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Data Collection Strategies for Assessing Artifact Zone Spatial and Associational Integrity on Sand Occupational Substrates

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Archaeological research in CRM settings should be undertaken within a problem-oriented research agenda. Expectations regarding the type of data that might be recovered based on limited or no prior testing are often used to justify proposed research questions that may serve to guide excavation for data recovery. Research conducted on subsurface hunter-gatherer archaeological zones often proposes to investigate the spatial structure of activity areas. Setting aside issues of the complex nature of temporal-sequential site use (Binford 1980), it is imperative that archaeologists who propose to analyze activity areas understand and utilize knowledge of site formation processes.

Site-formation studies emerged as part of a debate into the relationship between behavioral and geological/soils factors affecting the formation and destruction of sites (Binford 1980; Schiffer 1987). Numerous experimental studies were conducted as part of a research agenda directed toward understanding the effect of natural and cultural site-formation processes on the structure of the archaeological record and subsequent interpretations of that record (Schiffer 1978; Wood and Johnson 1978). Many of these studies borrowed from the principles of sedimentology, including particle (i.e., artifact) transport in various depositional environments, as well as from knowledge of taphonomic processes. These approaches have been applied in archaeological contexts mostly by academic archaeologists. CRM research designs sometimes mention processes of site formation and destruction, but often omit collecting data to explicitly evaluate the effects of these processes on the archaeological remains recovered from a site. In this chapter, we describe a site-testing method that takes into account site-formation and destruction processes by applying cost-effective and relatively simple techniques for excavation and data collection. This discussion suggests how CRM investigations can benefit from a geoarchaeological perspective, particularly in the early stages of site analysis (i.e., Phase II testing).

Despite a growing sophistication in analyzing formation processes (Brantingham et al. 2007; Mayer 2002), the magnitude of natural disturbance is sometimes not recognized until full-scale excavation has been completed. We argue here that careful analysis of testing and initial excavation data can prevent this from happening and, therefore, that the application of these techniques constitutes a form of "testing smarter" (Wintch, this volume). Implementation of a new data-collection strategy during testing at archaeological sites and employment of a visual tabulation or scoring method (based on the Burial Contextual Integrity Scale) provides a potential standardized means of assessing contextual integrity. The new method, which allows cultural zones to be ranked from very high to very low in terms of their potential subsurface contextual integrity, is based on collection and assessment of five categories of data derived from site test excavation: (1) cultural zone thickness and its comparison to predicted trample-zone thickness based on occupation substrate soil texture, (2) artifact orientation, (3) artifact refits, (4) krotovina volume (as an indication of degree of bioturbation), and (5) potential surface-occupation availability (based on upper and lower chronometric dates). We advocate in situ mapping of a sample of artifacts (typically with a maximum length greater than 20 mm), along with the use of artifact-level density plots, fabric-analysis/artifact-orientation data, artifact refits, and close-interval dating. As part of a strategic approach to testing, these data can help direct data-recovery efforts toward sites with the potential to illuminate problem-oriented research questions. These techniques are especially well suited to sandy settings, involving both aeolian and fluvial contexts. The Burial Contextual Integrity Scale provides a visualization tool to assess contextual integrity as individual attribute scores are combined to rank the overall integrity of the cultural deposit. If applied in an early stage of testing, excavation, and analysis, this strategy can guide decision-making about future data-recovery efforts at individual sites and allow more efficient problem-oriented research.

Site Formation and Destruction Processes

It is generally acknowledged that cultural levels containing artifacts and features that are in near-behavioral context and association are more amenable to activity-area analysis than are those in sites where artifacts are widely dispersed by noncultural processes or form complex temporal palimpsests. The purpose of identifying and analyzing site-formation and destruction processes is to determine if artifacts are located in or near their original behavioral context and associated with an appropriately time-limited deposit (Goldberg et al. 2001; Rapp and Hill 1998; Schuldenrein 2006; Stein 2001; Waters 1992). To make these determinations, archaeologists need to understand the types of site-formation and destruction processes that act to create, destroy, and bury cultural zones. One of the realities of archaeology is that artifacts found as close as possible to the original position where they were lost, discarded, or abandoned can reveal much more about human behavior than those that have been moved from that context. Various cultural and natural processes can move artifacts in this manner, and these processes make it more difficult to disentangle the complex formation history and extract relevant behavioral information. In the following sections we describe a few of the main site-formation and destruction processes, as identified by Wood and Johnson (1978).

