Fallen Between the Cracks

A Microarchaeological Study of a Late Neolithic Cobble Floor in Northern Jordan

Isaac I. Ullah

E.B. Banning

Introduction.

Identification and interpretation of activity areas are vitally important aspects of household archaeology, and while there are many methods that identify and quantify spatial patterning of artifacts in archaeological sites (c.f. Hodder and Orton 1976; Kintigh 1990), the major problem with identifying and interpreting this patterning is that due to natural and cultural site formation processes the objects of that patterning may be secondarily deposited in places they were not originally used or discarded (Brooks and Yellen 1987). Early work on site formation processes quickly identified that smaller artifacts may be less subject to disturbance by many site formation processes (LaMotta and Schiffer 1997); therefore microarchaeology (the study of very small cultural material) never before thought of as important, began to be seen as way to get around the problems associated with larger artifacts in activity area analysis (Metcalfe and Heath 1990). Microarchaeology has not, however, been used to its fullest potential, due mostly to widespread misunderstandings among the archaeological community as to what, exactly, microarchaeology is, what it entails, and how difficult it is to do. This paper attempts to address these issues and show that microarchaeology is a powerful archaeological tool that, when used correctly, greatly strengthens archaeological interpretations without prohibitively increasing cost, effort, or time in archaeological fieldwork and labwork, or reducing the quality of the data and the knowledge gained from their analysis. This paper pays special attention to the utility and methods of using microarchaeological data for spatial analysis in household contexts, evaluates and recommends specific sampling strategies, lab methods, and methodologies for spatial analysis of living surfaces, and puts these strategies to a test case in which we use microarchaeological data to analyze a house floor in the Late Neolithic village of Tabaqat Al' Buma in Norhtern Jordan.

Microarchaeology Defined

The question "What is microarchaeology?" seems straightforward and somewhat unnecessary, but the literature conflicts even on this basic issue, and it has been defined variably by different researchers. Because the lower size limit can potentially be at the molecular level (Dunnell and Stein 1989), the main point of contention has been the delimitation of the upper size limit for microartifacts. A quick summary of the literature reveals the issues surrounding this dilemma.

Fladmark (1982), one of the first practical researchers of the topic, originally defined microdebitage as any culturally created lithic material smaller than 1 mm. He arbitrarily assigned this maximum measurement because he felt that it is the lower limit of size for which individual flakes can be recognized by the naked human eye, and below which the use of microscopes are needed. This definition is followed by Hull (1987), Rosen (1986)(1986), and Vance (1987).

Dunnell and Stein (1989) later decided that microartifacts are culturally created material between 2 mm and .25 mm because this is the upper limit for coarse sand, and the lower limit of medium sand. These limits were chosen because they assume that microartifacts will follow the known sedimentological attributes of erosion and deposition of sediment grains for different flow regimes and depositional environments. Even though this is perhaps a more scientifically valid argument than Fladmark's, it is still somewhat arbitrary in an archaeological sense because it does not consider the cultural connections to the physical properties of small-sized artifacts. Studies that follow Dunnell and Stein's (1989) definitions include Metcalfe and Heath (1990), Sherwood and Ousley (1995), and Sherwood et. al (1995).

Still others (Healan 1995; Nadel 2001; Rainville 2000; Rosen 1989, 1993; Simms 1988; Simms and Heath 1990; Simms and Russell 1996) have discussed size-sorting of culturally derived material under 3 cm. These studies have set the upper limit variably between 1 cm and 3 cm, but all agree, either implicitly or explicitly, that the term "microartifact" should include larger size classes than only microscopic artifacts. These delimitations are suggested as they are the size threshold above and below which artifacts are subjected to different cultural site formation processes – artifacts smaller than these upper limits are less likely to be moved by sweeping, are more likely to be trampled into the ground, and are less likely to be picked up and moved or reused, and are therefore more likely to be in primary context (Gifford 1978; Hayden and Cannon 1983; LaMotta and Schiffer 1997; O'Connell, et al. 1990). They may also react differently than larger artifacts to natural site formation processes, and can still be related to knowledge of natural site formation processes imported from sedimentology.

