Chapter One

Geomorphically dynamic arid landscapes in western NSW are the focus of this research on Aboriginal stone artefact scatters.

Geomorphology, Archaeology and Geoarchaeology:

Introduction and Background

CHAPTER ONE

GEOMORPHOLOGY, ARCHAEOLOGY AND GEOARCHAEOLOGY: INTRODUCTION AND BACKGROUND

1.1 Thesis Aims and Scope

This thesis explores the interrelationships between geomorphology and Aboriginal archaeology in western New South Wales (NSW), Australia, in particular how geomorphic processes at a variety of scales influence the spatial and temporal distribution of the surface stone artefact record that archaeologists study. It also explores how aspects of the archaeological record can inform on past landscape change. A major outcome of the research is a new geoarchaeological approach to surface artefact survey and interpretation anchored by an understanding of geomorphic landscape dynamics.

Australian Aboriginal archaeology has, for most of its history, focused on stratified deposits found in rock shelters, caves and overhangs (Robins 1996), where traditional archaeological techniques of excavation and salvage have been employed (e.g. Allen 1996; Dortch 1979; Hale & Tindale 1930; Mulvaney & Joyce 1965; O'Connor 1995; Roberts et al. 1990; Smith 1987). This is in spite of the fact that surface scatters of stone artefacts, together with associated hearth remains, are the most ubiquitous form of Aboriginal archaeological record across the whole of the Australian continent (Hiscock & Hughes 1983; Holdaway & Stern, in press). Whilst there are many reasons for this discrepancy, a key issue is the lack of understanding of the interrelationships between the stone artefacts discarded by Aboriginal people in prehistory and the geomorphic processes that occur on the land surfaces upon which they are found, such that the surface archaeological record has often been dismissed as hopelessly contaminated in terms of trying to understand hunter-gatherer behaviour (Robins 1997). Because they are so common, surface artefact scatters are the mainstay of much field archaeology, particularly that connected with environmental impact assessment, and are the subject of many of the archaeological conservation decisions made in Australia (HOLDAWAY ET AL. 1998). However, few Australian studies have investigated the level of disturbance of surface artefact scatters (Robins 1993) and none have examined the impact of geomorphic landscape dynamics on the archaeological record of Aboriginal hunter-gatherer activity.

That is not to say that archaeologists have ignored or disregarded geomorphology and geomorphic processes. On the contrary, they have long been recognized as part of the suite of 'natural' formation processes that, together with cultural processes, determine the shape of the archaeological record (e.g. Nash & Petraglia 1987; Schiffer 1983, 1987; Wood & Johnson 1978). Geologic and geomorphic input is essential to interpreting the stratigraphic sequences of ‘sites’, especially the nature of the environments of deposition that are represented by the archaeological sediments. Indeed, a whole sub-discipline of archaeology - geoarchaeology - has grown out of these kinds of applications of standard geologic and geomorphic techniques (e.g. Rapp & Gifford 1995, Rapp & Hill 1998; Waters 1992).

In Australia, the interrelationship between geomorphology and Aboriginal archaeology has been dominated by the investigation of Late Quaternary palaeoenvironments, most notably the work of Bowler (1970, 1971, 1973, 1976) at Lake Mungo (Figure 1.1), in tandem with archaeological investigations that seek to determine the time of earliest colonization of the Australian continent by Aboriginal peoples (e.g. Bowler et al. 1970, 1972; David et al. 1997; Fullagar et al. 1996; O’Connell & Allen 1998; Thorley 1998b; Thorne et al. 1999; Turney et al. 2001). Related to this is the study of people/environment interactions, in particular the ways in which Aboriginal people adapted to the variety of environmental settings in which they lived (Holdaway & Stern, in press). Once the antiquity of Aboriginal occupation of the Australian continent was realized, prehistoric settlement patterns in relation to the distribution of resources such as water, and how this had changed over the tens of thousands of years of Aboriginal occupation, became a focus for research (e.g. Ross 1984; Ross et al. 1992; Smith 1989; Thorley 2001; Veth 1993). Conversely, evidence for modification of the environment by Aborigines has also been a focus for archaeological research (e.g. Hughes & Sullivan 1981; Jones 1968, 1969; Mulvaney 1969).

Not surprisingly, in view of the lesser attention given to surface artefact scatters, landscape-based archaeological studies are relatively few. Early work includes that of McBryde (1968, 1974) in northeast NSW and Hallam (1977) in southwest Western Australia (WA). More recently, landscape-based approaches have been attempted by archaeologists trying to understand regional patterning in artefact assemblages (e.g. Robins 1993; Thorley 1998a; Witter 1992). However, to date, there have been no published Australian studies where geomorphologists and archaeologists have collaborated from the outset to fully integrate geomorphological and archaeological survey and analysis methods to investigate spatial and temporal patterns of prehistoric Aboriginal activity.

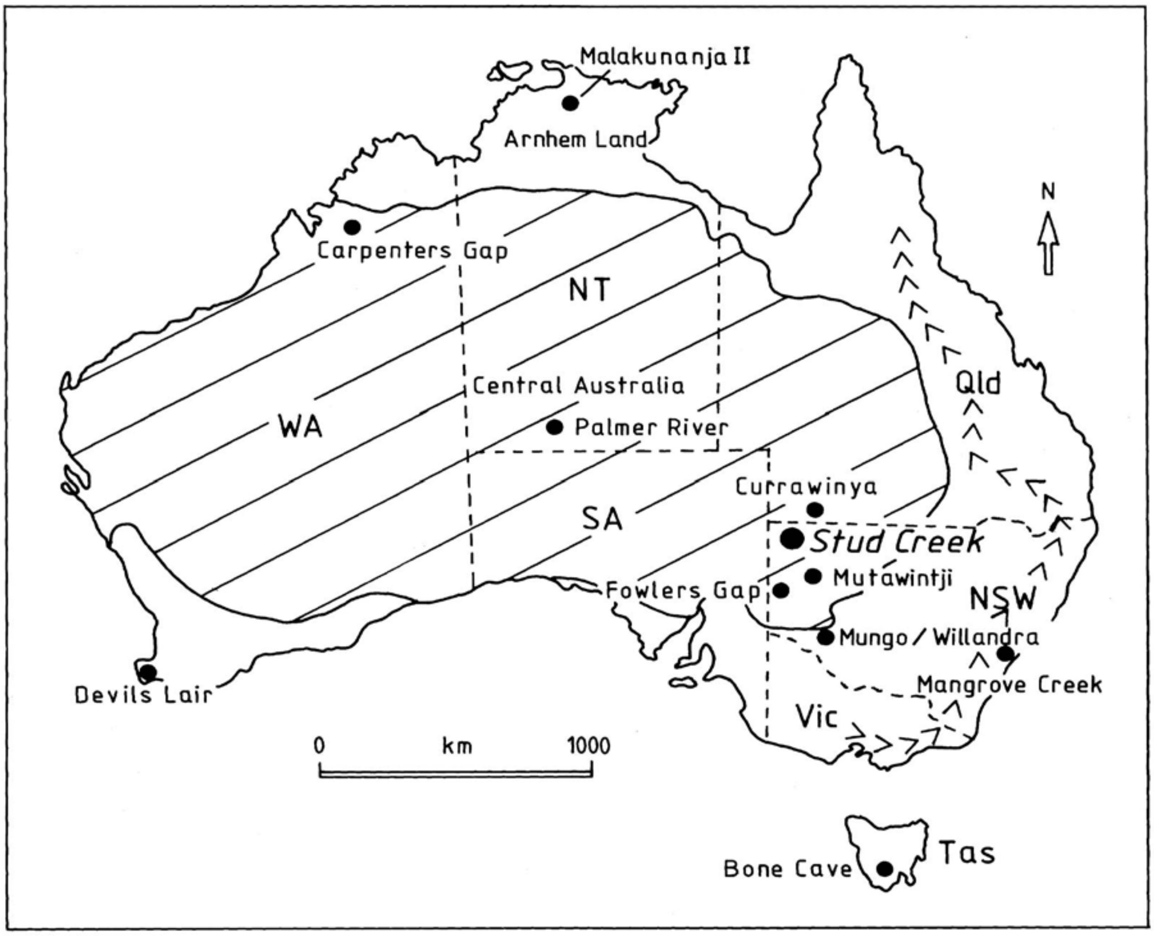

Figure 1: Australia showing the Stud Creek location and other places mentioned in the text. The arid zone, defined by the 250 mm annual rainfall isohyet, is indicated by hatching, and carets show the general location of the Great Dividing Range.

The research presented here fills that gap. It focuses on the landscape settings of surface artefact scatters, but utilizes the record of landscape change preserved in the landforms and underlying sediments to provide a temporal framework for those scatters. It also takes advantage of the fact that, in western NSW, exposure of artefact scatters is high. Large numbers of artefacts can be surveyed across many thousands of square metres without disturbing the remaining archaeological record by excavation, satisfying the desires of Aboriginal custodians for their cultural heritage to remain in place. Recent advances in digital technology have meant that a permanent record of the artefactual material, *within its landscape context*, can be made and retained, like a traditional museum collection, for future research.

The specific aims of the research are to:

1. investigate recent landscape change in western NSW and the contemporary geomorphic setting of surface artefact scatters;
2. determine the degree of disturbance of those scatters by geomorphic processes and whether it affects their potential for informing on prehistoric Aboriginal 'use of place';
3. develop a chronology for landscape history and Aboriginal occupation in the study area using absolute and relative dating of both the sedimentary and the archaeological record;
4. present a geoarchaeological framework for surface artefact survey and analysis that takes account of their contemporary geomorphic landscape setting and the history of landscape change.

1.2 Thesis Structure

The thesis is organised into five chapters. Chapter One sets out the aims and scope of the study, and the structure of the thesis. The origins and evolution of geoarchaeology are then reviewed, with particular emphasis on the development of landscape-based approaches to understanding and analysing the archaeological record, both internationally and in Australia. The background to the current research is then outlined. Two published papers that conclude the Chapter describe the results of a pilot study where several of the initial hypotheses were tested, and outline the scope of the research program.

Chapter Two presents geomorphic evidence for recent landscape change in western NSW that has resulted in the exposure of surface scatters of Aboriginal stone artefacts across extensive areas. The notion of a dynamic landscape setting for surface artefact scatters is established, and the significance for archaeological research outlined.

Chapter Three describes the artefact survey protocols developed to accommodate this dynamic landscape setting, and presents the results of analyses of the spatial distribution of surface artefacts designed to establish their lateral integrity.

Chapter Four presents a two-stage framework for establishing the chronology of surface artefact scatters in western NSW, using radiocarbon determinations from heat-retainer ovens as well as stratigraphic analysis and dating of valley fill sediments.

Chapter Five synthesises the outcomes of the research into a model of spatial and temporal variability in the archaeological record in western NSW. The veracity of the model is then tested using data from a pilot study at a different location within the region. The implications for current models of Holocene Aboriginal settlement patterns, and for various cultural heritage management issues, are discussed, and a new geoarchaeological framework for investigating surface artefact scatters that is anchored in an understanding of geomorphic landscape dynamics is proposed.

The bulk of the thesis comprises a series of papers, either published (7 papers), or submitted to a journal for consideration (1 paper). The introduction to each chapter summarises the respective papers, reviews additional relevant published material, and provides the context in terms of the overall aims of the thesis for the papers that it contains. Thus, the references for each chapter are listed at the end of that chapter. Papers which form part of this thesis are referenced in upper case throughout. Spelling and terminology follow Australian English standards, except where publication has required American English conventions.

1.3 Geoarchaeology: Origins and Evolution

Northern Hemisphere Perspectives

Geoarchaeology is generally regarded to be the application of the geosciences to solve research problems in archaeology (Butzer 1982; Pollard 1999). While the term was first used relatively recently (Renfrew in Davidson & Shackley 1976), interaction between the geosciences and archaeology goes back to the early nineteenth century, when geology and prehistoric archaeology developed essentially in parallel (Pollard 1999). Other terms such as archaeogeology, archaeological geology and archaeometry have also been used in the same context, and although the differences in meaning between them are considered to be trivial (Herz & Garrison 1998), there appears to be a general consensus that geoarchaeology is particularly concerned with geomorphology, pedology, stratigraphy, sedimentology and chronology (e.g. Gladfelter 1977; Pollard 1999). Rapp & Hill (1998) distinguish geoarchaeology from archaeological geology by considering the former to be part of archaeology itself, for example, analysis of the stratigraphy of archaeological sites, while the latter is research that is essentially geological in nature but that has implications for archaeology, for example, studies of coastal landforms and sea level change in the Mediterranean that had important repercussions for interpretation of the development of human societies and trade in the region.

Substantial advances in the knowledge of the earlier stages in human evolution, particularly in Africa, were the result of co-operative work between archaeologists, geologists and biological anthropologists, amongst others (Harris 1980). Koobi Fora in northern Kenya and Olduvai Gorge in Tanzania are "…good examples of well-investigated locations within sedimentary lake basins, where hominid remains and archaeological sites occur in a variety of [landscape] settings…" (Harris 1980: 63). In particular, advances in isometric dating techniques, notably potassium/argon age determinations on volcanic ash and lava, palaeomagnetic stratigraphy, and fission-track dating, provided the means by which environmental change as well as biological and cultural development at these locations could be assessed.

Geoarchaeology as a sub-discipline of both archaeology and geology is more formally recognised in the U.S.A. than elsewhere (Herz & Garrison 1998). Most of the monographs on the subject have been published in North America (e.g. Rapp & Gifford 1985; Rapp & Hill 1998; Waters 1992), as is the journal *Geoarchaeology*, and there are specialist geoarchaeology subgroups of both the Geological Society of America and the Society for American Archaeology (Goldberg et al. 2001). The impetus was the research focus of New World archaeology on when and how humans first colonised the American continents (Pollard 1999). The ephemeral nature of the archaeology of crucial early palaeoindian sites created the necessity for close collaboration between archaeologists, geomorphologists and sedimentologists, whose skills have been essential to understanding the archaeological record (Pollard 1999). The general impression of the nature of geoarchaeological study, as soil or sediment analyses from stratigraphic sequences providing palaeoenvironmental information and relative dating for the archaeological material they contain (Butzer 1982), was cemented by this research.

However, Gladfelter (1981) argued that, rather than taking a secondary role, geoarchaeological involvement should occur at all stages of archaeological investigations, i.e. design, excavation and analysis, and include geophysical exploration techniques, identification of the spatial context of sites, differentiation of natural and cultural formation processes in site formation, development of temporal contexts by absolute and relative dating, and reconstruction of palaeo-landscapes. In accordance with this view, a surge in studies of 'natural' (i.e. geomorphic and pedologic) site formation processes in the 1970s and 1980s helped to broaden the scope of geoarchaeology, although it mostly grew out of the desire by archaeologists to infer behaviour from artefacts (e.g. Schiffer 1972). To do this, the post-depositional effects of both natural and cultural processes had to be identified and accounted for (Stein 2001). Interestingly, much of the experimental and observational work on artefact taphonomy and post-discard redistribution processes was done by archaeologists rather than geoscientists (e.g. Petraglia & Nash 1987; Rick 1976; Shackley 1978; Schick 1987; Stein 1983; Villa 1982; Villa & Courtin 1983; Wandsnider 1989).

In the last two decades, there has been a proliferation of new approaches in archaeology that can be considered geoarchaeological in nature, particularly the expansion of spatial data recovery and analysis away from traditional focus on specific locations in the landscape, or archaeological 'sites', to the incorporation of distributional and non-site data from across extensive regions (Rossignol & Wandsnider 1992). Geomorphological analysis of landscapes has become increasingly important in analyzing archaeological materials and understanding the shape of the archaeological record (e.g. Bettis & Mandel 2002; Buck et al. 1999; Doleman 1992; Doleman & Stauber 1992; Doleman et al. 1992; Kuehn 1993; Seaman et al. 1988; Wandsnider 1989; Zvelebil et al. 1992). However, only a few of these studies combined geomorphological and archaeological survey and analysis techniques from the outset. The geomorphological dynamics of the landscape were more often examined *post-hoc* in order to explain the shape of the archaeological record. However, three recent publications (Wells 2001; Barton et al. 2002; Bettis & Mandel 2002) illustrate the importance of a fully integrated geoarchaeological framework for analyzing human land use and settlement patterns in the past.

Using case studies from coastal Peru and Cyprus, Wells describes "…methods by which geomorphology can be integrated into an archaeological survey to facilitate survey sampling strategies, prioritize survey regions, reconstruct palaeolandscapes, and provide an environmental framework for survey data interpretation…" (Wells 2001: 108). Echoing Gladfelter (1981) twenty years previously, she emphasizes the importance of geomorphologists being involved in survey project planning from the outset so that landscape analysis can provide the basis for sampling strategies. Subdivision of landsurfaces on the basis of relative stability aids in the determination of which surfaces are most likely to have archaeological material exposed at the surface, buried beneath sediments, or completely eroded away. In the Cyprus study, a geographic information system (GIS) was used to statistically compare the landscape classification maps with artefact distribution and density. A chronology provided by the relative dating of geomorphic surfaces allowed determination of which parts of the landscape were extant during any particular period of occupation. Thus, the method allowed for a spatial stratification of the landscape based on the highest likelihood for artefact discovery, resulting in the most efficient use of valuable field time.

Barton et al. (2002) have gone further and used these techniques to develop a diachronic model of land use change over the 80,000 years of human occupation of the Polop Alto valley in eastern Spain. A series of maps depicting spatial patterning in landuse over time were generated in a GIS by combining artefactual with landscape and stratigraphic data, and interpreted in terms of frequency, duration, density and area of occupation to construct a picture of 'use of place' by human inhabitants of the valley since the Paleolithic. Recognition of the dynamic nature of the geomorphic landscape assisted in the modeling of the dynamics of human use.

Finally, Bettis & Mandel (2002) summarise the controls of spatial and temporal patterns of fluvial system activity on the preservation and visibility of the archaeological record of past human activity in the central and eastern Great Plains of the U.S.A. Using a method of analysis reflecting earlier work of Waters (1991, 2000) and Waters & Kuehn (1996) in the American southwest, Bettis & Mandel (2002) summarise alluvial stratigraphies from selected river basins reflecting the range of landscapes across the west/east environmental gradient from south-central Kansas to central Iowa, and look for patterns in the record of alluvial sedimentation that may inform on preservation of the archaeological record in those basins. They found that periods of aggradation and channel erosion were diachronous throughout drainage networks across the region, and hence the Holocene sedimentary record is not uniformly preserved. This in turn determines the degree of preservation of cultural deposits dating to particular periods in different locations within the drainage basins. They attribute the relative abundance of Late Prehistoric sites to geomorphic conditions which favoured their preservation and visibility, and reject the notion that the greater number of sites dating to the late Holocene reflects dramatic population increases.

Geoarchaeology in Australia

Like ‘New World’ archaeology in North America, Australian archaeology has been largely dominated by the quest to find the site of earliest colonization of the Australian continent and to understand how and when Aboriginal people first arrived here. This work has always had a strong interdisciplinary flavour, with geologists, geomorphologists and pedologists making important site-specific contributions to a number of ‘classic’ studies of the pioneering period of archaeological research in Australia (Hughes and Sullivan 1982; Shawcross & Kaye 1980). However, geoarchaeology has had little recognition as a distinct sub-discipline of either archaeology or geology in Australian universities, with most archaeology being taught in Arts rather than in Science faculties. Nevertheless, many archaeological studies have been conducted in Australia that incorporate geological and geomorphological investigations of archaeological materials and their landscape settings.

Hughes and Sullivan (1982) published a review of Australian geoarchaeology in the proceedings of the first Australasian archaeometry conference held at the Australian Museum in January 1982 (Ambrose & Duerden 1982). However, the majority of papers at this and later conferences focused on the geoscientific applications to archaeology more commonly recognized as archaeometry, such as the chemistry and provenance of artefacts and archaeological sediments, and conservation of archaeological materials (e.g. Ambrose & Mummery 1987; Fankhauser & Bird 1993; Prescott 1988). One exception was a paper by Williams (1982), in which he used examples from the Nile Valley in Africa, the River Son in north-central India, and the Shaws Creek rockshelter in eastern Australia to emphasise a geomorphologist’s view that prehistorians need to take careful account of landscape change when interpreting archaeological deposits.