Occupation Trampling and Cultural Churn Zone Formation

Occupation trampling consists of two components, treading and scuffing. Treading results in vertical mixing of deposits, while scuffing causes horizontal artifact dispersal. The magnitude of occupation trampling varies with respect to substrate texture, occupation traffic intensity, and moisture content (Deal 1985; Nielsen 1991; Rapp and Hill 1998; Schiffer 1987). Experimental studies indicate occupation trampling produces a cultural churn zone within an occupation's sedimentary substrate. This churn zone results from the physics of walking on a yielding substrate. Based on an experiment using dry sand as a medium for locomotion, Lejeune et al. (1998) stated that:

> The muscle–tendon work performed during locomotion can be divided into two parts: the external work (Wext), which is the positive work necessary to move the centre of mass of the whole body relative to its surroundings (Wcom) plus the work done on the environment

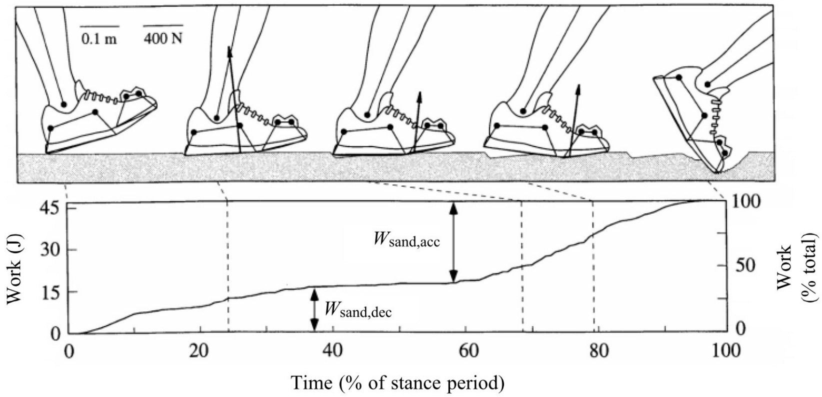

Figure 11.1. "Movement of the foot into sand showing Wsand,dec which is the work during the deceleration of body's [center of mass] COM, and Wsand,acc which is the work done during the acceleration of the COM." Also illustrated is the penetration of the foot into the sand (Lejeune et al. 1998, used with written permission).

> (Wenv), and the internal work (Wint), which is the positive work done to move the limbs relative to the centre of mass (COM). When moving on a hard and nonslippery surface, Wenv is essentially zero because wind resistance is negligible and the foot does not slip or displace the substratum. In contrast, when moving on sand, the foot moves the sand, resulting in additional external work. The total muscle–tendon work (Wtot) done while moving on sand is: Wtot = Wext + Wint = Wcom + Wenv + Wint [1998:2071].

The work done on a yielding substrate is depicted in Figure 11.1, which illustrates the force vectors (arrows) and the effect on the substrate.

When discarded, abandoned, or lost artifacts are walked on, the work done by the foot on the sand embeds the artifacts into the sedimentary substrate. The critical point to consider in this re-creation is that, at the completion of the full movement, the toe penetrates approximately 5–10 cm into the sandy substrate. Multiple, overlapping footfalls lead to deeper penetration. The result of a site's occupants walking through an area containing lost or discarded objects is the creation of a vertical artifact zone, or churn zone, in which artifacts from a single occupation may be dispersed to depths in excess of 5 cm.

