunal studies incorporated a general theory of behavior and spatial studies did not. As a result, only faunal analysis succeeded in its ability to extract meaningful information from the archaeological record.

The general theory of behavior that O'Connell advocates, and that is employed relatively often in faunal analysis, is human behavioral ecology (HBE). This theory, O'Connell argues, provides a useful framework for archaeologists to create a series of expectations and testable hypotheses derived from Darwin's theory of natural selection. If this framework is used to assess both the ethnoarchaeological and archaeological record, then meaningful and constructive information can be extracted from the latter. This theory is arguably more amenable to the study of food procurement than site structure for the simple reason that food procurement has a direct link to fitness, whereas spatial organization's linkage is more difficult to determine. In the next section, I will discuss the challenges of using an HBE framework in attempts to study spatial organization by examining two recent papers.

These critiques of intrasite spatial analysis came at a time when many archaeologists were already becoming disenchanted with the lack of behavioral interpretations for site structure. The distribution of debris within archaeological sites was the result of many overlapping behaviors resulting from occupations that spanned days to months and were often repeatedly occupied over the course of years or decades. They were then altered by geological processes and nonhuman organisms. Furthermore, ethnographic studies did little to help the interpretation of the resulting palimpsests beyond highlighting pitfalls to avoid and some potential causes of variation to keep in mind. Testable theories proved to be elusive, and without them meaningful conclusions that advanced our understanding of human behavior were lacking. This disenchantment likely explains the decline in interest in intrasite spatial analysis, yet studies have continued. In the next section, I will discuss more recent studies and whether the critiques have been addressed.

Have We Addressed the Criticisms? The State of Intrasite Spatial Analysis Today

Although there has been a marked decrease in the number of intrasite spatial analysis publications in the past decade, when controlled for overall growth in the field, there have been advancements in our approach to site spatial patterning. I will argue here that most studies are now asking the right questions of spatial patterning, but we have yet to implement a useful theoretical framework. In other words, the principles of site formation championed by Schiffer and Behavioral Archaeology have more or less been integrated into intrasite spatial analysis. A rigorous assessment of geologic processes is now standard practice. Archaeologists understand that behaviors represented in the systemic context do not always translate to the spatial configuration of space. To that end, archaeologists have shifted their focus away from the location of formal tools and are instead mapping the distribution of artifact categories that might be more meaningful in terms of interpreting spatial patterning, such as artifact size, technological stage, and whether the artifact was burned. However, there are still many hurdles remaining for intrasite spatial analysis studies. O'Connell's call for a general theory of behavior has mostly not been realized (but see Codding et al. 2010; Surovell and O'Brien 2016). And although archaeologists have a good understanding of the multitude of processes that contribute to assemblage formation, this understanding is not always integrated explicitly within our method and theory.

This last point can be best illustrated by our continued search for "activity areas" (Almeida 2007; Hovers et al. 2011; Spagnolo et al. 2018; Speth et al. 2012; Yvorra 2003). These studies now integrate a more complex understanding of discard patterns and long-term/repetitive site use. For example, at the Allen Site, a Paleoindian site located in Nebraska, Bamforth and colleagues (2005) identified locations where trash was consistently deposited over the course of numerous occupations. Speth and colleagues (2012) also identified conspicuous discard behaviors at Kebara Cave in Israel, where bones were concentrated in discrete spatial locations within the Middle Paleolithic Layer X.

Other studies simply aspire to find differential use of space, without necessarily identifying the specific behaviors that produced the patterning. Alperson-Afil and Hovers (2005) found that there was differential spatial patterning of artifacts within the Middle Paleolithic site of Amud Cave in Israel. This led the authors to conclude that Neanderthals exhibited a "complex" use of space. Many studies focusing on spatial structure within Middle Paleolithic (or earlier) sites often comment on the "complexity" of spatial use (Alperson-Afil et al. 2009; Henry 1998; Oron and Goren-Inbar 2014; Riel-Salvatore et al. 2013). This commentary is alluring because it gets at the big questions that we all aspire to address. However, differential distribution of artifacts within a site does not necessarily indicate a complex (read "modern") use of space. Many processes can produce a nonrandom artifact distribution, and even if we determine that the distribution is anthropogenically derived, it is a low threshold for a categorization of "modernity."

