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Spatial Structure in Mass Debitage Scatters

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Chipped-stone debris scatters, which consist of debitage resulting from prehistoric stone-working activity, represent an archaeological phenomenon that is nearly ubiquitous worldwide. If more than 99 percent of the human experience is that of hunters-and-gatherers who used tool kits composed principally of chipped-stone, then the importance of understanding the organization or structure of these debris scatters cannot be overstated. The analysis of past lithic technologies has been a focus of archaeological research for many decades, with much work concentrating on the byproducts of stone-working activity—chipped-stone debitage. Interest has centered principally on modes of production, technological characteristics, typologies, and attributes of shape and form (e.g., Bordes 1969; Crabtree 1972). A particularly useful tool in these studies has been experimental stone-working, or "flint knapping" (see Johnson 1978 for an excellent overview). Through it, archaeologists have gained many insights into stone tools and technologies worldwide.

In recent years, attention has moved away from the investigation of individual flakes and their attributes to include study of distributions of debitage in the aggregate, or what Ahler (1989) has termed "mass debitage distributions." This focus recognizes that chipping-debris scatters typically contain hundreds to tens of thousands of pieces of debitage and that, consequently, statistical tendencies inherent in these vast arrays of artifacts can disclose new understandings of past technologies and behaviors. Commonly examined are debitage size-grade distributions within assemblages or the relative composition of various types of flakes, broken or complete pieces, or cortex-bearing specimens (Ahler 1989; Shott 1994; Stahle and Dunn 1982; Sullivan and Rozen 1985). Differences found have been argued to be indicative of functional variation between assemblages or the result of different lithic technological strategies.

Although several studies have examined debitage assemblages spatially, by comparing distinct components within a single site (e.g., Sullivan 1992, 1995), analyses of mass debitage have ignored, for the most part, the spatial structure exhibited within single assemblages or scatters, even though mapped chipping-debris concentrations often suggest considerable patterning. There are a few important exceptions, but their focus tends to be tangential to an understanding of spatial organization. For example, a large number of refitting projects attempt to map flakes and other pieces that "fit together" across a site (see Cziesla et al. 1990). The goal of this research generally is to establish sequences of events and relationships between site areas. A few experimental studies have mapped waste-flake distributions, but little has been shown beyond the fact that knapping position (standing vs. sitting vs. squatting) has a major effect on the area of debris dispersal (Newcomer and Sieveking 1980; Schick 1986). Perhaps the best statement that can be made at present about large-scale chipping-debris spatial structure is that there are concentric density gradations analogous to a "bulls-eye" or "fried egg" (Ebert 1992: 24).

In the following sections, I attempt to correct for these past omissions by exploring the large-scale spatial structure exhibited by multiple archaeological chipping-debris scatters. This is accomplished by employing a "distributional" or siteless survey approach in an arid lands context where numerous surface-visible artifacts are easily recorded. After a review of field methodologies and the study region, I show that considerable and unforeseen patterning exists; specifically, chipped-stone debris exhibits various spatial sorting phenomena within debitage scatter concentrations. Several explanatory models are examined that might account for these observations and the results of stone-working experiments are employed as a test of one particular model. The end result is the definition of a formation process of debitage spatial distributions that may account for much of the structure observed in chipped-stone scatters.

Biases in Non-Site Survey

Archaeological phenomena generally do not occur in discretely bounded packages about which nice boundaries can be drawn on maps. Rather, archaeological materials are often scattered about the landscape in a strongly patterned way. In the arid regions of western North America, the site concept is indeed unfortunate. Chipped-stone scatters are highly visible on the surface, their density is quite variable, and some have more-or-less continuous distributions across many kilometers. Consequently, during the past 15 years, archaeologists increasingly have called for a "site-less" or "non-site" approach to field investigations where the artifact is the unit of analysis and their distributions are examined across broad regions (Dunnell and Dancey 1983; Ebert 1992; Rossignol and Wandsnider 1992). This approach is particularly advantageous in arid lands where the lack of dense vegetation makes surface artifacts readily visible.

A fundamental premise of the non-site survey approach is that data garnered from the surface are at least as good as information procured through excavation because buried deposits were at one time on the surface, exposed to the same impacts as modern surfaces (see Dancey, this volume). If the quality of the data is the same, then surface data offer a distinct advantage because information can be captured at a fraction of the cost of excavation and in much less time, allowing very large areas to be examined, something which is difficult to achieve through excavation alone (Dunnell and Dancey 1983).

In the practice of non-site archaeology, many studies have called for or claimed "full-coverage" survey of large tracts of land and, for the most part, results are based on the (usually implicit) assumption of survey completeness, which means that (nearly) all surface artifacts in the area under study have been recorded (e.g., Fish and Kowalewski 1990). Yet, contemporary field methods generally mirror those of traditional field walking. In the search for surface artifacts, linear transects typically are examined across the area under study, albeit with much tighter intervals between members of the survey team (15-m, 10-m, and even 5-m intervals have been reported; Ebert 1992). As a consequence of these field procedures, many "full-coverage" surveys have yielded, in reality, only *samples* of the surface archaeology, and probably very biased ones at that.

Several studies have examined the accuracy of surface survey results by focusing on the relationship between discovery rates and the obtrusiveness of artifacts (e.g., size, color), survey interval, and other factors (Schiffer and Wells 1982; Wandsnider and Camilli 1992). Because an individual surveyor can scrutinize only a 1–2-m width of ground, even with 5-m transects, only 20–40 percent of the ground surface is actually examined, for example. Additionally, it should not be assumed that all artifacts are actually discovered within each surveyor's 1–2-m observational swath. Large artifacts have a greater probability of being discovered than small ones, as are artifacts of brighter color or those offering greater contrast with respect to the background surface (Wandsnider and Camilli 1992). Differences in alertness and visual acuity between the individual surveyors, especially as a hot day wears on, must also be considered, plus the ever-present fact that an artifact's discovery may depend solely on which way a surveyor happens to be looking at a particular point along a transect. Wandsnider and Camilli (1992) present startling evidence, derived through controlled experiments, which suggests that a significant number—even a majority—of surface artifacts miss discovery in surface survey despite narrow (e.g., 5 m) crew intervals.