Churn-zone development is directly related to substrate texture (Gifford-Gonzalez et al. 1985; Hughes and Lampert 1977; Stockton 1973; Villa and

Table 11.1. *Churn Zone Thickness and Predicted Archaeological Implications*

Substrate texture	Common depositional environment	Churn zone (cm)	Horizontal scuffing	Ease of cleaning	Identify activities	Identify domestic areas
sand	aeolian dunes, well sorted fluvial sands	5-16	low	low	high	low
loamy sand	some slope deposits and alluvium	3-8	moderate	moderate	moderate	moderate
sandy loam and finer	overbank deposits, lacustrine deposits,and most slope deposits	<5	high	high	low	high

Courtin 1983) (Table 11.1). Well-sorted sands produce the thickest trampled cultural churn zones, ranging from 5–16 cm. Loamy sand will develop a 3–8 cm churn zone, whereas loam produces almost no occupation churn zone. Likewise, dry, clayey sediments require extremely high levels of traffic (or saturation) before any churn zone is produced. Pedestrian traffic on a cobble deposit will not produce a churn zone. Occupation trampling and churn-zone formation create a subsurface aspect to most surface occupations except for those on rock or coarse gravel. Less is known about trampling in moist substrates, and experimental work on this topic is still needed. When documenting the sedimentary sequence at archaeological sites, it is important to remember that the original substrate texture that was present during occupation can sometimes be altered by post-occupation pedogenesis. This can pose interpretative problems if the pedogenic alterations are not recognized. For example, a well-sorted sand that is subsequently enriched by clay during pedogenesis could be mistakenly recorded as loamy sand. This would result in an underestimation of predicted trample-zone thickness, while the cultural churn zone would appear to be overthickened. Georarchaeological analysis can prevent such an error by identifying and documenting pedogenic alteration of sediments at archaeological sites.

Occupation trampling can be viewed as both a positive and negative aspect of site formation. Cultural churn-zone formation on a soft substrate has the effect of blurring cultural stratigraphy (Hughes and Lampert 1977; Villa 1982), which may complicate the interpretation of sites that were reoccupied during a time of gradual sediment accumulation. A positive aspect of occupation trampling, on the other hand, is that it embeds artifacts into the subsurface, quickly removing them from cultural contexts and further dispersal or disposal as secondary refuse (Schiffer 1987). Since items are much easier to lose in soft substrates, there is a greater potential in these settings for discriminating areas of high primary-discard (lodges, hearth activity areas, etc.) from those of low primary-discard. Additionally, scuffing is minimal on loose substrates because items are less likely to skid when kicked.

An important but often overlooked aspect of occupant trampling is that the predicted thickness of a cultural churn zone can be used as a baseline for assessing the discreteness and completeness of an observed occupation zone. If the measured thickness of the occupation zone is much thinner than predicted for the associated trampled (churned) zone, then that occupation might be stratigraphically truncated. If the measured thickness is much greater than predicted, then (1) the zone is a specialized accumulation of anthropogenic sediment such as a dump or the fill in a hearth or house pit, (2) it is overthickened as a result of reoccupation under an aggradational depositional regime, (3) it is redeposited, or (4) it is turbated by soil processes. In any case, both truncated (thinner than predicted) and overthickened cultural churn zones suggest complicated formational histories.

Churn zones can remain as surficial cultural deposits for some time. The longer a churn zone remains at the surface, however, the more likely it is to be degraded by post-occupational turbation or truncated/removed by erosion. Rapid and deep burial of an occupation can help protect it from soil turbation and soil upbuilding and often protects bone from degradation. Rapid burial can also prevent mixing of cultural material from subsequent occupations, potentially resulting in stratigraphically discrete cultural zones.

Post-Occupational Turbation

A wide range of soil turbation processes act to disperse archaeological materials after formation of the initial churn zone (Butzer 1982; Gifford and Behrensmeyer 1976; Paton et al. 1995; Schiffer 1987; Waters 1992; Wood and Johnson 1978). Specific subcategories include salt crystallization, clay shrink-swell, and bioturbation, which includes insect and rodent burrowing, root growth, tree tip-out, subsequent trampling by either animals or later human occupants, and freeze-thaw. These processes act to disperse or concentrate both surface artifacts and subsurface items embedded in the churn zone. Post-occupation mixing processes cause artifacts that were originally part of an intact occupation churn zone to be dispersed or concentrated in a soil zone.