I would argue that evidence for maintenance behaviors, such as cleaning, as well as evidence for repeated group-level spatial structuring, are indicators of a "complex" use of space. However, this kind of information is often not accessible to the archaeologist. That is the reason why these studies often result in a less than satisfying outcome. Can we expect to see evidence for cleaning or group-level spatial structuring in a Middle Paleolithic rockshelter site that has been repeatedly occupied for thousands of years? Furthermore, even in a so-called "high resolution" site with presumably fewer repeated occupations, does absence of evidence mean that the site's occupants were incapable of complex spatial structuring? Or does it have to do with other factors, such as duration of occupation? The main advancements in the study of intrasite spatial analysis are not emerging from studies that seek to identify patterned behavior linked to discrete behaviors within archaeological contexts, but rather from studies that are rethinking how we approach intrasite spatial analysis and how we interpret the results.

The emphasis now has shifted. Instead of acknowledging the various processes that can "distort" the archaeological record but then moving on to the real task of obtaining information about systemic behavior, archaeologists are now using intrasite spatial analysis to directly address those distorting processes. And, in fact, many of these distorting processes, such as long-term or repeated occupations, are themselves a subject of great interest to archaeologists.

Often, the most accessible formation processes are geologic. Following the suggestion of Dibble and colleagues, many archaeologists now use spatial patterning of artifacts to make conclusions about the influence of geologic processes on site formation (Enloe 2006; López-Ortega et al. 2019; Mendez-Quintas et al. 2019; Sisk and Shea 2008). These studies use the orientation of elongated artifacts or the directionality of refitted lithics to determine whether the spatial patterning was influenced by running water or other natural phenomena. The results of these studies can be quite robust.

But geological processes are only the first step in understanding the formation of spatial patterning. One of the most confounding issues in hunter-gatherer archaeology, especially for older sites, is the "palimpsest problem" (Henry 2012). Instead of simply acknowledging the problem, many studies are now confronting it directly. Abric Romaní is a Middle Paleolithic rockshelter with low-density archaeological layers that are vertically discrete. For these reasons, it has often been labeled a so-called "high resolution" site (Carbonell 2012). Nevertheless, although some archaeologists might approach the site as a Middle Paleolithic Pompeii, scholars working at Abric Romaní confront the spatial patterning of archaeological remains with the understanding that each layer was likely the result of repeated visits to the rockshelter (Vallverdú et al. 2005; Vaquero et al. 2012). Vaquero and colleagues (2012) used the spatial distribution of lithic refitting and raw material units (RMUs) to establish that Level J was formed through a series of short-term occupations (see Machado et al. 2013 for a similar study). In a more recent article, Vaquero and colleagues (2019) use lithic refitting to deconstruct the various processes that can influence spatial patterning (such as recycling, social relationships, and discard strategies).

At Roc de Marsal, a rockshelter with much lower rates of sedimentation and consequently a much denser deposit, Reeves and colleagues (2019) used spatial analysis to ask how hominin use of space changed over time. Instead of viewing the dense archaeological layers as a disadvantage, they argued that time-averaged deposits are better suited to displaying processes operating on an evolutionary time scale. The methods they used were selected to account for the many occupations encapsulated in each archaeological layer, enabling them to identity patterning in the spatial distribution of the lithic artifacts that implied spatial use of the site was relatively consistent within each layer.