One purpose of non-site survey, often implicit in many discussions, is to yield data of greater accuracy and precision than were obtained through traditional survey. Yet, given current field methods, tremendous problems seem apparent in the data procured. If a goal is to understand complex archaeological patterns over broad areas, how can this be accomplished when only a biased part of that pattern is recorded? We must consider inventing new methods, and particularly a new attitude about what might be necessary, to achieve this end. In short, what is needed for true full-coverage survey is a new field methodology that does not yield biased coverage of an area (all regions covered uniformly), that does not bias the nature of the archaeological information recorded (all artifact types discovered with equal probability), and that can be implemented in a relatively rapid and cost-effective way.

Correcting Survey Biases

Areal Coverage

Resolution of the areal coverage problem requires that the entire survey region be examined with approximately equal intensity. This can be accomplished only if the field surveyors are forced to inspect each space in an equal manner, which implies some sort of control over where each of the crew walks.

The superpositioning of a physical grid over a region provides a way to achieve such control. The grid squares should be small, 1–5 m on a side, and may be laid out by meter tapes using pin flags or nails to mark grid corners (surveyors can "eyeball" grid boundaries between the nails). A 20-m × 20-m to 50-m × 50-m block of grid squares can be established at a time, and fairly rapidly by a team of two surveyors. The physical grid thus divides the region into many smaller spaces, each of which is fully inspected in its turn through 1-m-wide parallel survey transects, thereby ensuring uniform coverage of the entire region to be examined.

Grid size should be 5 m or less to ensure proper eyeballing of the parallel survey transects. Smaller grid sizes mean more grids, requiring greater set-up time, but if artifact provenience is to be by grid square (e.g., counts per grid data), then a smaller grid size might be desirable for locational control. In fact, if the spatial precision of the project is to be within only a few meters, the grid approach advocated is a clear advantage. Grid row and column numbers can be employed for provenience control. Otherwise, for point-plotted data (centimeter precision), some sort of marker, such as a nail or flag, might be placed adjacent to each artifact to allow its recording in a later mapping phase.

Artifact Obtrusiveness

Biases resulting from artifact obtrusiveness—size, shape, color, texture, or contrast—can be nearly eliminated through "saturation survey" of each grid square. What is implied here is intensive and multi-directional coverage. In experimenting with these methods, it was found that after walking a grid square south-to-north, additional artifacts could be discovered by walking north-to-south and again by walking east-to-west. When viewing the ground from a single direction, small blades of grass, parts of a low bush, or a clump of dirt can obscure artifacts, and the effects of sunlight angle, reflectance, and shadows play a similar role. By simply altering survey direction in a given space, new discoveries frequently can be made. If a 1-m-wide scrutiny width can be assumed, then each grid square should be surveyed with an appropriate number of transects to ensure its full inspection in first one direction and then in a second (e.g., a 4-m grid square will receive four transects in each direction).

Regardless of how well-saturated a survey area is, there is a finite limit to visual acuity, meaning that a size bias must exist against very small items. Because it is well recognized that getting on one's hands-and-knees and pouring through anthills will often yield small flakes, some lower limit of artifact size should be imposed, such as 5 mm, to ensure uniform results and to deny biases stemming from crew differences in discriminatory power.

The Colorado Study Area

Between 1988 and 1994, multiple surface scatters of chipped stone, containing in excess of 25,000 artifacts, were mapped in a remote and arid region on the Colorado Plateau, near Grand Junction, Colorado (Kvamme 1990, 1995). The area mapped is a contiguous region of approximately 6 ha. The remoteness of the project area, caused by a paucity of access roads and difficult-to-cross canyons, has guaranteed a remarkable surface record of relatively undisturbed debitage scatters, reflected by the presence, yet, of approximately 1,200 chipped-stone and ground-stone tools, including nearly 100 projectile points. Other advantages of this study area are its general lack of dense vegetation, which allows a high level of surface visibility, a situation of geologic deflation that yields numerous surface-visible artifacts, and the presence of a large number of high-density flaking-debris clusters, which provides multiple "units" of study.

The apparent high density of prehistoric activity in the study area is probably explained by its location adjacent to a canyon that harbors water, riparian, and wildlife resources. The canyon varies in depth between 60-m and 120-m and possesses shear-sided walls, except just below the project area where the wall has collapsed. Thus, easy access to the canyon is possible only at this locus or at the canyon mouth some 6 km distant.

This region of western Colorado was inhabited by hunting-and-gathering groups whose surface archaeological remains consist solely of chipped-stone tools, ground-stone tools, and manufacturing debris. It is quite likely that hunting parties of the Fremont Culture traversed the area (the Fremont practiced part-time agriculture, made ceramics, and occupied settled villages in nearby Utah from approximately A.D. 500–1300 [Jennings 1974]), but there is no evidence that specifically identifies their presence in the study area. Variation in projectile point form suggests occupation began in the early Archaic Period, although the area seems to have been used principally during the last 1,500 years (Buckles 1971; Nickens 1988).

Field Methods

Given the rich nature of the area's surface archaeology, and a goal of exploring structure and organization within and between the various chipping-debris scatters, full-coverage survey using the previously described methods was attempted. A grid of 4-m squares was superimposed over the study region; 100 such squares (10 rows by 10 columns for a 40-m × 40-m area) were laid out at a time by a crew of two surveyors using a transit and meter tapes. Pin flags and large flagged nails were employed to mark grid corners.

"Saturation" survey methods were employed in each grid to eliminate discovery biases. As a start-point, only those artifacts greater than 5 mm in size were considered, to allow greater uniformity in the recorded data. Each grid was inspected by a two-person crew. The team began in opposite corners of a square, with each person walking four 1-m-wide transects. This process was then repeated a second time with transects in an orthogonal direction. As a consequence, each square was surveyed four times with 1-m transects, and any locus was viewed from four different directions. The end result was "total coverage" survey, where few artifacts were overlooked (repeat surveys verified this to be the case). In addition to various artifact attributes recorded in the field (this was a "non-collection" survey), elevation, vegetation cover, soils, and geologic information also were recorded in each grid unit.