The first definition of microartifact size is based solely on the limits of the observer, and the second on sedimentology, while the third on the effects of cultural and natural site formation processes. The main problem with all these definitions of microartifact size, and especially with the first two, is that they are too rigidly narrow and bounded. It has been shown that, at least in certain cases, small sized refuse that is larger than 1 or 2 mm, but smaller than 1 or 2 cm behaves the same as the smaller (<1 or 2 mm) microrefuse but with the added advantage of being easier to recover and analyze (Healan 1995). For example Sherwood et al. (1995) show that, in their case study, microartifacts of size class 2 – 0.25 mm are actually more susceptible to movement by sweeping than the next highest size class of 2 – 4 mm because the smaller size class becomes incorporated into the loose dirt that is transported and uniformly distributed across the surface by sweeping while the larger size class is heavy enough to stay in place, but still too small to be pushed by the broom. This indicates that focusing on patterning of microartifacts of traditional size class for spatial analysis may give inaccurate results. Healan (1995) shows, however, that this is not a universal phenomenon and depends on a variety of factors including the physical properties of the substrate type and the amount and type of cultural and natural site formation processes. It therefore seems that the archaeologist needs to understand case-by-case the nature of all these factors at a site before making a judgment of the most cost-effective, in terms of time, money, effort, and knowledge gained, upper and lower size limits of microrefuse to be collected at that site.

Previous Work in Microarchaeology

The first important microarchaeological study was Fladmark's (1982) study of activity areas and site formation processes using lithic microdebitage. He was followed by other studies that also examined the relationship of microdebitage and activity area analysis (e.g. Healan 1995; Hull 1987; Nadel 2001; Vance 1987). This idea's relative simplicity is attractive for its use in archaeological studies, in that archaeologists only have to examine a single class of microrefuse, and in that most archaeologists already feel comfortable with lithic remains; however, it is because of this simplicity that this technique necessarily produces a very simplified picture of site activity and cannot speak to all activity types. Hull's (1987) model, which identifies primary, secondary, and de facto refuse based on the correspondence of macro and microdebitage patterns in excavation units, in particular proves to be a useful tool to identify activity areas versus secondary refuse areas and alternative use areas. She does not, however, take into account all possible cultural affects on site formation, especially living surface type and density, and refuse behavior such as scooping that can transfer microrefuse from its original context. Also, her study is specific to microdebitage, and her model may not be directly applicable to other types of microrefuse.

Evolving out of Fladmark (1982) and the other activity area studies of the early to mid 1980's came a small cluster of studies in the late 1980's and early 1990's that used new ideas in spatial analysis and site formation processes to look at house floors and other types of living surfaces and subsequently expanding from using only lithic microdebitage to using many different types of microrefuse. These include Simms and Heath (1990), Metcalfe and Heath (1990), the Sherwood et al. (1995), Rosen (1986; 1989; 1993), and more recently, Rainville (2000). For several reasons (e.g. difficulty level, time, cost, specialized knowledge) this type of analysis has been misconstrued as too difficult to do and has been undertaken only rarely, but is potentially the strongest type of microarchaeological study for spatial analysis in household archaeology (Sherwood and Ousley 1995). Perhaps most importantly, these studies serve to indicate the potential benefits of ethnoarchaeology in conjunction with microarchaeology, specifically the need for detail ethnoarchaeological study of how human behavior affects microrefuse production, patterning, and preservation, and especially how the mechanics of size-sorting of artifacts work. These studies use microrefuse to broaden the assemblage composition of the site by providing evidence of material that was not present at the macro level. They also show that microrefuse analysis can be used as a compliment to traditional artifact analysis, and comparison of spatial and other attributes between size classes gives better resolution of spatial patterning and enhances the accuracy of site structure and site formation interpretations.

