The surface archaeological record in arid Australia: geomorphic controls on preservation, exposure and visibility.

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ABSTRACT

The conventional approach to assessing the archaeological record in most parts of the world involves a combination of excavation of stratified deposits and extensive survey of surface deposits. Although widely applied in Australia, in both research based and management archaeology, the method does not conform well to the nature of the surface archaeological record here. Over much of semi-arid and arid Australia, archaeological ‘sites’ are, in fact, accretion phenomena that are not easily interpreted as the outcome of short-term behavioral events. Using results from twelve years of geoarchaeological research in western New South Wales, we demonstrate that there is considerable variability in landsurface age, and hence the ‘availability’ of archaeological surfaces, over relatively short distances. Therefore it cannot be assumed that stone artifact deposits, for example, that appear to be similar in character are of similar age. Data is also presented that demonstrates that the presence of artifacts on the surface, their apparent absence in sediments buried beneath the surface, and the apparent recent ubiquity of the archaeological record are all a function of geomorphic processes that, at the same time, expose some artifact deposits at the surface and erode and bury others amid large volumes of sediment. Interpreting the surface artifact record within a spatial and temporal geomorphic framework is crucial to understanding the past human behavior that the artifact deposits represent.

INTRODUCTION

When we think about archaeological fieldwork, the image that most often comes to mind is one of excavation: vertical exposure of deposits by excavation, identification of layers and descriptions of the macro- and micro-stratigraphy, and the construction of the three dimensional record of object location over a relatively confined spatial extent. The role of a geoarchaeologist in this kind of operation is usually to document and interpret the history of deposition of the sediments exposed by excavation, using skills and techniques adapted from geomorphology, stratigraphy, sedimentology, pedology, and so on (e.g. Goldberg and MacPhail 2006). A geoarchaeologist might also be concerned with any post-depositional changes to the sediments and how this might have affected the archaeological record (e.g. Stein 1987). They are frequently concerned with establishing a chronology for the deposit using absolute and relative dating techniques (e.g. Goldberg et al. 2001).

This approach and these techniques are commonly used in Australia, to investigate deposits in caves and rock shelters, and in other locations where sediments containing archaeological material have accumulated over time and remain relatively intact (e.g. Cosgrove 1996, Stern 2008). But, over semi-arid and arid Australia –about 70% of the continent – the archaeological record comprises surface deposits of stone artifacts commonly, but not always, associated with other archaeological remains such as mounds, burials, art sites and clusters of heat-cracked rock which are the remains of heat-retainer hearths, or earth ovens, once used to cooked food. Sites containing faunal material also occur, but only when the depositional environment favors preservation. Just like stratified sites, most surface deposits are not the product of single behavioral events but are accretion phenomena or ‘palimpsests’, the product of multiple behavioral events over time. Because they are aggregated onto a single surface, they are difficult to interpret using the traditional approaches outlined above. In addition, the landscapes in which surface artifact deposits are found today are quite often eroded and the integrity of the artifact assemblages may be affected to a greater or lesser degree by the processes that have exposed the material at the surface.

Researchers using traditional archaeological frameworks have struggled to deal with this record effectively, for a number of reasons. First, survey methods suitable for handling sites represented by large quantities of stone artifacts deposited across large areas are not well developed (Holdaway and Fanning 2008). Second, the artifact deposits lack stratigraphy defined in the conventional sense and hence the opportunity to develop a chronology using traditional approaches of dating the depositional layers in which artifacts are found (Fanning and Holdaway 2001b). Third, site formation studies are poorly developed largely because deflated surface deposits are thought to have lost spatial and temporal integrity (Fanning and Holdaway 2004). Finally, many sites lack obvious features such as the remains of permanent structures which would suggest a means for intrasite analysis and the behavioral interpretation of artifact forms (particularly stone artifacts that occur in very large numbers) is frequently ambiguous (Holdaway et al. 2004). Faced with these problems, and the lack of a geoarchaeological model of arid zone archaeological record formation, archaeologists have tended to take the record at face value: the ubiquity and age of the record indicates past population numbers and the presence of an archaeological record can be interpreted using a conventional settlement pattern approach (Holdaway and Wandsnider 2006). In this paper, we briefly review our twelve years of research in western New South Wales (NSW), Australia, which has used a framework based on a geoarchaeological assessment of the archaeological landscape and a targeted sampling strategy (Fanning et al 2007). We then present our most recent results that help to explain both the ubiquity of the record in certain locations and its absence in others, as well as its age, and discuss how the distribution of the record should be assessed. We conclude by considering the impact of our approach on current interpretations of the Australian Holocene arid zone archaeological record.