One issue in intensive surface mapping is the amount of field time, and therefore costs, required to map archaeological distributions across broad areas. Many studies (e.g., Ebert 1992) have "point-plotted" finds, which generally means recording their locations to the nearest centimeter, a time-consuming task. With the large number of artifacts I was faced with, and a desire to cover a large area, I decided to sacrifice precision for increased speed. Except for a single 20-m × 20-m test block containing 1,112 artifacts, each of which was point-plotted, every artifact was given the coordinate of its grid square, so most of the data were recorded to the

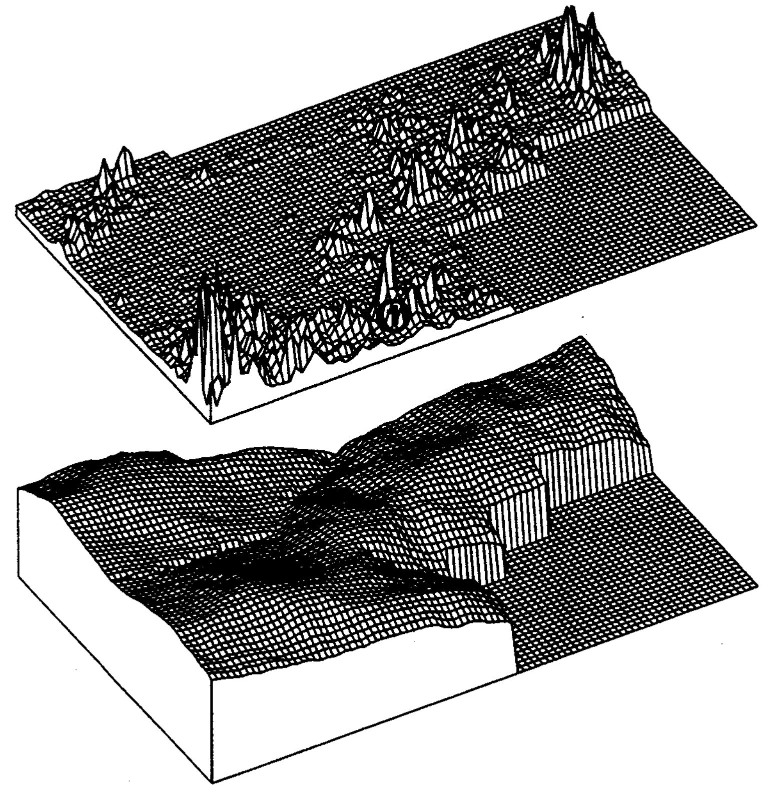

Fig. 8.1. The Colorado project area showing the total debitage count per grid square (top) and the topographic surface (bottom). The region measures 360 m × 240 m and is viewed to the northwest. The debitage cluster labeled "1" is the focus of quantitative analysis.

nearest 4-m datum. Given the scale of many prehistoric activities (percussion knapping, tool resharpening) and post-depositional factors like surface erosion, weather, and trampling by people and animals (deer, elk, cattle), which cause some amount of artifact movement, I believed 4-m precision would be sufficient to realize distributional patterning. The results given below confirm this to be the case.

A total of 3,600 grid squares (4-m × 4-m) have been examined (because each square measures 16 m^2, this yields a total of 5.76 ha). Within this area, 23,764 pieces of debitage, nearly 1,200 chipped-stone tools and ground-stone tools, and 183 cores were discovered. The mean density is 6.7 artifacts per square (0.42/m^2) with a range of 0–205 items (up to 13/m^2). In most of the analyses that follow, however, only a subset of the study region is explored, using data obtained in 1989 (2,975 squares or 83 percent of the study area). This region provides the necessary data for my focus here because the 1989 field season recorded a large number of attributes for 17,741 pieces of debitage.

Patterns of Archaeological Debitage Distribution

Computer graphics, obtained through a Geographic Information System (GIS), provide an excellent means for the investigation and portrayal of archaeological spatial distributions (Kvamme 1989). A mapping of the total debitage count per grid square (i.e., debitage >5 mm in size) indicates a series of waste-flake concentrations of varying size and density that are more-or-less continuous over a large portion of the region, but there are also significant gaps and breaks in the distributions, with several isolated "islands" of flaking activity (Fig. 8.1). Comparison of the archaeological scatters with the landscape indicates that they lie principally along the gentle ridge crests that cross the study area (Fig. 8.1). Overall, this mapping shows a rather complex series of overlapping and isolated stone working areas, and the maps of the various tool distributions (not considered here) suggest similar complexity.

Recording these chipping-debris clusters as traditional archaeological sites with discrete boundaries would certainly be a difficult undertaking in operational terms, and would be inappropriate as well. Perhaps this is why archaeologists who initially surveyed the region in the mid-1970s did not even attempt to do so. They recorded the entire study area, plus a huge surrounding region, as a single "site" with boundaries defined by a large irregular circle on a topographic map (records on file, Bureau of Land Management, Grand Junction, CO).

In Figure 8.1, it is clear that the overall structure of an individual flaking concentration (the peaks in the figure) is relatively simple: there is much material near its center with density falling off with distance—the "fried egg" pattern. A similar graphic can be made for any debitage size-class, where identical patterns seem to hold for each class (Fig. 8.2a–d). Much different and more insightful views can be obtained using GIS-based manipulation techniques (Kvamme 1989). For example, if we take a debitage size-class and divide it by the total debitage count, a *proportion* of debitage for that size-class is obtained in each grid square (Fig. 8.2g–i; note that g is paired with b, h with c, and i with d). In these cases, there is a tendency for higher proportions of large-sized debitage to occur not in the flaking concentration centers, *but along the various scatter margins*. Although for any size-class the bulk of the material lies at the scatter centers (Fig. 8.2a–d), the pattern of higher peripheral proportions for large debitage classes suggests that the width or variance of these distributions about each flaking center is greater for these classes.