Erosion and Sediment Transport

Erosion refers to processes that dislodge sedimentary particles (clasts) from a rock or sediment matrix, whereas sediment transport is how the clasts are moved from their source (provenance) to their point of deposition. These processes can potentially erode and transport artifacts as well as noncultural clasts and may involve multiple cycles of erosion and transport. Although the method discussed here is applicable to most sand substrates, our focus is on processes that might occur in sand-dune fields, both within dunes and in inter-dunal areas. Aeolian erosion and sediment transport predominates in dunes and sandsheets. The primary modes of aeolian transportation are via suspension and bed load, the latter including saltation and surface creep (Boggs 2001; Reineck and Singh 1980).

Post-occupational erosion and sediment transport can alter the contextual integrity of surface cultural churn zones. Erosion processes in and near dune fields include alluviation, colluviation, and wind deflation. Erosion and sediment transport processes can be ranked into categories based on their energy. Low-energy processes include alluvial overbank, sheet-flow (including slope wash), and aeolian sand erosion. High-energy processes typify alluvial-channel, debris-flow, and colluvial-erosional environments. Erosion, transport, and subsequent redeposition can produce a secondary deposit that contains cultural material but lacks contextual integrity (Butzer 1982; Schiffer 1987; Stein 2001).

Aeolian transport of surface artifacts and churn zone matrix can occur whenever wind shear exceeds the hold of gravity (Bagnold 1941). This can be a major source of dispersal for small artifacts unless they are quickly buried (Wandsnider 1988). Aeolian transport is not confined to dune fields but can occur whenever wind conditions are suitable. It is most effective on locations with minimal vegetation cover. Aeolian deflation can produce a lag of artifacts and coarse sedimentary clasts.

The formation of coarse lags (serirs) by deflations along with the construction of harvester-ant mounds can significantly enrich aeolian dune deposits with particles in the coarse sand to very fine pebble range (including artifacts). Redeposited aeolian sand is common and can be difficult to distinguish from intact sand deposits. Aeolian sand is commonly redeposited as (subsequent) aeolian sand, slopewash, and channel-transported alluvium. Erosion by wind can transport only artifacts small enough to be moved in this manner. Somewhat larger artifacts might be oriented by the windstream and bombardment by saltating grains, but they would nevertheless remain near their original locations. Erosion and transport by slope and alluvial processes within an aeolian setting is indicated by the presence of clasts too large to be transported by aeolian processes (>1 cm). In many cases, the bulk of sediment is derived from aeolian sand and, thus, retains a sand texture even when redeposited, making recognition by non-geologists difficult.

Slope wash and colluviation are two inter-dunal processes that transport surface artifacts. Colluviation is gravity-driven transport in which heavier and denser materials move further down slope than lighter, less-dense items (Rick 1976). Colluviation commonly occurs on relatively steep (>15 percent) slopes (Rick 1976). Slope wash, on the other hand, involves transport in a sheet-flow layer of water during storms (Butzer 1982; Reineck and Singh 1980). It can occur on low-angle slopes, especially if vegetation is sparse and infiltration levels are low. This type of transport follows hydrodynamic rules, in that smaller, less-dense material is transported the furthest down slope. Cultural zones transported by alluvium and slope wash can be subject to energy levels higher than aeolian sand. If sandy deposits are found on steep non-dunal slopes or in association with channels, it becomes more important to evaluate them for fabric-and-artifact orientation that might suggest non-aeolian redeposition.

Analyzing Formation Processes During Site Testing

Some sites are considered scientifically important or significant because their cultural content is in near-behavioral horizontal association, occurs in a chronologically discrete cultural zone, and contains perishable remains (regarded here as fauna and charcoal). Sites containing artifacts and features in near-behavioral context exhibit relatively minor post-occupational, burial, and post-burial disturbance. On average, sites that possess all three characteristics are ones that were buried relatively quickly after site abandonment by low-energy sedimentary processes. Artifact zones possessing these qualities occur on young surface sites that still contain perishable remains and have had little time to form complex palimpsests, on sites that are stratigraphically buried and bracketed to a narrow temporal range, and on sites that contain other evidence for a limited span of occupation (for the latter, see Surovell et al. 2005 and Odess and Rasic 2007). Regardless of the reason, if a site is considered potentially important or interesting it is beneficial to determine the nature and magnitude of site-formation and destruction processes sooner rather than later in the investigative cycle.

