EXPERIMENTS ON ARTIFACT DISPLACEMENT IN CANYONLANDS NATIONAL PARK

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INTRODUCTION

How materials discarded by humans change in character and context through time has become a topic of study that transcends theoretical approaches in anthropological archaeology. Identifying variables that are important to gaining some insight into the history of these artifact assemblages (i.e., formation processes) is, as Wandsnider (1987:150) aptly notes, "an immature avocation in archaeology." Nevertheless, the growth of the study of formation processes continues to provide optimism that the study of the organization of prehistoric cultural systems is a productive line of research in anthropology.

The integrity of the archaeological record is a dimension of research that is fundamental yet uniquely a problem to anthropological archaeology. Numerous studies have been conducted since the 1970s concerning the effects of the physical environment and animal (including human) activities on our interpretations of archaeological remains (e.g., Frink 1984; Fuchs et al. 1977; Gifford-Gonzalez et al. 1985; Nash and Petraglia 1984; Odell and Cowan 1987; Osborn et al. 1987; Pryor 1988; Roper 1976; Stockton 1973; and Yorston et al. 1990). The effects of natural processes on the archaeological record in arid and semi-arid regions is of special interest because the ground surface yields a highly visible archaeological record. These surface remains are therefore considered potentially useful in assessing behavioral manifestations of adaptations in the past.

The spatial configuration of artifacts and their association with other cultural and natural features is used often to build interpretative scenerios of activities at sites (e.g., Metcalfe and Heath 1990; O'Connell 1987; Simms and Heath 1990; Stevenson 1991; Stiger 1986; and Whallon 1984). Wandsnider (1989) emphasizes that the archeological record cannot be viewed as being formed through simple accumulation of debris from cultural activities, but rather through the interaction of cultural and natural processes on artifact assemblages. That is, an exposed archeological assemblage is subject to being a source of material for human activities as well as being vulnerable to disturbance by natural processes.

The present study reports an empirical investigation of artifact behavior in Canyonlands National Park in southeastern Utah. The park lies within the Canyonlands physiographic division of the Colorado Plateau, formed by the drainage system of the Colorado and Green rivers (see Hunt 1974; Stokes 1977). The area is characterized as having a cold, middle-latitude, semi-arid climate. Most of the soil is shallow, dry and without distinct horizons. Many areas have less than 20 inches to bedrock, although some areas are deeper. Eolian deposits cover several areas in this region.

Eight different microenvironments that vary in geomorphological position, but which are influenced by similar climatological factors were chosen for experiments on the displacement of lithic materials. These field experiments took place in the Island-in-the-Sky district of the park. This mesa north of the confluence of the Colorado and Green rivers lies at an elevation of 1,500–1,800 m.

The research of previous investigators suggests that predicting artifact movement on the basis of artifact attributes and/or the microenvironment of the artifact is complex. A thorough review of experimental studies of natural formation processes on lithic materials has been provided by Wandsnider (1989:398-423). No attempt is made here to reiterate this review, however several of these experiments have examined the displacement of lithic artifacts introduced into dune systems. With few exceptions, many studies to date have reported the effects of natural processes in limited time frames (e.g., Shelley and Nials 1983; Simms 1984).

Long term behavior of artifactual materials has been assessed using simulation techniques (e.g., Bowers et al. 1983; Wandsnider 1989; Yorston et al. 1990). The time frame upon which actual experimental data is collected for simulation trials is, however, critical to the interpretation of these long-term movement sequences. Wandsnider (1988, 1989) emphasizes geomorpological research that suggests the behavior of introduced objects on a land surface is likely to be highly active until the surface reaches a stable-equilibrium and the objects settle-in (e.g., up to one year).

Those conditions that determine the surface displacement of lithic artifacts with varying attributes yield variables that permit the exploration of relationships between these flakes, their movement, and the variability in their geomorphological position on the landscape. Environmental conditions that are considered to affect artifacts in these different microenvironments include precipitation, temperature, wind direction, and wind velocity. The complex relationships between artifact attributes, geomorphological position, and climatic conditions were investigated to ascertain the extent to which displacement from the position of discard was influenced by the effects of long-term environmental conditions.

Fundamental questions that arise when observing the variable density of artifacts visible on the surface in southeastern Utah include: how do meteorological conditions in this environment affect the integrity of archeological assemblages and secondly, is there some predictive means by which we can assess the state of assemblage integrity when attributes of artifacts, ground surface, and meteorological conditions are known (see Wandsnider 1988:20)?

This study was designed as an inductive investigation of the effects of natural processes on the archaeological record to provide a foundation for assessing the spatial integrity of lithic assemblages in the park. It should be emphasized that this research focused on the impact of non-human induced variables to artifact position. Livestock grazing is currently prohibited in the park and the experimental stations were situated so as to minimize potential disturbance by park visitors and staff.

PREDICTIONS

Previous studies of artifact movement in arid to semi-arid environments allow for several expectations about the horizontal displacement of lithics. Much of the previous empirical investigations concerning artifact movement in the American Southwest has focused on sand dune geomorphology because of their observed change and the high number of lithic scatters observed under these conditions. The geomorphological history and current conditions of the Island-in-the-Sky area permit the assessments of these experiments to be used as comparative data in establishing some understanding of assemblage integrity in this environment. Expectations for this study are summarized as follows.