This perspective is enhanced through an examination of other data. By mapping the *minimum* debitage size per grid square (Fig. 8.2f), it is clear that the flaking concentration centers are made up of smaller flakes, while larger materials seem to occur consistently around the scatter margins (cf. Figs. 8.2a and 8.2f). Similarly, although the absolute count of cortex-bearing flakes is greatest at the centers of the many flaking concentrations (Fig. 8.2e), when expressed as a proportion of the total debitage, the largest also occur in the outer reaches of the scatters (Fig. 8.2j). This parallels the pattern of the larger size classes and stems from the well-known fact that the presence of cortex tends to be correlated with size; that is, the initial flakes struck from a core tend to contain cortex and are of large size (e.g., Ahler 1989: 90). The cortex debitage pattern, then, is merely an expression of the size phenomenon (Table 8.1).

The sorting tendencies explored thus far may be examined in greater detail, and quantitatively, by focusing on patterns exhibited in one of the debitage clusters (indicated by the series of peaks immediately above the label "1" in Fig. 8.1). This cluster measures 52 m × 60 m (13 × 15 grid squares) and contains 2,254 pieces of debitage. Sixty-six contiguous and centrally located grid cells were taken to represent the cluster's central area, with the remainder (129 cells) as its periphery. The amount and proportion of debitage in each size or cortex class could then be determined in each of the two zones (Table 8.2). It is evident that the data clearly support the findings obtained visually. While the highest counts of most of the size classes occur in the central

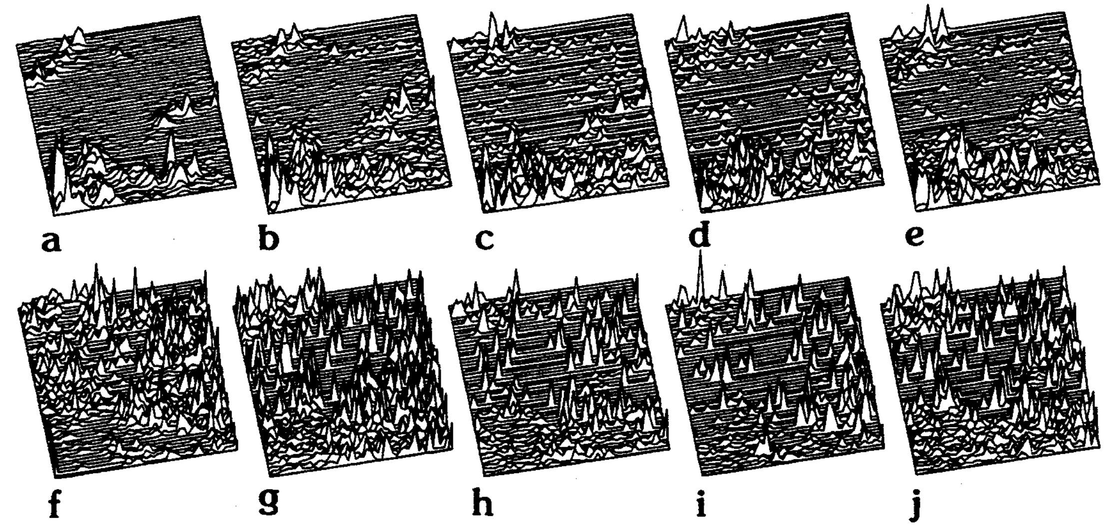

Fig. 8.2. Mappings of several debitage variables per grid square in the southern portion of the study area: (a) frequency of 5–19-mm debitage; (b) frequency of 20–29-mm debitage; (c) frequency of 30–39-mm debitage; (d) frequency of 40+-mm debitage; (e) frequency of cortex-bearing debitage; (f) minimum debitage size per grid square; (g) proportion of debitage 20–29 mm; (h) proportion of debitage 30–39 mm; (i) proportion of debitage 40+ mm; and (j) proportion of cortex-bearing debitage. This 200-m × 200-m region is viewed to the west (cf. Fig. 8.1).

	Debitage Size Class (mm)					
	5–9	10–19	20–29	30–39	40+	TOTAL
CORTEX:						
Present	40	646	590	321	473	2,070
	(.019)	(.312)	(.285)	(.155)	(.228)	(.117)
Absent	2,749	8,634	3,073	868	347	15,671
	(.174)	(.551)	(.196)	(.055)	(.022)	(.883)
Total Debitage	2,789	9,280	3,663	1,189	820	17,741
	(.157)	(.533)	(.206)	(.067)	(.046)	(1.000)

Table 8.1. The relationship between the presence or absence of cortex and debitage size in the Colorado scatters. Parenthetic figures are row proportions except for those in the last column that refer to assemblage-wide proportions.

	Debitage Category (mm) 5–9	20–39	40+	Cortex	Total
SCATTER ZONE					
Center (66 squares)	1,339 (.803)	291 (.175)	37 (.022)	208 (.125)	1,667 (1.000)
Periphery (129 squares)	340 (.579)	205 (.349)	42 (.072)	94 (.160)	587 (1.000)
Total Debitage	1,679 (.745)	496 (.220)	79 (.035)	302 (.133)	2,254 (1.000)

Table 8.2. Data from one of the Colorado debitage scatters by size and cortex classes showing differences between center and periphery zones (row proportions are given parenthetically).

region of a flaking cluster, greater proportions of large debitage and of cortex pieces exist along the scatter margins (Table 8.2).

Explanatory Models of Debitage Sorting

Even a cursory examination of the archaeological literature on site formation processes suggests that a number of factors might account for the observed debitage size-sorting. Studies that explore the post-depositional effects of trampling and scuffage on artifact scatters, whether by humans or animals, have asserted size-sorting effects. One of the most forceful of such pronouncements is that of Stevenson (1991) who claims that trampling, which tends to push smaller artifacts into the ground, and scuffage, which generally displaces larger items to the side, cause a significant size-sorting effect, to the point where it constitutes a major site-formation process. Stevenson's arguments, however, do not specifically refer to chipping debris, but pertain instead to artifacts and other debris (bone, rocks) in general, and are not supported with quantitative data.

Several studies have examined the effects of trampling and scuffage specifically on chipping debris, but with generally inconclusive results. Nielsen (1991) reports a non-significant positive correlation between flake length and distance moved, while Pintar (1987; reported in Nielsen 1991) derived a non-significant negative correlation. These findings are in agreement with those of Villa and Courtin (1983), who concluded that no relationship exists between artifact weight and horizontal displacement.