Hughes and Sullivan (1982) identified two main groupings of Australian geoarchaeological studies: those drawing on the methods and theories of geomorphology, geology and pedology which have been largely site-specific in approach, and those drawing additionally on the geographical sciences which have tended to be regional in focus, utilising a wide range of environmental and spatial approaches. From the first group, they reviewed investigations of the stratigraphy and chronology of rockshelter sites, the nature and sources of raw materials for stone artefact manufacture, and rock art conservation studies. Two further areas of investigation, namely palaeoenvironmental and chronological investigations of ‘open sites’ like Lake Mungo and river terraces in Victoria, and the impact of Pleistocene and Holocene environmental changes, particularly sea level change, on the pattern of

Aboriginal settlement along the southeastern Australian coastline, are mentioned but not reviewed.

Writing in 1982, Hughes and Sullivan indicate that landscape-based archaeological research was just gaining interest in Australia at that time. Worrall (1980) set out to investigate the theme of “man…as an agent of geomorphic change” in the Mangrove Creek catchment in coastal NSW (Figure 1.1), but instead discovered that geomorphic dynamics had significant impacts on preservation of the archaeological record of human activity. Unfortunately, this important insight was never pursued. Most early attempts at landscape-based archaeology in Australia focused on developing models of prehistoric settlement patterns based on the interpretation of sites in their Holocene paleoenvironmental context (e.g. Bonhomme 1983; Ross 1981, 1984; Smith 1988). However, in contrast to the serendipitous approaches of earlier archaeological research in Australia, these researchers used systematic surveys to look for sites, with stratified random sampling based on geomorphic criteria. More recently, Witter (1992) undertook a study of regional variation in stone artefact assemblages across NSW using geographic criteria, including Land Systems classification, to try to predict site locations and contents across a broad range of environments, from the humid Great Dividing Range to arid northwestern NSW (Figure 1.1). An objective of this study was to develop criteria upon which the assessment of site significance could be based for cultural heritage management purposes. However, the scale of the study was at odds with the nature of the stone artefact assemblages, with within-site variability overwhelming any regional trends. A predictive model never eventuated.

Robins’ (1993) study of the archaeology of the Currawinya Lakes region of southwest Queensland (Figure 1.1) was the first comprehensive attempt by an Australian archaeologist to test the utility of a landscape-based approach to identify and explain patterns of archaeological variability through time and space. Robins used non-site archaeological survey (after Thomas 1975) to identify spatial patterns in the archaeological record at a regional scale, and geomorphological survey, taphonomic experiments, and excavation and dating of several hearths and rockshelter deposits to try to understand those patterns. His stratified, systematic, transect-based sampling strategy was based on broad physiographic units (sandplains and dunefields versus dissected residuals) and land systems (Robins 1997). Regional availability of key resources (water and stone) was the major determinant of archaeological site patterning in the study area (Robins 1993, 1997).

While recognizing at the outset that "…the archaeological story…will be inextricably bound up with the geomorphic history…" (Robins 1993: 7), only limited integration of geomorphology into the methodological and analytical framework was undertaken. A major limitation of the study was the lack of consideration of geomorphic landscape evolution over time scales commensurate with human occupation of the study area, particularly European, and its control of artefact exposure and visibility. Despite a reference (Robins 1993: 93) to a particular location being "…extensively modified by European development…", Robins appears to assume that the geomorphic landscape has changed little in the time since Aboriginal occupation of the region, and that the landscape characteristics observable today were also present to more or less the same degree when stone artefacts were manufactured, used and discarded. This is certainly not the case for western NSW (FANNING 1999) and is unlikely for southwestern Queensland, although detailed studies of recent geomorphic landscape evolution in this region have not been published. It will be demonstrated in Chapter Two of this thesis that the land use change that accompanied European occupation of western NSW resulted in widespread erosion of topsoils in some areas, deposition of sediments in others, and incision of formerly stable valley floors, and that these processes had significant effects on artefact exposure and visibility. Moreover, episodes of geomorphic landscape instability have been characteristic of all parts of the Australian arid zone throughout the Late Quaternary. Without survey and analysis methods that take account of these influences on the shape of the archaeological record, only very coarse associations between patterning in artefact scatters and human behaviour are possible.

A regional landscape-based approach was also used by Thorley (1998a) to investigate arid zone settlement patterns and human adjustment to environmental change. Whereas previous investigations had utilized isolated sites spanning the central Australian ranges and their hinterland (e.g. Smith 1989; Veth 1993), Thorley chose sites that were bounded within a single catchment. Intensive, systematic surveys that incorporated both archaeological and geomorphological data were carried out in three study areas that reflected different landscape characteristics within the Palmer River catchment of Central Australia (Figure 1.1). Thorley (1998b, 1999) expected to find differences in occupation history at the three locations based on differences in water permanency, landforms, and positioning in the catchment. But in spite of supposedly abundant resources, especially water, and the relatively large area sampled (60,000 m^2), only 411 artefacts were found. While dismissing differential visibility as a factor, Thorley (1998a, 2001) acknowledges that sediment loss in the catchment has accelerated since the introduction of pastoralism in the late 1800s. However, his research neglects the geomorphic dynamics of the landscape and the effects it might have had on preservation of the archaeological record, and instead seeks explanation in ethnographic accounts of place use (Thorley 2001).

1.4 A New Landscape-based Geoarchaeological Approach to Australian Surface Artefact Scatters

Rossignol (1992: 4) defined a landscape-based approach as "…the archaeological investigation of past land use by means of a landscape perspective, combined with the conscious incorporation of regional geomorphology, actualistic studies (taphonomy, formation processes, ethnoarchaeology), and marked by on-going re-evaluation of concepts, methods and theory…" While regional geomorphology (e.g. Witter 1992) and studies of artefact taphonomy (e.g. Robins 1993) have provided a physical landscape context for studies of surface artefact scatters, and ethnography a social landscape context (e.g. Thorley 1998a), the most critical shortcoming of landscape-based archaeological research in Australia to date, as highlighted by the foregoing review, is the lack of Rossignol's "re-evaluation of concepts, methods and theory". In particular, Australian archaeologists have failed to recognise the impact of geomorphic landscape dynamics, at a range of scales, on the spatial and temporal patterning of the archaeological record, except in a fairly superficial sense through a few artefact taphonomic studies. As a consequence, they have continued to apply survey and analysis methods and to develop Aboriginal hunter-gatherer settlement models that assume spatial and temporal uniformity in the magnitude and frequency of landforming processes and, in some cases, stable landscapes since the time of formation of the archaeological record.

However, geomorphic processes are not homogeneous in operation over a wide variety of spatial scales (Chorley et al. 1984), and are temporally variable, particularly in arid environments. In Central Australia, for example, rainfall is 10 to 20 % more variable than the world average for comparable areas, and episodic events largely shape the environment (Friedel et al. 1990). Together with human-induced environmental change, this episodicity of landforming events has compounded the direction of geomorphic landscape evolution set by Late Quaternary climate change, as first documented by Bowler et al. (1976). Geomorphic landscapes show evidence of both functional (i.e. form – process) and historical influences, and are a palimpsest[1] of relict and modern forms (Chorley et al. 1984), episodically modified by contemporary geomorphic processes. There are many parallels with archaeological landscapes, which are themselves highly variable in time and space: a palimpsest of artefacts surviving multiple behavioural events (e.g. Aston & Rowley 1974; Barker 1982). In fact, archaeological landscapes are a complex mosaic of landsurfaces of variable ages containing records of human activity of variable lengths. The key to understanding the archaeological record initially lies with understanding the dynamics of the geomorphic landscape in which it is found.

Wells (2001) and Barton et al. (2002) have recently demonstrated the importance of the integration of geomorphology in archaeological investigations in Cyprus and Spain. The research presented in this thesis adopts a similar approach to surface artefact scatters in arid Australia, independently developing a landscape-based framework for artefact survey and analysis anchored by an understanding of geomorphic landscape dynamics. Regional landform pattern is not simply used as a static basis for spatial sampling stratification (e.g. Robins 1993; Thorley 1998a; Witter 1992). Instead, the morphodynamics and geomorphic evolution of the landscape are used to focus artefact surveys on those parts of the landscape where the degree of exposure and preservation of the archaeological record are likely to be maximised. Whereas artefact taphonomic studies have been primarily used to prove post-discard disturbance, and hence devalue surface scatters as a suitable vehicle for archaeological research, here they are used to demonstrate the overall lateral integrity of those scatters. Differential artefact visibility at the time of archaeological survey can be viewed as a function of contemporary landscape processes, allowed for in the survey protocol.

Temporal frameworks need not depend on the relatively few reliable chronologies built from absolute dating of long stratigraphic sequences preserved in caves or rockshelters and extrapolated across the continent. Local chronologies can be developed from absolute and relative dating of geomorphic surfaces and the archaeological materials, such as hearths, that they preserve. Rather than seeking to date individual *events*, whether behavioural or geomorphological, the goal of landscape-based archaeological research should be to seek *patterns* in both the spatial and temporal record of events that will allow a detailed

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[1] Greek: *palin* – 'again', *psao* – 'rubbed smooth'; 'writing-material or manuscript on which the original writing has been effaced to make room for a second writing; monumental brass turned and re-engraved on the reverse side' (*The Concise Oxford English Dictionary*, 6th edition. Clarendon: Oxford.)

prehistory of Aboriginal 'use of place' (*sensu* Wandsnider 1989) to be developed. The Western New South Wales Archaeology Program was established to pursue that goal.

1.5 The Western New South Wales Archaeology Program and the TIB13 Pilot Study

Archaeologist, Dr Simon Holdaway, initiated the Western New South Wales Archaeology Program (WNSWAP) in 1995. A stone tool specialist with experience in applying Geographic Information Systems (GIS) to archaeological problems, his aim was to develop new techniques for examining the surface stone artefact record in ways that would inform on the spatial and temporal patterns of prehistoric Aboriginal hunter-gatherer activity. As indicated by the foregoing review, surface scatters had previously been largely dismissed by archaeologists because they were unbounded, lacked the stratigraphy considered essential for establishing a chronology of occupation, and appeared to be significantly disturbed by post-depositional formation processes.

Initial discussions with Dr Dan Witter, then Western Region archaeologist with the NSW National Parks and Wildlife Service, led to the selection of a pilot study area in Sturt National Park in far northwestern NSW that Witter had designated the 'TIB-13 site' (see Figure 1 in HOLDAWAY ET AL. 1998 for location map). As noted by Witter (1992: 142), the site had been '…heavily eroded and all of the artefactual debris are [*sic*] resting on a hard clay surface…' This meant that the artefacts were easy to see and to survey, but erosion processes that had exposed them may have compromised their vertical and lateral integrity. The need to undertake the artefact survey within a geomorphological framework was obvious.

The first of two papers that comprise the rest of this chapter (HOLDAWAY ET AL. 1998) describes the results of that pilot study, and the second (HOLDAWAY ET AL. 1997) summarises the rationale for future directions for WNSWAP research. Our main aim in undertaking a pilot study was to investigate whether, by studying surface scatters of stone artefacts, we could detect variability in the spatial deposition of artefacts in the past. At the same time, we investigated the influence of post-discard geomorphic processes on those spatial patterns, and the suitability of newly developed rapid data capture technology and GIS for investigating problems of this type. As suggested by Wandsnider (1992), landscape-based distributional approaches to artefact survey requiring large volumes of feature and artefact attribute data have only been made possible by these technological advances.

The outcomes of the research confirmed that our approaches to tackling the problems associated with surface artefact scatters were sound, and warranted further development. There was a clear correlation between artefact density and landsurface type, most likely reflecting visibility differences across the study area. Artefacts located on or close to areas of concentrated water flow, such as rills, appeared to be size-sorted, but there was no clear relationship between artefact size and distribution pattern on lagged surfaces away from the rills. By limiting assemblage analysis to only those artefacts found on lagged surfaces, we detected significant spatial patterning in assemblage variability across the site (HOLDAWAY ET AL. 1998).

While the time frame for deposition of the artefacts at TIB-13 could only be inferred to be mid- to late Holocene, based on tool typology, there was sufficient geomorphic evidence to indicate that a chronology for landsurface change at this and nearby locations could be developed by sedimentological analysis and absolute dating of the valley fill sediments upon which the artefact scatters were now resting. This would provide a maximum age for deposition of the artefact scatters. At the same time, radiocarbon dating samples from the exposed remains of numerous heat-retainer ovens (also called ‘hearths’) associated with the artefact scatters had the potential to provide a chronology of occupation across the site, thereby answering the critics who considered surface scatters to be undateable because they lacked the stratigraphy usually required. The range of dates from the radiocarbon determinations would indicate an ‘envelope of time’ during which the associated artefacts were deposited.

We had the team and the technology (Figure 1.2); the money came in the form of an Australian Research Council Industry Collaborative Grant between our research team and the NSW National Parks and Wildlife Service for further research in Sturt National Park from 1996 to 1998. Entitled ‘Predictive Modeling of the Distribution of Archaeological Materials in Sturt National Park’, the project aimed to develop a generally applicable set of methods for archaeological research and heritage management by abandoning the archaeological concept of ‘sites’ and substituting a geomorphic landscape framework upon which to undertake artefact survey, analysis and assessment of scientific significance. The second paper in the chapter (HOLDAWAY ET AL. 1997) outlines the scope of this research. It was originally published on CD ROM and has been reformatted and condensed for reproduction here.

The research presented in the rest of the thesis largely draws on the outcomes of this research project. I focus on my geomorphic contribution, particularly in recognizing and documenting the processes of landscape evolution responsible for preservation of the archaeological record and its exposure at the surface, and the impacts of contemporary processes on differential visibility and lateral integrity of surface artefact scatters. I demonstrate how an understanding of geomorphic landscape history and dynamics is essential for building a chronology of Aboriginal occupation of the Australian arid zone.

Figure 1.2: The WNSWAP team of (l. to r.) Trish Fanning, Dan Witter and Simon Holdaway “demonstrating” some of the technology to visiting press. The eroded valley floor of Stud Creek, with the field crew analysing artefacts, can be seen in the background.

1.6 References

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New approaches to open site spatial archaeology in Sturt National Park, New South Wales, Australia

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Abstract

Surface scatters of stone artefacts are ubiquitous in the Australian landscape and form the basis for the majority of archaeological conservation decisions. The research reported here proposes a distributional approach for analysing this record founded on the artefact as the minimal recording unit rather than the site. A method of assemblage definition is proposed to permit the study of assemblage composition across space. The method is applied to artefacts exposed on the surface as a result of recent erosion at TIB13 (Sturt National Park, NSW). All stone artefacts greater than 20mm in maximum dimension were recorded by locating each artefact in three-dimensional space and analysing it in place. The distribution of these artefacts was then compared to the nature of the landform on which they rested through the use of a GIS. Analysis of assemblage composition indicates significant differences across an area of approximately 30,000m^2.

Surface scatters of stone artefacts are the most common phenomenon in the archaeology of Aboriginal sites in Australia yet their study has probably contributed the least to our understanding of Aboriginal prehistory. The reasons why are not difficult to find. Open sites normally lack the stratigraphy that is fundamental to the analysis of many sets of artefacts, they are areally extensive with no clear boundaries, they contain few features with which to demarcate groups of stone artefacts, the stone artefacts themselves are not easy to interpret, and their identification is controlled by exposure and visibility related to ground surface conditions. Yet because they are ubiquitous, open site stone artefact scatters are the bread and butter of much field archaeology in Australia, particularly that connected with Environmental Impact Assessment (EIA), and they are the subject of many of the major archaeological conservation decisions made in Australia.

This paper outlines initial results of a project aimed at developing new ways of dealing with this form of archaeological record. Rather than look at the distribution of sites across a region, we argue that the conventional concept of a site is unproductive and that regional studies should begin by developing an understanding of the way the archaeological record has formed on an artefact by artefact basis. Artefacts may then be combined into spatially defined assemblages and variability in assemblage composition investigated at a landscape level. We report here the results of one such analysis of TIB13, a location in Sturt National Park, NSW (Witter 1992).

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The definition of stone artefact assemblages

Whether archaeologists excavate artefacts from stratified deposits in rockshelters or collect those distributed on the surface, they analyse artefacts by using their common location in time and space to search for pattern representing repeated behaviour. Only rarely can we see the individual at work in such situations; instead an average picture of behaviour is reconstructed from the material abandoned by many individuals at one particular location. For stone artefacts this behavioural average is most clearly seen by studying processes such as procurement, manufacture, use and discard.

In rockshelters the walls ultimately limit space, although more often than not the limits are those of the excavation unit; time is proscribed using a number of techniques (in Australia those that provide absolute age determinations are the most common). The assemblages of artefacts created by the use of time and space units reflect a particular scale of resolution. Even the best-dated site (where chronology relies on radiocarbon) will have a temporal resolution measured in decades or centuries. This means that archaeologists, of necessity, analyse long term accumulations of artefacts no matter what type of record they investigate.

In this sense studying a surface scatter is no different to excavating in rockshelters. In both situations artefacts accumulate through time and are grouped together on the basis of their common location. Where these types of record differ is in the way time may be controlled: stratified rockshelters offer the opportunity to study artefact accumulation through time via the creation of multiple temporal units whereas surface scatters normally offer the opportunity to define only a single chronological unit. Rockshelters and surface scatters differ, therefore, in terms of our ability to categorise time, but not necessarily in the level of precision with which such units are defined. If the age of the surface on which artefacts lie can be determined this in effect dates the artefacts at a precision given by this surface's age. While many surfaces may accumulate artefacts over millennia rather than decades or centuries, a chronology with a precision measured in millennia is not unknown for rockshelter sites (Cosgrove 1995). Of course, what is lost in the ability to study chronological change through time with surface scatters is replaced by the ability to investigate change across space. While rockshelter sites sometimes show intrasite differences there is a much greater opportunity to investigate spatial variability in surface scatters where the effect of natural boundaries is much reduced.

This study aims to investigate stone artefact assemblage variability by analysing surface scatters, rather than stratified rockshelter deposits, to determine whether variability in the spatial deposition of artefacts in the past has left patterns that can be detected archaeologically. The example we discuss draws on work being conducted in Sturt National Park under the auspices of the Western New South Wales Archaeological Program (WNSWAP). One aspect of this program involved the location and analysis of 10,000 stone artefacts across an area of 29,930 m^2 identified as TIB 13 (Witter 1992:142). All data retrieved has been integrated into geographic information system (GIS) software (ARCINFO and ARCVIEW). In this paper we discuss the rationale for using this software, the field methods adopted, and the analytical techniques developed using the GIS. We provide details of the analysis of this data to illustrate the type of results we hope to recover during future periods of research.

Alternatives to sites as an analytical category

Without rockshelters, the boundaries of a site are much harder to determine; in fact, in the absence of clear evidence that occupation was spatially constrained (permanent houses for instance), the use of a site as an analytical unit becomes problematic (Ebert 1992; Dunnell 1992). This is particularly true in Australian archaeology where surface scatters of artefacts predominate. In heritage management, for instance, where the concept of a 'site' is central to the entire industry (and to conservation decision making) definitional problems abound. The New South Wales National Parks and Wildlife Service originally considered that two artefacts within 50m of each other constituted a site. This is no longer considered appropriate (NSW NPWS 1997) but it has proved difficult to provide a definition for documenting the distribution of archaeological evidence in units suitable for management purposes. Clearly, different units need to be considered when describing the archaeological record for management purposes and for assessment in terms of prehistory, but few techniques for doing this have so far been proposed.

Criticisms of the site concept are not new (see Dunnell & Dancey 1983), and overseas at least, much work has been devoted to developing alternatives to the site based approach culminating in a variety of distributional and landscape archaeologies (Ebert 1992; Rossignol & Wandsnider 1992). In many such studies 'site' has been replaced by 'artefact' as the minimal recording unit. But while using the artefact as the recording unit gets around the problem of site boundaries, it introduces a different problem, that of defining assemblages. Since the site forms the ultimate unit from which an assemblage may be defined, removing this assemblage definition is problematic.