Microbotanical analysis has historically been thought of as separate from other types of microarchaeology because it is usually only used to reconstruct paleoenvironment, paleodiet, site seasonality, and site identification (Lennstrom and Hastorf 1995) (e.g. Simms 1997; Wohlgemuth 1996). Microbotanical remains have, however, been at least suggested for use in some types of spatial analysis (e.g. Lennstrom and Hastorf 1995) and have been included in some microarchaeological studies (e.g. Metcalfe and Heath 1990; Rainville 2000; Rosen 1989; Simms and Heath 1990).

Sampling Strategies

The small size and large quantities of microartifacts in archaeological sites presents many problems to the archaeologist. Quantification of microartifacts is one of the foremost problems archaeologists have dealt with in microarchaeology. Most of the recent microarchaeological studies use very large sample sizes and therefore were accompanied by the caveat that although microrefuse studies are important they are very time consuming and expensive (Healan 1995; Sherwood and Ousley 1995) (e.g. Fladmark 1982; Metcalfe and Heath 1990; Simms and Heath 1990). Some of these researchers sorted and counted all microartifacts present in their soil samples (e.g. Simms and Heath 1990) while others have used visual approximation as a way to save time (e.g. Fladmark 1982), but the results were either offset by the length of time and tediousness of the procedure or were affected by decreased data quality and increased bias and error. Still others advocate using smaller sample sizes and doing different types of microartifact quantification including specialized computer software to greatly reduce the amount of time, effort, and cost of microrefuse studies without a reduction in data quality so that the earlier caveat is no longer valid (Sherwood and Ousley 1995; Sherwood, et al. 1995). In this same vein, it is our contention that multi-stage cluster sampling (Orton 2000) in conjunction with Geographic Information Systems (GIS), usually used for larger scale archaeological studies, can also be adapted to the small scale necessary for microarchaeological research, and subsequently provide the greatest tools for intra-site spatial analysis of microartifacts. Multi-stage cluster sampling involves using groups of smaller units of a sample to understand the whole sample, and then to extrapolate the character of the entire population from these samples, and is the most cost-effective way to deal with the very large amount of elements typically present within the population of microartifacts on a site (Orton 2000).

Proper sampling techniques coupled with better analysis methodology can help to greatly reduce the cost of microarchaeology in terms of time, effort, and money with out a reduction in data quality or knowledge gained. There is no single correct sampling technique however; rather, the archaeologist must be able to decide what sampling strategy is best for their particular site and research goals with respect to costs versus benefits. The same idea applies for laboratory procedures for microartifact quantification in that the archaeologist must decide which classes of microartifacts to count, what method of counting and recording to use, whether to subsample or not, and if so, how many subsamples to analyze. All these decisions must be made on a case by case basis after careful consideration of the variables that might affect the outcome of the study.

Microrefuse and Spatial Analysis of a Single Living Surface

Common methods of spatial analysis that can be used to identify and quantify patterning in larger sized artifacts on living surfaces cannot be used with microartifact data from living surfaces because the small size and great numbers of microartifacts in archaeological sites would make performing these methods impossibly time consuming and prohibitively expensive (Sherwood and Ousley 1995). Hodder and Orton (1976) recommend methods that use inter-artifact distance indices from point coordinate data, such as nearest neighbor analysis and Hodder's *A* coefficient, for study of the spatial attributes of artifacts and archaeological sites over other methods, such as quadrat analysis. Kintigh (1990) adds local density analysis, pure locational (*k*-means) clustering, and unconstrained clustering to Hodder and Orton's list of methods of spatial analysis. Most of these methods, however, require precise coordinate plotting of artifacts on archaeological distribution maps and are therefore not suited for use with microartifact data. As we will see below, however, some of them can be adjusted for use with grid based cell frequency data. Although not explicitly stated in any of the microrefuse studies that looked at intra-surface spatial variability, all have had to use a similar approach: in order to quantify microartifacts in a way that is conducive to spatial analysis they all record microartifact frequency over some sort of grid (e.g. Fladmark 1982; Hull 1987; Metcalfe and Heath 1990; Nadel 2001; Rainville 2000; Sherwood, et al. 1995).