If a site is being investigated for its potential to produce spatial and associational relationships indicative of past human behavior, these qualities are best evaluated in the earliest stages of site investigation, testing, and initial excavation. Historically, the use of thin arbitrary excavation levels (5 cm or less), refit analysis, backplots, and large-sample orientation analysis has been reserved for academic research excavations. Such strategies are generally not employed in testing, especially within a CRM framework. However, the inclusion of these methods during the testing phase can greatly facilitate the identification of intact cultural zones. The more of these data that are collected during testing the more likely that excavation and data recovery will be able to address postulated research questions that require spatial and contextual associations. Conversely, if a testing plan makes an effort to backplot, refit, and collect orientation data, and these data indicate that the cultural zone has low contextual integrity, then there is high likelihood that data recovery directed toward reconstructing the structure of activity areas will be unsuccessful. In some (but by no means all) cases, sites containing buried artifacts may not yield scientifically interesting, important, or significant data.

It is useful to document, tabulate, and rank data recovered from testing in order to determine whether the site might yield data to address problem-oriented research goals requiring contextual integrity. Here we present a Burial Contextual Integrity Scale that ranks the integrity of artifact zones as very high, high, moderate, low, or very low. Five attributes are considered when ranking the contextual integrity of cultural churn zones. First, the thickness of the cultural zone is evaluated to see if it is within the range of a predicted trample zone. If the thickness of the churn zone appears as predicted, then four characteristics are scored:

1. artifact orientations (degree of artifact transport based on sediment texture and long-axis orientations of artifacts),

2. artifact refits (evidence for contemporaneous cultural deposition based on presence/absence of artifact fragment conjoins),

3. krotovina quantity (degree of post-occupation turbation as indicated by the percentage of zone disturbed by burrowing, indicated by krotovina), and

Table 11.2. *Evaluation of Burial Context in Aeolian Sand Settings from Testing Data*

Attributes	Scoring Rules	Score
Artifact Orientations	artifact long-axis trend and plunge orientation: statistically significant (patterned/non-random) = 0; non-statistically significant (random) = 1	0 or 1
Artifact Refits	refits absent = 0; refits present = 1	0 or 1
Krotovina	krotovina occupy ≥50% surface area = 0; <50% = 1	0 or 1
Time Span	bounding and/or within-zone dates statistically not identical = 0; bounding and/or within-zone dates statistically identical = 1	0 or 1
Total Points		minimum = 0; maximum = 4

4. cultural-zone time span (artifact-zone temporal limits as derived from bounding and/or within-zone chronometric dates) (Table 11.2).

If the cultural churn zone is considerably thinner or thicker than predicted based on the substrate texture, then additional testing and geoarchaeological analysis may determine areas suitable for activity-area analysis. The four variables—artifact orientations, artifact refits, krotovina, and time span—are given scores of 0 or 1, with the sum of the four scores indicating the degree of burial contextual integrity (Table 11.2). A maximum score of 4 predicts that the churn zone has very high integrity, whereas a score of 0 implies very low integrity. The categories of high (3), moderate (2), and low (1) fall in between these two endpoints.

Cultural Zone Thickness

The thickness of artifact zones (Table 11.1) helps in determining the potential intactness of cultural zones. Zone thickness refers to non-pit (excluding house pits and hearths) portions of an occupation surface. Non-pit cultural zones that are thinner than predicted are potentially degraded by erosion (deflation, alluvial truncation). Zones that are thicker than predicted often result from special use function or complicated occupational histories. Sometimes, over-thickened cultural zones are the result of reoccupation under slow sedimentation regimes that produce occupational palimpsests. Alternatively, turbation can produce over-thickened zones. Unless thick artifact zones are shown to be part of a specialized feature or incorporate finer cultural substratification, data from either truncated or over-thickened zones may not readily contribute to any research question that relies on high-quality contexts and associations within individual occupations.