THE GEOMORPHIC CONTEXT

Our study areas are located on the valley floor margins of ephemeral streams draining catchments of between 30 and 300 km^2 in western NSW on the south-eastern margin of the central Australian arid zone (Figure 1). The climate today is arid, with mean annual rainfall less than 250 mm and pan evaporation exceeding 2000 mm in most locations (Holdaway et al. 2000). Vegetation cover is sparse and patchy, comprising chenopod shrublands with trees confined to the larger watercourses. Extensive areas of stony (‘gibber’) and bare surfaces mantle the slopes and plains. Changes in vegetation cover (Johnson et al. 2005) and geomorphic processes occurred with the shift from Indigenous hunter-gathering to European-style pastoralism in the nineteenth century (Fanning 1994, 1999; Noble and Tongway 1986; Pickard 1994). Topsoil lost from the hillslopes was deposited on valley floors as laminated and cross-bedded sandy sediments (variously termed ‘post-settlement alluvium (PSA) or post-European material (PEM) – Gore et al. 2000:117). Streams then incised into the valley fills, forming knickpoints that can move rapidly up the main and tributary channels in response to high magnitude rainfall events (Fanning 1999). Renewed erosion on the valley floors followed, leaving hard-setting, saline subsoils exposed at the surface upon which archaeological materials, mostly stone artifacts, now rest.

Episodic flood events, resulting in erosion in some areas and deposition in others, are a feature of our study area (Fanning et al. 2007). Mean annual rainfall is relatively low but variability is high (greater than 50%), and the bulk of the rain falls during short, intense rain depressions, especially in summer. During one such event in February 2000, for example, rain passed across a large area of western NSW resulting in extensive flooding, but at our Fowlers Gap study area (Figure 1) its effects were extremely patchy. At one of our sampling locations, water overflowing from a shallow rill network created a new channel that removed surface sediments including artifacts that we had surveyed just a few months before. However, at another location only a few kilometers away, the effects of the storm were not nearly so dramatic, with the main effect appearing to be an increase in vegetation cover (Fanning et al. 2007).

Episodic events like this also affect the Holocene sedimentary record. Where the contemporary creek lines are cut into alluvial sedimentary sequences, unconformities are observed that represent either substantial hiatuses in valley floor aggradation or, more likely, periods dominated by valley floor erosion. For example, the sequence recorded at Stud Creek contained gaps of several thousand years in the depositional record of the Holocene (Fanning and Holdaway, 2001b; Holdaway et al., 2004). The absence of buried paleosols in this sequence suggests that the unconformities represent more than just the product of stable periods in the evolution of the landscape, when aggradation temporarily ceased. Any older record of occupation was therefore most likely destroyed by erosion represented by the unconformities in the stratigraphic sequence (Fanning and Holdaway, 2001b: 99).

Evidence for episodic activity in the Holocene record of environmental change is relatively widespread in the western NSW region (e.g., Williams et al. 1991). Jansen and Brierley (2004), for example, documented a 4000-year sedimentary record of floods of Sandy Creek at Fowlers Gap, adjacent to one of our sampling locations. The pre-European floodplain surface probably accumulated as slackwater deposition during erosion episodes (Jansen and Brierley, 2004) that occurred between 1530 and 960 years ago. Our Optically Stimulated Luminescence (OSL) dating of sediments obtained from a shallow gully traversing the valley floor confirms this interpretation: sediments within 30 cm of the surface are late Holocene in age and conform to Jansen and Brierley's erosion episodes 1 and 2 (Fanning et al. 2007).

In addition to the slackwater deposits referred to above, sediments eroded during floods in these ephemeral channel systems are carried downstream and deposited at variable distances from their sources, depending on the magnitude and duration of the individual flood event. Endoreic drainage is common in the Australian arid zone, and fluvial sediments are deposited in intermediate and terminal flood-outs (Tooth, 1999) either at tributary junctions or where stream gradients decline below the minimum threshold required for maintaining single-thread channels. The lack of integrated channel networks means that only rarely do floods reach their topographic base level, usually lake basins (Gore et al. 2000: 114). Sediment concentrations are relatively high, and sediments are carried simultaneously as bed load and suspended load, largely due to the availability of sediments with a wide range of particle sizes (Tooth, 2000: 78). Many authors report that sediment tends to move through dryland rivers in a series of waves over various time periods, from hours to centuries, and that scour and fill is rarely spatially synchronized with some reaches scouring at the same time that others are filling (Tooth, 2000: 79).