There are, however, several problems associated with grid based methods of spatial analysis including problems of scale, the inconsistencies from reality formed by arbitrary placement of grid units over real concentrations of artifacts, and trouble keeping spatial relationships of artifacts between grid units intact (Hodder and Orton 1976; Johnson 1984). There are, however, ways of overcoming these problems, and Johnson (1984) discusses some of them, including the problems of scale. He says this problem can be easily overcome by increasing the resolution of the study by decreasing cell sizes. Small, high resolution cells show small scale spatial patterning, and can be lumped into larger cells in order to resolve larger scale patterning. Theoretically, the smaller the cell size, the higher the resolution of data and therefore the more scales of spatial patterning that can be analyzed. This can continue to the infinitely small cell, or the point, which is what coordinate data gives us (Johnson 1984). However, this sort of piece plotting of microartifacts is functionally impossible due to the extraordinary amount of time and labor it would take. Cell size, like sample size, must be minimized on a case by case basis by balancing the resolution needed to answer the research questions in hand with the budget of time, labor, and money available for both fieldwork and labwork, and with the logistical problems present at each particular site. Density contours can now be automatically generated by various means of interpolation in a GIS. This method is optimal because it "fills in the blanks" and predicts the patterning at a resolution much greater than the input grid size. This means that a moderately small cell size can be used to show all the important patterning on a site.

Hodder and Orton (1976) also discuss this problem of cell analysis with respect to the effects of the shape of cells as scale is increased in traditional quadrat analysis. They point out that if scale is increased twofold each step every other step will result in rectangular cells and the orientation of the rectangles may inhibit their ability to discover linear or oval shaped clusters of artifacts that are oriented in a different direction from the cells. This can be overcome by increasing the scale fourfold at each step, making each step result with square cells four times the area of the previous step. While this may increase the gap in resolution between scale steps, it eliminates the bias introduced by non-square cells. Again, the use of GIS to draw contours from grid based density data can eliminate this problem.

Johnson (1984) also discusses how local density analysis, a method of quantitative spatial analysis that is usually used for point plot data, can be used for grid based cell frequency data and how this method smoothes the inconsistency of this data from the actual patterns and incorporates the spatial relationships between cells. Local density analysis would normally involve comparing densities of each artifact class present within a circle of a given radius from each plotted artifact with the global densities of each artifact within the entire site. To use this analysis with cell frequency data, each cell must be treated as if it were a point and instead of circles of given radii, all cells within a certain distance are included. Local density analysis "smoothes" the density data of each class of artifact from the cell by mathematically incorporating the density of each artifact class from all included surrounding cells. This creates a matrix of indices of association of each artifact class to all other artifact classes in their "neighborhood". Positive associations between artifact classes are identified when the index of association for the "neighborhood" is higher than the average index of association between the two classes over the entire site. Dissociations are shown by a smaller than average local index of association and no association is shown by local densities that equal the global density. The distance can be increased or decreased to include more or less surrounding cells, which, correspondingly, resolves larger or smaller scale patterning (Johnson 1984; Kintigh 1990). One potential problem of local density analysis is that it is symmetrical. It can identify reciprocal associations between two artifact classes, but it fails to identify asymmetrical relationships between artifact classes where one artifact class A is associated with another artifact class B, but class B is not associated with class A (Kintigh 1990).