Trampling and scuffage by humans and animals were undoubtedly at work in the Colorado study region. Yet, even if we assume that these processes can produce significant size-sorting in debitage scatters, it would also have to be assumed that trampling and scuffage were confined principally to the centers of each of the flaking concentrations depicted in Figure 8.1—trampling to push the small debitage into the ground and scuffage to move large pieces to the scatter peripheries. The data indicate that flaking activity often was spatially distinct from other activity areas (supported by the mapping of tool distributions, such as those for ground-stone tools). Consequently, people most likely walked and trampled artifacts *everywhere* along the study area's ridge tops (Fig. 8.1), not just at the centers of the flaking concentrations. It is unlikely, therefore, that this process accounts for the observed debitage size-sorting.

Post-depositional scavenging behavior is another process that might have an influence on size-sorting. Prehistoric visitors to the study region undoubtedly scavenged lithic raw materials from previously existing debris scatters on occasion, especially when such stone was in short supply. Chipping-debris scatters can provide a ready source of raw material, particularly for small and expedient tools (Camilli and Ebert 1992). In most cases, there was probably a selection preference for larger pieces of debitage that would yield more material for flint-knappers to manipulate. For scavenging behavior to have caused the observed size-sorting, it would have to be assumed that generally large pieces were selected principally from each of the flaking cluster centers, and that it was a fairly intensive and consistent activity from scatter to scatter. It seems more likely, however, that scavenging of lithic resources was more haphazard and that it affected all portions of the many scatters that cover the study region's ridge crests (Fig. 8.1).

Gradient and slopewash have been used to explain size-sorting (Schiffer 1987), but this process, too, seems unlikely to account for the debitage sorting pattern. The general principle is that larger items tend to migrate downslope somewhat more rapidly than small items, although in some cases, particularly with fluvial action, the reverse can occur (Allen 1991; Rick 1976). The ridge flanks of the study area generally possess very mild slopes (5–8 percent grades), although in one small region the slope does achieve nearly a 25 percent grade (Fig. 8.1). All of the chipping-debris concentrations exist on the ridge crests, however, which are very level (slope <2 percent). Although slope movement might exacerbate size-sorting where the chipping-debris occasionally spills down the sides of the ridges, it cannot account for the sorting on the level ridge tops, especially where the proportion of large debitage increases in up-ridge directions.

I believe that a simple physical process stemming from the mechanics of percussion flaking may explain the size-sorting characteristics seen in the Colorado scatters. In percussion-based stone-working it is well known that the creation of a large flake generally requires a stronger blow than a small one (see Cotterell and Kamminga 1987 for a discussion of the mechanics of this process). Simply put, it is this stronger blow that causes larger flakes to travel somewhat farther from the point of impact than small flakes. Additionally, large flakes, with more mass and momentum, will generally bounce or rebound a greater distance on the ground than small ones, further contributing to a greater overall dispersal of artifacts.

Given the preponderance of percussion-based knapping in prehistoric North America and elsewhere (Bordes 1969; Crabtree 1972), it is quite likely that the simple mechanics resulting from this stone-working practice principally account for the observed size-sorting structure—a phenomenon so robust that it remains apparent in the somewhat coarse resolution data (the 4-m database) and despite the numerous post-depositional processes that can affect chipping-debris scatters, namely, scavenging, trampling, scuffage, and gradient and erosional transport. In order to test this physical process model, and to explore further the nature and mechanics behind percussion-based knapping, experimental stone-working was undertaken.

An Independent Test of the Debitage Sorting Phenomenon

A series of controlled stone-working experiments were designed to test the hypothesis that the physical processes associated with percussion flaking create a debitage sorting phenomenon. Four debitage-producing flaking episodes were performed by Kenneth C. Rozen, a stone-worker of national renown, using exclusively percussion-based knapping. Two of the experiments were intended to produce as many large flakes as possible (which presumably could be used as implements or could be retouched to produce tools) by reducing coarse-grained and fine-grained quartzite cores through hard-hammer (stone) percussion. The remaining two experiments attempted to produce bifaces from large flakes of English flint and obsidian using soft-hammer (deer antler) percussion. Each flaking episode was performed at a single fixed locus, in a standing position, on a rough concrete floor.

It should be noted that most archaeologists assume

		5–19 (mm)	20–39 (mm)	40+ (mm)	No Cortex	Cortex
FLAKING EXPERIMENT						
Hard-Hammer 1 (coarse-grained quartzite)						
	mean	0.712	0.995	1.089	0.733	0.928
	s.d.	0.719	0.894	0.778	0.717	0.888
	n	617	76	50	617	126
Hard-Hammer 2 (fine-grained quartzite)						
	mean	0.915	1.343	1.055	0.938	1.098
	s.d.	0.863	1.026	1.083	0.892	0.979
	n	263	44	40	244	103
Soft-Hammer 1 (English flint)						
	mean	0.348	0.377	0.532	0.343	0.634
	s.d.	0.501	0.632	0.879	0.519	0.723
	n	851	75	31	926	31
Soft-Hammer 2 (obsidian)						
	mean	0.285	0.18	0.111	0.212	0.316
	s.d.	0.414	0.262	0.174	0.402	0.422
	n	1,206	110	9	1,216	109

Table 8.3. Distance (m) from flaking locus statistics by size and cortex debitage classes for each of four stone-working experiments.

that aboriginal peoples sat or squatted while working stone. The few available ethnographic examples support this view (Binford and O'Connell 1984; White and Thomas 1972), although some lithic technologists argue that upright stances may have been occasionally employed. The standing position tends to produce a wider scatter because as each flake is struck from the core it follows an arcing trajectory. The greater distance of the knapper's hands from the ground when standing (about 1 m, instead of 30–50 cm when squatting or sitting) means that the debitage must come to rest a greater distance away, a fact well illustrated by Schick (1986) and Newcomer and Sieveking (1980), who explored the effects of knapper stance on debitage dispersal. Thus, the knapper's position must affect only the extent of the overall scatter, not the presence of size-sorting patterns that might be inherent in it. The concrete floor undoubtedly augmented the rebound factor, causing debitage to bounce farther than on an earthen surface, thereby creating an additional amount of dispersal (cf. Newcomer and Sieveking [1980] who used a wooden surface to reduce this effect in their experiments).