The thickness of an artifact zone is evaluated during test excavation or initial excavation by using plots of artifact density by excavation level. In low to moderately sloping strata, 5-cm excavation levels are required to provide the necessary detail. Very steep slopes are more problematic. If the original occupation zone slopes steeply (> 10 degrees), backplots of artifacts recovered in situ can be used to determine the thickness of the artifact zone; however, this requires the point plotting of in situ artifacts as opposed to their recovery through screening. Another option is to determine the slope of visible depositional strata and then to excavate stratigraphically or, if that is not practical, in arbitrary levels that conform to this slope. Alternatively, the subdividing of horizontal, 1-x-1-m excavation levels into 50-cm quadrants for excavation and analysis can minimize the effect of slope. Artifact densities can then be analyzed by quadrant to approximate the original slope.

Long Axis Orientation of Natural Clasts and Artifacts

The orientation of natural clasts and artifacts within their matrix constitutes the sedimentary fabric of the deposit. Clast and artifact orientation refers to the position of the object in three-dimensional space. Geologists describe the orientations of planar and elongated objects in different ways. The orientations of planar objects are recorded using the strike and dip of the plane, whereas those of elongated objects are recorded using the concepts of trend and plunge. When the goal is to detect the potential of artifact transport from sedimentary processes, it is most productive to focus on elongated objects, and thus trend and plunge are typically employed for documenting the spatial arrangement of objects within a deposit (Rogers 1994) (Figure 11.2).

The use of orientation data requires the following assumptions about the original horizontality of deposited artifacts: namely, when objects are dropped haphazardly, their long-axis direction tends to be random, and their angle of deviation from horizontal conforms to the surface upon which they were dropped (Dibble et al. 1997). If the surface is smooth and level, the objects will be flat-lying. If the surface is flat but sloping, their original angle of inclination from horizontal will conform to the slope. However, occupation surfaces in sand become dimpled with footprint depressions, and artifact inclinations will conform to this irregularly dimpled surface. Repeated footfalls upon any single artifact might be expected to further randomize both the horizontal and directional orientation. It is reasonable to assume that artifacts resting in loose sand are easily trampled, which should result in

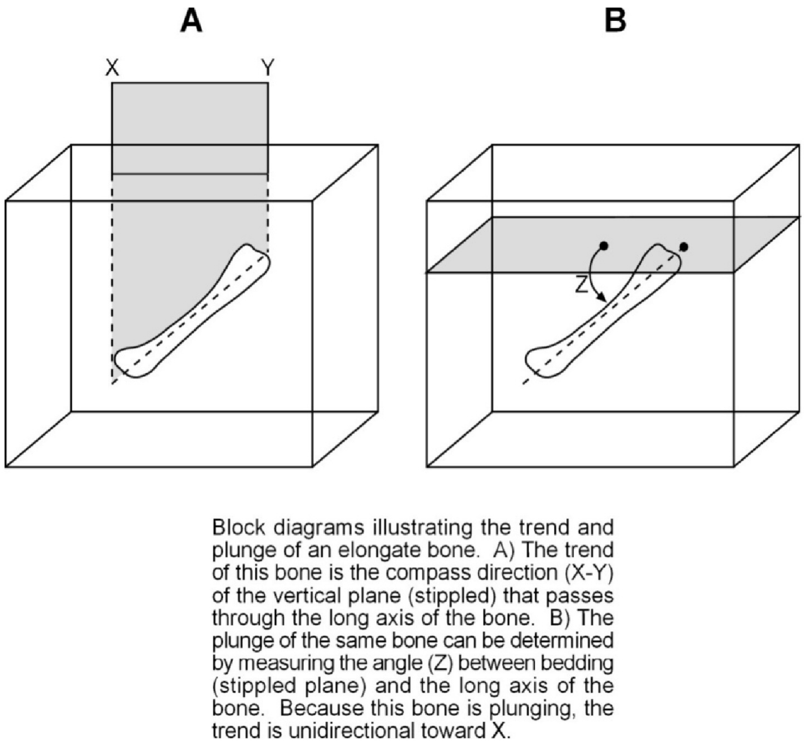

Figure 11.2. Recording trend and plunge of an in situ elongated object. Figure reproduced from Rogers (1994:Fig. 3.3) and used with author's permission.

relatively random orientations and inclinations. In firmer substrates such as loams, silts, and clays, on the other hand, occupant trampling may not be adequate to randomize the attitudes of surface artifacts.