Kintigh (1990) suggests unconstrained clustering as a method of spatial analysis that can use grid based data. Unconstrained clustering is similar to local density analysis but uses circles centered on the vertices of the grid, and is therefore arbitrary and not constrained to locations of artifacts like local density analysis. The grid with its circles is placed over an archaeological distribution map of point plotted data, and the density of all artifact classes is calculated within the given radius. Because each circle partially overlaps the circles from the surrounding vertices, the densities are "smoothed", making them more suitable for use in contour maps. These relative densities are then subjected to cluster analysis and the clusters are plotted on a map. The individual artifact class components of each cluster grouping can be identified from these maps. Kintigh suggests that using squares centered on the vertices instead of circles can help overcome the unequal weighting of artifacts created by the uneven overlapping of the circles, and this will also allow cell frequency data to be used in addition to point plotted data.

An additional method that Kintigh (1990) suggests is unsmoothed grid based unconstrained clustering. In this method, grid-square frequency data is subjected to *k*-means clustering analysis, an analysis that uses the sum-squared error as a goodness-of-fit test to assign each grid square to one of a predefined number of possible clusters. The analysis reveals the center of each cluster, and shows which cells belong to each cluster. A line, made by plotting the sum-squared errors of the different cluster number levels as percentages of the single-cluster sum-squared error against the total number of clusters, shows at its inflexion points the scales at which natural clustering exist. This is not a test of clustering however; rather, it is a way of identifying clusters and their constituents.

Spatial analysis of living surfaces using microartifacts must use a grid based system to record artifact frequency rather than a system that requires point plotting each individual microartifact. The use of a GIS greatly simplifies this task and increases the accuracy immensely. In addition to this, local density analysis, unconstrained clustering, and unsmoothed grid based unconstrained clustering with *k*-means clustering analysis are all ways to improve the accuracy of spatial analysis for grid based data. In order to obtain the highest possible reliability, multiple types of analysis should be used and the results compared before making any interpretations of spatial patterning of microrefuse at a site.

Density contour maps and identified clusters and associations of microartifacts mean very little on their own, however, and must be interpreted according to some set of ideas about human behavior and natural and cultural site formation processes. Simms and Heath (1990) advocate ethnoarchaeological modeling to obtain these types of ideas, and ethnoarchaeology data has been used for interpretation to some extent in most microarchaeological studies. Carr (1990) endorses contextually sensitive methods of spatial interpretation and multi-model induction rater than single model deduction of site structure. Regardless of interpretation type, the data must first be filtered through models of the effects of site formation processes on the spatial integrity of the deposit (Hull 1987). Microartifacts may be affected less drastically by most site formation processes, but are not completely immune to all of them (Dunnell and Stein 1989). Any interpretation of intra-site spatial patterning of microrefuse must identify and correct for any effects of site formation processes before any conclusion can be made about the nature of the patterning.

Ethnoarchaeology as a tool for interpretation.

Although examination of how different site formation processes affect micro refuse is outside the scope of this paper, there is one important topic in this category that deserves mention here as an important area that needs more study in microarchaeology and that can increase the accuracy of spatial analysis from microarchaeological remains with specific interest for household microarchaeology. The real effects of different floor substrate types on microartifact distributions is largely unknown with respect to cultural and natural site formation processes. The effects of floor type on the composition and distribution of small-sized artifacts have been discussed since the late 1970's (e.g. Gifford 1978), but most authors have not gone beyond a cursory mention that small sized artifacts penetrate the ground more easily, and that porosity and density of the soil have some affect on which sizes of artifacts can penetrate it (e.g. Brooks and Yellen 1987; Brooks 1993; Hayden and Cannon 1983; Healan 1995; Hull 1987; LaMotta and Schiffer 1997; McKee 1997), and only a few have examined these effects at any length at all. Similarly, many authors have briefly mentioned the affects of sweeping and trampling (e.g. Brooks 1993; Hull 1987; LaMotta and Schiffer 1997; McKee 1997), and only a handful have gone more in depth on how this behavior affects microartifacts.