SURFACE EXPOSURE

Surface visibility and therefore the quantity of the surface archaeological record is highest where there is an absence of vegetation, and the surface is lagged (or winnowed) forming scalds (Fanning and Holdaway 2004). Scalds (Figure 2) are described in the Australian soil conservation literature (e.g., Houghton and Charman 1986) as forming where ‘topsoils’ (more correctly, sediments forming the uppermost sedimentary unit) are removed by a combination of wind and water erosion, exposing saline subsurface sediments that form a relatively hard, impermeable surface distributed intermittently across the valley floor. Stone artifacts and heat retainer hearths are exposed on scalds as the finer sediments are removed by unconcentrated overland flow. On slopes greater than two degrees, overland flow can also move small artifacts (with a maximum clast dimension [b axis length] less than 20mm). Lateral movement is much less discernable amongst the larger artifacts, as demonstrated by both our own studies (Bryant 2007, Fanning and Holdaway 2001a), experimental work carried out by Schick (1987), and the results of hydrological modeling in one of our study areas (Pigdon 1997). In areas where water flow is concentrated, such as rills, gullies and channels, there is the potential to move all artifacts; however these geomorphic features cover only a small area of many scalds. Remnant “islands” of uneroded sediment, and patches of vegetation where the surface is not fully exposed, or places disturbed by bioturbation and trampling, such as animal tracks and ant nests, also account for only a small proportion of scald surfaces (Fanning and Holdaway 2004). Scald formation thus leads to the exposure of artifacts but not their lateral movement. Artifacts are deflated onto a common surface but otherwise remain where they were discarded. In a sense, therefore, sediment erosion has ‘excavated’ the archaeological record offering a unique opportunity for investigation of large quantities of this record distributed across the landscape.

The magnitude of surface exposure can be gauged from one of our study areas. At Peery Lake (Figure 1), the area of measured scalds on the valley floor of Rutherfords Creek, an ephemeral stream draining to the lake, amounted to 1,675,982 m^2 in a 10 km long by 1-2 km wide valley, or around 13% percent of the total valley floor area of 13,186,552 m^2. On a random sample of scalds making up approximately 5% of the total scald surface area, 24,354 artifacts were recorded giving an overall density of 0.29 artifacts per square meter. Extrapolating these figures to the whole valley floor means that, potentially, 487,080 artifacts are lying exposed on scalds, and a further 3.3 million artifacts may be buried beneath the undisturbed surface sediment deposits. On individual scalds, artifacts are clustered in high density patches with intervening areas of lower density, rather than being spread uniformly across the surface (Figure 3). This spatial pattern, together with analyses of the relationships between artifact size and various topographic parameters (Fanning and Holdaway, 2001a), illustrates the conclusion reached above: while the vertical integrity of the original artifact deposits may be lost, the lateral integrity remains intact.

The high visibility of the record is one of the factors that attracted us to work in western NSW, but interpreting the significance of the quantity of artifacts visible, as well as those that remain buried, must be related to the geomorphic history of the sediments on which they rest. The abundant surface record apparently dating to the late Holocene has previously been widely interpreted by some Australian archaeologists as reflecting increased human population levels accompanying cultural intensification (see Holdaway et al. 2008 for a detailed review of this thesis). Such statements must be tempered, however, by an understanding of how long it took for the artifacts to accumulate, as well as a detailed understanding of what types of behavior the artifacts are related to. Artifacts appear on the surface in large numbers in many parts of Australia, but they have attracted relatively little attention largely because their interpretation is dependent on establishing the time period over which they were deposited. Establishing a chronology for surface deposits has, until recently, been an intractable problem for Australian archaeologists.

DETERMINING A CHRONOLOGY FOR SURFACE ARTIFACT DEPOSITS

Surface artifact deposits may appear to lack stratigraphy in the sense that they are not buried. For a geoarchaeologist, however, surface deposits of artifacts are simply clasts that lie unconformably on the uppermost layer of sediment in a stratigraphic sequence. Establishing the age of the sediment deposit that forms the surface on which artifacts now rest provides a means to define the age of the ‘minimum archaeological stratigraphic unit’ (following Stern 1994) into which surface artifacts may be grouped. In our western NSW study areas, we use a combination of Optically Stimulated Luminescence (OSL) and radiocarbon age estimates to build a chronology of the surface archaeological record (Holdaway et al. 2002, 2005, 2008; Fanning et al. 2008, in press; Rhodes et al. in press).

Application of the method at three sampling areas at Fowlers Gap Arid Zone Research Station (Figure 1) well illustrates the nature of the results obtained. At these three locations, various surfaces have accumulated artifacts over different periods of time reflecting the geomorphic environments present. As described in detail in Fanning et al. (2008), sediment samples were obtained for OSL age determinations at each of the three locations by collecting samples from various depths below the landsurfaces upon which stone artifacts currently rest. The OSL technique determines the length of time since the sediments were last exposed to light, i.e. the time of burial when the sediments were deposited (Aitken 1998: 6). We used a small aliquot single aliquot regenerative-dose (SAR) protocol (Murray and Wintle 2003) measuring sand-sized quartz grains. Gamma dose rates were measured in-situ using a portable NaI gamma spectrometer, and beta dose rates were calculated using measured concentrations of K (ICP-OES) Th and U (ICP-MS) at Genalysis, Perth, Australia. All dating procedures and age calculations were similar to those described in Rhodes et al. (2003).