Those interested in landscape approaches have turned to techniques developed for intrasite analysis to solve this problem (Ebert 1992). Early intrasite studies relied heavily on direct ethnographic analogy with assemblages defined in terms of 'living floors', 'activity areas', and 'toolkits' (Freeman & Butzer 1966; Whallon 1973, 1974). But this has changed in the face of criticisms that co-variation in space need not necessarily reflect a simple functional association (Schiffer 1972:161–2) and ethnoarchaeological evidence that activity areas may not be discernible in the archaeological record (O'Connell *et al.* 1991:73–4; Yellen 1977:85–6). With a few exceptions (Carr 1984:106), these criticisms have been accepted; researchers are no longer searching for short term ethnographic explanations for intra-site patterns in assemblage composition.

The change in theoretical orientation should not, however, be seen as diminishing the utility of the methods developed for intrasite analysis. Many of the techniques are useful for assemblage based pattern recognition; it is the explanation of the pattern that has changed. Rather than the identification of tool kits and activity areas, ethnoarchaeological research is increasingly being directed at asking how and why behaviour is organised as it is at particular locations, how this organisation is reflected in the distribution of refuse and whether knowledge of these relationships can be applied to the types of pattern apparent in time transgressive archaeological contexts (O'Connell *et al.* 1991).

Recent ethnoarchaeological work provides a number of observations relevant to the interpretation of surface stone artefact scatters. It tells us, for instance, that the longer the duration of occupation, the greater the chance that there will be patterns in the distribution of abandoned artefacts. We may expect a more structured distribution of artefacts near resources when their utility, nature and location, required extended time for exploitation (O'Connell 1987; O'Connell *et al.* 1991; Cameron & Tomka 1993; Wandsnider 1996). Patterns in the distribution of artefacts will be apparent over large areas (thousands of square metres) and identifiable as general trends in the frequency and size of abandoned artefacts. And they will probably not be visible with the conventional archaeological samples of a few tens of square meters or less (Wobst 1983). These studies suggest that we should not be attempting to

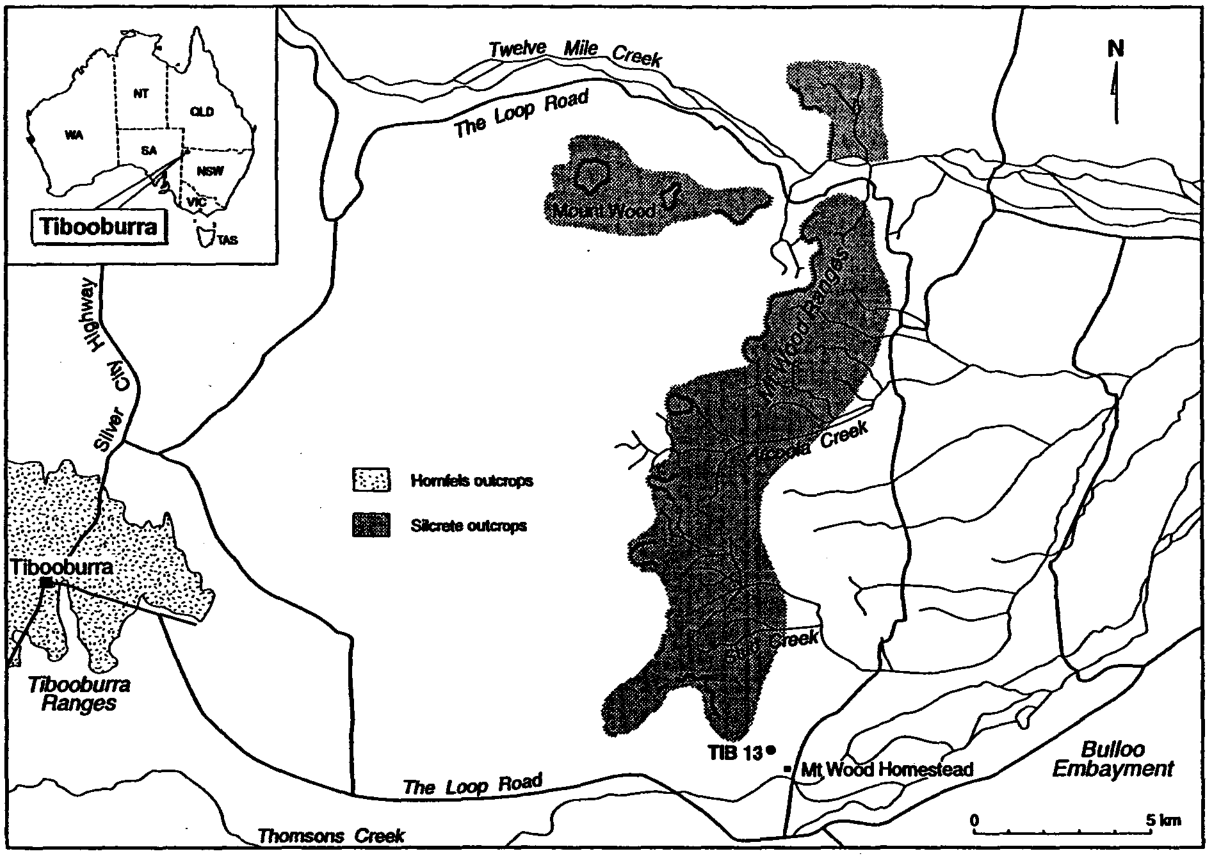

Figure 1. Location Map.

identify living floors, activity areas or toolkits but developing methodologies capable of defining assemblages without recourse to sites across areas that are very large compared to those recorded in conventional archaeological fieldwork.

It is our suggestion that we can undertake such studies by adapting the techniques applied to intrasite studies, using them to discover patterns in surface artefact scatters. What is needed is a set of methods for defining assemblages (one of which we describe below) and a set of techniques for analysing the composition of the resulting assemblages in terms of artefact manufacture. Here, we provide one set of examples based on our work at TIB 13 where we seek patterns in assemblage composition across space that can be used to define long term trends (just how long, and how time is to be defined, is discussed below) in the way refuse was discarded across a landscape in the past. Given sufficient research, these patterns may be able to be interpreted in terms of stone resource exploitation, manufacture, use and discard within a particular geographic region but at present we limit our discussion to the techniques that enable us to identify these patterns at a single location.

The study area — TIB 13

Since WNSWAP was conceived to promote new methods for tackling the archaeology of surface stone artefact scatters, the project personnel were recruited from a variety of backgrounds to ensure a multi-disciplinary perspective. We currently have a geomorphologist (PF), a heritage manager (DW) and an academic archaeologist (SH) together with a geophysicist (RM) working on the project. As a consequence, the project has developed a number of research areas designed to address the four problems with surface scatter archaeology identified above:

- absence of clear boundaries,
- the lack of methods for grouping artefacts into assemblages for analysis,
- the difficulties involved in extracting information from stone artefacts, and
- the problem of chronology when faced with the lack of stratigraphy.

The location we discuss, TIB 13, was originally identified by one of us (DW) during an earlier phase of research at Sturt National Park. It was selected as a location to trial the recording and analytical systems we describe here because it seemed to encompass a broad range of features typical of archaeological deposits in the region within one relatively constrained area. Of these, the most critical was the degree of erosion and stripping of the landsurface which has occurred since sheep grazing was introduced to the region in the late 1800s. In effect this erosion has 'excavated' an archaeological 'site' for us, exposing many thousands of artefacts on lagged surfaces. For archaeologists interested in using the artefact as the minimal depositional and analytical unit, this erosion has produced the ideal landscape. We have tens of thousands of squares meters of 'excavated' land on which to search for interpretable patterns of artefact deposition. Moreover, we are able to do this without further disturbance to the material, acceding to the wishes of the Wangkumara people, on whose land we are working, that their heritage be left in place.

The TIB13 location is adjacent to an unnamed left bank tributary of Thomsons Creek within a kilometre of the Mt. Wood homestead in Sturt National Park (Figure 1). A low escarpment comprising Cretaceous marine sediments capped with silcrete forms the eastern boundary, with the creek forming the western boundary. In between is a flat valley floor surface underlain by alluvium. It is currently devoid of vegetation, except for a few gidgee (*Acacia cambagei*) along the watercourse and scattered chenopod shrubs and grasses, as well as mulga (*Acacia aneura*), on the slope below the escarpment. Rainwash and wind erosion has removed topsoil down to the level of the hardsetting bleached A2 horizon of the original duplex soil profile, which has formed in the alluvium. Incision below this level has occurred along rills, exposing the domed columnar structure of the red silty clay subsoil. Gravel is scattered over much of the valley floor surface as a lag, except where it has been buried by transported sediment from upslope, forming features which have been termed 'sediment islands'.

Along the watercourse, deposits consisting of sands, granules and gravel in a grey clay matrix, which probably accumulated in ephemeral waterholes, have been overlain by at least 30cm of red sandy sediments derived from the topsoils eroded from catchment slopes. This material is variously referred to as either 'post-European material' or 'post-settlement alluvium' (PSA). Radiocarbon determinations of charcoal from Aboriginal fireplaces buried by this alluvium at Mootwingee and Fowlers Gap (Fanning 1996) indicate that it postdates European occupation of the region and it is therefore likely to be the product of the initial phase of disturbance of the vegetation cover by sheep grazing and associated activities. Channels subsequently incised the valley floors, exposing these materials in the channel banks. The channels are continuing to enlarge by incision, widening and knick-point retreat since the hydrodynamic instability initiated by land-cover change in the late nineteenth century has not completely worked its way through the upland catchment systems (Fanning 1996).

Field methods

The field methods we developed for work at TIB 13 reflect both the erosional characteristics of the region and our interest in recording individual artefacts as the minimal depositional and analytical units. Because we are dealing with such a large area and many artefacts, we considered the use of a graphical relational database (a vector Geographic Information System (GIS) — ARCINFO) essential to our operation.

The field methods consisted of two parts:

- the construction of a map of the geomorphological features within the study area, and
- recording the location and nature of the stone artefacts distributed across the landscape.

Experience showed that these two tasks were conducted most efficiently by two separate crews. Ideally, geomorphological mapping of a segment of the study area should be completed before the artefact-recording crews proceeded with their tasks.

All mapping was conducted in three-dimensional Australian Map Grid (AMG) coordinates from a datum location established with a Global Positioning System (GPS). This was done to allow seamless integration with other data mapped in AMG (i.e. commercially available digital maps). It is important to note that AMG coordinates are double precision numbers. This can cause problems for some software packages.

Geomorphological mapping

Geomorphological mapping aimed to record the nature of the land-surfaces on which the artefacts were resting in terms of their depositional or erosional history. A modified version of the regolith/terrain mapping system of Pain *et al.* (1991) was used. Four landform elements were mapped (Figure 2): erosional surfaces that retained gravel and artefacts as a lag; areas of sediment deposition; incised depressions into the landsurface such as rills, gullies and channels; and the strip of land adjacent to the main stream channel where overbank deposition of alluvium was dominant and almost completely masked the archaeological record. As will be detailed below, these mapped surfaces were then analysed in terms of their effect on artefact visibility and taphonomy. Mapping was achieved using an electronic total station (Sokkia SET 5C) connected to a hand held computer (SDR 33), using a crew of three people. A geomorphologist (PF) determined the landform element boundaries and recorded the details in a field notebook.

Artefact mapping

Details of artefacts were recorded in two separate databases that were linked by the use of a common identification number for each artefact: a locational database to

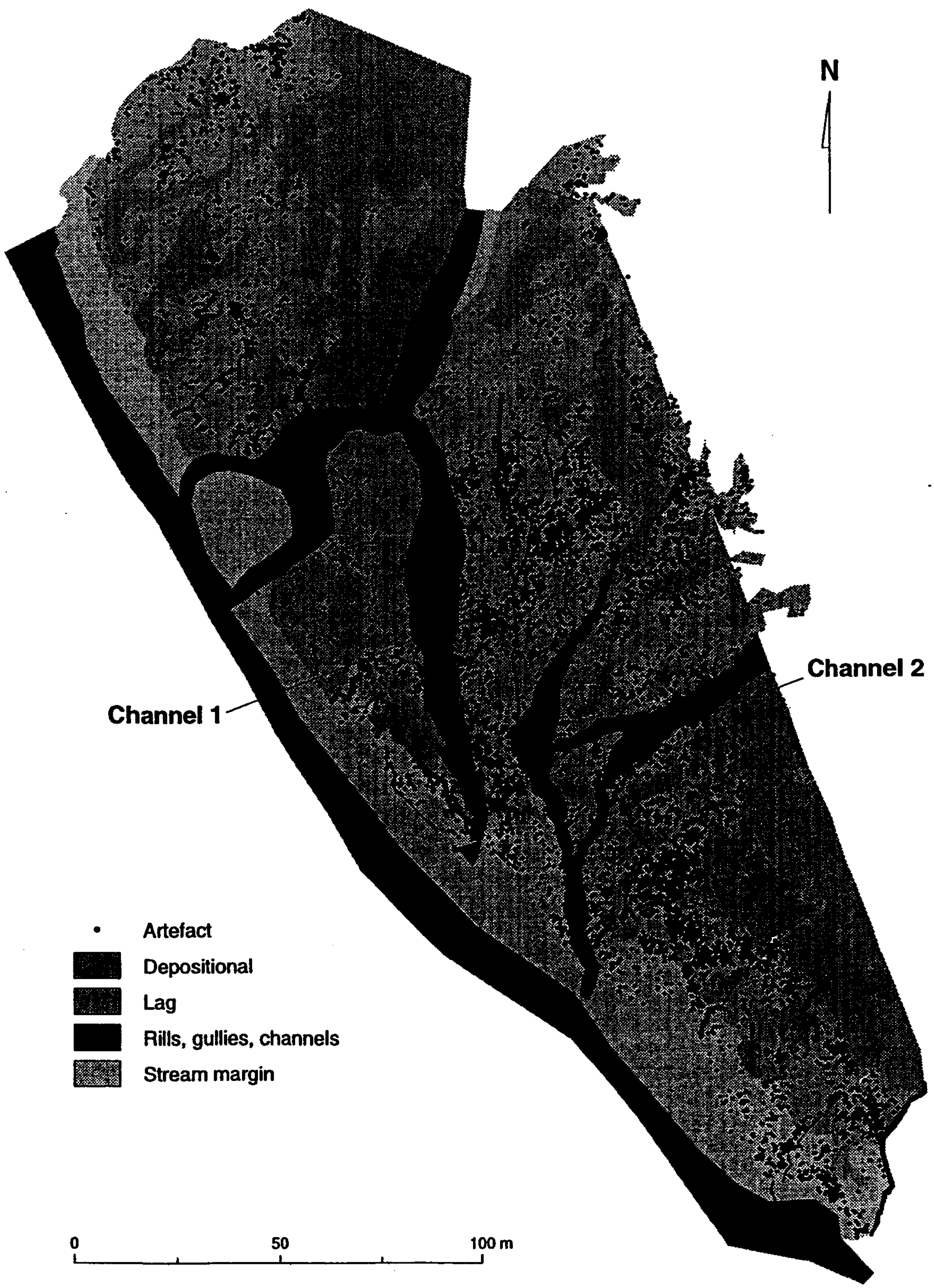

Figure 2. Landsurface types and artefact distribution at TIB 13.

Attribute	Value	Description
Data-class	Complete flake	Has a platform and a termination
	Proximal flake	Retains a platform and no termination
	Distal flake	A termination with no platform
	Medial flake	No platform and no termination
	Complete tool, proximal tool, distal tool, medial tool.	As above, but with macroscopic retouch.
	Core	Negative flake scars including both producer cores and nuclear tools
Material	Quartzite	
	Silcrete	
	Quartz	
Distal end	Feather	Tapering termination
	Abrupt	Non-tapering termination
	Plunge	Curves toward the ventral surface
	Hinge	Curves toward the dorsal surface
Form	Blade	Parallel flake scars
	Expanding	Proximal end narrower than distal end
	Intermediate	All other flake forms
	n/a	Form cannot be determined
Platform type	Unifacial	Struck from a unifacially flaked or cortical platform
	Bifacial	Struck from a bifacially flaked platform
Tool type	Scraper	Continuous macroscopic scalar or stepped retouch
	Notch	Retouch forming one or more single cuspate notches
	Utilised	Edge nibbling that may be discontinuous
	Point/backed blade	Backed blades and unifacially retouched points
	Adze	Tula or burren
Core types	Unifacial	Platforms flaked from a single direction
	Bifacial	Platforms flaked from two directions
	Microblade	Multiple parallel flake scars across core surface
Dimensions	Maximum length	Longest dimension in any axis. Measured on all pieces
	Maximum width	At right angles to maximum length, only on complete flakes and tools
	Maximum thickness	Where length and width intersect, only on complete flakes and tools

Table 1. Artefact attributes and values recorded at TIB 13.

Land-surface	*Number of artefacts*	*Area in m²*	*Artefacts per m²*
Depositional	608	4475.2	0.14
Channels 1 & 2	567	5969.5	0.09
Lags	7856	13972.8	0.56
Margin	634	5132.9	0.12
Rills	169	379.9	0.44

Table 2. Landsurface areas and artefact density.

record the three dimensional spatial co-ordinates of the artefact, and an attribute database that contained values for a range of technological and typological variables. Once the geomorphological mapping of a part of the study area was completed, a large crew of archaeological field workers surveyed the area. To ensure that the total area was covered, this survey was very intensive, with workers separated by only a metre walking in several lines abreast. All artefacts with a maximum dimension of 20mm or more (after Schick 1987 — see below) were identified. When an artefact was found, a nail with a coloured tape attached was placed next to it. The survey crew of three then mapped each artefact. The coordinates were stored in the SDR memory, and a sequential ID number allocated. The EDM operator advised the target holder of the number via radio contact, and this was written on the coloured tape.

Once the location of the artefacts had been recorded, a separate team recorded technological and typological information for each artefact. The list of attributes recorded and their definitions is provided in Table 1. Because TIB 13 was recorded at an early stage of the project a very basic set of attributes were used. Subsequent work at Sturt has expanded the range of attributes taken.

Recording was achieved by logging directly into palmtop computers (HP 200LX) running data entry software (ENTRER TROIS [McPherron & Holdaway 1996]). This software prompts the users for input making extensive use of menus for nominal or ordinal values. The identification number on the coloured tape was recorded for each artefact uniquely identifying it and providing a link to the locational database.

After each day's work, the co-ordinate data and artefact descriptions were downloaded from the data loggers and palmtops. Co-ordinates were stored both in a conventional relational database and as converted GIS elements (points, lines and polygons). For our purposes land-surfaces were recorded as polygons (a sequence of points joined by lines that close back to the starting point) and sometimes lines (a series of points connected by lines that do not close). Artefact locations were recorded as points. The GIS elements were then labelled according to the type of land-surface or artefact form they represented (Figure 2).

Results

Analysis using a GIS

The GIS allows us to integrate the locational and attribute databases for the artefacts together with the locational database for the geomorphological land-surfaces. Database queries may be constructed that combine any of the spatial and analytical data that we recorded. The practical application of this software is illustrated in a series of analyses below. We begin by considering the effect of the erosional processes that have exposed the artefacts, particularly issues of artefact visibility and movement by water. We then introduce a method for assemblage definition based on the spatial distribution of artefacts. The results of analyses based on this method are presented to show the type of assemblage level spatial patterning present at TIB 13. We finish with a brief discussion of our future analytical goals.

Artefact density on land-surfaces

Figure 2 illustrates the pattern of artefact dispersal across four landform elements identified at TIB 13. It is clear from this figure that artefact density varies considerably with landsurface type, and this is confirmed when true densities are calculated (see Table 2). Area can be easily calculated for each landform element with the GIS software, as can the number of artefacts that are located on each element.

The results indicate two sets of density values. Depositional and Stream Margin landforms have low densities, around 0.1 artefacts per square meter, while Lag and Rill landforms have densities that are four to five times higher, around 0.5 artefacts per square metre. It is likely that this difference in density reflects visibility differences; some artefacts in the Depositional and Stream Margin landforms are buried so were not recorded (cf. Witter 1992:84–7). Alternatively, there may have been fewer artefacts deposited in the Depositional Surface and Stream Margin areas in prehistory. Channels have the lowest density of artefacts reflecting removal by water flow (see below).