Wind-scouring and other processes of erosion tend to remove footprint depressions, to re-orient objects' long axes, and to align their angles of inclination to the erosional slope. Patterned or nonrandom orientations of elongated artifacts that are in the appropriate size classes may indicate redeposition or deflation after site occupation (Dibble et al. 1997; McPherron 2005). Only artifacts smaller than ~ 2–3 cm will be oriented by the wind, but much larger artifacts might be oriented by alluvial processes in inter-dunal areas. Fabric can be analyzed by comparing artifact orientations to experimental samples produced under controlled conditions (McPherron 2005).

In soft substrates like sand, if nonrandom orientations characterize the data set (given the depositional setting), then sedimentary transport of objects may have occurred. If the sample of artifacts within a cultural zone exhibits a significant orientation, a score of 0 is applied. Alternatively, if there is no significant orientation (orientations appear random), the zone is considered to be untransported and a score of 1 is applied.

Artifact Refits

Refitting analysis can be undertaken in an attempt to differentiate intact cultural stratigraphy from redeposited artifacts. Artifact refit studies assess the movement of artifacts in both the horizontal and vertical planes (Hofman and Enloe 1992). In cases in which an adequate sample of artifacts has been recovered and large numbers of refits are identified across the horizontal plane, either cultural (multiple activity areas, sharing, etc.) or natural (scuffage, aeolian or alluvial) transport may be likely. Refits across the vertical plane provide direct evidence of mixing and may be used to evaluate the extent of churn-zone thickening and other post-depositional processes. In extreme cases, such as those in which a large proportion of the artifacts can be refit, actual prehistoric events and activities might be identified. More commonly, only a subset of the total artifact inventory can be refit. The presence of multiple artifact refits within a discrete artifact zone conforming to the thickness of an intact churn zone implies that the activities leading to artifact deposition (i.e., manufacture, breakage, and discard) occurred within a discrete occupation. Based on testing data, if refits are present the artifact zone is scored as 1. If no refits are present, a score of 0 is assigned.

Krotovina

Burrowing is the most destructive form of bioturbation in aeolian sand deposits (Ahlbrandt et al. 1978). Estimating the percentage of krotovina within the artifact zone is helpful in determining the extent of bioturbation. If an artifact zone, as expressed in the test-unit walls, contains ≥ 50 percent krotovina, the zone should be considered heavily bioturbated (score = 0). Those that exhibit < 50 percent krotovina are impacted less and are more likely to retain minimal integrity (score = 1).

Time Span

The length of time that the artifact zone was available for occupation is an important consideration. Reconstruction of the activities that occurred on an occupation floor is more easily undertaken if a single occupation is represented. Palimpsests form when multiple occupation events took place on the same living floor over a period of time, and their presence complicates interpretation of the behaviors that produced the living floor. Although the assumption that an assemblage is a palimpsest has important implications for archaeological interpretation, reconstructing behavior from spatial context and inferred associations is facilitated when the occupation surface is demonstrated to represent a limited duration. Efforts to estimate the duration of occupation are greatly facilitated by the recovery, during testing, of samples with dates that bound the cultural zone and other dates that come from within it.

Until recently, it was difficult to age-bracket an occupation zone because dating was limited to organic materials contained within the archaeological assemblage itself, primarily in hearths. The dating of samples from hearths and other features provides ages for the facilities themselves but does not produce an age-range for the occupation surface with which they are affiliated. Several techniques that do not require the presence of organic material have now been developed, however, including optically stimulated luminescence (OSL), infrared stimulated luminescence (IRSL), and thermoluminescence (TL) (Feathers et al. 2006; Mayer and Mahan 2004; Stokes and Gaylord 1993). OSL and IRSL measurements are collected by exposing the sediment particle (grain) to light, whereas TL exposes the grain to heat. Especially useful in aeolian sand, OSL measures a mineral grain's last exposure to sunlight (bleaching), typically interpreted as indicating when the grain was buried (Mayer and Mahan 2004). Luminescence dating can be used to bracket the age of occupation zones. The OSL method can generally provide dates to within a 100-to-200-year error range. Bounding dates will provide a limiting age within the combined age range of an upper and a lower date. Statistically identical OSL dates at the upper and lower bounding surfaces of the cultural zone will generally result in an age range of <400 years. If the dates are not statistically identical and are in proper stratigraphic order, the occupation zone probably formed during a time period greater than 400 years in length.