Following the laws of superposition, the OSL age determination for the uppermost sedimentary unit provides an estimate of the maximum age of artifact deposits resting on its surface, assuming that the artifacts have been lagged onto this surface by the winnowing of finer grained sediments. At the SC sampling location (a proximal floodout subject to episodic channel change), sediments sampled from a single sequence range in age from modern at the surface (K0151) to a maximum of 4230 y BP at 62 cm depth (K0112). Similarly, at the ND sampling location (a modern floodplain surface), sediments range in age from a minimum of 1170 y BP at 18 cm depth (K0122) to a maximum of 3730 y BP at 52 cm below the surface (K0124). In contrast, the sediments forming an alluvial terrace at the FC location were deposited up to 10,920 years ago (K0147), reflecting the greater age of the sediments preserved at this location when compared with the active proximal floodout environment at SC and the floodplain environment of ND (Fanning et al. 2008, Table 1).

The archaeological records preserved on these different surfaces (which we have termed ‘archaeological surfaces’ – Rhodes et al. in press) have quite different histories, even though they may appear, at first inspection, to be very similar. While excavation and dating of the sediments beneath these surfaces reveals a long history of erosion and deposition, buried artifact deposits are non-existent, at least in the locations we have studied. As discussed later in this paper, the rich archaeological record is a surface or shallow sub-surface phenomenon.

The second component of our chronological framework is a suite of age estimates from the remains of heat-retainer hearths with which the stone artifact deposits are usually associated. Charcoal from cooking fires may be preserved beneath a capping of fire-cracked rock. The rocks once lined a fire pit in which food was buried and cooked, but over the centuries, erosion has removed the sediment cover, leaving the clusters of stones as a protective cap. Age estimates obtained from clusters of hearths provide a chronology of occupation at each location, the pattern of determinations distributed through time indicating both periods of hearth construction and, equally, times when no hearths were constructed (Holdaway et al. 2002, 2005). Descriptions of typical hearths, and charcoal sampling methods, are described elsewhere (Holdaway et al. 2002, 2005, 2006).

At Rutherfords Creek catchment near Peery Lake (Figure 1), for instance, the remains of 1054 hearths were recorded. Groups of hearths were defined on the basis of spatial proximity, and a sample of 256 hearths excavated to extract charcoal samples for radiocarbon determinations. Only about one third of the hearths contained enough charcoal for conventional (i.e. radiometric) radiocarbon determinations with the rest either containing no charcoal, or in a state that was too disturbed to excavate.

Analysis of the hearth age determinations reveals two important patterns. First, a discontinuous distribution of hearth age determinations within clusters is evident, with groups of hearth ages separated by gaps in time. This is especially the case in hearth Clusters 16 and 26 and to a lesser extent in Clusters 11 and 40 (Figure 4). We infer that these patterns are the outcome of multiple occupations of the same locations but separated by long periods when no hearths were constructed, suggesting local abandonment. Such a discontinuous pattern is similar to that reported from our previous research at Stud Creek and Fowlers Gap (Holdaway et al. 2002, 2005), and may reflect a behavioral response to environmental change. We are currently exploring this hypothesis by comparing our hearth dates with various environmental proxies (Holdaway and Fanning 2007).

Second, maximum ages for clusters of hearths reflect local geomorphic history. Clusters 11 and 40, for example, exhibit wider age ranges than hearths in Clusters 16 and 26 (Holdaway et al. 2008). OSL dating of the sediments beneath these hearths indicates that Cluster 16 and Cluster 26 are excavated into comparatively recent surfaces compared with Clusters 11 and 40 (Table 1, Figure 5). The former are located on a floodplain surface remnant between two anabranches of Rutherfords Creek, while the latter are located on higher elevation surfaces some distance from the modern channel. This suggests that differential preservation of landsurfaces may be controlling the preservation of the archaeological record.

When combined, the two sets of age determinations (OSL determinations from the underlying sediments, and radiocarbon determinations from the heat-retainer hearths) define the ‘minimum stratigraphic unit’ (Stern 1994) or ‘envelope of time’ (Fanning 2002:211) during which the artifacts are assumed to have accumulated. Radiocarbon dating of charcoal from the remains of all of the hearths within a cluster provides an indication of the time span over which that particular location was occupied. Further, the law of superposition says that the hearths must be younger than the sediments into which they were excavated, and older than any sediment which buries them. Thus, determining the time of deposition of the sediments in the valley fills gives a maximum age for the hearths, and absolute dating of the charcoal in the hearths gives a maximum age of the sediments that once buried them. The time span, defined by the youngest of the dated hearths at one end and the age of the sediments into which they were excavated at the other, is the ‘envelope of time’ during which hearth building activity took place at each location. It is then assumed to be the time period during which the associated stone artifacts were discarded, since the artifact deposits cannot be older than the sediments on which they are currently resting. The only exception might be if artifacts from older, reworked deposits were transported and deposited onto younger depositional surfaces by geomorphic processes like overland and channel flow; however, they would not be included in our artifact surveys since depositional surfaces, and rills and channels, and the artifacts they contain, are deliberately excluded.