One way to differentiate between these possibilities would be to excavate the Depositional Surface and Stream Margin landforms and record the distribution of buried artefacts in each. While possible, such an undertaking would be extremely time consuming, and as discussed above, not likely to win support from either the Wangkumara Aboriginal Community or the NSW NPWS. The alternative, which is discussed below, is to develop techniques that enable us to exclude landforms that may have lower densities of artefacts, possibly as a result of visibility problems, without compromising the ability to analyse the spatial distribution of artefacts across the site as a whole.

In the analyses that follow we treat TIB 13 as an analytical location by looking for patterns in the distribution of artefacts on the Lag Surface. In this case the location is bounded by Depositional Surface and Stream Margin landform elements that totally surround the Lag Surface element. The location boundary is definable but is still arbitrary in the sense that the land-surfaces that define it are the result of recent geomorphological changes removed in time from the date when the artefacts were deposited.

The simple analysis presented here demonstrates the point made some years ago (Witter 1992) that surface exposures are liable to be quite variable depending on the nature of the surface geomorphology. Simply attempting to assess artefact densities (a measure that has in the past been used as an indicator of site significance [Holdaway 1993]) on the basis of surface exposure alone may lead to quite variable results depending on the nature of post-depositional geomorphic and pedologic changes. However, rather than viewing the results presented here as a 'cautionary tale', we consider that our mapping strategy offers the opportunity to control for differential visibility. By excavating small sample areas, it should be possible to model the degree to which different land-surfaces are hiding artefacts perhaps providing quantifiable indices to allow true artefact densities to be estimated. If these densities are to continue to form a part of archaeological significance assessments then further research on the subject needs to be undertaken.

	Number of Artefacts	*Mean maximum dimension*	*Standard deviation*
Channel 1	297	37.1	14.5
0–2m buffer	269	34.6	13.0
2–4m buffer	249	33.8	11.5
4–6m buffer	194	35.6	13.3

Artefact mean maximum dimension in Channel 1 and 2, 4 and 6m buffers from channel. $F = 3.21$, $df = 3, 1005$, $p = 0.02$

	Number of Artefacts	*Mean maximum dimension*	*Standard deviation*
Channel 2	257	38.5	15.9
0–2m buffer	340	36.1	13.7
2–4m buffer	292	35.5	14.8
4–6m buffer	351	36.6	13.3

Artefact mean maximum dimension in Channel 2 and 2, 4 and 6m buffers from channel. $F = 2.25$, $df = 3, 1236$, $p = 0.08$

Table 3. The effects of water sorting in channels.

The effect of water movement on artefact horizontal integrity

As discussed above, the Lag surfaces at TIB 13 are considered to be the result of sheet erosion caused by the action of rainsplash and water run-off on land subject to overgrazing. While this erosion is essential to the creation of an archaeological record amenable to the recovery systems discussed here, there remains the possibility that this erosion has substantially affected the location as a whole, moving artefacts horizontally to such an extent that the patterns in their distribution relate more to recent erosion than to processes connected with use. Clearly, resolving the degree to which water has affected the location is critical because the viability of the project as a whole rests on the existence of an archaeological record that has been lagged i.e. is recognised to be vertically displaced, but retains much of its horizontal integrity.

The question of movement was addressed in three ways. First, a lower size limit was imposed (20mm in maximum dimension) below which artefacts were not recorded. This was based on experimental work by Schick (1987:96) that suggested artefacts smaller that this dimension were particularly susceptible to movement through sheetwash erosion. Artefacts larger than 20mm were moved short distances by water but then tended to become stationary with time. Two tests were then undertaken: first, artefacts present within the Channels landform unit were compared with those on the Lag Surface unit immediately adjacent and second, in an independent study, the hypothesis of water movement affecting artefact distributions across the site as a whole was tested and rejected (Pigdon 1997:102).

The rationale for comparing artefacts in Channels to those on bordering Lag Surface was based on the assumption that Channels mapped at TIB13 were a recent feature formed by concentrated runoff. The artefacts they contain should, to some extent, show the effect of water transport, particularly size sorting (Schick 1987), since small artefacts will tend to be differentially removed in regions subject to rapid water flow. If the effects of water transport were limited to Channels we would expect the effects of size sorting to be absent from neighbouring Lag Surface. Only if the whole site were size sorted would this test fail to indicate the effect of water movement, a possibility assessed in the second set of tests below.

The test for the effect of artefact movement within Channels compared to those found distributed along their banks used the Buffer command in the GIS software to subset groups of artefacts at given distances from the edges of Channels. Individual rills and channels within the Channel coverage varied considerably in their dimensions (Figure 2); many having widths less than 30cm. Because these rills and channels were small, they contained very few artefacts making it difficult to detect size sorting by water flow. A few of the rills and channels were larger, and in these there were sufficient artefacts to allow meaningful tests. Table 3 gives the results of buffering experiments undertaken on two of the largest channels (Figure 2; Channel 1 area = $903m^2$; Channel 2 area = $989m^2$). For each, artefacts falling within the channels and those located within 0–2m, 2–4m and 4–6m buffers constructed on either side of the channels were compared in terms of the mean maximum dimension for all stone artefacts. For Channel 1 there is a significant difference in the mean dimension of artefacts from each of the buffers, with artefacts falling inside the channel having a slightly greater maximum dimension than those artefacts bordering the channel. For Channel 2 the same difference in the means is apparent, but the results of the ANOVA test have a two tailed probability slightly greater ($p=0.08$) than the accepted cut-off point. These results are consistent with water flow moving relatively small artefacts, and therefore increasing the overall mean maximum dimension of artefacts within the channel. But there is little evidence for size sorting at increasing distances away from these channels. Since the channels are almost certainly recent (last 150 years) features in this landscape we may assume that artefact deposition in prehistory had a negligible effect on the distribution of artefacts in the channels and on their banks. There can be no doubt that the artefacts on the lagged surfaces have moved to some degree (through deflation), but our findings suggest that only in the larger channels is this movement sufficient to be detectable as size sorting. It seems likely that as Schick (1987) observed, once the 20mm size cut-off is exceeded, artefacts do not continue to move unless subjected to flow conditions normally only found in channels.

Similar results were obtained in an independent study designed to test for water activity across the location as a whole (Pigdon 1997). A three dimensional model of the TIB13 surface terrain (a triangular irregular network or TIN) was created using a GIS and the mean length and density of artefacts compared for each contour interval. The results showed no clear patterning across the site as a whole. Only when the lag and channel deposits were tested separately did artefact characteristics show patterning within the channels as predicted by experimental water movement studies (Nash & Petraglia 1987; Schick 1986, 1987).

In light of the results from these analyses we decided to consider only artefacts from within the Lag Surface landform element since they alone seem to have been relatively unaffected by post-discard reworking or burial.

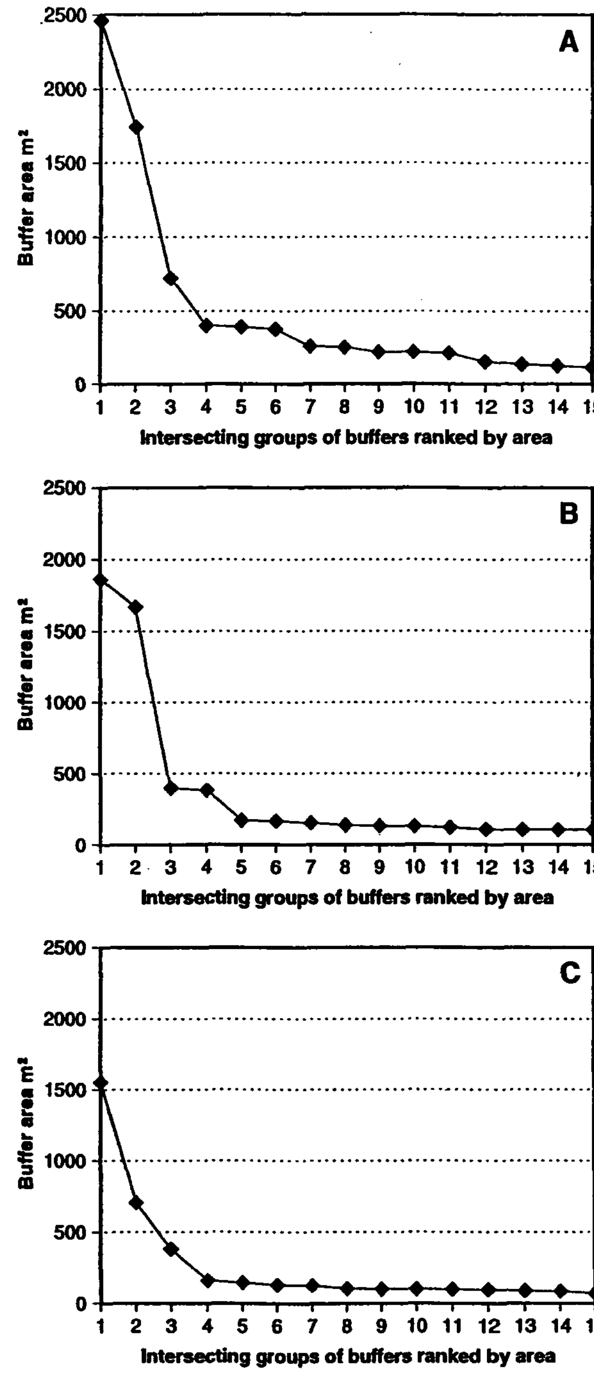

Figure 3. Ranked buffer areas based on circles of 4m radii drawn around cores and nuclear tools (A), scrapers (B) and notches (C). The ranks below 15 have been omitted.

Assemblage definition

As discussed above, we wished to develop a means of analysing assemblages across space independent of the site concept, and because of our use of artefacts as the minimal depositional and analytical unit, we were drawn to the intrasite spatial analysis literature (albeit from a regional rather than site based perspective). We were, however, mindful of the geomorphological characteristics of our study area. Lag surfaces with high visibility and horizontal integrity are interspersed with channels and sediment islands. As noted above, controlling for differential visibility and integrity required that certain surfaces be omitted from analysis. We could not use techniques that demanded a continuous distribution, nor could we

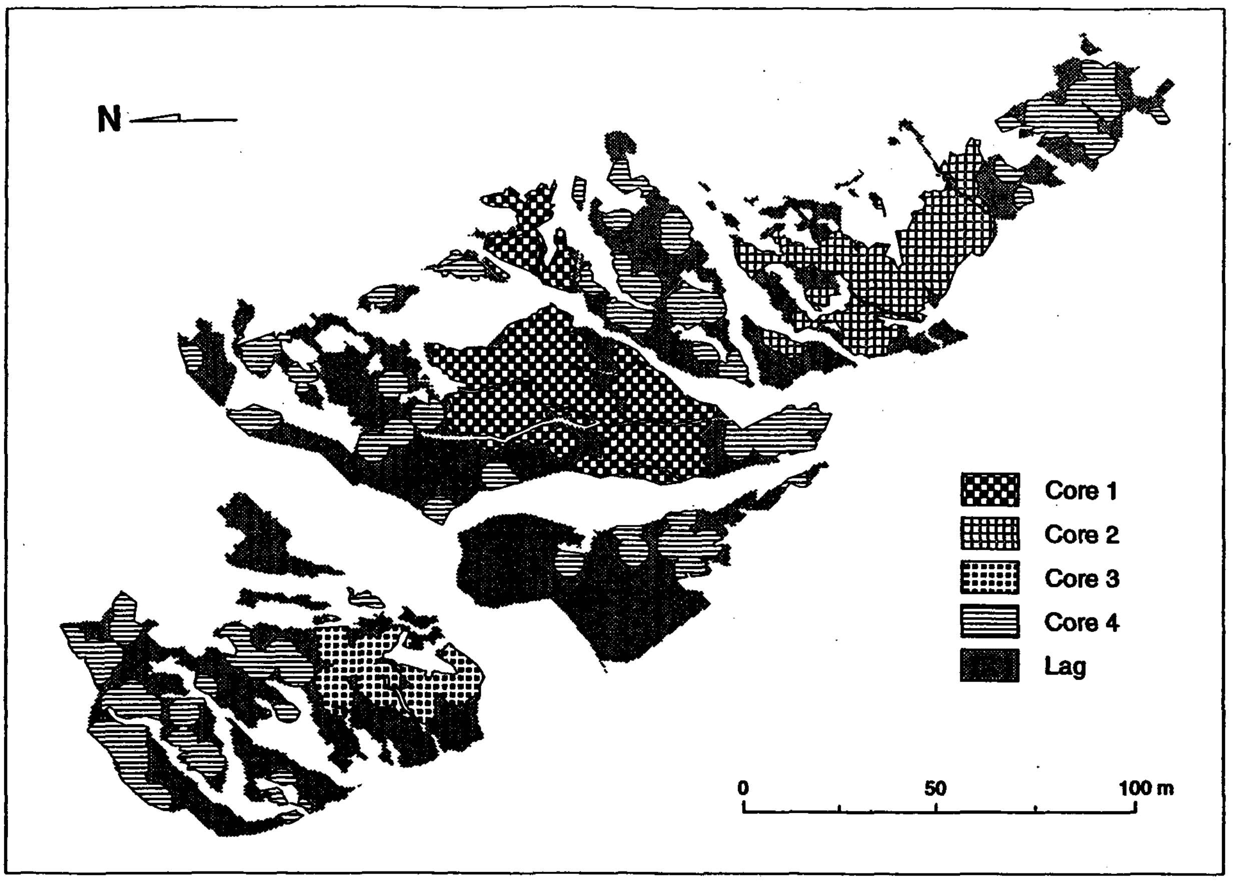

Figure 4. Core assemblages based on circles of 4m radius.

use hierarchical and non-hierarchical cluster techniques that grouped artefacts together on the basis of the existence of breaks in the artefact distribution. To have done so would have given priority to landsurface features that are the product of post-European geomorphological processes. This problem also restricted the utility of the raster based techniques adapted from image analysis that have recently been proposed (Wandsnider 1996).

Fortunately, in reviewing the literature on intrasite spatial analysis (see, for instance, Blankholm 1991) we discovered a technique suitable for our purposes, a variant on Local Density Analysis (LDA — Johnson 1984). Johnson's original formulation of this technique involved establishing the local density of a category of objects by counting the number of those objects within a circular sampling unit, radius *r*, centred on an object from a second category. The resulting measure had two uses: it was used to calculate an index of association between the two categories, and it also could be used as an aggregation indicator where the first and second categories were the same.

For our purposes LDA offered a flexible method for defining assemblages in open site scatters without the need to define sites, and a method that allowed us to incorporate the discontinuous nature of the artefact exposure. These are aspects of LDA that set the technique apart from approaches proposed by other researchers (eg. Ebert 1992; Wandsnider 1996). Our use of LDA is similar to Johnson's in that it employs circular sampling units centred on a given artefact category, and varying radius lengths to explore different scales of spatial patterning. When circular sampling units are laid out on a map of the study area, density patterns of the selected category can be readily observed. Overlapping sampling units represent areas where more than one artefact is found within *r* metres. Where dense clusters exist, several units will overlap.

Cluster patterns of a single artefact type may be of interest in their own right, but they can also help to provide a framework for investigating more complex patterns of assemblage composition. To this end several key artefact categories, such as cores and common tool types, were chosen. Each formed the basis for a separate analysis of the study area. A radius length was selected, and circular sampling units were mapped. Overlapping units were combined to form a single unit, so that the perime-

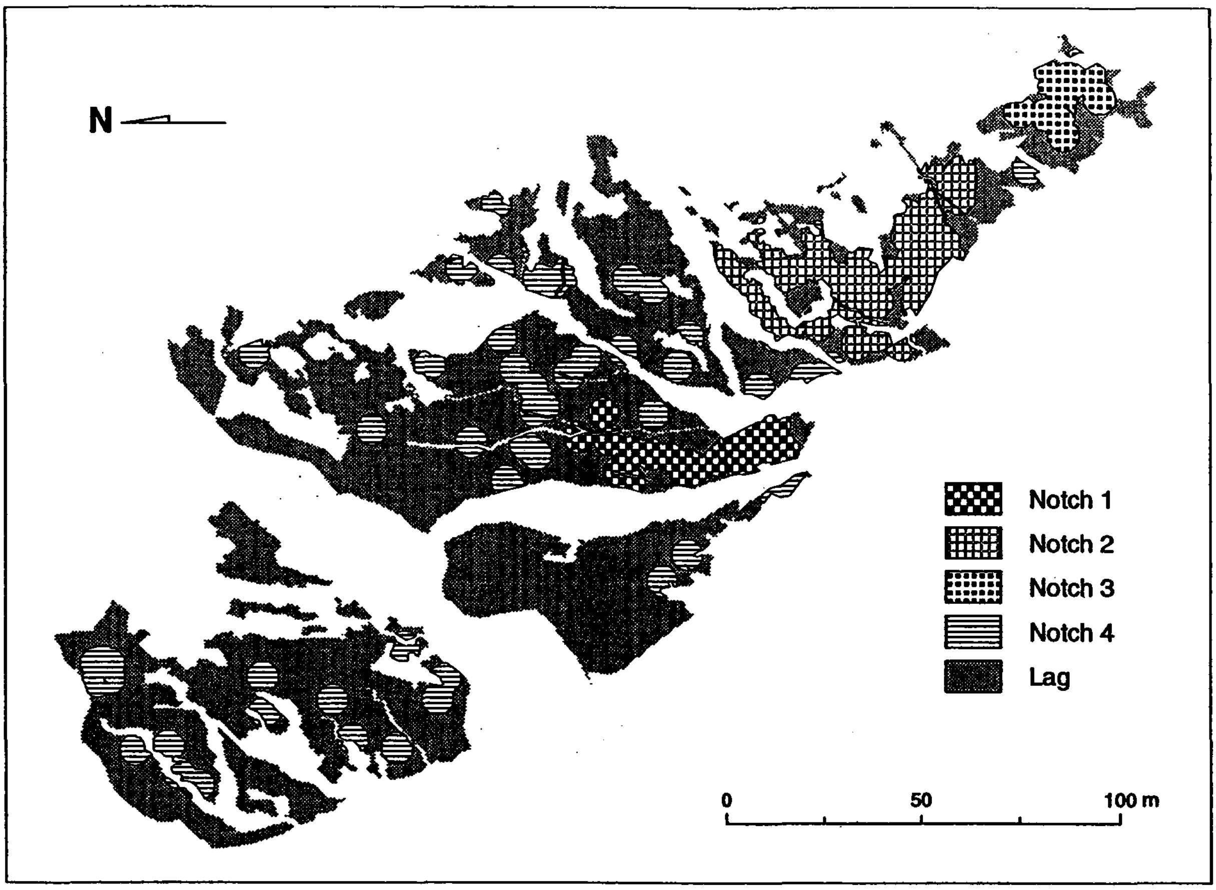

Figure 5. Notch assemblages based on circles of 4m radius.

ter length and area of the units varied. The values for perimeter and area were then plotted on simple line graphs and the point of inflection used to determine the most significant clusters.

Following our interest in examining assemblage composition in terms of artefact manufacture, use and discard, the significant cluster zones were used to define assemblages and these were analysed statistically using a range of technological and typological variables. Each assemblage had a common characteristic, in that its artefacts were spatially associated with high-density concentrations of a given artefact category. The object of the analysis was to identify the other ways that the assemblages were alike, and the ways that they were significantly different. This procedure was repeated several times, using different radius lengths and then different artefact types as the circle centroids.

This use of LDA allowed us to search for pattern across space skipping regions where the artefact distribution was disturbed as long as these regions fell within the radius dimension selected. As demonstrated below, in searching for interpretable spatial patterns assemblage composition is largely invariant no matter what the scale used for assemblage definition. The goal then becomes to make sense of the distribution of these assemblages across space based on what we know of stone artefact production, use and discard in the past.