Although only a few studies have been done, ethnoarchaeology is a promising way to obtain this type of data. Gifford (1978) probably has the earliest and most in depth ethnoarchaeological study of substrate permeability, trampling and their effects on small artifacts in archaeological site. She presented a series of six hypotheses about the behavior of these small artifacts in response to trampling given certain substrate types. Subsequent archaeological testing of these hypotheses, however, shows no overwhelming proof or disproof, and their validity, therefore, is still in question (Rosen 1986). O'Connell et. al (1990) mention that in Hadza activity areas, some of the smaller artifacts were trampled into the ground where surface sediments were softer and looser and thereby escaped being swept into secondary refuse areas. With the help of an informant, Savelle (1984) discussed refuse disposal at a recent historical Inuit snow-dwelling site on Somerset Island in northern Canada. He mentions that refuse is discarded vertically down through the floor as well as horizontally away from the dwelling. Refuse items are discarded by simply pushing them into the floor, and when the floor becomes too dirty, a new layer of snow is simply layered on top of the debris. Also, the major disturbance of this refuse came in spring as the floor melted away. The resulting refuse pattern was largely an effect of alluvial processes where some refuse was "trapped" behind rocks and in depressions as it was being transported downslope by meltwater. Simms (1988) and Simms and Russel (1996) report the affects of sweeping at the ethnographic Bedouin tent camp site during their stay at Bayt Qublan in southern Jordan in 1986. They note that most debris under 3 cm, and some linear debris over 3 cm escapes removal by sweeping with a leafy bough, and debris under 1 cm is even more likely to be unaffected by sweeping. They also note that sweeping tends to cover debris with dirt as often as actually moving the debris away. When they returned to Bayt Qublan in 1988 after it had been abandoned for two years, they noted that the living surface that had been regularly swept had a bare and compact appearance, and most artifacts left on the surface were less than 1 cm. The density of surface artifacts was less than half of what it was at the time of abandonment. In 1990, they returned again, and found the living floor partially vegetated and covered with 1 – 2 cm of aeolian sand deposits, and by 1994 this deposition had become 3 cm thick. In 1990, three flotation samples were taken from the site, and analysis of microartifacts revealed preservation of evidence of activity types that had been documented while the site was occupied, but no spatial analysis of activity areas was attempted.

Other researchers have examined this problem archaeologically. Rosen (1986) notes that plaster floors tend to have higher percentages of potsherds of the smallest size fraction than other types of floors in her study. She hypothesizes that the hardness and impenetrability of the plaster kept small sherds from traveling downward, keeping them on the surface and allowing them to be subjected to much more trampling than would occur on a more permeable surface. In another study (Rosen 1989) she mentions that the clay floors in her site contained high percentages of small sized charcoal. This, she says, is in contrast to deposits of mudbrick debris where most of the small sized charcoal disintegrated during brick manufacture, and can be used to help identify floors levels. She also mentions that water can concentrate microartifacts in certain areas of a floor depending upon slope or undulation of the surface. As mentioned earlier, Sherwood et. al (1995) discuss the affects of sweeping on a compact silt-loam floor substrate. They note that it seems likely that the smallest microartifacts are likely to be transported with the loose dirt as it is swept, and therefore become uniformly dispersed across the floor. Only microartifacts larger than 2 mm are heavy enough to stay in place while still being small enough to evade being pushed by the broom. They also mention that trampling increases the amount of microsherds and also increases the likelihood of their being embedded in the floor. Metcalfe and Heath (1990) find evidence in the clay floors of the Heartbreak Hotel site indicating that while sweeping may not remove microartifacts from a floor, it does move microartifacts around within the room, and therefore affects intra-room interpretation of spatial distributions of microartifacts. They also say that threshold type affects sweeping behavior. A substantial threshold prevents sweeping material directly out the door. At the Heartbreak Hotel, thresholds were substantial on doorways between major rooms and on outside doors, but nonexistent on doorways from major to minor rooms. They interpret high concentrations of microartifacts in minor rooms (such as entryways) as evidence that the inhabitants of the site swept debris from the major rooms into the minor rooms because thresholds prevented sweeping material anywhere else.