COMPARING SEDIMENT LOSS RATES WITH ARTIFACT ‘LOSS RATES’

Ironically, the same suite of geomorphic processes that leads to the formation of scalds, and therefore high surface visibility, precludes the development of buried artifact deposits. Overland flow moves artifacts resting on surfaces with gradients greater than two degrees (Bryant 2007; Fanning and Holdaway 2001a). Artifacts, like other clasts, are transported by overland flow into ephemeral channel systems and are carried downstream where they may eventually be deposited in intermediate and terminal flood-outs. Once they are moved, artifacts become incorporated into the poorly sorted, mixed load deposits that are characteristic of ephemeral dryland streams. Because sediment loads are high, the volume of stone artifacts eroded and transported is likely to be low relative to the total volume of sediment eroded at any one location, adding to the loss of artifact visibility.

This can be illustrated by considering the NN99 sampling unit at Fowlers Gap (Figure 1). NN99 is located at the confluence of two tributaries within an ephemeral stream system. Rill and gully erosion of the channel margins and valley floor at this location is extensive, and is believed to have been initiated by the introduction of sheep grazing to the region in the mid nineteenth century (Fanning 1994). Stone artifacts, as well as non-artifact clasts and the remains of heat-retainer hearths, are visible on the bare valley floor surface upslope of the rills and gullies. Using a systematic grid square sampling method (Fanning and Holdaway, 2004), 530 artifacts located across 239 m^2 of flat valley floor surface were analyzed. Figure 6 shows the contour and slope surfaces derived from the three dimensional coordinates of each of the squares. Using maximum clast dimension (b-axis length) as the dependent variable, regression analyses testing the impact of contour interval and gradient were run. Results of the regression (Table II) indicate that both the steepest slopes and lowest contour intervals (i.e., closest to the channels) have significantly larger artifacts than flatter slopes or higher surfaces, evidence consistent with winnowing of smaller artifacts by sheet wash (Fanning and Holdaway 2001a).

An indication of the volumes of sediment eroded through time is provided by a longitudinal study of surface lowering by erosion conducted by Fanning (1994) on the valley floor adjacent to the NN99 artifact survey area described above. A grid of 160 galvanized steel erosion pins was established in July 1978. The pins, each 200 mm long, were driven into the ground leaving 10 mm protruding above the surface. A galvanized washer was placed over the pin head, which was split to prevent the washer from slipping off. Measurements of erosion at each pin, determined by the position of the washer below the pin head, were made in February 1981 and May 1991, and average sediment loss rates over the ten year period calculated (Fanning 1994). In July 2001, the pins were resurveyed and two measurements recorded with an electronic total station. One measurement was taken at the base of each pin head, now significantly above the ground surface, and a second at the ground surface at each pin.

The coordinates of the pins were used to calculate three dimensional surfaces corresponding to the 1978 and the 2001 levels (Figure 7). Points belonging to each set of measurements were converted into a TIN (Triangular Irregular Network), and the ArcGIS 3D Analyst Area and Volume Statistics tool was used to calculate volumes above the 215m contour (an arbitrary point below the lowest measurement recorded in 2001). The volume above this datum was calculated for the ground surface as it existed in 1978 and compared with that calculated for the ground surface measured in 2001. The difference – 34.4 m^3 – is the volume of sediment eroded from the plot over a period of 23 years. Thus, over 23 years, 34.4 m^3 of material has eroded from an area of 351 m^2, giving an average sediment loss rate of approximately 40 m^3 per hectare per year.

The artifact survey data for NN99, described above, may be used to calculate an artifact ‘loss’ rate to compare with the total sediment loss rate just described. While this estimate of the artifact ‘loss’ rate is relatively coarse, given the number of assumptions that such a calculation requires, it does however provide an indication of the *maximum* potential volume of artifacts eroded relative to the total volume of sediment eroded per unit area.

The total volume of the 530 artifacts recorded in an area of 239 m^2 at NN99, calculated by multiplying artifact length, width and thickness, is 0.003812 m^3. Assuming equal artifact density across a hectare (but see discussion below), this is equivalent to an artifact volume of 0.15 m^3 per hectare. The sediment loss rate in similar terrain, calculated from the erosion pin plot previously described, was 40 m^3 per hectare per year. Assuming that all artifacts were eroded within a single year the artifact ‘loss’ thus represents only 0.004% of the total annual sediment loss.