One weakness of intrasite analysis studies is that they are nearly always performed at only one site. The spatial characteristics of individual archaeological sites are often unique, and methods must be tailored to each circumstance. Moreover, archaeologists often do not have access to the spatial data of more than one site at any given time. I was able to overcome these dilemmas when presented with a series of French Middle Paleolithic open-air sites, all excavated by INRAP (*Institut national de recherches archéologiques préventives*) (Clark 2015, 2016, 2017, 2019). I created two methods to study the spatial patterning within these sites, which made use of refitting data, technological attributes, and the spatial location of lithic artifacts. These methods were applied to all seven sites in the sample. The spatial patterning within these sites mostly documented the reduction of chert nodules, as they were all situated close to raw-material sources, but use wear analysis indicated that other activities took place at these sites as well. I used spatial analysis to unravel the formation of these sites through lithic knapping and the movement of lithics from where they were knapped. I also studied the way occupation dynamics (the number and length of occupations) influenced the spatial structures of these sites. Furthermore, I was able to identify selected (utilized or cached) lithics by isolating those lithics that had been moved more than a few meters from where they had been knapped (Clark 2019). Such a study was possible because these sites were similar in that lithic knapping was a primary activity and the excavation and analysis were conducted using the same methods.

It is clear, then, that archaeologists can gain a substantial amount of information regarding ancient behavior from careful consideration of the formation of intrasite spatial patterning. I find the use of spatial patterning to decipher the occupation dynamics of archaeological layers to be particularly important. An understanding of the extent to which a deposit was the result of a few—or many—occupations is crucial if we hope to reconstruct settlement patterns and land use. Once we understand the effect of occupation dynamics on spatial structure more thoroughly, we can move on to studying how social structure influenced spatial patterning.

Occupation dynamics distort the spatial patterning of some sites more than others, particularly sites situated at attractive locales (rockshelters, springs, raw-material sources). Other sites, however, might be more conducive to identifying areas of artifact discard or use, or even household units. The identification of social units is a highly sought piece of information for archaeologists. The number of units and their configuration can indicate group size, the social relatedness between group members, and the general structure of the group (Fisher and Strickland 1991; Gargett and Hayden 1991; O'Brien and Walker, this volume). However, most sites do not show obvious evidence for habitation structures. Waguespack and Surovell (2014) used artifact density and rates of burned lithics to identify houses at Barger Gulch, a Folsom site in Middle Park, Colorado (see also Gingerich, this volume, and Surovell and Waguespack 2007 for an application of Stapert's ring and sector method). They noticed that there was an inverse relationship between artifact density and percentage of burned lithics by unit. There were only a few excavation units that did not conform to this pattern, and these were the units that contained a hearth. Waguespack and Surovell predicted that this pattern was a product of cleaning hearths within a structure and depositing the hearth contents outside. This would result in high densities of unburned lithics within the shelter, but a high percentage of burned lithics outside the shelter where there was little other debris. They were also able to identify potential "walls" where artifact density suddenly dropped and rates of burning went up. Waguespack and Surovell rightly point out that this technique can only be applied to contexts where the primary work areas occur indoors. However, they demonstrate that simple manipulations in the way we view artifact patterning can have a big effect in the identification of features and discard patterns.

Although many of the studies discussed here have successfully extracted meaningful information about human behavior and spatial structure using a myriad suite of methods, the search for a unifying theory of spatial analysis remains elusive. Schiffer's Behavioral Archaeology has had a large influence in these studies, although many scholars wouldn't necessarily name Behavioral Archaeology as their theoretical framework since it provides few guiding principles beyond a rigorous concern for formation processes. O'Connell advocated Human Behavioral Ecology as a framework for studying intrasite spatial patterning, especially in the case of ethnoarchaeology. A benefit of HBE is that it relies on formal mathematical models, and therefore one must be explicit about the various processes at work and how they might relate to one another (Surovell 2009). To my knowledge, only two studies have attempted to apply HBE to intrasite spatial analysis, and both are based on ethnographic data.

Codding and colleagues (2016, see also Codding and Zeanah, this volume) used the Marginal Value Theorem to study spatial structure within Martu dinnertime campsites. The Marginal Value Theorem (MVT) assumes foragers are situated within a patchy environment and predicts when a forager might leave one resource patch and move to another patch. In this study, Codding and colleagues use the MVT to predict how landscape-scale decisions would influence site structure in each "patch" (the dinnertime campsite). The MVT can be used to predict the number of people in a patch and the time spent there based on foraging yields. Moreover, ethnographic and archaeological studies have shown us that there is a relationship between site structure, number of site occupants, and duration of occupation. Because each site is treated as a patch, the MVT can then be used to make predictions about foraging yields based on site structure.