Although theses studies have all made important steps, they have barely touched the surface of the problem. There is a great need for a comprehensive and systematic study that couples ethnoarchaeological and/or experimental approaches with archaeological case studies. Such a study needs to fully describe the attributes of many different substrate types (clay, silt, sand, loam, plaster, wood, cobble, flagstone, snow, ice, etc.) and how cultural and natural site formation processes (cleaning and sweeping, trampling, water, wind, animals, etc.) combine with substrate attributes to affect the spatial and physical characteristics of microartifacts. This information is badly needed both as way to assess the quality of microarchaeological data for use in spatial analysis and as a way to strengthen interpretation of microartifact patterning.

Test Case: Archaeological Description of Tabaqat Al' Buma

Data presentation and interpretation

Conclusion.

Most archaeologists see microarchaeology's cost in terms of time, effort, money, and specialized knowledge as major drawbacks to its usefulness in archaeological studies. I have shown that in actuality these things are not problems with microarchaeology, but are instead problems invented from archaeologists' misconceptions about microarchaeology. Some very real problems, however, are inefficient sampling and quantification of micro artifacts, the lack of sufficient amounts of samples of small sized artifacts at most archaeological sites, use of poor methods of spatial analysis, and poor understanding of the effects of different substrate types and site formation processes. This paper has attempted to make headway on a course to resolve these problems and specific field and lab methodologies have been recommended to help reduce the cost and difficulty of microarchaeological research without reducing and perhaps even increasing the quality of data recovered and the strength of interpretations made from that data. Microarchaeology is a useful tool that, when coupled with more traditional forms of archaeological investigation, allows us to understand more about spatial variability of activities in household contexts than what we can understand from analysis of macroartifacts alone.

References

Brooks, A. S. and J. E. Yellen

1987 The preservation of activity areas in the archaeological record: archaeological and ethnoarchaeological work in northwest Ngamiland, Botswana. In *Method and Theory of Activity Area Research*, edited by S. Kent, pp. 63-106. Columbia University Press, New York.

Brooks, R. L.

1993 Household abandonment among sedentary Plains societies: behavioral sequences and consequences in the interpretation of the archaeological record. In *Abandonment of Settlements and Regions: Ethnoarchaeological and Archaeological Approaches*, pp. 178-187. Cambridge University Press, Cambridge.

Carr, C.

1990 Left in the dust: contextual information in model-focused archaeology. In *The Interpretation of Archaeological Spatial Patterning*, edited by T. D. Price. Plenum Press, New York.

Chang, C. and H. Koster
1986 Beyond bones: toward an archaeology of pastoralism. *Advances in Archaeological Method and Theory* 6:97-148.

Dunnell, R. C. and J. K. Stein
1989 Theoretical issues in the interpretation of microartifacts. *Geoarchaeology* 4(1):31-42.

Fladmark, K. R.
1982 Microdebitage analysis: Initial considerations. *Journal of Archaeological Science* 9:205-220.

Gifford, D. P.
1978 Ethnoarchaeological observations of natural processes affecting cultural materials. In *Explorations in Ethnoarchaeology*, edited by R. P. Gould, pp. 77-101. University of New Mexico Press, Albuquerque.

Hayden, B. and A. Cannon
1983 Where the garbage goes: refuse disposal in the Maya Highlands. *Journal of Anthropological Archaeology* 2:117-163.

Healan, D. M.
1995 Identifying lithic reduction loci with size-graded macrodebitage: a multivariate approach. *American Antiquity* 60(4):689-699.

Hodder, I. and C. Orton
1976 *Spatial Analysis in Archaeology*. Cambridge University Press, Cambridge.

Hull, K. L.
1987 Identification of cultural site formation processes through microdebitage analysis. *American Antiquity* 52(4):772-783.