To make sense of this result, it is instructive to compare it with the density of artifacts from excavated deposits. At the Tasmanian Pleistocene cave site of Bone Cave (Holdaway 2004), the mean proportion of artifacts (from Square C, 7mm or greater in dimension) to sediment (based on weight because maximum dimensions of artifacts were not recorded) is 2.3%. The Holocene site of Burkes Cave in the Scopes Ranges of western NSW (Shiner et al. 2005, 2007) has a mean proportion of artifacts (based on artifact volume) to the volume of sediment excavated of 3.5%. Artifacts from both of these buried deposits form a much higher proportion of the total regolith (by three orders of magnitude) than the volume of artifacts eroded from the NN99 location. Moreover, the assumptions underlying the calculation at NN99 mean that it is more likely to be an overestimate of the true artifact volume ‘lost’ than an underestimate. For example, numbers of artifacts per hectare estimated from the number recorded in 1 m x 1 m squares are likely to be much higher than true densities. Nor is it likely that all artifacts would be removed in a year. Similarly, the sediment loss rate is based on a yearly average, yet we know from repeat surveys (Fanning et al. 2007, p. 277) that instantaneous sediment loss rates in single rainfall events can be much higher. The net result of these assumptions is that the real percentage contribution made by artifact volume to the total sediment volume is likely to be even lower than that calculated above. In this sense, the higher densities in the excavated cave deposits are even more significant. They are much higher than the volume of artifacts in the eroded regolith despite the fact that they took many years to accumulate. From this we conclude that very low densities of artifacts entering modern channel systems would be ‘swamped’ by the total volume of other sediment, and become virtually undetectable. This goes some way to explain why artifacts that have been eroded and transported by concentrated flow in channel systems and then redeposited within fluvial sediments are, at least in our study areas, so difficult to detect.

Another way to approach this question is to actually examine the sediment deposits in rills and gullies to see whether they contain transported artifacts, and to compare the volume of artifacts with the total volume of sediment in the rill system. Three rill networks on the valley floor of Rutherfords Creek near Peery Lake (Figure 1) were chosen for this experiment (Bryant 2007). The landsurfaces surrounding the rill networks were covered with a low density of artifacts, as well as non-artifact clasts (Figure 8).

Before excavation commenced, a dense grid of points were surveyed using a robotic total station, and the data used to create TIN models of each rill network. Artifacts visible on the surface were surveyed and recorded including measurements of the maximum length (b-axis length) and weight. Loose sediment within the rills was excavated using a trowel and brush, and sieved through a 0.5 cm mesh sieve. Sediment deposited in alluvial fans at the junctions of each rill network with the adjacent gully or trunk channel was also excavated and sieved. The excavated sediment was weighed using a plastic bucket and a fish-weighing scale, and the total weight to the nearest 0.1 kg was recorded. The artifacts and non-artifact clasts (NACs) retained on the sieve, and measuring more than 5 mm in length, were weighed and their maximum dimensions recorded. The total combined weight of artifacts and NACs was also recorded.

Very few artifacts were recovered from within the rill networks and the deposits at the junctions with the higher order channel networks (Table III). They make up less than 0.2% of the total mass of sediment within the networks. This value is higher than that calculated from the Fowlers Gap NN99 sediment and artifact loss data, but, as discussed above, estimates based on plot data are always likely to overestimate the true value of sediment loss (field pin plot based erosion estimates are critiqued by, for example, Evans and Brazier, 2005, Parsons and Stone, 2006, and Boix-Fayos et al., 2007). It is also worth noting that, even when the artifacts are compared to the weight of NACs at Rutherfords Creek, they occur only as a very small proportion (0.001%). Artifacts are therefore rare in rill systems, even amongst clasts of similar size. Thus, the direct measurement of the total volume of artifacts transported in rills as a proportion of the total sediment load confirms that artifacts are likely to represent a vanishingly small proportion of the sediment load transported in rills, gullies and channels within our western NSW sampling locations.

ACCOUNTING FOR THE PRESENCE AND ABSENCE OF SURFACE ARTIFACTS: A SYNTHESIS

Geologically, Australia is characterized as an ancient land with rocks from the late Archaean to Mesoproterozoic (2400 Ma - 1,600 Ma) but such generalizations belie a more complex geomorphological history where, at a local scale, sediments deposited in the immediate past are juxtaposed with surfaces exposed for periods of time much longer than human colonization. The reasons for this relate to episodic climatic events discussed above, particularly severe, localized rainstorms that move large quantities of sediment including archaeological 'clasts' or artifacts. Because the effects of these events are so localized, and the events themselves show little long-term regularity, the outcome is a geomorphological environment best described as a spatial and temporal mosaic. Spatial proximity has little influence on temporal proximity meaning that surfaces separated by short distances may differ in age by centuries or millennia, or if the duricrusts are included, by many millions of years. In many instances, there is little surface indication of the age of the sediments lying beneath, and therefore no easy way, without the use of absolute dating techniques, to determine for how long a surface has accumulated an archaeological record. This is particularly true for surfaces adjacent to drainage lines that in many cases preserve an extensive archaeological record.