TIB 13 Assemblage composition

As an illustration of the method, four metre buffers were created around three of the most frequent artefact types from TIB 13: Cores, Scrapers and Notched Tools (see Table 1 for definitions). The areas of the resulting clusters of buffers were calculated using the GIS software and are graphed in Figure 3. In each case there is a clear point of inflection in the graphs suggesting the definition of three larger assemblages for Cores and Notched Tools together with a large number of smaller assemblages, and either two or four larger assemblages for Scrapers. These assemblages, together with an assemblage formed from all other circles combined are analysed here (the four assemblages have been selected for scrapers — see Figures 4, 5, and 6). The results are then compared to determine what generalisations at the 4m scale can be determined for TIB 13.

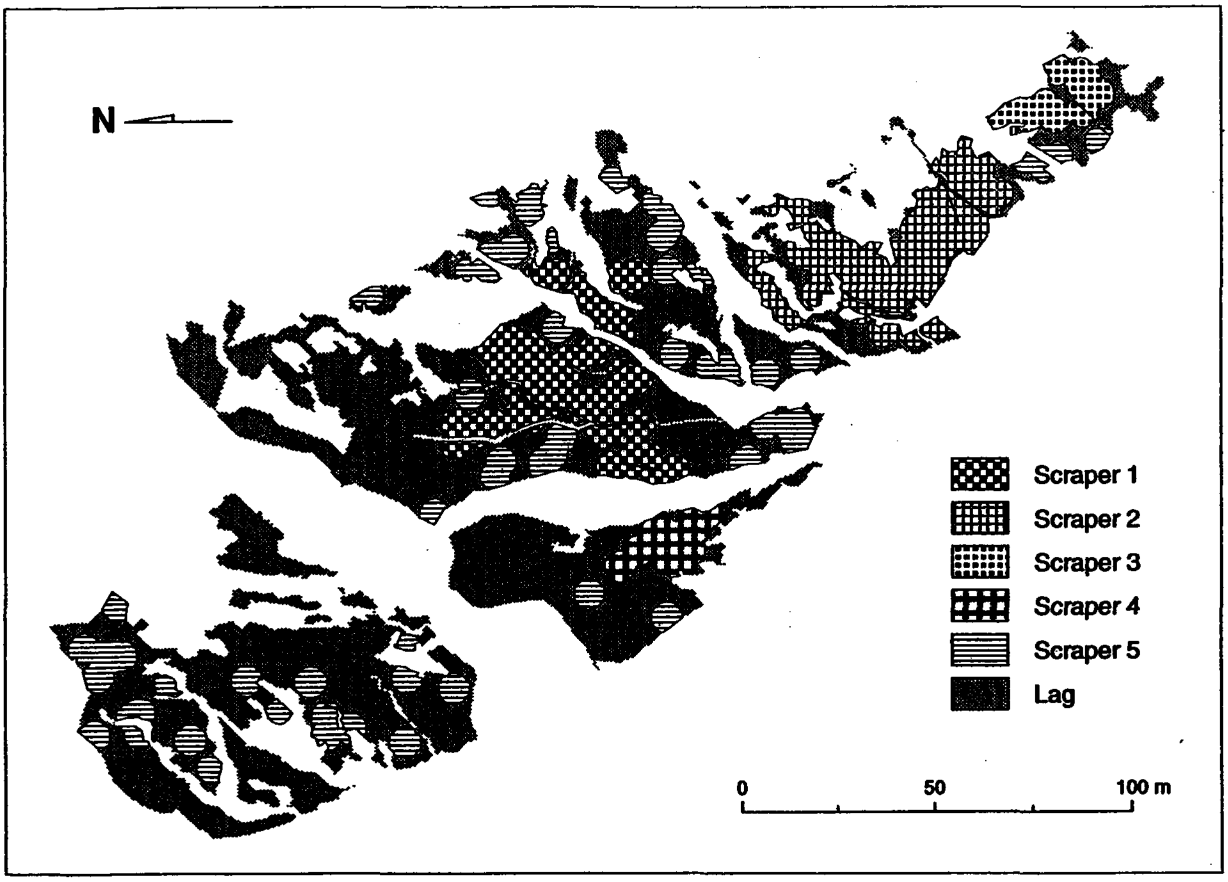

Figure 6. Scraper assemblages based on circles of 4m radius.

Assemblage distribution

Although assemblages were created by centring circles on different tool forms, there are similarities in the spatial distribution of a number of the assemblages. Thus, in the north-central region of the site Scraper Assemblage 1 and Core Assemblage 1 are spatially quite close. Three assemblages, Scraper Assemblage 2, Notch Assemblage 2 and Core Assemblage 2 share a common South Central Location, while Scraper Assemblage 3 and Notch Assemblage 3 are located in the southern part of the site. In contrast, Notch Assemblage 1, Scraper Assemblage 4 and Core Assemblage 3 are isolated in the sense that they do not intersect substantially with any of the other major assemblages (although they do intersect with some of the smaller groups of buffers). This distribution corresponds to patterns in the distribution of the artefacts selected for buffering. The Notched based assemblages are distributed across the southern part of the site, as are the scraper based assemblages except that uniquely Scraper Assemblage 4 is located to the west, and the Core based assemblages are distributed across the whole site including an assemblage (Core Assemblage 3) north of the stream channel. Tests based on the frequency of artefact forms confirm that assemblages that share a common spatial location are statistically indistinguishable while significant differences occur among assemblages that occur in different parts of TIB13 (Table 4).

Assemblage comparison

These general patterns may be refined by analysing the nature of the artefacts that intersect with the assemblages in terms of simple technological and typological attributes (Tables 5 & 6). In Figure 7 several technological indices are graphed that show a largely consistent north-south trend in assemblage composition across TIB13. The southern assemblages show relatively high values for the ratio of tools to complete flakes, but relatively low values for the proportion of blades in relation to all other flake forms, and a low proportion of complete to broken flakes. The ratio of cores to complete flakes shows relatively high values in the south-central and southern regions with the highest values in the north-

	Assemblages defined with:	Chi-square	d.f.	p	phi Cramer's V
Complete tool vs. Complete flake					
	Core	56.77	3	< 0.001	0.13
	Scraper	42.27	4	< 0.001	0.11
	Notch	35.13	3	< 0.001	0.12
Complete, broken, proximal, distal flakes					
	Core	47.67	9	< 0.001	0.10/0.06
	Scraper	32.20	12	= 0.001	0.09/0.05
	Notch	34.37	9	< 0.001	0.10/0.06
Flake form, blade, expanding, intermediate					
	Core	80.41	6	< 0.001	0.14/0.10
	Scraper	117.03	8	< 0.001	0.17/0.12
	Notch	77.77	4	< 0.001	0.16/0.11
Complete flake to core ratio					
	Core	35.26	3	< 0.001	0.1
	Scraper	15.06	4	= 0.005	0.07
	Notch	11.53	3	= 0.01	0.07
Core types, bifacial, microblade, unifacial					
	Core	26.45	6	<0.001	0.29/0.20
	Scraper[1]	24.75	6	<0.001	0.31/0.22
	Notch	18.89	6	= 0.004	0.31/0.22
	Scrapers and notches				
	Core[2]	5.28	2	= 0.07	
	Scraper	15.96	4	= 0.003	0.20
	Notch	4.76	3	= 0.19	
Scrapers, notches, points, adzes and utilised					
	Core	24.96	8	= 0.002	0.21/0.15
	Scraper[3]	36.96	8	< 0.001	0.27/0.19
	Notch	29.21	9	= 0.001	0.25/0.14

1. Scraper 4 not included due to low number of cores (n=4).
2. Core 3 not included due to low number of scrapers and notches (n=5).
3. Scraper 3 and Scraper 4 not included due to zero frequency for points and adzes.

Table 4. Chi-square values for technological comparisons between assemblages defined around cores, scrapers and notches.

west and low values in north-central, central and central-west regions. The southern and south-central assemblages show relatively low proportions of microblade cores compared to cores of other forms, while north-central and central assemblages show high proportions of this core type.

Tool forms show a more complex pattern (see Table 6). There is a clear north-south distribution in the proportion of notched tools, with southern assemblages showing the highest proportion of notched tools (Scraper 3, 45.0%; Notch 3, 48.7%) and the central-west assemblage Scraper 4 recording only 12.5%. Among the southern and central notch assemblages the highest proportion of notches occur in the assemblages (Notch 2 and Notch 3) that flank Notch 1. The proportion of scrapers reverses this pattern, with the highest proportions in assemblages toward the centre of TIB13. The highest proportion of scrapers occurs in Scraper 4 in the central-west. Points and adzes show low frequencies, but proportionally they occur more frequently in the north than the south (except for Notch 3 in the south where the proportion of adzes is 12.8%). Tools classified as Utilised are proportionally more frequent in the central regions.

Taken together, these results show patterns in the association of artefacts that largely make sense functionally

Assemblage	Tool and flake fracture class frequency						Flake morphology frequency			Core morphology frequency		
	Complete Tool	*Broken Tool*	*Complete Flake*	*Broken Flake*	*Proximal Flake*	*Distal Flake*	*Blade*	*Expanding*	*Intermediate*	*Bifacial Core*	*Microblade Core*	*Unifacial Core*
North-West												
Core 3	4	5	114	53	17	15	20	35	60	12	4	9
North-Central												
Core 1	119	42	1227	228	161	220	212	318	1111	36	28	36
Scraper 1	109	42	983	162	126	172	179	213	924	22	23	25
Central												
Notch 1	53	21	324	63	57	90	42	122	341	5	8	12
Central-West												
Scraper 4	13	4	84	19	10	14	17	27	78	1	1	3
South-Central												
Scraper 2	182	77	787	143	147	143	70	367	780	31	7	59
Notch 2	162	70	700	132	138	131	60	327	696	25	9	51
Core 2	159	83	717	140	142	141	64	341	718	29	9	55
Southern												
Scraper 3	30	10	121	27	32	21	11	40	145	9	1	7
Notch 3	28	11	130	28	31	23	12	41	146	9	1	6

Table 5. Artefact frequency for technological attributes by assemblage.

Area	Assemblage	Scraper	Notch	Point	Adze	Utilised
Nth-W	Core 3	3 (33.3)	2 (22.2)	1 (11.0)	0	3 (33.3)
Nth-Cen	Core 1	62 (39.0)	24 (15.1)	10 (6.3)	27 (17.0)	36 (22.6)
Nth Cen	Scraper 1	67 (45.0)	19 (12.8)	9 (6.0)	26 (17.4)	28 (18.8)
Cen	Notch 1	18 (24.7)	22 (30.1)	3 (4.1)	8 (11.0)	22 (30.1)
Cen-W	Scraper 4	12 (75.0)	2 (12.5)	1 (6.3)	0	1 (6.3)
Sth-Cen	Scraper 2	93 (36.2)	50 (19.5)	6 (2.3)	24 (9.3)	84 (32.7)
Sth-Cen	Notch 2	70 (30.2)	56 (24.1)	6 (2.6)	20 (8.6)	80 (34.5)
Sth-Cen	Core 2	69 (30.8)	49 (21.9)	6 (2.7)	21 (9.4)	79 (35.3)
Sth	Scraper 3	13 (32.5)	18 (45.0)	0	3 (7.5)	6 (15)
Sth	Notch 3	10 (25.6)	19 (48.7)	0	5 (12.8)	5 (12.8)

Table 6. Tool types: number (percentage) for each assemblage

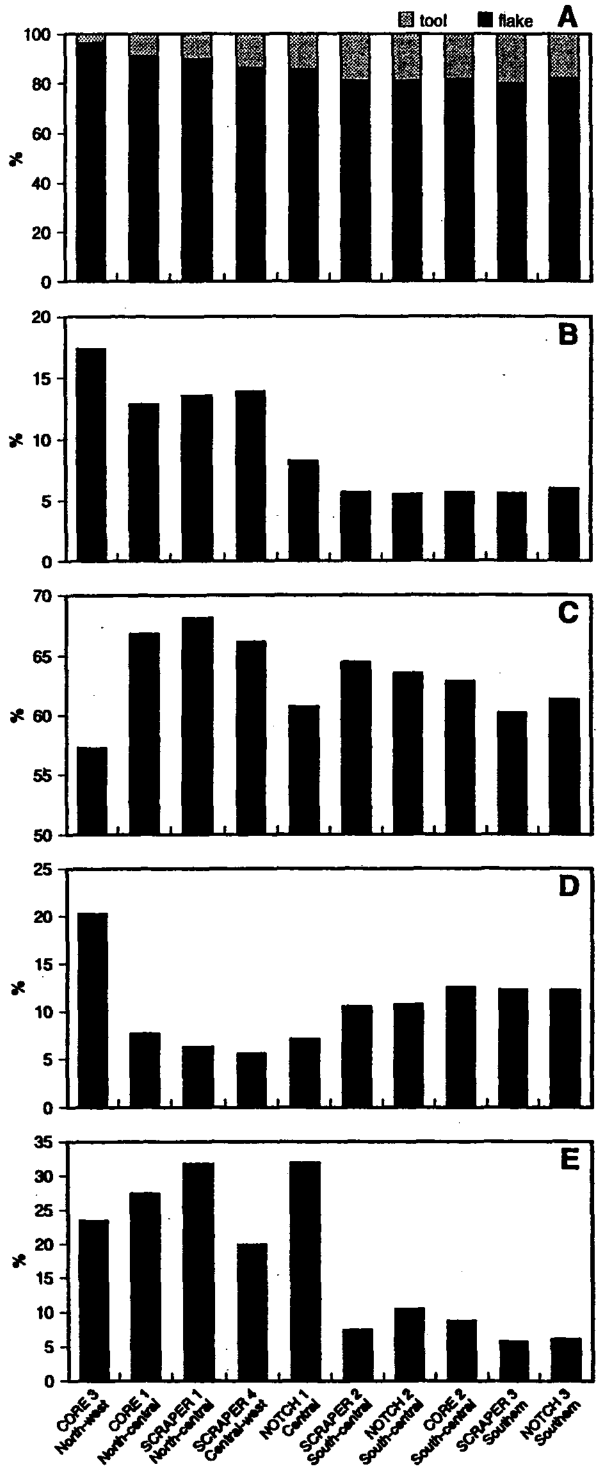

Figure 7. Technological comparisons by assemblage ranked north to south according to their relative location. A. Flake and tool proportions, B. blades as a percentage of total flakes, C. complete flakes as a percentage of all flakes, D. core to complete flake proportion, E. microblade cores as a percentage of all cores.

and technologically. Southern and central assemblages have higher proportions of tools with more notches and utilised edges. Technologically they contain a higher proportion of cores, but not of the microblade variety. To the north, there are lower proportions of tools overall, but higher proportions of scrapers, backed blades and adzes compared to other types. Blades are relatively more frequent as are microblade cores.

These patterns become clearer if new assemblages representing the intersection of the buffered polygons are created (Figure 8). Three new assemblages, North Central, South Central and Southern are created through intersection, with 1511, 1397 and 252 artefacts respectively. Table 7 summarises chi-square values for a series of technological comparisons. There are significant, and frequently strong, differences between the North Central assemblages and those in the South Central and Southern parts of the site. There are proportionally more tools and cores in the southern parts of the site and more blades together with more microblade cores in the north. Comparisons of tool type frequency show more scrapers, points and adzes to the north and more notches to the south.

Discussion

TIB13 is only one location, and it would be dangerous to generalise too much given such a limited spatial sample. On the other hand, based on the data available, our analysis using a modified form of LDA has allowed us to detect a significant spatial pattern in terms of assemblage variability. In the southern portion of TIB13 we have assemblages that suggest general core reduction together with artefact manufacture involving tools that lack heavy retouch. To the north, adzes and scrapers were discarded more frequently, possibly to work wood, and we have evidence for the knapping and production of backed blades possibly to manufacture projectiles.

There are, of course, a number of explanations that could be offered for the spatial variation we have detected. We might, for instance, seek a direct ethnographic analog based on accounts of Aboriginal camp structure at European contact. But before we draw such inferences we need to consider that we are dealing with a statistically derived pattern in the distribution of artefacts at a location that was almost certainly occupied more than once. As discussed above, the method for analysing open sites proposed here is not built around direct ethnographic analogies for patterns we are able to detect — even if these patterns seem to fit perfectly with such explanations. The pattern that we have identified at TIB13 will only become interpretable once additional areas have been recorded and this pattern, or others, repeated. Eventually we may be able to comment on stone procurement, use and discard and suggest why some locations retain a patterned distribution of artefacts and some do not. But for the moment demonstrating the existence of significant patterns in the composition of spatially distinct assemblages is sufficient.

	Chi-square	d.f.	p	phi Cramer's V
Complete tool vs. Complete flake	23.01	2	< 0.001	0.11
Complete, broken, proximal, distal flakes	11.63	6	= 0.07	
Flake form, blade, expanding, intermediate	80.48	4	< 0.001	0.19/0.13
Complete flake to Core ratio	15.42	2	< 0.001	0.1
Core types, bifacial, microblade, unifacial	20.78	4	< 0.001	0.37/0.26
Scrapers and notches	15.35	2	< 0.001	0.28
Scrapers, notches, points, adzes, utilised	41.30	6	< 0.001	0.35/0.25

Table 7 Technological frequency comparisons between the intersection assemblages.

Chronology

We have only a limited idea at present when the artefacts at TIB13 were deposited. Given the typology of the tools (backed blades and tula adzes), it is likely that they are no older than the mid-Holocene. With the application of modern dating techniques we will be able to refine this somewhat, but it is unlikely that we will ever be able to determine the number of times the location was used in prehistory. Instead we plan to treat chronology in a similar way to our analysis of artefacts — to search for interpretable pattern that is the result of multiple behavioural events. At the time of writing, we are only able to report the techniques we intend to apply in our research at Sturt, although research along all the lines discussed here has begun.

We plan to deal with chronology in two ways. First, we intend to develop a landscape chronology by identifying sedimentary units within a catchment and dating those units. This will allow us to determine the maximum and minimum ages for the sedimentary sequence currently preserved in the valley fill. We will use this chronology to suggest a maximum age for the artefacts currently exposed on the surface. In effect, the sediment chronology will give us a resolution similar to the occupation periods frequently defined by archaeologists working on stratified deposits; an indication of the general time frame in which artefacts were deposited without the identification of specific depositional events. Studies undertaken so far indicate the feasibility of constructing a sedimentary chronology by obtaining charcoal for radiocarbon determinations and quartz sands for optically stimulated luminescence (OSL) from the sediments in the valley. Of these, OSL has the potential to produce a more detailed chronology since it is better suited to alluvial sediments than thermoluminescence, has a broad temporal range (70 years to >800 k years), and is not limited by the availability of charcoal (Murray *et al.* 1995). As only a small sample is required, the chances of modern contamination via post-depositional processes such as bioturbation can be minimised by careful selection of the samples.

Our second method involves the definition of an archaeological chronology by obtaining radiocarbon and archaeomagnetic determinations for the numerous hearth or oven features that are associated with the stone artefacts in the locations where we are working. Excavation of several hearths at a second study location (some distance from TIB13) within Sturt National Park, undertaken with permission from the NSW NPWS and the Wangkumara people, reveals in many cases lenses of charcoal beneath heat cracked stones. A pilot series of ten radiocarbon determinations indicates that we can obtain sufficient charcoal for conventional dates. Archaeomagnetic dating of these same hearths will provide a check on the radiocarbon determinations and aid in determining the degree of displacement of hearth material since they were in use. During the course of the project we plan to obtain a large number of additional samples from hearths both exposed and buried at our study location. Exposed hearths are pedestaled on eroded surfaces but the heat cracked stones have acted to maintain the integrity of the hearth and to protect the charcoal from erosion. We plan to use a magnetic susceptibility meter to detect buried hearths. When fitted with a ground search loop, the susceptibility meter can be used to detect concentrations of ferrimagnetic minerals that occur in hearths a few centimetres below the ground (Thompson & Oldfield 1986).