Johnson, I.
1984 Cell frequency recording and analysis of artifact distributions. In *Intrasite Spatial Analysis in Archaeology*, edited by H. Hietala, J. Cambridge University Press, Cambridge.

Kintigh, K. W.
1990 Intrasite spatial analysis: a commentary on major methods. In *Mathematics and Information Science in Archaeology: A Flexible Framework*, edited by A. Voorrips, pp. 165-200. Bonn, Bonn.

LaMotta, V., M. and M. B. Schiffer
1997 Formation processes of house floor assemblages. In *The Archaeology of Household Activities*, edited by P. M. Allison, pp. 19-29. Routledge, New York.

Lennstrom, H. A. and C. A. Hastorf
1995 Interpretation in context: Sampling and analysis in paleoethnobotany. *American Antiquity* 60(4):701-721.

McKee, B. R.
1997 Household archaeology and cultural formaion processes: examples from the Ceren site, El Slavador. In *The Archaeology of Household Activities*, edited by P. M. Allison. Routledge, New York.

Metcalfe, D. and K. M. Heath
1990 Microrefuse and site structure: the hearths and floors of the Heartbreak Hotel. *American Antiquity* 55(4):781-796.

Nadel, D.
2001 Indoor/outdoor flint knapping and minute debitage remains: the evi-

dence from the Ohalo II submerged camp (19.5 KY, Jordan Valley). *Lithic Technology* 26(2):118-137.

O'Connell, J. F., K. Hawkes and N. B. Jones
1990 Disrtibution of refuse-producing activities at Hadza residential base camps: implications for analyses of archaeological site structure. In *The Interpretation of Archaeological Spatial Patterning*, edited by T. D. Price. Plenum Press, New York.

Orton, C.
2000 *Sampling in Archaeology*. Cambridge Manuals in Archaeology. Cambridge University Press, Cambridge.

Rainville, L.
2000 Microdebris analysis in Early Bronze Age Mesopotamian households. *Antiquity* 74(284):291.

Rosen, A. M.
1986 *Cities of Clay: The Geoarchaeology of Tells*. University of Chicago Press, Chicago.

1989 Ancient town and city sites: a view from the microscope. *American Antiquity* 54(3):564-578.

1993 Microartifacts as a reflection of cultural factors in site formation. In *Formation Processes in Archaeological Context*, edited by M. D. Petraglia, pp. 141- 148. Monographs in World Prehistory. vol. 17. Prehistory Press, Madison.

Savelle, J. M.
1984 Cultural and natural formation processes of a historical Inuit snow dwelling site, Somerset Island, arctic Canada. *American Antiquity* 49(3):508-524.

Sherwood, S. C. and S. D. Ousley
1995 Quanifying microartifacts using a personal computer. *Geoarchaeology* 10(6):423-428.

Sherwood, S. C., J. F. Simek and R. R. Polhemus
1995 Artifact size and spatial process: macro- and microartifacts in a Mississippian house. *Geoarchaeology* 10(6):429-455.

Simms, S. R.
1988 Archaeological structure of a Bedouin camp. *Journal of Archaeological Science* 15(2):197-211.

1997 Tur Imdai rockshelter: archaeology of recent pastoralists in Jordan. *Journal of Field Archaeology* 24(4):459-473.

Simms, S. R. and K. M. Heath
1990 Site structureof the Orbit Inn: an appliction of ethnoarchaeology. *American Antiquity* 55(4):797-813.

Simms, S. R. and K. W. Russell
1996 *Ethnoarchaeology of the Bedul Bedouin of Petra, Jordan: Implications for the Food producing Transition, Site Structure, and pastoralist Archaeology*.

Vance, E. D.
1987 Microdebitage analysis in activity analysis: an application. *Northwest Anthropological Research Notes* 20(2):179-189.

Wohlgemuth, E.
1996 Recource intensification in prehistoric Central California: Evidence from archaeobotanical data. *Journal of California and Great Basin Anthropology* 18(1):81-103.