First, the MVT predicts that as the number of people in a patch rises, so does in-patch competition, and consequentially lower per capita foraging yields. This means that because site size increases with group size, site size should have an inverse relationship with per capita foraging yield. Second, the MVT predicts that foragers should stay longer in a high-yielding patch, and therefore longer duration is correlated with higher foraging yield. This means that because occupation duration increases with the degree to which artifacts are size sorted (cleaning becomes more necessary the longer occupants remain on site), size sorting should have a direct relationship with foraging yields. Because this was an ethnographic study, all variables could be collected. The foraging yield was measured by the kcals obtained from their prey (monitor lizards). The degree of size sorting was measured based on the distribution of bones within meter-square units. The number of occupants and time spent at the site were directly observed. When site size was plotted against per capita foraging yield and size sorting was plotted against foraging yields, the excepted relationships were observed, but neither was very strong. While the archaeological implications of this study are clear, it is doubtful whether these relationships would hold up in archaeological contexts. Nevertheless, Codding and colleagues provided a clear avenue for the application of HBE to intrasite spatial analysis.

One disadvantage of the Marginal Value Theorem is that by viewing the entire site as one unit (a patch), it is difficult to move beyond large-scale characteristics of site structure. Surovell and colleagues (2016) instead use Baker's migration equation to predict the movement of people within sites. The migration equation simply predicts that an animal should move when a neighboring habitat is more suitable than its current habitat. Surovell and colleagues apply this model to data they collected documenting the spatial positioning of Dukha people within their campsites. The Dukha are reindeer herders living in northern Mongolia. This model was used to predict how strongly distance might influence where individuals chose to position themselves after departing from a common location, in this case a doorway. They found that distance was a strong factor in the places individuals chose to perform their activities. In other words, most activities were performed in close spatial proximity to the doorway. Surovell and colleagues refer to doorways and other features such as woodpiles, reindeer corals, and pathways as "spatial attractors." They argue that spatial attractors, and particularly doorways, would be a good predictor of artifact concentrations within archaeological sites, particularly concentrations of primary refuse because tasks are often concentrated there. Doorways might potentially be identified even without evidence for architecture.

The reality is that it is more difficult to apply HBE to intrasite spatial analysis than to other elements of the archaeological record, such as faunal analysis. Faunal analysis operates at larger scales where ecological factors and optimality are more likely to have a strong impact. Binford (1983) pointed out that spatial structure is largely driven by the physical positioning of human bodies. Codding and colleagues (2016) agree with Binford, which is why they chose to consider the site as one unit instead of studying the relationship between intrasite units, the normal course of study for intrasite spatial analysis (and essentially what defines it). Surovell and colleagues (2016) created a spatial model showing us that people will move as little as possible, unless there is a spatial attractor. This is a good place to start, but it is difficult to envision HBE having a large effect in such a low-cost environment, i.e., maneuvering oneself within a relatively small area. This again would support O'Connell's claim that we need to excavate much larger areas if we are to uncover spatial patterning that can be meaningfully evaluated.

Nevertheless, applications of HBE to ethnoarchaeological contexts are a welcome change from the descriptions of site structure that characterized studies from the 1970s and 1980s. HBE captures large-scale patterns that can be modeled mathematically instead of simply making observations that may never be robust enough to be documented in the archaeological record. In that way, it is much more amenable to the time-averaged deposits that characterize the archaeological record. In fact, one might say that the ethnoarchaeological work of the 1970s and 1980s was in some ways detrimental to intrasite spatial analysis because it spurred archaeologists to search for patterning that is unlikely to be preserved in archaeological deposits, especially for older sites. However, I believe that the aspirations of archaeologists searching for such patterning was rightly placed; we simply need to modify these ambitions to focus on patterning that can be seen in time-averaged deposits and to reorient our methodologies to reflect the archaeological, rather than the ethnographic, record.