1. The effect of natural processes (precipitation, temperature, wind) resulting in artifact movement is assumed to vary with the degree of exposure to these factors. Vegetation characteristics of the ground surface are also known to affect eolian processes (Thomas 1988). It is expected that the total displacement of each class of artifact by size varies significantly between the eight different microenvironments studied. The attribute of size is used predominantly in these analyses because size is recognized as a determining factor in the life-history of the artifact in terms of cultural forces (i.e., discard and loss) and geomorphological forces that operate on subsequent incorporation of the artifact into sediments (see Schiffer 1983, 1987:267-269; Wandsnider 1987, 1988).
2. Geomorphological study suggests that the movement of introduced particles to a surface is greatest during the first few weeks after placement, subsequently becoming more spatially stable as part of the surface context (Wandsnider 1988, 1989). It is expected that displacement of artifacts will be greatest at all eight experimental stations during the first period (seven months) of monitoring.
3. Artifact movement is expected to vary differentially based on morphological characteristics of lithic material. It is expected that the degree of movement of lithic artifacts will be conditioned by the size and weight of the artifacts. The smaller the size and weight of the artifact, the greater the horizontal movement in all eight microenvironments.

METHODOLOGY

In March of 1984 manufactured flakes were systematically placed at eight experimental stations in the Island-in-the-Sky district of the park. Each station contained a systematic arrangement of 38 flakes produced from reddish chalcedony from the Cedar Mesa formation (Cedar Mesa Chert). (Station 4 was plotted with only 37 flakes due to an error in field placement.) Prior to field placement each artifact was weighed, its maximum length and width recorded, and

Table 1. Artifact Assemblage by Size Grade

Size Grade	N[a]	$\bar{x}^b$ length (cm)	$\bar{x}^2$ width (cm)
1	24	6.01	3.81
2	40	4.18	2.71
3	64	3.18	2.16
4	88	2.29	1.57
5	88	1.51	1.27

[a]N = Number
[b]$\bar{x}$ = Mean

size graded into five classes.[1] This artifact assemblage was sorted using a variable size grid template drawn on K and E metric scale paper. Individual pieces were moved across this template until their total surface area most closely approximated that for a particular size. Table 1 reports the mean dimensions for each size grade used in the experiment.

Each station was plotted with an equal number of artifacts per size grade. Experimental plots were layed out on intersecting axis of 1 m length, forming a 2 m x 2 m surface from which to orient measures of movement (cf. Bowers et al. 1983; Nash and Petraglia 1984). Steel spikes were used to mark the end of each one meter axis as well as the intersection of the x and y axis. Axis (Y) was aligned with magnetic north using a Brunton field compass.

Artifacts were positioned along each axis at 10 cm intervals. Each flake was situated so that the long axis of the artifact lay perpendicular to the up-down slope of the experimental plot. Flakes were numbered with India ink and coated with clear lacquer polish. This artifact number faced the ground surface to avoid deteriorating effects of the sun as well as to minimize attention to the experimental station by park visitors. Subsequent measures of displacement were made using portable meter grid frames subdivided into one hundred 10 cm x 10 cm cells. A photographic record including black and white and also color photographs was kept of each station. This documentation also included photographs taken of each cardinal direction from the experimental station.

The coordinates of each artifact's position were measured five times between March 1984 and October 1989. The frequency or intervals for these observations could not be predetermined at the outset of the experiment (cf. Wandsnider 1988:19; 1989:44). Periods between artifact observations ranged from approximately seven to 25 months. All stations were examined and artifacts measured on the same day or consecutive days, and not independently of each other.

The analysis reported here is of the horizontal movement of these artifacts. Some flakes, however, were buried by natural processes, and some buried items subsequently reappeared on the surface. A summary of the rate and frequency of artifact burial for each of the eight microenvironments studied is presented below.

Meteorological data were compiled from daily records kept by park staff using instruments located on the mesa near the current visitor's contact station. The data used here dates from March 1984, when the experimental stations were introduced, to May of 1990, encompassing the overall period in which the experimental stations were monitored. These daily records are logged on National Oceanic and Atmospheric Administration forms (WS Form E-15) that record temperature, precipitation and water equivalency, and wind data. Wind data was described using cardinal directions. Cardinal direction was translated to degrees from north for the purposes of computing. When the wind velocity was recorded as calm by park staff, direction was recorded as 0. Wind data is complete for all days except for the period from March to September 1988, during which time instruments were inoperable. Table 2

Table 2. Mean Meteorological Data by Time Period Between Artifact Measures

Period (dates)	Wind Direction*	Wind Velocity (mph)	Low Temperature (F)	High Temperature (F)	Precipitation (inches)
1 (3/84-11/84)	163.4	6.2	47.4	68.5	1.35
2 (11/84-10/85)	43.9	6.1	42.2	62.8	1.08
3 (10/85-6/86)	121.6	6.2	36.2	56.6	.53
4 (6/86-9/87)	108.3	5.2	45.1	66.0	.84
5 (9/87-10/89)	72.3	2.3	38.9	61.3	.55

*Expressed in degrees from north

summarizes the data used in these analyses by period for each observation.

EXPERIMENTAL STATIONS

Placement of the eight experimental stations was conditioned by several factors; (1) stations were located in diverse microenvironments but representative of those surfaces where similar prehistoric materials are observed; consequently many are located near prehistoric sites. (2) Experimental stations were positioned so that the likelihood of disturbance by park visitors would be minimized, yet access to the stations would allow for subsequent and repeated artifact observations. Table 3 summarizes the environmental context of these stations.