We need to date a large number of hearths because the archaeological chronology relies on detecting patterns among large numbers of determinations. Because the stratigraphy has been disturbed by erosion, we cannot associate artefacts with particular dates, but we can look at the range of values for determinations across space. Use of a particular location at one time will result in more hearths dating to the same period; use of a location through time will produce hearths with a spread of dates. We are less interested in the magnitude of single points in time, rather we seek clusters of dates that may correlate with patterns that we can detect in the distribution of stone artefacts. One cluster of dates with a particular assemblage type will not be very useful since it is possible that the artefacts and the hearths were deposited at different times. A repeated association, on the other hand, will reduce the probability that dates and artefacts are present in the same location by chance.

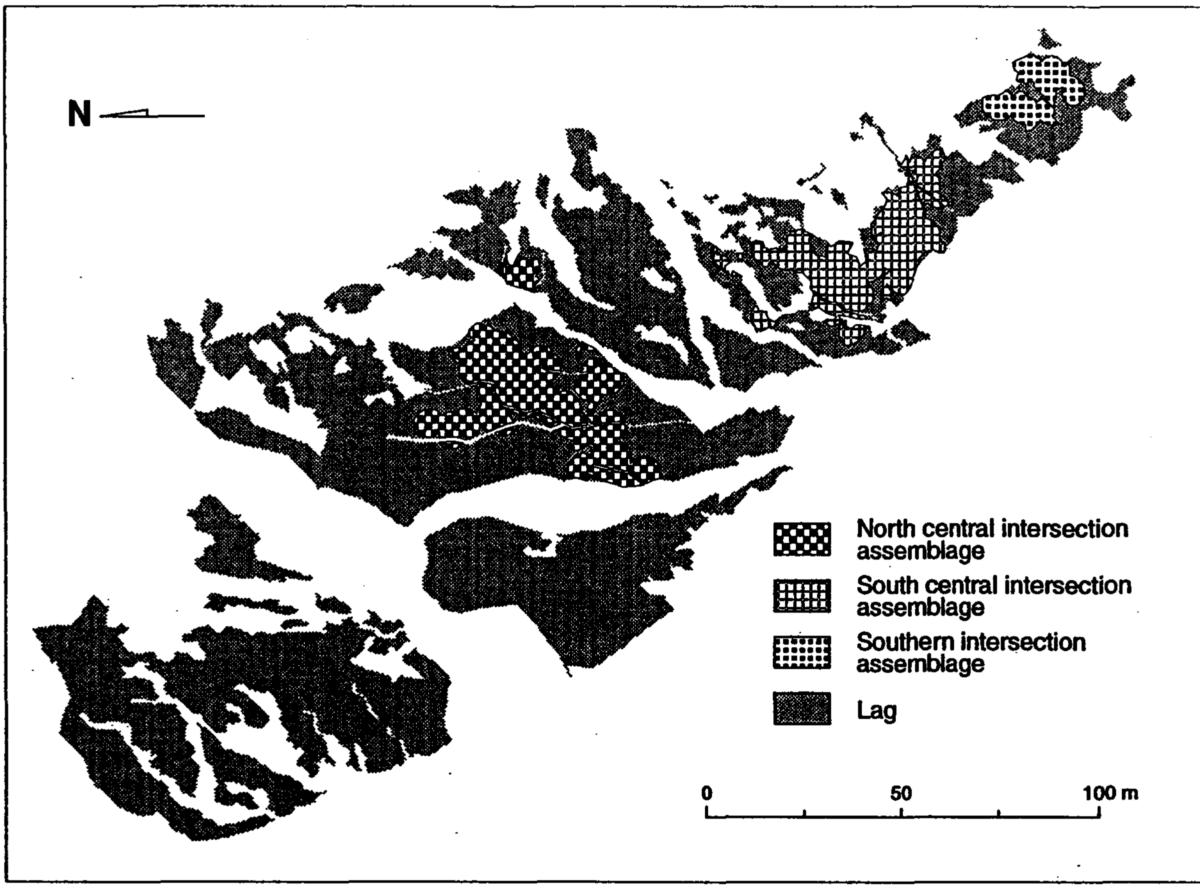

Figure 8. Regions where assemblages defined with 4m circles intersect.

Raw materials

At TIB13 raw material was identified as silcrete, quartz, and quartzite (Table 1).

Since this location was recorded, Ph.D. research (TD) has commenced focusing on identifying the sources of lithic raw material represented in the archaeological record of the region. An area stretching from the Thomson's Creek to the Twelve Mile Creek Gorge and across to the township of Tibooburra has been surveyed (Figure 1) revealing four categories of abundant, high quality lithic material: silcrete, quartz, quartzite and hornfels. Silcrete occurs along the Tertiary capping of the Mt. Wood Ranges or within the stream catchments exposed through erosion. In contrast, hornfels occurs only as an isolated metamorphic/igneous island near the Tibooburra township (Figure 1). Within this zone, nodules of quartzite and milky quartz are found on gibber plains. The Mt Wood Ranges also have limited amounts of quartz nodules found within a mainly silcrete gibber.

The silcrete can be divided into two main and four sub groups based on hand specimen variation in texture, fracture and matrix of the material, and ranges from a crystalline quartz matrix with a coarse texture to an amorphous, fine textured material (Sullivan & Simmons 1978:56; Watts 1978). A total of 35 silcrete sources have been located and described in terms of material type, colour, lithology, outcrop form, production, size and density (Watts 1978; Hiscock & Mitchell 1993). The majority of the sources are silicified from a sandstone with a medium to fine texture (25 sources), and outcrop as weathered boulders, while localised inclusions of silicified siltstones form fine, amorphous silcrete (eight sources). The quality, size and type of outcrop has affected the density and extent of reduction with larger, high quality sources tending to have more debitage. These larger sources conform with Wilke & Schroths' (1989) definition of quarries and will be used to research on the nature of direct procurement strategies undertaken at the sources.

Expected outcomes

Both the research reported here, and that outlined for the future, will allow us to construct a model of the way artefact assemblages were deposited at different locations and times within the landscape taking into account the nature of archaeological surface exposure. Our geomorphological research will allow us to characterise these locations in terms of their sedimentary history and allow some degree of palaeoenvironmental reconstruction. For each location we will be able to offer an interpretation of the way artefacts were abandoned related to the possible significance of artefact associations related to stone procurement and artefact manufacture, use and discard. In terms of writing prehistory, the points of most interest will begin to appear as more locations are investigated and a variety of models for artefact abandonment developed. The sophistication of our explanations will develop as we identify locations where our models should fit — but apparently don't. It will then be up to us as prehistorians to provide explanations for these anomalies.

Clearly this is a long-term research endeavour. We are not searching for a single predictive model that will allow the archaeological record to be interpreted in all places. But we do consider that the research we are undertaking provides one way around the impasse currently faced by many archaeologists dealing with surface artefact scatters. It is well recognised by those working with such material that the significance of this type of record is best assessed in terms of a regional settlement model (Holdaway 1993). What has been lacking until now is not so much the models, but a set of methods that will allow these models to be truly tested against spatially defined artefact assemblages. The methods discussed in this paper suggest one way that we may begin to search for the types of patterns that should be there according to the theoretical literature.

The other major outcome is the application to the conservation of the archaeological record. It is now possible to see what the distribution of archaeological materials over a landscape is like. In management archaeology it is very difficult to conceptualise what it is that we are trying to protect since the conditions of exposure and ground surface visibility are normally very patchy and the observable artefact assemblages difficult to interpret. Sub-surface testing is hampered by the lack of knowledge of what sample sizes are appropriate (Wobst 1983) so the conservation of open site archaeology is frequently little more than guesswork. The methodology described here shows that the patterned distributions of cultural evidence over the landscape are much more extensive than usually considered in management practice.

Conclusion

The location discussed in this paper is not particularly large on a landscape scale, but at just under 30,000m² it is probably as large as any in Australia with near continuous visibility to have been analysed on an artefact by artefact basis. With 10,000 artefacts we have a reasonably large database, and by analysing this spatially, we are able to detect a pattern in the distribution of artefacts at an assemblage level that may be functionally interpretable. We view this result as encouraging and it gives us the confidence to extend the research program to investigate additional areas in the hope of identifying repeated pattern in time and space. The technology we have employed enables us to work at a much larger scale, both spatially and in terms of the number of artefacts recorded, compared to many other archaeological projects in Australia. Theoretical works on hunter-gatherer site formation tell us that we must think in spatially extensive areas. In Australia we are fortunate in having very large exposures available covered with tens of thousands of artefacts. This record has great potential — we hope that our research will stimulate other groups to begin working on this record.

Acknowledgments

Field work at TIB 13 was undertaken during June 1995 and April 1996 with accommodation and logistical support provided by the NPWS Tibooburra District Office. There was close liaison with the Tibooburra Local Aboriginal Land Council and the Wangkumara Tribal Council to ensure that they were satisfied with our non-invasive methods. Financial support was provided by a Central Starter grant, La Trobe University to SH, a Macquarie University Research Grant to PF, an Australian Institute of Aboriginal and Torres Strait Islander Studies small grant to SH and a Collaborative Australian Research Council grant to SH and DW. Funding for equipment was provided by the Standing Committee on the Allocation of Equipment Funds, La Trobe University through a grant to SH. Versions of this paper were presented at seminars in the Department of Palaeoanthropology and Archaeology, University of New England, and in the Departments of Anthropology at the University of Pennsylvania, University of Michigan, University of Utah and the Bishop Museum. We thank Caroline Bird, Brad Dilli, Tim Murray, Peter Mitchell, Jim Rhoads, Robin Torrence, LuAnn Wandsnider and Peter White for critical comments on drafts of this paper. Badger Bates, Phillip Kerwin, Cecil Ebsworth, Ainsley Ebsworth, Daphne Monaghan, Jenny Tulloch, Denis Gnaden, Rita Olsudong, Bill Kerse, Rudy Frank, Ming Wei, and Philip Purcell helped with the fieldwork. Ming Wei drew the figures.

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GIS Analysis of Artefact Distributions on an Eroding Landscape: The Western New South Wales Archaeological Project

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1. Aims

The aims of the Western New South Wales Archaeological Project are to:

- Investigate an archaeological landscape with the artefact as the minimal depositional unit;
- Investigate the surrounding geomorphological landscape in order to control for post-depositional effects, including deflation, water movement and artefact visibility;
- Having controlled for these effects, determine the composition of spatially associated assemblages;
- Investigate the chronology of landscape use, looking for repeated patterns in assemblage composition and landscape re-use;
- Develop a predictive model of site re-use, based on landscape attributes, for heritage management purposes.

Figure 1
The study area

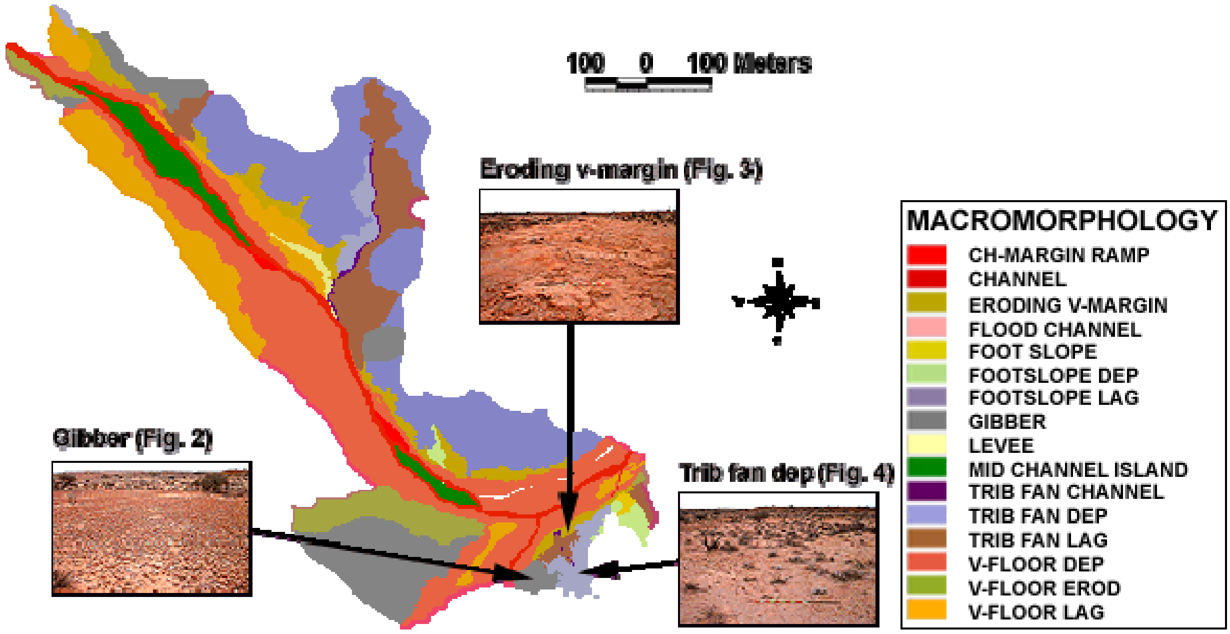
2. Background

Much of the arid and semi-arid parts of western NSW have been significantly affected by erosion following the introduction of sheep grazing in the late 1800s. Topsoils have largely been removed, leaving gravel lags and subsoils exposed at the surface. The eroded material has accumulated in valley floors, filling waterholes with sandy sediments and altering hydrogeomorphic regimes along most of the upland creek systems. The erosion has exposed many thousands of Aboriginal stone artefacts at the surface, allowing investigation of the spatial distribution of the artefacts without the need for excavation. Deflation by wind and water has affected the vertical integrity of the assemblages, but the horizontal integrity appears to have remained largely intact.

3. Macromorphology

Identification of landform elements is the basis of geomorphic mapping in the study area. Boundaries between elements are recognised by field reconnaissance and surveyed using GPS and EDM equipment. GIS images are built and displayed using Arc/Info and ArcView. Sixteen such landform elements have been identified so far in the Stud Creek catchment in Sturt National Park, on the basis of spatial location, topography and dominant process *i.e.* whether they are stable (lagged), actively eroding or depositional.

Exposure of artefacts is considered to have the greatest potential on lagged and actively eroding elements, and the least on those where deposition dominates (such as channel margins on the valley floors). Areas where runoff is concentrated into rills are also mapped, since the potential for downslope transport of clasts (including artefacts), and hence disturbance of the spatial integrity of assemblages, is highest in these areas. Preliminary results from a pilot study on a site in the area (TIB13) show that, as expected, the mean size of artefacts in rills declines in the downslope direction. A buffered area around all rills will therefore be eliminated from the assemblage analysis.



4. Micromorphology

Even where erosion is dominant, such as on the *Eroding Valley Margin* and *Valley Floor Lag* elements, there are patches of different surface materials which may influence artefact recovery. A micromorphological coverage has therefore been compiled for these elements **(Figure 6)**. Seven different units have been recognised so far; with the exception of 'vegetation', the labels describe the nature of the dominant surface material or regolith within that unit:

1. mud (fine sediment deposition);
2. sand (medium sediment deposition);
3. gravel (coarse sediment deposition);
4. sand & gravel (mixed medium and coarse sediments);
5. cemented gravel (coarse sedimentary material now exposed at the surface by erosion);
6. subsoil (structured clay-rich material now exposed at the surface by erosion);
7. vegetation (usually growing out of sediment mounds; may be grasses, shrubs or trees).

Mapping at this level allows a comparison of the way artefacts are clustered or dispersed in relation to post-depositional surface processes.

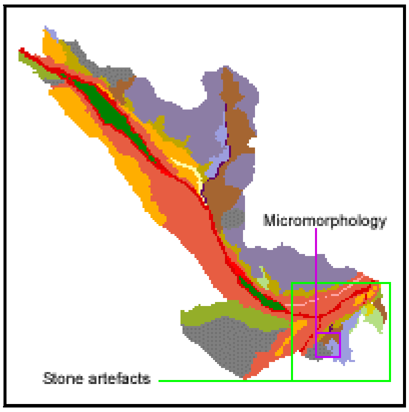


Figure 5
Boundaries of the micromorphological (purple) and stone artefact (green) surveys

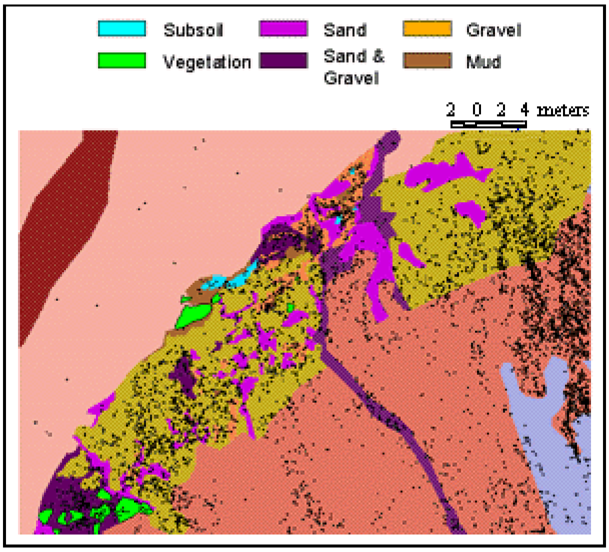


Figure 6
Micromorphological survey

5. Stone artefact analysis

All stone artefacts with a maximum dimension of 20mm or above have been located in three dimensional space with EDM equipment, c. 24,000 pieces within an area of just 0.045 sq. km (**Figure 7**). Attributes are recorded for each artefact by logging into palmtop computers, and include a range of typological and technological attributes, such as: completeness; flake form; presence and proportion of cortex; platform type; termination; and length, width and thickness dimensions. The material type is also recorded.

Data are down-loaded from the palmtops each day and linked to the GIS database in a field computer laboratory. After allowing for post-depositional disturbance, the GIS is used to define assemblages which are compared among each other using univariate statistics. The comparisons allow us to search for patterns related to the technology of artefact production. They will also allow us to identify regions that may have been used for different functions. By relating stone tool assemblages to regolith terrain units, a predictive model of artefact location can be developed. The assessment of the significance of the archaeological record can be made on a regional basis, rather than a site basis, which will facilitate environmental impact assessment of proposed activities, such as mining and infrastructure development.

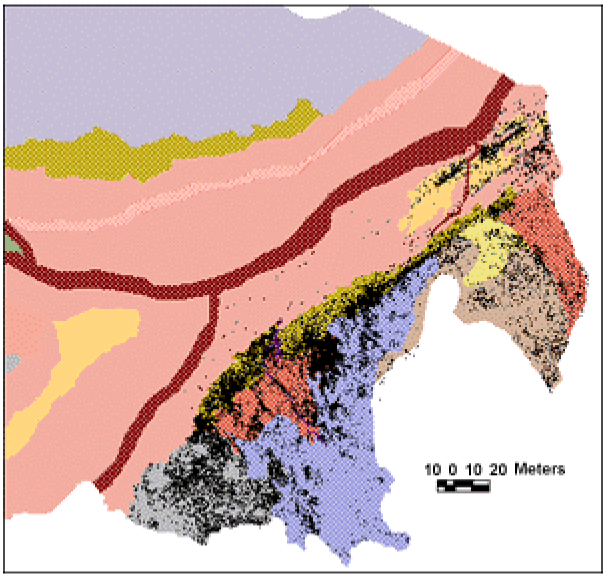


Figure 7
Study area for stone artefact analysis, showing 24,000 artefacts as a point coverage

6. Landscape history

The landscape evolution in the study area is being investigated at the same time, via stratigraphic and geophysical analysis of valley fills. Together with radiocarbon and archaeomagnetic dating of Aboriginal hearths exposed at the surface, it is expected that these investigations will provide a temporal envelope for landscape usage by Aboriginal people. Work to date indicates that, prior to European occupation, the stream channels contained waterholes lined with muds, which would have held water for considerable periods after rain and hence provided the people with a relatively stable water source. As **Figure 8** shows, these muds are now overlain by red sandy sediments derived from erosion of the hillslopes higher up in the catchment.

Figure 8
Section showing sediments eroded from catchment slopes overlying waterhole muds

Chapter Two

Silcrete flakes, cores and tools forming a lag on a surface exposed by erosion.

Surface Stone Artefact Scatters:

Why Can We See Them?

CHAPTER TWO

SURFACE STONE ARTEFACT SCATTERS: WHY CAN WE SEE THEM?