The same processes can, at certain times and places, lead to the erosion and therefore destruction of the surface record. In other instances these processes promote its exposure over comparatively large areas. Wind and water erosion can lead to the development of scalds and because artifacts, particularly stone artifacts, are of a size that are not easily moved on slopes less than two degrees, they are lagged onto the hard scald surfaces. In this way, very large numbers of artifacts are exposed, although at overall densities that are not particularly high. Extensive exposure offers the opportunity to record and analyze the archaeological record of entire drainage systems, as at Rutherfords Creek, for example (Holdaway and Fanning 2008; Holdaway et al. 2008). This offers an enormous potential for archaeologists to study the spatial patterns in artifact deposits even though, as our research on the geomorphic settings of such exposures indicates, artifact assemblage formation cannot be assumed to be contemporaneous.

Artifacts form lag deposits but, because they are sometimes removed through severe erosion brought on by extreme rain events, accumulation durations may differ markedly between locations. Thus while it may appear that artifacts have accumulated on comparable surfaces and therefore the resulting assemblages may be directly compared, this is not always the case. Erosion events distributed through both time and space act like a series of stochastic events, one of the outcomes of which is the apparent proliferation of more recent surfaces compared to surfaces that are preserved from more ancient times. As discussed below, this has important implications for estimates of the rates of culture change in the Australian arid zone.

A highly visible surface and near surface record is not matched by a rich deeply buried record, except where post-depositional geomorphic conditions have favored preservation, such as on river terraces or within lunette dunes like those found at Lake Mungo. Erosion leads to the movement of artifacts, transported via ephemeral streams and incorporated into poorly sorted, mixed sediment deposits. Sediment volumes greatly exceed the volume of artifacts transported, meaning that buried artifacts are effectively invisible.

Since the majority of the archaeological record is made up of stone artifacts that are prone to damage during transport, it is unlikely that the rare artifacts, if encountered, would even be identifiable in the unlikely event that permission could be obtained from heritage authorities to excavate the huge volumes of sediment required.

The outcome of the geomorphological processes that continue to shape the surface of the arid regions of southeast Australia is a surface artifact record that offers much opportunity for archaeologists if it is correctly interpreted using a geoarchaeological perspective. Surface exposure means that substantial numbers of artifacts can be analyzed very economically leading to new insights on the nature of assemblage composition (e.g. Holdaway et al. 2004; Douglass et al. 2008). However, failure to understand the nature of erosion and aggradation, and the episodic nature of events that shape surface sediments including the archaeological record, can lead to quite erroneous conclusions (Holdaway et al. 2008).

ARCHAEOLOGICAL IMPLICATIONS

The research outlined above explains why the southeastern Australian arid zone archaeological record is rich on the surface but rarely found as buried deposits. It also provides an indication of the temporal scale for behavioral interpretation. As noted in previous studies (Allen et al. 2008; Stern 2008), behavioral interpretation of artifacts needs to be matched to the temporal scale at which artifact groupings can be resolved. The age of the surface deposits on which artifacts unconformably rest provides the means for determining the length of time represented by the ‘minimum archaeological stratigraphic units' (Stern 1994) that can be used to group artifacts (largely stone artifacts). As reported above, lengths of time represented by these units vary, but many are in the range of one to two millennia in length, with rare occurrences measured in multiple millennia. These lengths of time have important archaeological implications.

First, it is best to avoid explanations that reflect short-term ethnographic time scales when dealing with periods spanning at least several centuries. As argued elsewhere (Allen et al. 2008), this is a tendency apparent in discussions of the late Pleistocene Mungo archaeological deposits: despite a detailed sediment chronology (Bowler 1998), archaeologists continue to discuss events involving the activities of groups of individuals, illustrated most recently by discussions of the Mungo 'footprints' (Webb et al. 2006). Our studies indicate that the temporal scale at which sedimentary processes operate are also of significance for Holocene surface deposits. As with the Mungo example, attempts to identify functional site types such as base camps etc., based on the surface record, are bound to fail simply because of the nature of the surface artifact deposits. As Bailey (2007) has recently discussed, the surface artifact deposits discussed here are both temporal and spatial palimpsests. Interpretation must take the nature of these deposits into account.