Conclusion

In O'Connell's 1995 critique of ethnoarchaeology and site structure, he reflects on Binford's model for reconstructing hearth-related activities: "The key question is whether its application yields any important insights on past human behavior and its evolution. It is difficult to see not only how it does but how it ever could" (p. 219). This quote distills the disenchantment that many archaeologists have experienced concerning intrasite spatial analysis. Can spatial patterning really tell us something new and interesting about human behavior in the past? This appears especially doubtful when we simply try to identify where particular activities occurred or where trash was deposited and is the reason why so many Paleolithic studies attempt to address whether the use of space is "complex," even if there is little data to support such inferences and no agreed definition of what a "modern" use of space looks like.

I am not immune to the allure of these questions. Indeed, this is what I had hoped to address in my study of Neanderthal open-air sites. But the patterning that dominated these open-air sites had little to do with whether they were modern or not, or if it did, I could not evaluate it without similar sites from different time periods. Instead, I observed patterning that was the result of a prodigious amount of core reduction whose products were dispersed through a variety of processes and influenced by the number and duration of occupations. So I, like the team working at Abric Romaní and many other archaeologists, must be content for the time being with the task of understanding how these many processes lead to spatial patterning *within archaeological deposits*. The large body of ethnoarchaeological work produced in the 1970s and 1980s will sustain us with information pertaining to site structure for many years to come. But these studies will only go so far in helping us interpret a site such as Roc de Marsal where artifact densities average 940 lithics/m² (10 cm in depth) in Layer 9 (Reeves et al. 2019). Even at open-air sites or "high-resolution" rockshelters such as Abric Romaní, we must understand how occupation dynamics influence spatial patterning before we can embark on addressing "high-order" questions such as social structure or modernity.

An understanding of occupation dynamics is not simply a means to an end, however. Information about the number and duration of occupations is interesting in and of itself and can help us interpret land use patterns. Furthermore, the more we understand the formation of spatial structure at more recent sites, the better we will be able to interpret spatial patterning within sites of a greater antiquity. Approaches such as that used by Waguespeck and Surovell at Barger Gulch and Gingerich (this volume) might not be immediately applicable to (most) Middle Paleolithic sites, but similar strategies might be possible. At the very least, it is important to know how social structure is manifested at younger sites so that we can establish baselines of comparison to older contexts.

In fact, many of the "high-order" questions that we strive to address might only be visible at lower resolutions. Thus, what we think of as a detriment to archaeological inquiry might actually be an advantage. As Reeves and colleagues (2019) observed, the "palimpsest problem" may not be a problem at all but might allow us to see processes that are evolutionarily significant (see also Yeshurun, this volume). Other research foci within archaeology have integrated this idea fully into their methodology (Kuhn and Clark 2015; Premo 2014). But intrasite spatial analysis suffers from what Henry (2012) calls the "wow factor." We experience a sense of awe in cases where we are able to reconstruct moments in time from the past—where a certain activity occurred, or if we can determine the positioning of individuals around a hearth. But this does little to address anthropological questions. In fact, we must avoid the tendency to seek these moments and instead use spatial patterning to provide information on an assortment of anthropological issues. Many of these issues can be addressed through the novel use of intrasite spatial analysis.

Instead of focusing only on activities and use of space, intrasite spatial analysis is now being used to study many other aspects of past human behavior. An understanding of the duration and number of occupations is essential for reconstructions of regional strategies of mobility and land use. This body of information was previously explored only through other sources of information, such as raw material transfers or assemblage composition. Similarly, we might be able to use site structure to explore continuity of occupation by the same group. For example, spatial patterning that is evident in dense, time-averaged deposits, as with Roc de Marsal or Amud Cave, might not be telling us anything especially revolutionary about the "use of space." Instead, it might indicate that the site was used consistently by the same group (Miller-Atkins and Premo 2018).

Finally, although the detection of social structure has always been a goal of intrasite spatial analysis, it has yet to be realized in most contexts. However, recent work focused on identifying households using more subtle material signatures (e.g., Surovell and O'Brien 2016; Waguespack and Surovell 2014) could potentially provide a model for the identification of social units at sites more distant in time.

Acknowledgments

This chapter benefitted from conversations with Todd Surovell, Joe Gingerich, and the participants of the SAA symposium that preceded this volume. Thank you to Shane Miller for helpful comments that led to a stronger manuscript.