2.1 Introduction

Western NSW is an ideal location to undertake the kinds of geoarchaeological research presented in this thesis. Its current arid climate and related sparse vegetation cover mean that surface artefact scatters are relatively easy to see (Figure 2.1). Moreover, artefact exposure has been enhanced over much of the region by geomorphic dynamics, particularly accelerated erosion that is a consequence of the introduction of sheep grazing in the mid- to late 1800s. A sparsely scattered human population and relatively low intensity pastoral land use mean that much of the archaeological record remains available for examination.

Figure 2.1. Stone artefacts lying on an eroded surface in the Stud Creek study area, Sturt National Park. Depositional surfaces containing sediments which obscure artefacts from view can be seen in the background.

2.2 Recent Geomorphic Landscape Change in Western NSW

In the first of two papers in this chapter (FANNING 1999), I describe geomorphic evidence for landscape change in the last 150 years or so since European occupation in three catchments in western NSW (see Figure 1 in FANNING 1999 for location map). Observations and measurements include topsoil loss and surface lowering using erosion pins at Fowlers Gap Arid Zone Research Station, channel enlargement and knickpoint retreat using repeated measurements at monumented cross-sections along Homestead Creek in Mutawintji National Park, and analysis and absolute dating of valley fill regolith sequences in both these and Stud Creek catchment in Sturt National Park.

An indication of the time of onset of this latest phase of geomorphic landscape evolution in the catchments studied has been in part provided by archaeological evidence. In the paper I describe the typical stratigraphic context in which the remains of Aboriginal heat-retainer ovens are found across the region and the evidence this provides for erosion of topsoil and surface lowering since the ovens were last used. Radiocarbon determinations on charcoal sampled from ovens along Stud Creek (see Chapter Four: HOLDAWAY ET AL. 2002, Table 1) indicate that some were in use as recently as 220±55 y BP. Thus, the surfaces into which the cooking pits were dug were probably relatively intact just prior to the time of European contact, about 150 years ago. I also describe a stratigraphic section from Giles Creek in Mutawintji National Park in which heat-retainer ovens dating to 220±50 and 270±50 y BP have been buried by red sandy sediments. These dates also suggest that the landsurfaces into which the ovens were dug were relatively intact at the time of European contact, and that their subsequent burial by loose red sandy sediments may reflect disturbance of catchment regolith cover when sheep grazing was introduced.

Other researchers describe similar sediment sequences from widespread locations across the region, and indeed across the whole state of NSW (e.g. Crighton 2000, Gore et al. 2000, Jansen 2001, Pickard 1994, Starr 1989, Wasson et al. 1998). These authors present abundant evidence that the red sandy sediments which cap older floodplain deposits (Figure 2.2), variously referred to as ‘post-settlement alluvium’ (PSA) or ‘post-European material’ (PEM), post-dates European occupation. I conclude that the geomorphological and archaeological evidence is overwhelming for the most recent phase of geomorphic landscape change across the western NSW region being post-European i.e. less than 200 years old (FANNING 1999). A model is presented which illustrates the role of geomorphic dynamics, encompassing process/response mechanisms, in determining the type and direction of landscape change in the recent past in western NSW. This then becomes the foundation upon which a landscape-based framework for studying Aboriginal stone artefact scatters is developed in Chapters Three, Four and Five.

2.3 Significance of Landscape Change for Archaeological Investigations of Stone Artefact Scatters

In the second paper (HOLDAWAY ET AL. 2000) the significance of this landscape change for archaeological research into prehistoric Aboriginal occupation of the rangelands of western NSW is outlined. The record of Aboriginal hunter-gatherer activity, i.e. the stone tools they manufactured, used and then discarded needs to be studied in spatially extensive sets. The recent erosion in western NSW described in the previous paper (FANNING 1999) allows archaeologists to undertake such studies because it has, in effect, 'excavated' thousands of square metres of surface in any one place, areas far larger than even the most extensive archaeological excavations. Moreover, erosion of the fine sediments surrounding and supporting the stone artefacts has meant that the discard products of Aboriginal activity have been conflated, that is, vertically deflated and concentrated into a single layer. In effect, the artefact scatters have become 'time-averaged' (*sensu* Stern 1994) or 'trans-episodic' (*sensu* Wandsnider 1989) deposits in which the products of many individual behaviours are now concatenated. But rather than confounding attempts by archaeologists to understand human behaviour by analysing lithic scatters, artefact conflation can make spatial discard patterns easier to see, as shown by the results of the pilot study at TIB 13 (HOLDAWAY ET AL. 1998). By looking at the nature of the artefacts accumulated over time in different places in the landscape, archaeologists are able to distinguish those places which were used frequently from those that were used less often, and those used for a larger number and greater variety of activities from those used more sparingly. A 'place use history' (*sensu* Wandsnider 1989) can then be developed.

The paper presents some results of preliminary analyses of artefact data from Stud Creek in Sturt National Park (see Figure 2 in HOLDAWAY ET AL. 2000 for location map) to illustrate these new approaches to surface artefact scatters. The region has a rich lithic resource base, dominated by silcrete occurring both as massive outcrops and pavements of closely packed subspherical cobbles, called 'gibber' (Dury 1970). The gibber (Figure 2.3) is

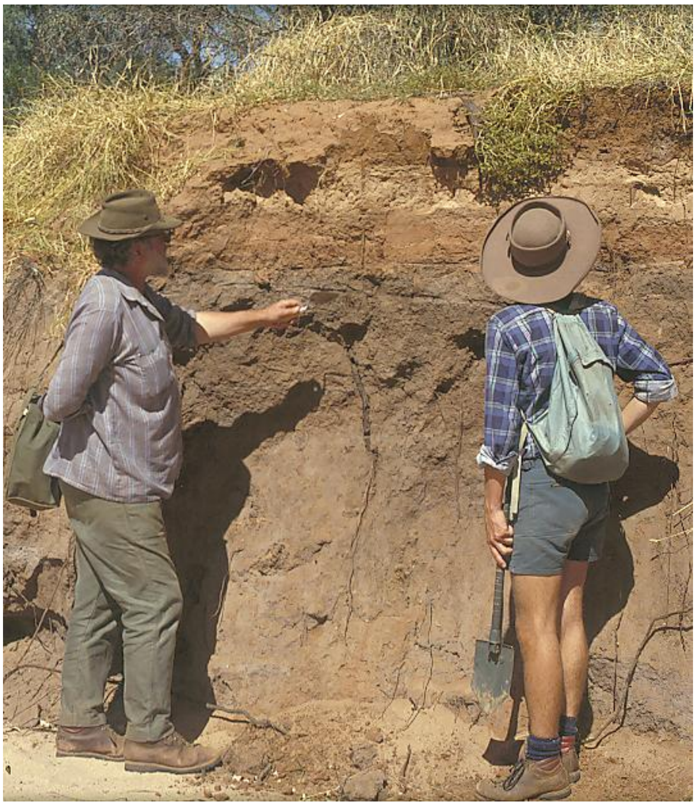


Figure 2.2. Dan Witter and John Jansen examining the sharp contact between bright red post-European material (PEM) and darker buried floodplain sediments in the sidewall of Homestead Creek at Mutawintji National Park.

Figure 2.3: Gibber pavement in the Stud Creek study area, used as a stone source for tool making by Aboriginal people. Field crew are marking artefact locations with pink flagging.

derived from concretions within the upper layer of silcrete developed in Early Cretaceous sediments that outcrop along the western edge of the Stud Creek catchment. The lower layer is more massive and columnar, and has been extensively quarried by Aboriginal people (Doelman et al. 2001).

The geomorphic mapping which forms the framework for stratified sampling of the artefact data sets is also briefly described in this paper; a more complete description and analysis can be found in FANNING AND HOLDAWAY (submitted) in Chapter Three.

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Publication

Due to copyright laws, the following article has been omitted from this thesis. Please refer to the following link for the abstract details.

Fanning, Patricia C. (1999). Recent landscape history in arid western New South Wales, Australia: a model for regional change. *Geomorphology*, 29(3-4), 191-209. http://dx.doi.org/10.1016/S0169-555X(99)00014-8

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Holdaway, Simon J., Fanning, Patricia C. & Witter, Dan C. (2000). Prehistoric aboriginal occupation of the rangelands: Interpreting the surface archaeological record of far western New South Wales, Australia. *Rangeland Journal*, 22(1), 44-57.
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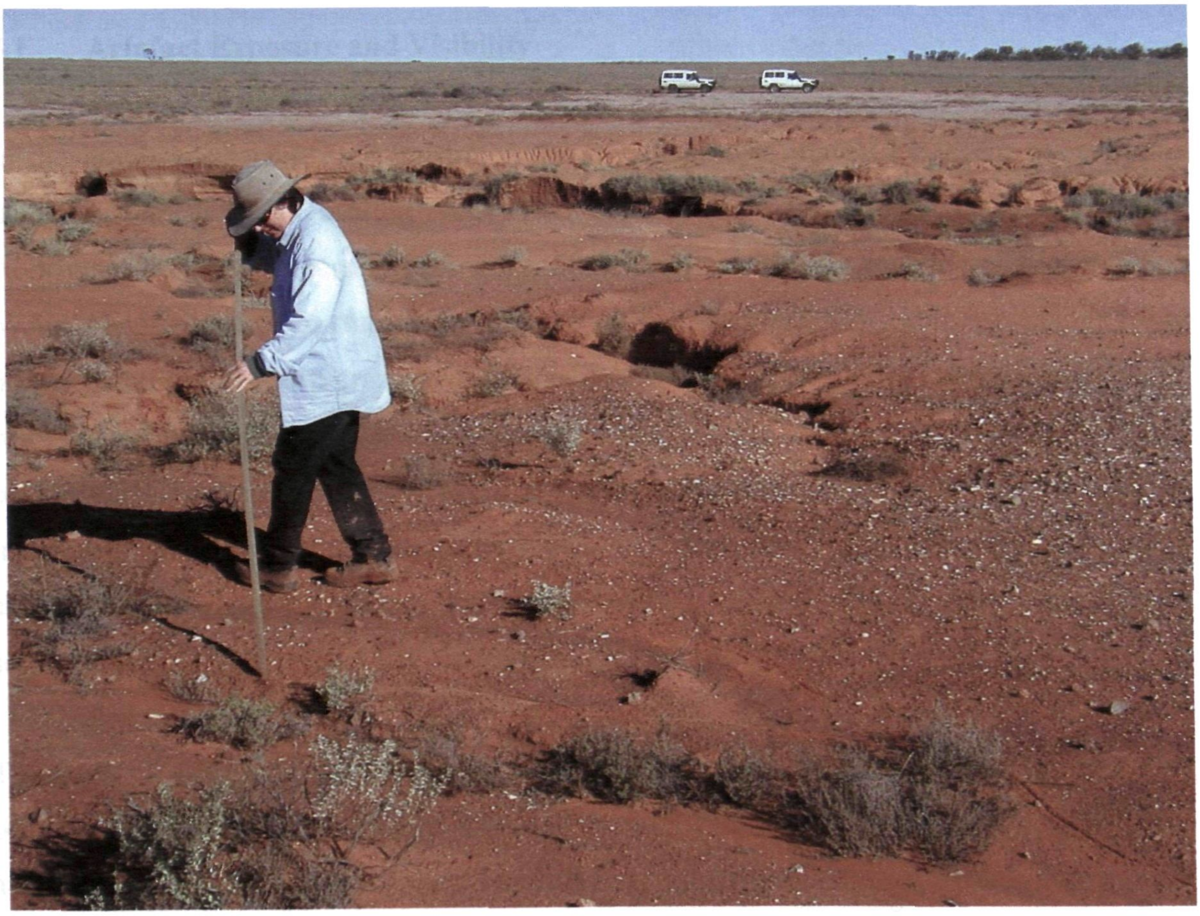
Chapter Three



Trish Fanning marking the boundary between landsurface units prior to landform and artefact survey.

Geomorphic Controls on Spatial Patterning of the Surface Stone Artefact Record

CHAPTER THREE

GEOMORPHIC CONTROLS ON SPATIAL PATTERNING OF THE SURFACE STONE ARTEFACT RECORD

3.1 Artefact Exposure and Visibility

In the previous chapter, I demonstrated the significant role played by recent geomorphic landscape change in “excavating” valley floor deposits and exposing artefacts abandoned by Aboriginal hunter-gatherers in prehistory. Stone artefacts and the remains of heat-retainer ovens are visible at the surface today because erosion, accelerated by land use change from hunter-gathering to sheep grazing, has removed the finer sediments into which the artefacts were incorporated after abandonment, leaving them as a conflated lag – or “blanket” – lying on landsurfaces across extensive areas of arid western NSW. As a result of valley floor incision, channel widening, knickpoint retreat and channel avulsion associated with these changes, some artefact scatters have been entirely eroded away, while valley floor sedimentation in other places has resulted in artefact burial.

These geomorphic processes operating differentially across the physical landscape are the principal determinants of artefact preservation, exposure and visibility in the study area, and, as a consequence, the principal determinants of the nature of the archaeological record at the time of artefact survey (the archaeological ‘document’ *sensu* Wandsnider & Camilli, 1992). In this chapter, I discuss the geomorphic controls on artefact exposure and visibility in the Stud Creek study area and how artefact surveys can be designed to accommodate this.

I distinguish between “exposure” and “visibility” as follows. *Exposure* determines the chance of artefacts being present on the surface, i.e. their ‘discoverability’ (Camilli & Ebert 1992). In the Stud Creek study area, it is a particular function of, amongst other things, contemporary landsurface morphodynamics and geomorphic history, not simply a result of erosion as stated by Hiscock and Hughes (1983). Exposure of artefacts is not uniform across the landscape because, in addition to non-uniform artefact discard by people, morphodynamics and geomorphic histories vary from place to place.

Surface *visibility*, on the other hand, determines the chances of artefacts being detected if present (Hiscock & Hughes 1983), and is also not uniform, even across surfaces where there is high artefact exposure. Many consider that surface visibility simply refers to the extent to which the ground surface recorded during the survey was covered in vegetation (e.g. David 1996; Hiscock 1991 in Thorley 1998; Schiffer 1987; Seaman et al. 1988; Thorley 1998) but others such as Wandsnider & Camilli (1992) recognise that it is more complex. For example, fine-grained surface sediments comprising sands and mud may obscure artefacts through burial (e.g. Wandsnider 1989) and bioturbation (e.g. Johnson 1990), but coarse-grained sediments such as gravels and cobbles may enhance their visibility through surface armouring. All of these processes act at a range of spatial and temporal scales.

These themes are explored in detail in the first of two papers in this chapter (FANNING & HOLDAWAY, submitted). New approaches to survey and analysis of surface artefact scatters are described, incorporating stratified systematic sampling using a hierarchy of geomorphic landscape features. While archaeological survey stratification on the basis of landscape is not new, with Butzer in 1982 defining the landscape context of archaeological sites at micro, meso and macro scales, the emphasis here is on morphodynamics rather than the more static and climatically deterministic morphogenetic approach (e.g. Butzer 1972, 1982). Areas of high artefact exposure (Figure 3.1) are targeted using known relationships between geomorphic form, contemporary processes and the recent landscape history previously described (FANNING 1999). Wells (2001) recently developed a similar approach by stratifying the geomorphic landscape according to the relative stability of surfaces.

I also attempted to control for differential visibility by mapping surface condition across the survey area and quantifying the effects of variable surface cover types on artefact density (Figure 3.2). I confirmed the expected relationships between erosional surfaces and high artefact densities, and depositional areas and low artefact densities, but my attempts to precisely quantify these relationships were thwarted by considerable variation at the local level. There is, in fact, dynamic interplay between patterns of artefact visibility as controlled by surface condition and patterns of artefact discard that is very difficult to quantify.

Figure 3.1: Eroding Valley Margin (EVM) geomorphic unit in the Stud 1 study area. Erosion has extended down to the columnar blocky subsoil surface, resulting in maximum artefact exposure. The coloured scale bar is 1 m long.

Figure 3.2: Sandy vegetated hummock on sand/gravel surface in the Stud 2 study area. Microtopographic features and surface condition types like these were surveyed and stored as a separate coverage in the GIS. The scale bar is 1 m long.

Doleman (1992) reached similar conclusions in a study of archaeological materials of the Tularosa Basin in New Mexico, U.S.A. He initially proposed two alternative hypothetical models to explain the relative roles of natural and cultural formation processes in determining the distribution of artefacts on the basin floor. The Holocene Litter Model (HLM) proposes that semi-continuous surface artefact scatters are a product of highly dispersed foraging/extraction activities that result in an archaeological record that is primarily controlled by behavioural processes. In contrast, the Geological Disturbance Model (GDM) proposes that the geomorphic processes of erosion and deposition that formed the modern-day geomorphic features, such as coppice dunes, sandsheets and interdunal deflation areas, have formed aeolian windows, whose placement and size are more or less random. Deflation opens these windows through the aeolian mantle, exposing and concentrating artefacts and other objects too heavy to be carried away by the wind. Because the windows control the exposure of archaeological materials, the GDM proposes that geomorphic processes result in a "highly localised and biased archaeological record" and that the geomorphic processes involved were "…expected to have collapsed and smeared portions of the original archaeological distribution…" (Doleman, 1992: 73). However, analyses of the artefactual data led Doleman (1992: 104) to conclude that "…geomorphic processes…have failed to eradicate behaviourally conditioned spatial patterning in at least some contexts…" In other words, the signature of the original artefact discard behaviour was still recognisable despite the geomorphic influence on differential artefact visibility. As is the case at Stud Creek, no simple relationship between micro-scale geomorphic features and artefact spatial patterning could be found.

In a later study aimed at testing Doleman's models, Buck et al. (1999) measured the linear correlation between artefact density (n/ha) and a range of microtopographic geomorphic variables, including the density of coppice dunes (n/ha), the surface area of the dunes (m^2/ha) and the surface area of the deflation zone or aeolian 'window' (m^2/ha). The aim was to determine whether or not geomorphic processes of deflation affected artefact density. Their results showed no linear relationship between artefact density and dune density, and only a weak positive correlation between artefact density and surface area of the dunes. Of greater importance to the testing of the model was the finding that there was no linear correlation between artefact density and the surface area of aeolian windows. A logistic regression analysis was performed to predict the presence or absence of artefacts in a hectare based on the number of dunes in that hectare. The regression coefficients were statistically significant from zero; however, the coefficients were so small that the prediction function is essentially constant. Thus varying the number of dunes produces no marked trend in the probability of finding an artefact in the hectare. The authors concluded that modern geomorphic features appear to be having no marked effect on the distribution of artefacts at a microtopographic scale. However, other studies by Doleman & Stauber (1992) have shown high correlation between surface artefact densities and landform type at the macrotopographic scale in the Tularosa Basin. Thus, scale is a major factor in both the geomorphic influence and expression of the archaeological record in arid environments (Buck et al. 1999; Linse 1993).

3.2 Lateral Integrity of Surface Artefact Scatters in the Stud Creek Study Area

The artefact survey protocols outlined in FANNING & HOLDAWAY (submitted) target landsurfaces with the greatest potential for exposure of the archaeological record. I have also attempted to accommodate differential artefact visibility at the time of the survey by including assessment of surface cover and quantifying its effects on artefact density. Observer variability in recording artefact attributes is also accounted for by applying corrections for errors statistically determined from double analysing a random sample of the recorded artefacts (Gnaden & Holdaway 2000). Finally, the lateral integrity of the visible scatters included in the survey needs to be established before archaeologists can draw behavioural inferences from the spatial distribution of the recorded artefacts.

Archaeologists have long recognised that artefact assemblages are subject to post-discard modification by both cultural (i.e. human-induced) and natural (i.e. non-human) formation processes (e.g. Schiffer 1983). Indeed, some have argued that all archaeological deposits are modified to some extent, except for those instantaneously captured and preserved by rapid burial – the so-called 'Pompeii Premise' (Binford 1981). Human-induced disturbance includes scuffing, treadage, deliberate burial, scavenging, reuse and recycling. Natural disturbance encompasses the whole range of geological processes from earthquakes and volcanic eruptions to bioturbation by ground-dwelling invertebrates (see Wood & Johnson 1978, Nash & Petraglia 1987, and Stein 2001 for comprehensive reviews).