Several variables were recorded for each piece of debitage, including maximum length, the presence or absence of cortex, and the debitage's spatial coordinates in a locally established grid system. Some of these data, for one of the hard-hammer experiments, are shown in Figure 8.3. What is noteworthy is the strong similarity in the experimental scatter patterns and those seen in the Colorado archaeological scatters (Fig. 8.2). Specifically, the largest amount of debitage occurs near the scatter center for any size-class and for cortex-bearing

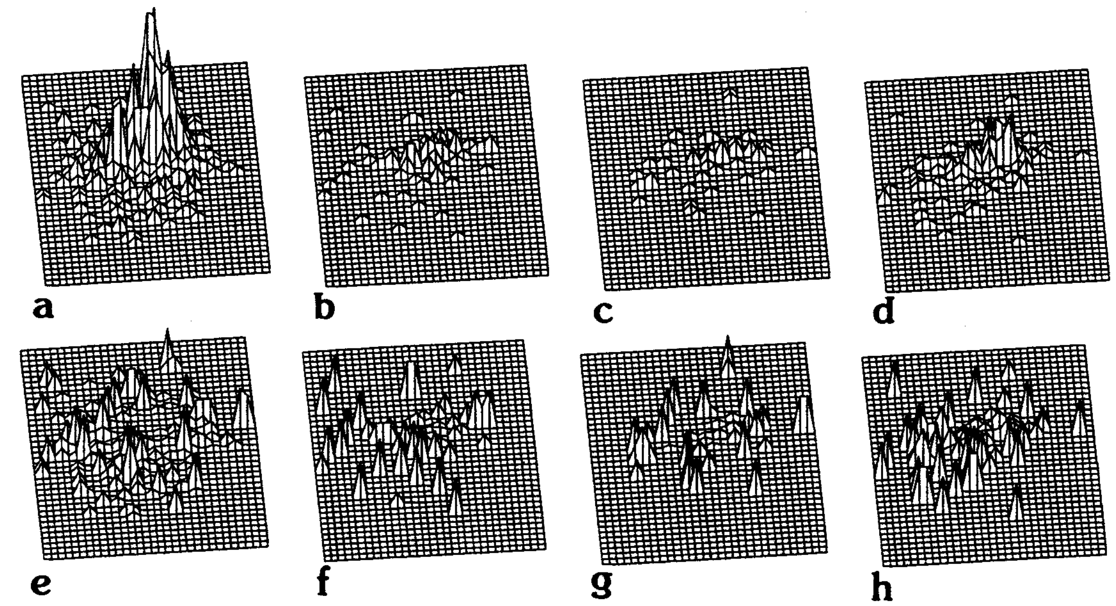

Fig. 8.3. Results of one hard-hammer percussion-flaking experiment mapped in 20-cm × 20-cm grid squares: (a) frequency of 5–19-mm debitage; (b) frequency of 20–39-mm debitage; (c) frequency of 40+-mm debitage; (d) frequency of cortex-bearing debitage; (e) minimum debitage size per grid square; (f) proportion of debitage 20–39 mm; (g) proportion of debitage 40+ mm; (h) proportion of cortex-bearing debitage.

debitage (Fig. 8.3a–d), while the minimum flake size and the proportion of large debitage and cortex flakes are greatest about the scatter periphery (Fig. 8.3e–h).

In order to examine the experimental results quantitatively, a computer program was written to calculate the Euclidean distance between each item of debitage and the locus of flaking, defined as a 20-cm radius circle (to allow for hand movement) between, and slightly in front of, the knapper's feet. These data are summarized in Table 8.3 for each of the four experiments. Clearly, the mean distance from the flaking locus tends to be greater for the larger flake classes than the smaller ones, a property also reflected by larger standard deviations in the distance statistics (Table 8.3). Consequently, with increased distance from the knapper, a greater proportion of large items must occur, a tendency illustrated in Figure 8.3f–g. This circumstance is made even clearer in Figure 8.4, which graphs the proportions of debitage for large, small, and cortex classes that are to be found beyond various distances from the knapping locus for the same hard-hammer experiment shown in Figure 8.3. For example, only 0.27 of the 5–19-mm debitage extends beyond 1 m, but 0.40 of the 20–39-mm and 0.53 of the 40+-mm material were recovered at this or greater distances. The data also illustrate similar tendencies between the cortex and non-cortex debitage (Fig. 8.4).

An important exception to the foregoing patterns lies in the second soft-hammer percussion experiment, which was performed using obsidian (Table 8.3). The amount of force required to remove an obsidian flake is considerably less than what is necessary to drive flakes from English flint or the coarse-grained and fine-grained