ANALYSES

The effect of natural processes (precipitation, temperature, and wind) on artifact movement is expected to vary with the surface on which the artifacts are placed. The interaction of these variables is, however, complex. Wandsnider (1989:62) outlines a complex set of interactions between artifact attributes, geomorphological, and meteorological variables. Although fewer sets of variables are considered, the question of interest here is how a basic set of meteorological variables affect artifact movement of various sizes in different microenvironments.

Precipitation, wind direction and velocity, and temperature are, of course, highly related in terms of meteorological and climatological dynamics. The effect of temperature on artifact movement is difficult to assess intuitively in this environment. However, we do know that in cold deserts there exists extreme seasonal differences in temperature and that temperature variation is often associated, in many complex ways, with precipitation and wind velocity. Precipitation, as used in these analyses, includes the water equivalency of snowfall.

This data was subjected to the least squares method of multiple regression analysis using SPSS-PC version 3.0. Multivariate analysis produced measures of the strength of the linear relationship between two variables after controlling for the effects of the other independent variables. An examination of the partial correlation coefficients allowed for an assessment of the expectations of artifact behavior and natural processes in this environment.

Some general patterns about the effect of these basic natural processes on artifacts of various sizes in different microenvironments were noted. One is that temperature had a minor effect on artifact movement, and in some cases acted as a suppressor variable, inhibiting the strength of the relationship between the other variables. Larger size artifacts (i.e., size grades 1–3) were, however, somewhat affected by temperature, although no geomorphological similarity

Table 3. Experimental Station Descriptions

Station	Soil/Substrate	Vegetation	Remarks
1	sandy	rice grass, wheat grass	level/dunes;juniper surrounds station
2	sandy/pebbles	blackbrush, piñon	gradual slope south
3	cryptogamic[a]	piñon, juniper, blackbrush	slope 10% south
4	sandy	juniper, blackbrush, miscellaneous grass	level clearing; stablized dunes
5	sandy	dense grass	level/dunes
6	cryptogamic[a]	yucca, *Opuntia*	level/on small rise surrounded by slickrock
7	sandstone	none	slickrock gradual slope to southwest
8	sandy	piñon, blackbrush, miscellaneous grass	deflated area in stablized sand dunes

[a]Cryptogamic soil is a microbiotic crust formed by cyanobacteria that, because of their ability to stablize soil particles, capture nutrients and retain moisture. These characteristics allow them to colonize areas of bare rock and soil forming a surface mass that is ubiquitous to the semi-arid cold desert of the Colorado Plateau.

between experimental stations is apparent where this effect occurs.

Wind velocity and precipitation, as may be expected, dominate in effects on artifact movement, with wind velocity showing a slightly stronger role than precipitation. Precipitation influenced movement of artifacts of a wide range of sizes in grass covered stabilized dune surfaces (experimental stations 1, 4, and 5) and in cryptogamic soil (experimental station 6). Effects of precipitation on artifacts on slickrock (experimental station 7) were also apparent but strongest on small artifacts (size grades 4 and 5), when controlling for the effects of wind velocity and both mean low and high temperature. Wind velocity showed strong association with artifact movement within a broad range of artifact sizes in sandy vegetated surfaces (experimental stations 1, 2, and 4), and especially at station 3, cryptogamic soil, irrespective of temperature conditions. It should be emphasized, however, that both precipitation and wind velocity showed strong effects at station 3, when controlling for each other and temperature.

Analysis of variance procedures was used to ascertain significant differences in the distances moved for each size grade at each experimental station during each of the five measures (time periods) made. Artifact movement in station 7 was significantly different ($P < .05$) from that of other stations in the case of at least one artifact size in multiple time periods. Table 4 shows the artifact size grades for which the difference in mean distance moved between station seven and all others by period were statistically significant. Of primary interest here is the size grades for which this difference exists. Size grade four is shown to be the most prevalent in terms of its statistical difference in mean distance moved through time. The small size of these artifacts likely accounts for this activity in all microenvironments studied. However, the absence of size grade five in each column of Table 4 beyond that of period one also reveals the vulnerability of small artifacts to the natural processes of the cold desert environment. Figure 1 shows the prevalence of size grade five to being buried in sediments of each experimental station (ES), when compared to all other size grades.[2] The variance in burial of these artifacts by weight is shown in Figure 2. Those artifacts in the 0–2 g category are those most likely to be buried in all experimental stations observed. Wandsnider (1987, 1988, 1989) also found that, in general, small artifacts are more often buried than are larger artifacts but that this tendency is enhanced by the compactness of the substrate. These analyses suggest that the smaller the artifact the more likely it will not be

Table 4. Artifact Size Grade for Which There is a Significant Difference ($P < .05$) in Mean Artifact Movement Between Experimental Station 7 and All Other Stations by Time Period

Time Periods	Experimental Stations						
	1	2	3	4	5	6	8
1	3,4,5	3,4,5	4,5	3,4,5	3,4,5	3,4,5	4,5
2	4	4	4	4	4	4	
3	3		3	3	3	1,3	
4	4	4	4	4	4	4	4
5			4	4	4	4	4
All Periods	2,3,4,5	3,4,5	2,3,4,5	2,3,4,5	3,4,5,	2,3,4,5	4,5

visible on the surface regardless of the microenvironment and that movement prior to burial is greater than artifacts of a larger size.