Second, while the temporal scale of the surface deposits precludes ethnographic scale explanations, ironically the durations over which many artifact assemblages have accumulated allows either similar or, at times, better chronological resolution than that obtainable in many stratified deposits, particularly those found in caves and rockshelters. Burial neither precludes post-depositional changes nor does it guarantee fine chronological control. Minimum stratigraphic units in some Australian cave sites may span centuries or millennia (e.g. Stern 2008). The presence of ancient rocks in Australia makes it appear as though all landsurfaces are ancient, therefore it is easy to fall into the trap of thinking that all ancient surfaces have accumulated artifacts since human arrival in the continent. As demonstrated here, this is not the case. Some surfaces, like those on the plateau and mesa tops, are many millions of years old (e.g. Alley et al. 1996, Benbow et al. 1995, Fujioka et al. 2005), but many others are much more recent. Resolution in many cases is at the scale measured in centuries rather than the millennia of some cave deposits. Moreover, surface artifact exposure is widespread providing the opportunity to study variability both across space and through time. In arid Australia, much attention is given to the excavation of cave deposits and much less to surface deposits. While results obtained from caves and rockshelters can be useful (e.g. Shiner et al. 2005, 2007), it is also true that the taphanomic problems involved in the study of caves may be underplayed (e.g. Stern 2008). Analyses are sometimes undertaken on buried deposits that distort the true chronological resolution, resorting to techniques like the creation of age-depth plots in an effort to relate the rate of artifact deposition to ethnographic scale behavior. Such measures have little validity when implications of discontinuous site use are considered (Holdaway 2004). Surface deposits have depositional histories no more complex than cave deposits and can sometimes provide minimum archaeological stratigraphic units that are shorter in duration than those obtainable from stratified deposits. As a result, more attention should be given to detailed considerations of surface material via extensive dating programs since this will provide the opportunity to develop regional chronologies unobtainable from relatively small numbers of widely dispersed stratified cave sites.

Third, the spatial variability in surface age has implications for landscape-based approaches to the past. For instance, many settlement pattern studies rely on the comparison of sites with similar accumulation histories distributed across a landscape. Results from our study area demonstrate that accumulation histories differ substantially across relatively small geographic areas. Therefore simply locating archaeological ‘sites’ in space is not a sufficient basis from which to reconstruct past settlement systems. Geoarchaeological analysis including dating cannot be relegated to a study undertaken once the distribution of archaeological material is obtained via survey. A ‘dots on map’ approach has little utility in an environment where sediments adjacent to drainage systems may have quite different accumulation histories (Holdaway and Fanning 2008). Instead, understanding the geomorphological landscape history is an essential *prerequisite* for archaeological research (Holdaway et al. 2008) and a sophisticated analysis of artifact assemblage composition is required that accommodates differences in accumulation histories.

A rich surface and immediately subsurface record exposed on surfaces that tend to have more recent rather than ancient ages, combined with an effectively invisible deeply buried record, makes it appear as though the volume of the archaeological record has increased dramatically during the course of the Holocene. Archaeological interpretations sometimes have equated this increase in abundance with increased human population levels and related social responses, changes discussed as evidence for a late Holocene cultural intensification in Australia (as summarized in Holdaway et al. 2008). Acceptance of the geoarchaeological framework described above means there is no need for intensification to explain the apparent increase in the quantity of archaeological materials. The empirical evidence used to support the theory of intensification can be accounted for by the action of geomorphic processes that have preserved the record from particular times in certain places but not in others. Increases in the abundance of the record through time simply reflect the cumulative action of chance erosion events. Over time, ancient surfaces will gradually disappear as sediments are eventually removed through erosion until the ancient surfaces become absolutely rare in the landscape. Ancient artifact deposits do exist in the Australian archaeological record, but the best known are restricted to a relatively few well dated sequences where the preservation potential is very high. The greatest potential for preservation of the oldest deposits occurs in caves and rock shelters, as well as some dominantly depositional environments like lake shorelines and lunettes, and sand dunes. Elsewhere, contemporary erosion and deposition effectively swamps the archaeological record making it invisible in a huge volume of sediment.

CONCLUSION

Geomorphology, not human behavior, determines the preservation, exposure and visibility of the archaeological record in our study areas in western NSW, and therefore the size and density of archaeological ‘sites’. Surface artifact deposits are not distributed evenly across the landscape, nor are all deposits equivalent. Differences in the age of surfaces and therefore the history of record accumulation mean that propositions like, for example, there is a uniform background ‘scatter’ of artifacts, have no utility. Equally, researchers must determine what it is that is being sampled before claiming that a representative sample has been obtained. These points have implications for the management of cultural heritage. If erosion exposes surface archaeology, and this process is ongoing, what is it that archaeologists and heritage managers should record? Ancient surfaces are only rarely distinguishable from more modern surfaces on the basis of their artifact content, so the only solution is to study the geomorphic history of a particular region before archaeological work is undertaken. Without such studies, any conclusions about the distribution or quantity of the archaeological record or its representativeness will be suspect.

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