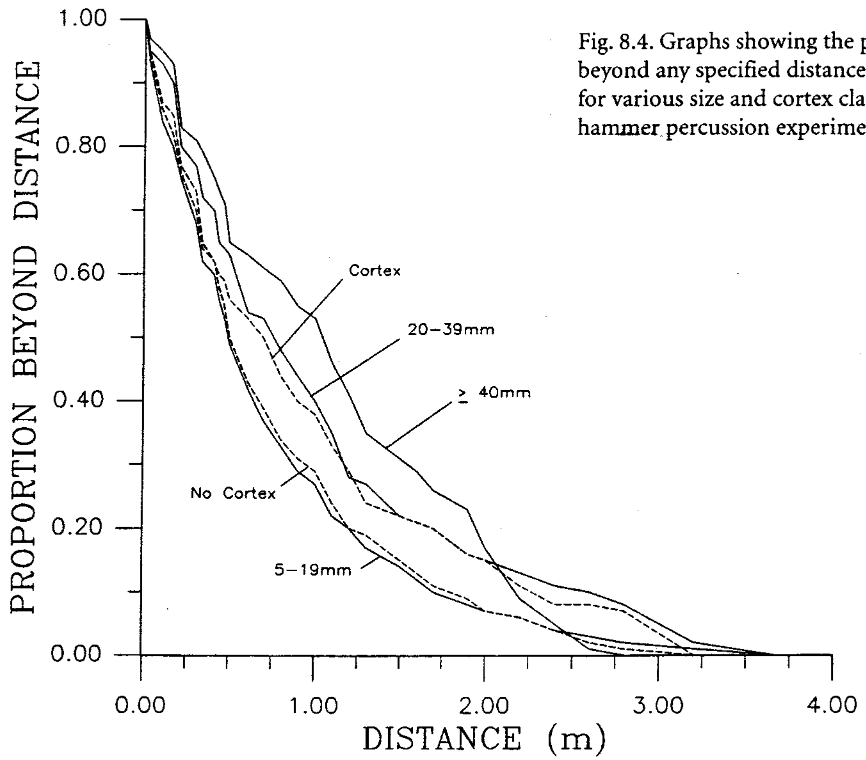

Fig. 8.4. Graphs showing the proportion of debitage beyond any specified distance from the flaking locus for various size and cortex classes yielded by the hard-hammer percussion experiment (cf. Fig. 8.3).

quartzites employed in the other experiments. It was also observed that the more finely controlled and softer blows caused many of the larger flakes to fall directly into the knapper's hand. Periodically, the knapper would empty his hand, dropping these flakes to his feet, thereby producing the reverse sorting order seen in Table 8.3 (this occurred to a much lesser extent in the other biface-producing experiment that employed more difficult-to-flake English flint). Thus, percussion flaking with obsidian and other highly vitreous or flakable materials may produce an exception to the general rule of debitage size-sorting in spatial distributions (incidentally, no obsidian was encountered in the Colorado data set; most of the material consisted of quartzites and cherts). Clearly, additional work is needed, some of which is underway (Kvamme 1996). In any case, the weight of the evidence presented here suggests that certain forms of percussion-based stone-working produce a size-sorting effect. This phenomenon may, therefore, represent a key formation process of chipped-stone debitage spatial distributions.

Discussion

If we acknowledge that debitage size-sorting in the spatial domain results from a single percussion-based flaking event, how is it that the Colorado scatters, which are clearly the result of numerous flaking events (evidenced

by many diverse stone types), still yield overall indications of size-sorting? In answering this question we might imagine several successive knapping events conducted at the same spot; in this case, the sorting phenomena would have an "additive" effect, strengthening the overall pattern. More often, however, new flaking episodes would probably only partially overlap earlier ones (Carr 1984; Sullivan 1992). In these cases, the centers of the new episodes would overlay various margins of the older ones, thereby "overwriting," to a large extent, sorting that might have been previously obvious (because of the large amount of debitage at the new flaking event center). Each new flaking episode would, however, extend the perimeter of the cumulative scatter, and it is in this margin that debitage size-sorting will remain obvious. Thus, as the areal extent of a debitage scatter grows through time, its perimeter will contain a higher proportion of large debitage while the increasingly dense interior, composed of the flaking episode centers, will be dominated by a preponderance of small material. The consequence is that debitage size-sorting remains obvious despite the cumulation of numerous, haphazardly placed flaking events. The mechanics of this process are clearly illustrated through computer simulation studies (Kvamme 1996).

Conclusions

I have identified an intrinsic spatial property of chipped-stone debitage scatters; specifically, a subtle sorting in space by flake size, and therefore by type (owing to correlations with size), is discernible in the archaeological surface record. This discovery was made possible because new intensive survey methodologies ensured uniform surface coverage and eliminated artifact discovery biases. By obtaining unbiased full-coverage surface information from a broad region, a complete picture of debitage spatial distributions was obtained for a host of flaking-debris scatters. Biased samples, even from 5-m survey intervals, would have yielded an incomplete picture and quite likely would have precluded the discovery of the patterns reported here. It should also be noted that the identification of these patterns was greatly facilitated by the visual exploratory data analysis capabilities provided by GIS computer graphics.

A number of post-depositional formation processes were examined that might account for this phenomenon, but all were ruled unlikely. Rather, a model was advanced that focuses on the physical processes associated with percussion-based knapping itself as the principal cause of size-sorting in surface archaeological debitage deposits. Simply put, the stronger blows necessary for the removal of large flakes in all but the most vitreous of materials (e.g., obsidian) impart to them a tendency to travel somewhat farther than small flakes from the knapping locus. This model was tested with experimental stone-working data, which clearly showed that large pieces of debitage do tend to travel a greater average distance from the knapper than small ones. Maps of the resulting experimental distributions paralleled completely the patterns observed in the Colorado archaeological scatters.

Given that chipped-stone scatters are probably the most prevalent archaeological phenomenon worldwide, the recognition of this pattern may be an important step toward their better understanding. In any case, debitage size-sorting in the spatial domain caused by percussion-based flaking activity may constitute a fundamental formation process of archaeological debitage scatters.

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SURFACE ARCHAEOLOGY

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Preface
Surface Phenomena in Archaeological Research

Alan P. Sullivan III

In the concluding chapter of *Myth in Primitive Psychology* (1926), Bronislaw Malinowski bluntly asserted that studies of myth ought to be based on high-quality fieldwork, or "open-air anthropology" (p. 93). Malinowski euphemistically exhorted his colleagues to get off their verandas, to embrace the difficulties of gathering primary field data, and to make some real progress regarding perennial questions in anthropology (e.g., Wright and Dirks 1983). Such boosterism would seem appropriate today for the study of surface archaeological phenomena. This book, in fact, is intended to refocus attention on them and their interpretive potential.

Anthropological archaeologists typically examine variability in the archaeological record and assess its implications for inferring aspects of the cultural past. Regardless of venue, problem, or funding source, archaeologists routinely initiate the research process by acquiring, through numerous methods, variation that is expressed by contemporary properties of the archaeological record's superstratum, or its surface. Because of their diverse, dynamically contingent origins, surface archaeological phenomena range from barely discernible anomalies embedded in natural background settings to highly patterned temple-city layouts—the scope of phenomena explored in this volume.