Whether dated using OSL or ^{14}C, an occupation zone that formed on a sub-aerial surface for greater than 400 years must be suspected of including materials from more than one occupation event, especially since occupational density over time can be high in areas of aeolian sand. Any research hypothesis that proposes to extract spatial-behavioral information from such a zone must take into account the possibility of more than one occupation event and propose methodological and theoretical constructs to accommodate this large temporal range. Artifact zones that produce statistically identical bounding dates or identical inner-zone dates suggesting short formation time are considered more intact and are given a score of 1. Those that formed over a much longer time span are given a score of 0.

Conclusions

Intact cultural churn zones in aeolian sand settings are ≤ 20 cm thick (ideally falling within the predicted range of 5–16 cm) and achieve a very high score on the Burial Contextual Integrity Scale. An intact churn zone in a sandy substrate exhibits the following characteristics: (1) artifact orientations are random/non-patterned (i.e., there is little evidence for preferred artifact orientation that might indicate wind transport or redeposition); (2) artifact refits are present; (3) krotovina occupy < 50 percent of the cultural churn zone; and (4) the time span represented by the occupation zone is limited (as documented by occupation-zone bounding dates). On the other hand, artifact zones that lack integrity score very low on the Burial Contextual Integrity Scale and exhibit many of the opposite characteristics: (1) artifact orientations are non-random or patterned; (2) artifact refits are absent; (3) krotovina occupy ≥ 50 percent of the zone; and (4) the time span of the occupation zone is relatively long. The other intermediate classes (high, moderate, low) reflect incremental departure from the very high and very low endpoints of the Burial Contextual Integrity Scale.

Implementing this proposed strategy for evaluating contextual integrity involves changing research design development, particularly during the testing phase and prior to data recovery. To that end, we suggest that test units or initial block excavation units be dug with greater precision. An ideal scenario would see those excavations proceed in arbitrary or stratigraphic 5-cm levels and within 50-cm quadrants of a 1-x-1-m grid. Elongated artifacts ≥ 2 cm in length should be mapped in situ, with trend and plunge data collected for each item. Such excavation protocols are common in academic-oriented projects throughout interior western North America, and some CRM firms are now implementing similar strategies, at least as a sub-sampling method. Artifact refitting is a time-consuming but insightful exercise that is conducted in the lab. At a minimum, chipped stone analysts can use minimum analytical nodule analysis (MANA) as a proxy for artifact refits (Hall and Larson 2004; Ingbar et al. 1989; Larson et al. 1992; Larson and Kornfeld 1997).

Assessing burial integrity also requires a thorough dating program, which needs to be considered well in advance of and during the planning stages of test excavations. Multiple ^{14}C dates should be obtained from within an occupation. More importantly, bounding dates for artifact zones, whether based on ^{14}C, OSL, IRSL, or TL, can aid in determining the age range of an occupation surface, which in turn informs archaeologists about the potential for reoccupation. Other variables (occupation-churn-zone thickness and bioturbation) are simple to document and aid in the overall assessment of contextual integrity.

The Burial Contextual Integrity Scale provides a simple method for assessing contextual integrity and for determining which sites (or cultural zones within sites) have the best potential to provide valuable data. Testing "smarter" (see other papers in this volume) may require potentially excavating smaller areas in greater detail. Our proposed protocol aids in decision making during a project's testing phase concerning data recovery and the mitigation of adverse impacts to archaeological sites. This data-collection strategy will largely be conducted by archaeologists themselves, but will benefit greatly from input by geoarchaeologists. Ultimately, the implementing of new research designs and excavation protocols can provide better information about local and regional archaeological records, which is of value to everyone involved in prehistoric research.

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