Artifact movement across the eight microenvironments studied appears to be quite variable (see Figures 3 and 4). Figure 5 shows this movement by size grade and weight. Station 7, an experiment of artifact displacement on slickrock is, not surprisingly, the surface on which movement was greatest when all measures are compiled. Artifacts in stations 3, 4, and 6 show the least overall displacement. Two of these experimental stations (3 and 6) are positioned in cryptogamic soil and station 4 lies in stabilized sand near the base of vertical Navajo sandstone rock.

The greatest movement during each observation is characterized, for the most part, by those of the smallest size. One exception is during period 4 (June 1986–September 1987) during which time larger, heavier artifacts moved substantially relative to other size grades at stations 2 and 4. Both of these surfaces are sparsely vegetated. However, it also can be noted that large size grades also moved a greater distance, relative to other sizes in cryptogamic soil (station 6; see also station 3).

Similar to the results of Wandsnider's study, the mobility of artifacts in all microenvironments studied here was not significantly greater during the first period of observation (March 1984–November 1984) than in later periods. As Wandsnider (1989:44) points out "Artifacts in an eolian context may be repeatedly subjected to destablizing forces and so may never come to an equilibrium position within the surface system." On the other hand, she presents evidence that an experimental study of less than ten years may be insufficient to detect a settling-effect considered by some geomorphologists to be characteristic of particles introduced to a surface.

Multivariate analysis of variance was used in a nested design to hypothesize that there was no difference in distance moved by artifacts of the five size grades within the eight experimental stations across all five time periods of observation. A statistically significant difference (Pillai's = 0.68816, $P < .0005$) between the mean distance moved by artifact size within stations across the five time periods was found. Univariate analysis results for all periods show a significant difference ($P < .05$) in artifact movement by size in all stations with the exception of periods two and three (see Table 5). No apparent meteorological cause for this lack of significance is available from the kinds and scale of variables used here. It may be worth noting that, in fact, average wind velocity for both period 2 (12 months) and period 3 (8 months) was over six miles per hour, greater by nearly two miles per hour than the mean wind velocity of the entire duration of the experiment. Furthermore, mean precipitation for period 2 (1.08 inch per month) was the second highest of the five monitoring periods.

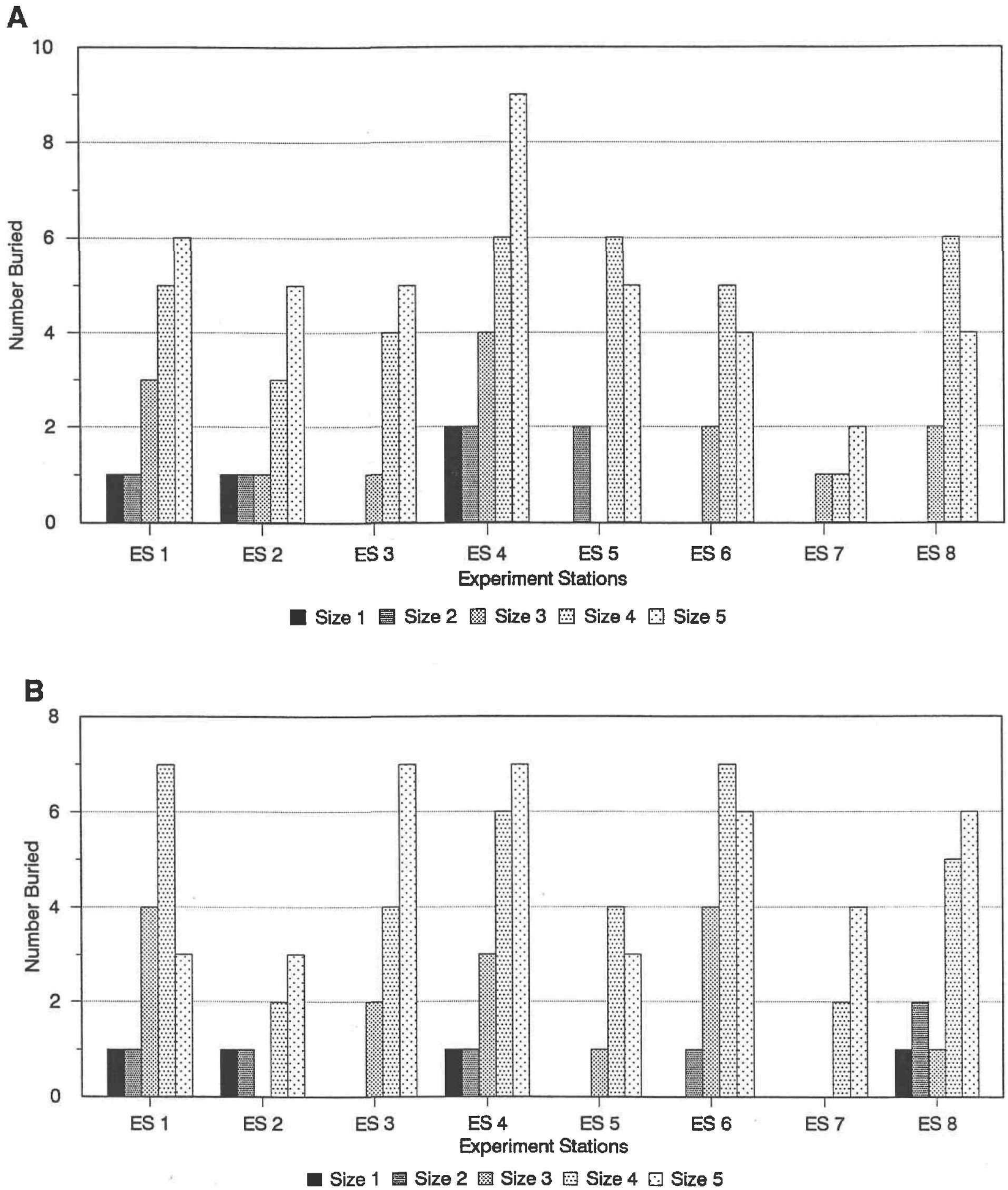


Figure 1. Exposure according to artifact size: (*A*) items found buried for at least one observation; (*B*) items found buried at final observation.