Approaches for investigating surface archaeological phenomena can be grouped heuristically into two classes, which are illustrative rather than exhaustive (see Lewarch and O'Brien [1981] for a comprehensive review). First, some archaeologists presuppose that inherent and essentially uncontrollable biases attenuate dramatically the interpretive potential of surface archaeological phenomena. An extreme but not uncommon view is that surface phenomena, especially those encountered in agricultural fields that have been plowed repeatedly, are indeed so sullied that they can be either discarded or ignored in order to get at "genuine" or "good" (i.e., pristine or uncontaminated) subsurface archaeological data. Second, in those circumstances when surface archaeological phenomena have been neither discarded nor ignored, it is commonly asserted that their limited research potential is exhausted if they serve as beacons simply for locating subsurface archaeological phenomena. In both cases, importantly, surface archaeological phenomena are denied interpretive value in their own right.

In marked contrast, the contributors to this volume share the conviction that surface archaeological phenomena have intrinsic interpretive potential that largely has gone unexplored. They further hold that the value of surface archaeological phenomena neither depends upon nor derives from characteristics of subsurface archaeological phenomena (cf. Ebert 1992). In fact, as several of the chapters illustrate, mystifying subsurface archaeological patterns can be clarified only after an exhaustive study of the surface material.

In sampling a broad range of archaeological contexts, the studies in this volume sustain the important theoretical point that the interpretive potential of surface phenomena is affected by the degree to which their origins can be ascertained reliably (Lewarch and O'Brien 1981: 298). If indeed there are limitations in the interpretive value of surface archaeological phenomena, then those limitations need to be demonstrated analytically rather than simply assumed. Along these lines, it is worth recalling Dunnell and Dancey's (1983: 269) aging but nonetheless timeless observation that the subsurface record is ultimately derived from surficial depositional events and processes. The obvious and crushing logical consequence of their sagacious comment is that if, as some archaeologists allege, the surface archaeological record is flawed, then the interpretive sanctity of the subsurface record may be somewhat overrated.

This volume consists of five interrelated thematic sections. In Part I, "Surface Archaeology of Landscapes," the chapters by William S. Dancey and LuAnn Wandsnider provide a basis for appreciating how the surface archaeological record is formed under various circumstances and how archaeologists may take advantage of that knowledge for sundry research problems. Specifically, Dancey illustrates how strong inferences regarding the evolution of settlement patterns can be developed from the systematic examination of regionwide occupational debris, which includes plowzone assemblages. Wandsnider shows how ethnoarchaeological observations among nomadic herders in India assist in unraveling the complexity of archaeological landscape use and formation in arid lands.

Part II, "Surface Archaeological Data and Prehistoric Settlement Dynamics," consists of studies by Michael P. Smyth, by Robert P. Connolly and me, and by James M. Bayman and M. Guadalupe Sanchez. These chapters elucidate the extent to which our knowledge of the cultural past is enriched by detailed analyses of surface archaeological data and, coincidentally, how fragile our models may be if they do not incorporate a consideration of superstratum variation. For example, Smyth finds scant basis for the common assumption that monumental Mayan architecture is invariably associated with urban elite residence. Connolly and I develop evidence for extensive domestic habitation at Fort Ancient, a large earthworks that has been interpreted conventionally as principally a vacant ceremonial center. Bayman and Sanchez illustrate the usefulness of several methods for inferring the tremendous spatial scale that was entailed by the organization of Classic Period Hohokam political economy.

In Part III, "Surface Data, Subsurface Data, and the Reconstruction of Depositional Histories," studies by Rebecca A. Hawkins and by Christian E. Downum and Gregory B. Brown examine the relation between surface and subsurface archaeological data sets. Hawkins's intriguing findings indicate that a consideration of the full content of the plowzone is crucial for reconstructing the spatial organization of Fort Ancient villages in the Midwest. Downum and Brown's analysis of Hohokam data reminds us of the extent to which formation processes influence the emergence of variation in the surface and subsurface abundance of different artifact classes—sometimes in predictable ways, sometimes not.

Part IV, "Surface Archaeological Phenomena and Archaeological Methodology," consists of two chapters. Using results from experimental archaeology and "saturation" surface survey methods, Kenneth L. Kvamme tests models that pertain to the very origins of surface phenomena themselves. Many archaeologists will find both disturbing and sobering his conclusions regarding the factors that influence debitage size-sorting and the formation of large artifact-scatters. In a related study, Anthony S. Tolonen and I explore how reliably different diversity indices measure assemblage variability in light of the seemingly intractable sample size-richness dilemma. Although some issues regarding the sources of the dilemma were clarified with our simulations, a general solution to this perennial problem is not yet within our grasp.

Finally, in Part V, "Global Significance of Surface Archaeological Phenomena," Alan H. Simmons and Joseph A. Tainter each discuss, from slightly different perspectives, the theoretical importance of surface phenomena for global heritage management. Drawing on his extensive firsthand experience with a wide range of archaeological contexts, Simmons provides compelling examples of how serendipity and astute observation affect profoundly our models of regional prehistory, especially when small sites, "unpromising" sites, and previously unrecorded archaeological phenomena are considered. Similarly, Tainter eloquently argues that our criteria for what constitutes an appropriate venue or subject for archaeological investigation are embedded in educational traditions and public institutions whose short-term

agendas lurch about largely independently of professional archaeology. As Tainter shows, these problematic factors affect our interpretive models, research designs, and the management policies that govern the conservation of the surface archaeological record itself worldwide.

Some readers might be disappointed to find no "universal overarching body of formal theory of surface phenomena" (Lewarch and O'Brien 1981: 300), although snippets may be found in every chapter. Part of the difficulty is that we have just begun to gauge the magnitude of such a task as we encounter and try to make sense of surface archaeological phenomena and their variation (cf. Clarke 1973: 7–10). Another aspect of the problem is that we have only recently started to appreciate the inferential potential of "open air" archaeology (apologies to Malinowski) as we expand and test new methods for investigating surface remains (Cherry et al. 1991; Steinberg 1996). At the least, *Surface Archaeology* will have had an impact if it simply inspires archaeologists to reflect upon how they might employ this historically abused, though primary, source of data in their research.

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