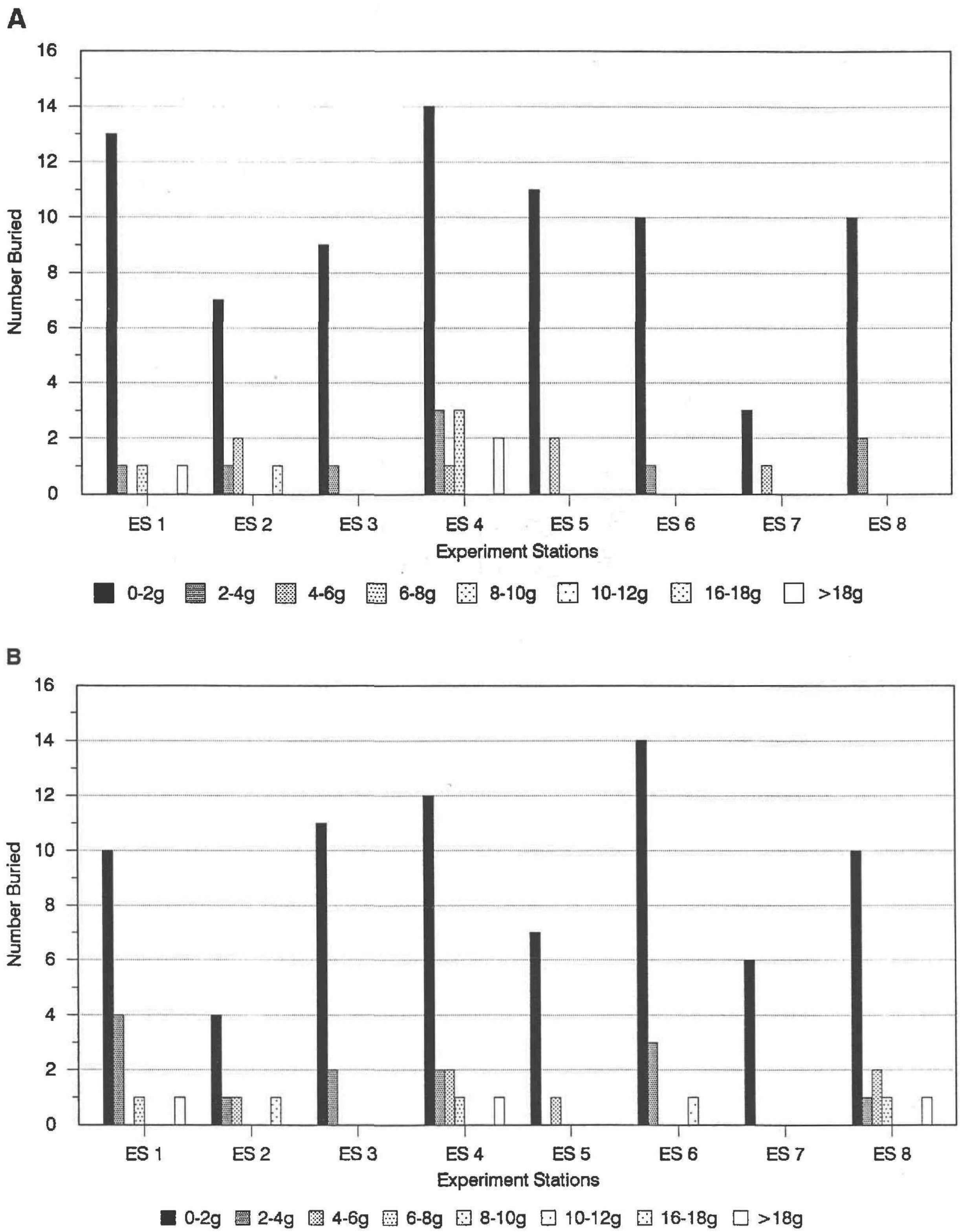


Figure 2. Exposure according to artifact weight: (*A*) items found buried for at least one observation; (*B*) items found buried at final observation.

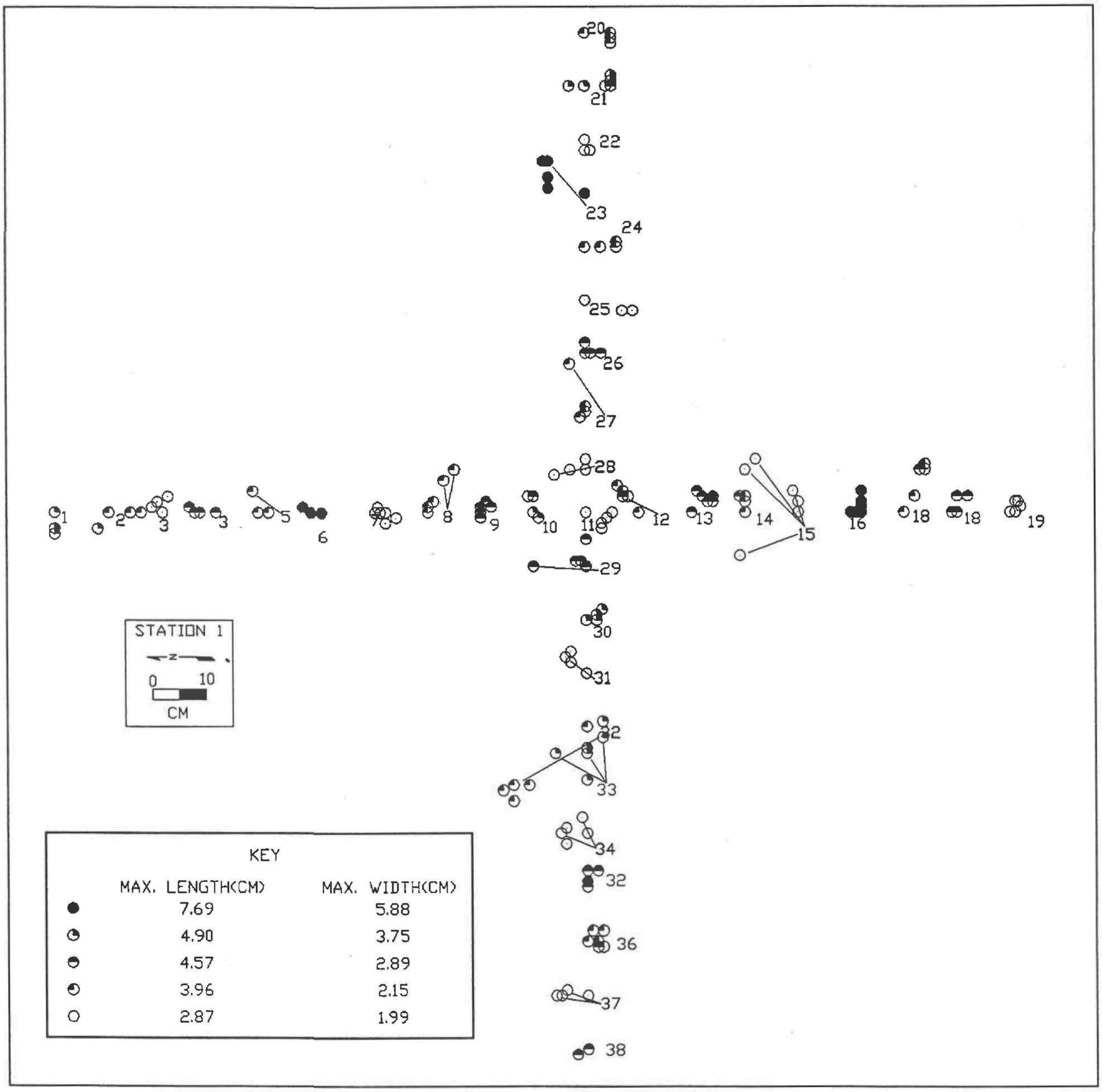


Figure 3. Artifact movement at experimental station 1 for the duration of the study.

CONCLUSIONS

One of the fundamental goals of this experiment was to assess the spatial integrity of lithic assemblages found in the study area. This assessment was needed to help establish the scale at which the surface density and diversity of artifactual materials might most profitably be analyzed. Results of this experiment permit two generalizations that are pertinent to archaeological research in this portion of the Colorado Plateau.

1. The smaller the artifact the more mobile that artifact will be through time, irrespective of the microenvironment. Smaller artifacts will be underrepresented in surface assemblages, due to their greater potential for burial. Wandsnider's (1989:16) long-term simulation analysis suggests

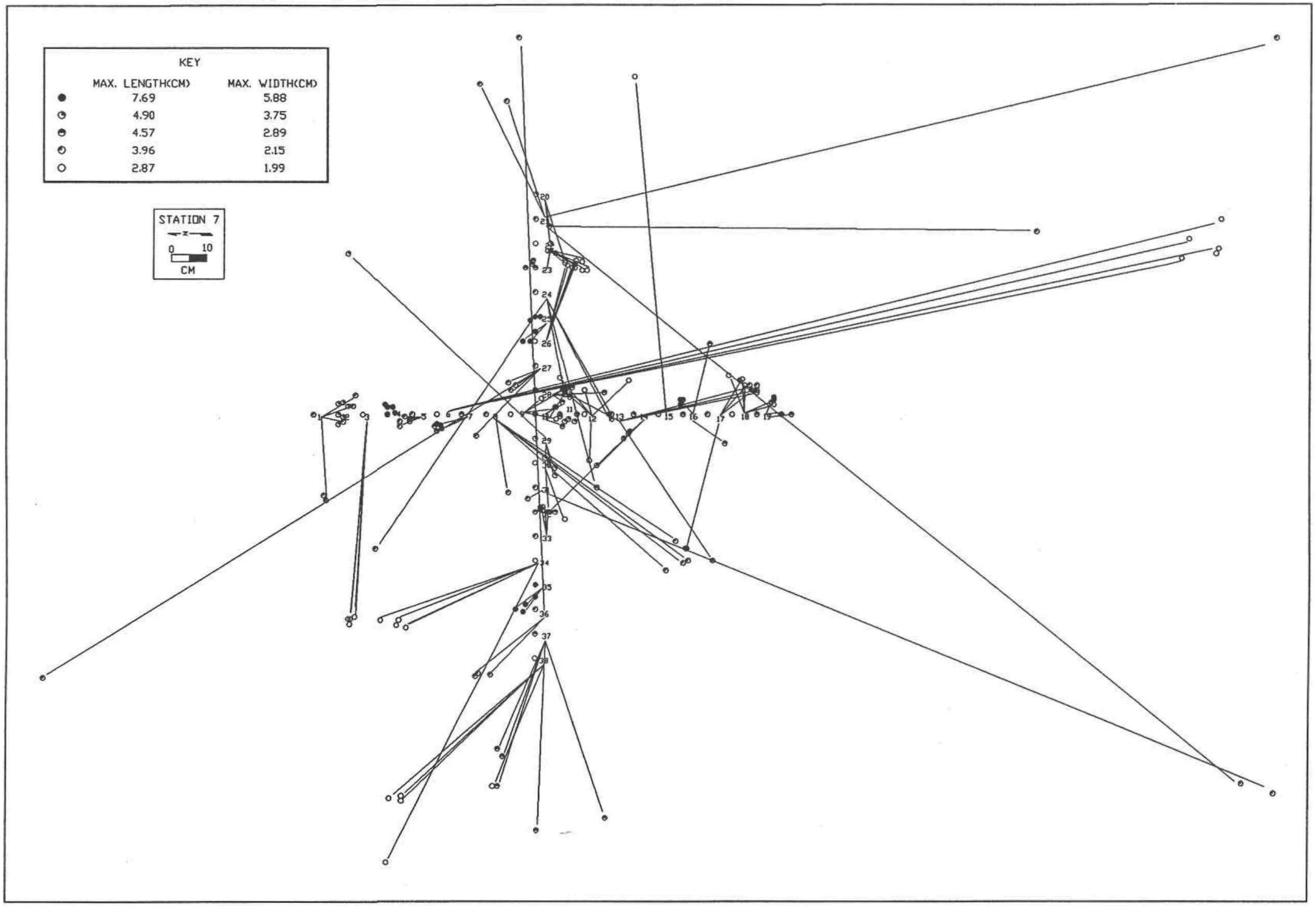
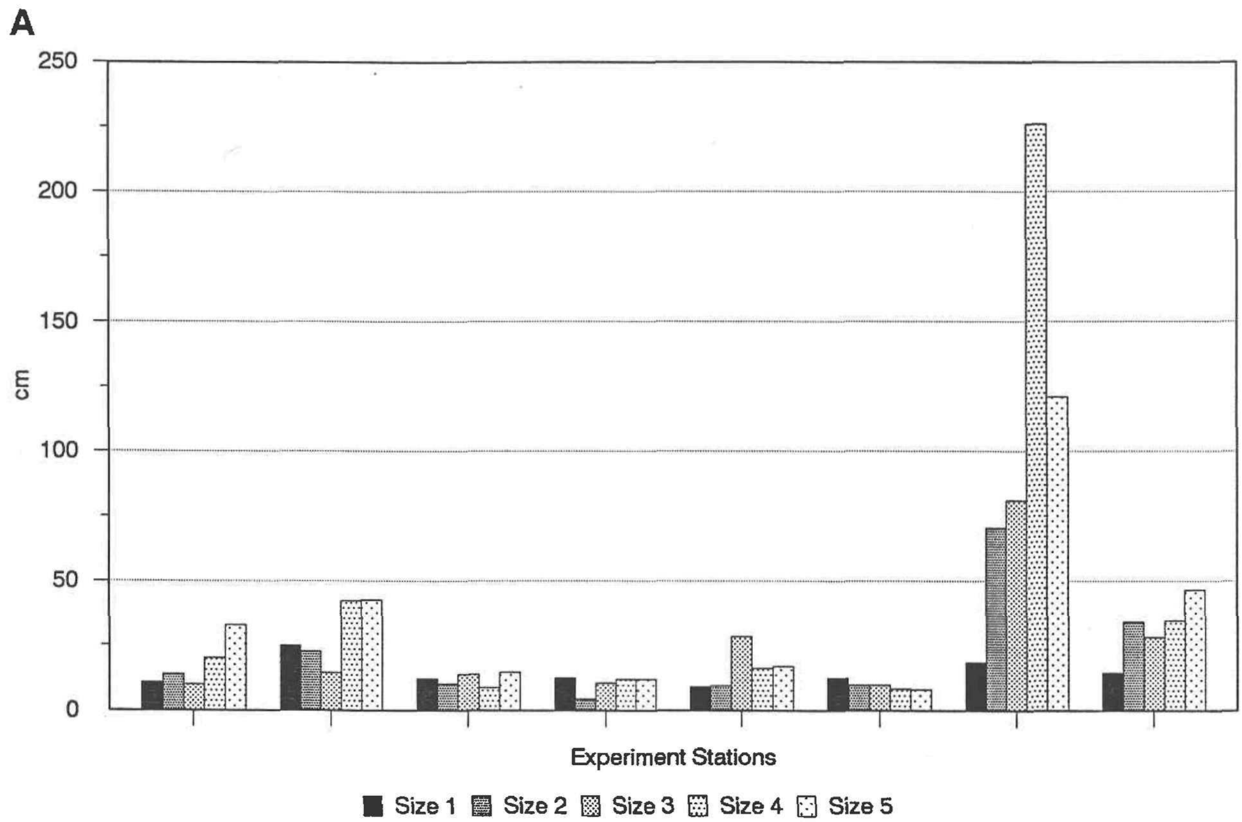


Figure 4. Artifact movement at experimental station 7 for the duration of the study.



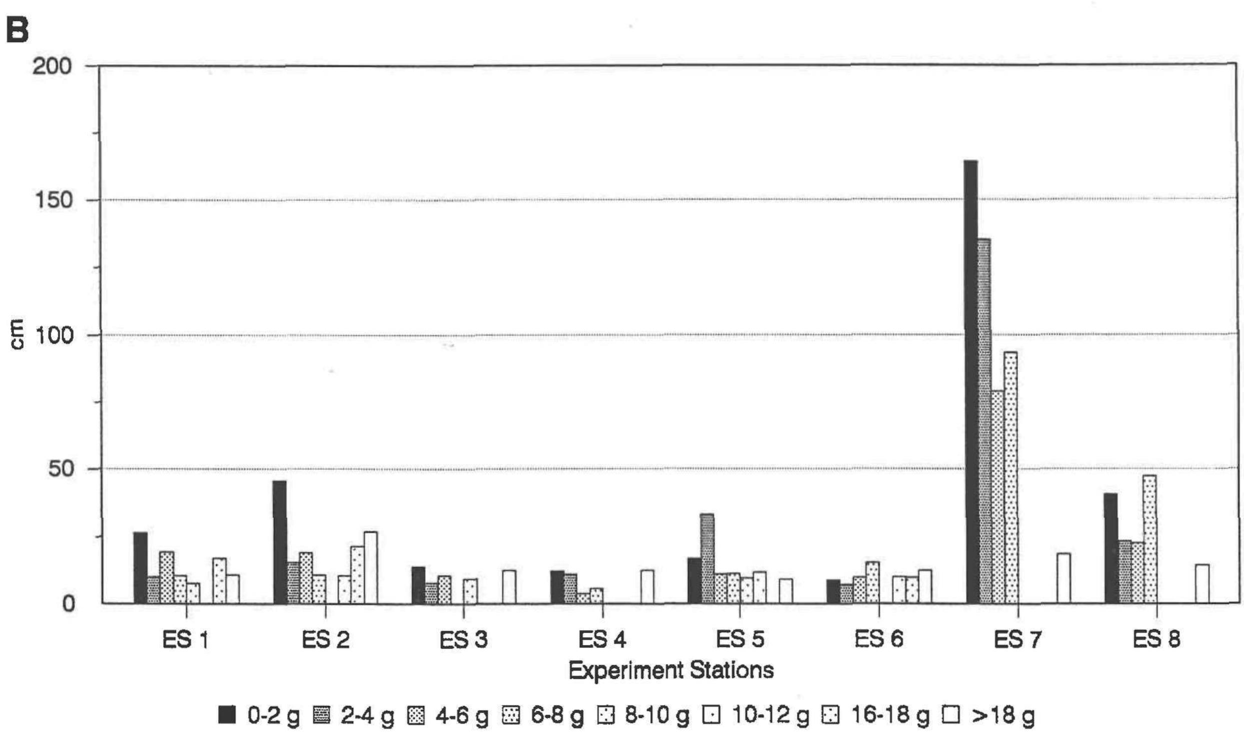


Figure 5. (*A*) Mean distance moved according to artifact size for all periods; (*B*) Mean distance moved according to artifact weight for all periods.

Table 5. Univariate F-Tests by Period

Period	F Score	Significance
Period 1	3.37973	.000
Period 2	1.45560	.070
Period 3	0.76751	.797
Period 4	1.86956	.006
Period 5	1.51747	.050

that the amount of dispersion an assemblage incurs is related to the size distribution of that assemblage. The dispersion depicted in these experiments is therefore potentially greater than that of an assemblage of approximately the same size artifacts deposited at any one point in time, due to the broad range of artifact sizes comprising each station.

2. The spatial integrity of artifactual assemblages on the Island-in-the-Sky district is sensitive to the microenvironment in which they were deposited. Artifact displacement, however, does not detract from the spatial information inherent in these assemblages when interest in patterns is on the order of .5 to 1 square meter (cf. Wandsnider 1988, 1989). The only exception to this generalization is the event of an artifact assemblage deposited on slickrock, a phenomenon characteristic of few sites located in this area.

The experimental stations described here remain in place. Hence, the mapping of horizontal displacement can be monitored indefinitely. Potentially more advantageous might be the systematic excavation of these plots to compile vertical data on artifact movement. This combined horizontal and vertical information can then be converted to data that allows systematic comparison with the data of other research for incorporation into long-term simulation analysis. Only by continuing analysis of the effect of natural processes on artifact assemblages will we be able confidently to adjust our scales of spatial analysis in different environments.

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NOTES

1. The assemblage of artifacts used in this experiment were categorized by weight in 2 gram increments, up to 18 grams with those weighing more than 18 grams included as one category. Descriptive analysis of artifact behavior by weight is presented here as comparative data only. Some statistical tests could not be justifiably considered here because not all weight classes were represented at all stations. No artifacts weighing 12–16 grams were found in the assemblage, with the exception of one flake (13.7 g) placed at station 7 that has moved a total of 18.05 cm to date.

2. The burial of an artifact in this study is defined as being a minimum of 50% below surface at time of observation.

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