Studies of natural formation processes have tended to focus on demonstrating disturbance of artefact deposits (e.g. Lancaster 1986; Petraglia & Nash 1987; Reid & Frostick 1985; Rick 1976; Schick 1986; Shackley 1978), rather than on proving lateral integrity (e.g.

Wandsnider 1989). In Australia, many archaeologists bypassed surface scatters of stone artefacts because they were considered to be too disturbed to be of much use in the quest for archaeological indicators of the earliest habitation site. Actualistic studies of artefact taphonomy (after Hiscock 1985, 1990) from open sites are relatively scarce (but see Cameron et al. 1990; Greenwood 1997; Robins 1999). They are also usually limited in scope, in terms of both the area over which disturbance processes are observed and the length of time they are monitored. For example, Cameron et al. (1990) monitored the movement of artefacts out of ten 1 m squares for three years, and Robins (1993, 1999) monitored the appearance/disappearance of stone artefacts in eight 1 m squares also for three years. Process monitoring of this type is usually limited by the duration of PhD research programs and the tenure of research grants, and the chance of capturing rare, catastrophic events is highly unlikely (but see Cameron et al. 1990). Studies of geomorphic processes in the Australian arid zone have shown that trends towards erosion or deposition on a range of surface types can only be detected by monitoring over much longer periods of time, preferably decades (Fanning 1994).

Rather than trying to monitor contemporary artefact disturbance at the Stud Creek study sites, we were more concerned to find out whether or not the effects of disturbance processes that had occurred prior to our artefact survey were detectable and hence might confound any behavioural analysis of the patterns of artefact distribution over the study area. The second of the two papers in this chapter (FANNING AND HOLDAWAY 2001a) presents the results of these investigations. As a consequence of the pilot study previously conducted at the TIB-13 site (HOLDAWAY ET AL. 1998 in Chapter One), we had already controlled for post-discard disturbance effects in two ways. First, we restricted the artefacts recorded in the surveys to those larger than 20 mm maximum dimension (after Schick 1987), and second, we eliminated from the analysis those artefacts that were located in and immediately adjacent to areas of concentrated surface flow, such as rills, gullies and channels (Figure 3.3). The aim of the investigation was to use known relationships between clast length and hydro-geomorphic processes, especially inter-rill overland flow which is the dominant contemporary geomorphic process over the study area, to test whether any evidence of post-discard movement of artefacts by overland flow could be detected in the spatial distributions of the artefacts we had recorded.

The results indicate that, while artefact size and slope angle (a proxy for hydrologic stream power) are statistically significantly related, the variance in maximum dimension explained by gradient is very low. The significant regression result was probably only detectable because of the very large data set used (n = 17,128). We concluded from this result that the spatial distribution of artefacts in the surface scatters we studied is unlikely to have been significantly altered by post-discard hydro-geomorphic processes like inter-rill overland flow. While the surface artefact scatters in the study area are certainly vertically conflated, and thus unlikely to preserve "living floors" in the short-term, functional sense, their apparent lateral integrity means that meaningful associations of artefacts are likely to be detectable. If a temporal framework for the formation of the archaeological record could be constructed, then the artefact scatters present on the surface today could be used by archaeologists to investigate long-term place use by Aboriginal people.

These issues are addressed in Chapter Four.

Figure 3.3: Shallow watercourse traversing the Stud Creek study area. Areas of concentrated water flow like this are eliminated from the survey by marking and surveying a line around the outer boundary. Any artefacts within the gully system are likely to have been laterally displaced from their original discard location and are therefore not included in the survey.

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Stone Artifact Exposure and Visibility at Open Sites in Western New South Wales, Australia: A Geomorphic Framework for Survey and Analysis

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Abstract

Surface visibility is a significant constraint in archaeological survey, and estimates of surface visibility are a common addition to Cultural Resource Management reports. Despite this, relatively few studies have attempted to identify the factors affecting visibility and quantify their effects. We report the results of such a study based on analysis of surface stone artifacts discarded in prehistory by Aboriginal hunter-gatherers from the Stud Creek area in what is now Sturt National Park, western New South Wales, Australia.

While we are able to demonstrate and quantify relationships between high artifact visibility and erosional surfaces, and low visibility and vegetated or depositional surfaces, our findings also indicate a high degree of local variability. This variability sometimes obscures the predicted relationships. The outcomes of the research lead us to question the way some sampling designs for archaeological survey are constructed.

Introduction

Surface scatters of stone artifacts dominate the archaeological record of the Australian Arid Zone and potentially provide a means of understanding landscape use by Aboriginal people in the past. Survey provides the most common approach to this record (e.g. Thorley 2001, Veth 1993), sometimes based on a siteless or distributional approach (e.g. Robins 1997). Archaeologists seek to draw inferences from the correlation between such variables as site type, artifact assemblage composition or artifact density and environmental factors thought to reflect resource availability in the past. From such data, inferences are drawn concerning the operation of settlement systems in the past (e.g. Ross, Donnelly and Wasson 1992, Smith 1996, Veth 1993). These approaches form the backbone of the Australian Cultural Resource Management (CRM) industry where the goal is significance assessment (e.g. Bowdler 1984, Flood 1984, Hiscock and Mitchell 1993, Pearson and Sullivan 1995), frequently as a response to the threat of destruction of the archaeological record through developments such as mining.

As in other regions of the world, the areas over which the archaeological record is dispersed are frequently too great to permit total coverage survey, therefore a variety of survey designs are employed. Techniques used often involve stratified random designs based on a desire to obtain both estimates of the differential distribution of artifacts across a landscape and the population density of artifacts at any one location (e.g. Thorley 2001).

It is not our intention in this paper to describe or critique sampling methods directly since this is a topic that is well covered in the literature. Instead we focus on the processes responsible for differential artifact visibility, since this is a primary determinant, along with human behavior, of the nature of the archaeological record at the time of the survey. We have previously addressed the effects of post depositional artifact movement on the data collected during artifact survey (Fanning and Holdaway 2001a) and of variability introduced by archaeologists as observers (Gnaden and Holdaway 2000). Here, we consider the degree to which geomorphic processes, the nature of the ground surface, and the presence of vegetation obscure or enhance the ability of archaeologists to observe artifacts.

A number of archaeologists have mentioned surface visibility as a significant influence on the results of archaeological survey (e.g. Hughes and Koettig 1989; McDonald et al. 1994; Smith 1991) but have made these comments in relation to surface vegetation. Grass, leaf litter and trees obscure the surface, making it difficult to see the stone artifacts that form the majority of the archaeological record in Australia. However, lack of vegetation does not automatically ensure that artifacts will be uniformly visible. Surface sediments also obscure artifacts through burial and hence act as an important constraint on estimating artifact density at any particular point in space and ultimately the effectiveness of a particular sampling design. Thus, considerations of visibility need to be extended beyond vegetation to consider the effect of different forms of regolith as well as processes that contribute to the ground surface condition.

In this paper we report on a geomorphological framework for archaeological survey and analysis developed for the Western New South Wales Archaeological Program (WNSWAP) in Sturt National Park near Tibooburra, in arid far northwestern New South Wales (NSW), Australia (Figure 1). The method uses standard techniques of geomorphic landscape mapping to target areas of high artifact exposure. An essential component is an understanding of the geomorphic history of the study area, as well as contemporary landforming processes. Incorporated into our survey design is an assessment of surface condition at a number of different spatial and processual scales discussed below. We present the results of a series of investigations on the effect these processes have on artifact surface visibility.

The Study Area

The rangelands of arid Australia cover 70% of the continent and offer a unique opportunity for archaeologists interested in using surface artifact scatters to study landscape use by Aboriginal people in the past (Holdaway, Fanning and Witter 2000). Since vegetation cover is naturally discontinuous under the prevailing dry climatic conditions, the rangelands are characterized by high levels of artifact visibility. Furthermore, the introduction of European pastoralism in the mid nineteenth century led to accelerated erosion of selected parts of the rangelands, which has enhanced artifact exposure, making the western NSW region an ideal location for development of the framework of archaeological investigation outlined in this paper.

The area chosen for initial investigation was the catchment of Stud Creek, located in Sturt National Park in the far northwestern corner of NSW (Figure 1). It is about 30 km^2 in area and underlain by Cretaceous sedimentary rocks dipping gently to the northeast. Silicified units (silcrete) within the sequence form west-facing escarpments and mesas that mark the eastern boundary of the study area. Much of the catchment consists of low-angled slopes mantled with a pavement of silcrete cobbles or 'gibber' (Dury, 1970), while sand patches sometimes abut the base of the west-facing escarpments. The valley floor comprises a relatively thick sequence of alluvial sediments, partially exposed in the walls of the incised channel of Stud Creek. Vegetation cover is sparse, comprising mostly chenopod shrubland, particularly saltbush (e.g. *Atriplex vesicaria*), with occasional trees such as mulga *(Acacia aneura*) scattered across the slopes, and gidgee (*Acacia cambagei*) along the watercourses.

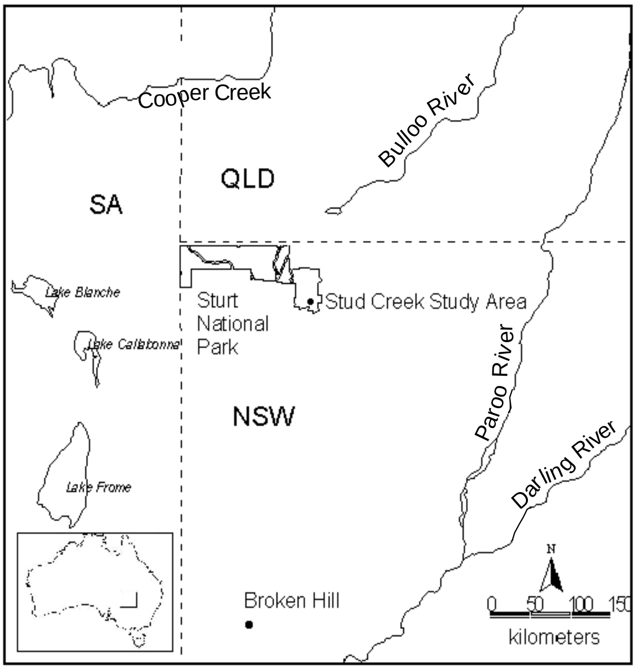

Figure 1: Location of the Stud Creek catchment study area in Sturt National Park, northwestern New South Wales, Australia.

Prior to being incorporated into Sturt National Park in 1972, the area formed part of a pastoral lease for the grazing of sheep and cattle. The introduction of pastoralism in the mid to late nineteenth century led to reduction in vegetation cover and accelerated erosion of topsoil and sediments (Fanning, 1999). Stone artifacts and the remains of heat retainer hearths have been exposed at the surface by this erosion, as the finer topsoil and sediment have been eroded away. The artifacts are mostly located on the valley floor of Stud Creek, adjacent to the contemporary watercourse.

However, while the recent erosional history and the prevailing dry climate means that artifact exposure and visibility is relatively high, it is not complete. Although trees are sparse and mostly restricted to riparian zones, across the rest of the landsurface, low shrubs and grasses grow when and where soil moisture conditions are favorable. As in other areas of Australia, artifacts discarded where the vegetation now grows are obscured. However, contemporary geomorphic processes that have deposited sediments in discrete locations across the landscape, have also acted to cover any artifacts that may be lying on the pre-depositional surface. Animal tracks and various kinds of ant nests are common in the Stud Creek catchment, and indeed across the region. Artifact visibility is therefore also likely to be affected by surface and subsurface faunal activity, through bioturbation and trampling.

Mapping the Geomorphic Landscape to Characterize Differential Artifact Exposure and Visibility

Three aspects of the geomorphic landscape are of particular importance when examining surface scatters of stone artifacts, namely

1. the controls on preservation the archaeological record that are imposed by landscape change over historic, prehistoric and geologic time scales,
2. spatially variable exposure and burial of artefacts due to erosion and/or deposition, and
3. the differential visibility of archaeological materials due to contemporary environmental processes.

These landscape attributes have commonly been grouped under the umbrella of natural (as opposed to cultural) formation processes (e.g. Schiffer 1983, Nash and Petraglia 1987), although this division attempts to separate what are in fact the results of two related sets of processes. In the Australian Arid Zone, for instance, the ‘natural’ erosion that has exposed surface archaeological remains has a ‘cultural’ initiation, resulting from over stocking by pastoralists starting in the late 19^{th} century.

Whether thought of as natural or cultural processes, in our study area geomorphic dynamics are the main determinants of artifact exposure, and hence of the proportion of the archaeological record that is available for study at any one time and place. Geomorphic dynamics are reflected in the nature of the landsurface that results from "time-averaging" (after Stern 1994) of the geomorphic environment, i.e. a landsurface is a palimpsest of a set of individual erosional and depositional events operating at a variety of temporal and spatial scales. Averaged over tens to hundreds (and maybe thousands) of years, different parts of the landscape will exhibit a trend to accumulation of sediment (i.e. dominantly depositional), removal of sediment (i.e. dominantly erosional), or no change (i.e. residual). Maximum exposure of the archaeological record is found in those parts of the landscape that are dominantly erosional, while least exposure is found where deposition of sediments is dominant. Therefore, in a distributional approach to the archaeology of surface artifact scatters (Ebert 1992), stratification of the landscape on the basis of dominant geomorphic process allows archaeologists to target surveys where exposure of the archaeological record (though not necessarily its density) is likely to be at a maximum.

The rationale for stratification adopted here is similar to that employed in more recent Australian studies where geomorphological criteria are used (e.g. McDonald et al. 1994, Robins 1997, Thorley 2001). However, our method improves on these by placing weight on the processes that have lead to the preservation, modification and, at times, destruction of the archaeological record as an initial basis for sampling before behavioral inferences are drawn. To some degree it can be contrasted with approaches that rely on ethnographic models as a source of information on which to base survey sampling strategies (e.g. Veth 1993).

Closely related to the identification of depositional, erosional and residual landforms is the question of the identification of the rate, and chronological scale, over which these landforms evolve. While arid regions may present the appearance of an unchanging landscape, the opposite is in fact the case. In our study area, the stratigraphic record dating back to the late Pleistocene is dominated by erosional unconformities (Fanning and Holdaway 2001b). Regional discontinuity in deposition is the norm, leading to a patchwork distribution of landsurfaces differing substantially in age. Rates of deposition or erosion can vary markedly. Some processes take place over tens to hundreds, or even thousands, of years. Others are literally instantaneous. In the Australian summer of 1999/2000, for example, one rain event denuded an area of approximately 7,000 square meters in one of our study areas covered with artifacts and heat retainer hearths. Both artifact and non-artifact clasts were washed into an adjacent gully. This same rain event left other nearby areas relatively unaffected. Such events occurring in the past would effectively reset the archaeological record by wiping out archaeological evidence at a local level.

Understanding the significance of the 'archaeological document', i.e. the proportion of the available archaeological record that is visible to archaeologists at the time of the survey (Wandsnider and Camilli 1992), therefore requires a detailed study of landscape change, like that undertaken at Stud Creek (Fanning and Holdaway 2001b, Holdaway et al. in press). But equally, the archaeological document is a function of contemporary, local scale environmental processes, including erosion and deposition of sediments, bioturbation, and vegetation growth. Current land use practices are also significant, for example whether or not the surface is ploughed, compacted by machinery, or covered by concrete. While also a time average in the sense previously discussed, the contemporary nature of these processes mean that they reflect different temporal and spatial scales to the longer term landscape dynamics discussed above.

Survey Strategy

Our survey strategy reflects this temporal and spatial variability in geomorphic dynamics, and characterizes the geomorphic landscape at three distinct spatial scales. At the regional level, the sampling and survey methodology makes use of available Land Systems mapping, a form of regional reconnaissance mapping developed by Christian and Stewart (1953) and applied to extensive tracts of Australia (e.g. Story et al., 1976). Land Systems are defined as “an area or group of areas throughout which there is a recurring pattern of topography, soils and vegetation" (Christian and Stewart, 1953). Land Systems represent a synthesis of the natural environment, and provide, amongst other things, a basis for assessment of land capability and for the study of land use problems (Mabbutt et al. 1973). Land Systems are distinguished on the basis of air photo patterns, and their characteristics are identified by ground observations at sample sites chosen from air photos. Their spatial scale is usually of the order of tens to hundreds of square kilometers.

Since Land Systems are primarily defined by their topographic signature, using remotely sensed data (i.e. airborne and satellite imagery), those geomorphic and other environmental processes that affect artifact exposure and visibility are expected to vary more between Land Systems in a particular region than within any one of them. Therefore Land Systems surveys provide a convenient means of assessing which parts of a region are most likely to exhibit maximum artifact exposure.

At the second or meso-scale level, our survey method focuses on the smaller landform units and landform elements that make up Land Systems, as these reflect the operation of geomorphic processes over the contemporary to historic timescales, which are the most appropriate for surface stone artifact survey. Standard aerial photograph interpretation and field survey methods are used to map landform elements and classify them on the basis of dominant geomorphic environment i.e. residual, transportational/eroding, fully lagged or depositional. In this way, the physical landscape is subdivided on the basis of both landform and dominant processes.

The third or micro-scale level within the survey method concentrates on documenting local variability in landsurface condition that reflects the operation of processes with a short time scale of perhaps hours to days. These landsurface conditions affect the archaeological record at the moment of survey. Such processes include local erosion and deposition of sediments, vegetation growth, and bioturbation.

The method we use to integrate these three survey scales involves the use of a vector GIS (ARCINFO/ARCVIEW) (Holdaway, Fanning and Witter 1997). Each of the three survey scales is mapped as separate polygon coverages in the GIS independent of the distribution of artifacts, which is also mapped as a separate coverage. Data tables hold descriptive information on the nature of each of the polygons. This format permits comparison of the interaction of the three survey scales with the distribution of artifacts. In addition, because of the vector format, data acquisition in the field at all three scales can progress independently.

Implementation at Stud Creek

Land Systems maps, at a scale of 1: 250,000, of the whole of the Western Division of NSW, an area of some 32.5 million hectares, are available from the NSW Department of Land and Water Conservation. The Land Systems are grouped on the basis of major landform types, i.e. ranges, tablelands, hillslopes and footslopes; rolling downs and lowlands; alluvial plains, sandplains and dunefields; and playas and basins. The survey area of Stud Creek is contained within the tablelands group, mostly within the Quarry View Land System (Qv), characterized by "stony tablelands with relief to 60 m…escarpments and fringing plains with brown loamy lithosols, moderate mulga, gidgee and belah over bluebush and saltbush" (NSW Soil Conservation Service 1978).

Geomorphic Unit Type	Geomorphic Unit Name and Code	Relative Area	Landform Type	Dominant Process(es)	Expected Artifact Exposure
Residual	Mesa (RM)	Minor	Flat-topped, isolated upland remnant capped with silcrete; bounded by cliffs to 3 m	Cliff retreat via weathering and block fall	High
	Residual Hill (RH)	Minor	Rounded low hills below escarpment mantled with dense stone cover	Surface lowering by slow removal of fines via bioturbation and surface wash	High
Lagged	Tributary Fan (TFL)	Extensive	Eroded surfaces of tributary alluvial fans	Surface wash of fines by overland flow; aeolian deflation	High
	Footslope (FSL)	Moderate	Straight low angled slopes below escarpment mantled with sparse stone cover	Surface wash and aeolian deflation of fines	High
	Valley Floor (VFL)	Extensive	Eroded surfaces of main valley floor mantled with gravel lag	Surface wash and aeolian deflation of fines	High
Eroding	Valley Margin (EVM)	Moderate	Severely eroded distal valley floor margins	Surface wash around domed, hardsetting subsoil surface	High
	Valley Floor (EVF)	Moderate	Actively eroding surfaces of main valley floor	Rilling and gullying	Moderate
	Tributary Fan Channel (TFC)	Minor	Channel traversing tributary fan	Concentrated channel flow	Dispersed
	Channel	Minor	Incised distributary channels on main valley floor	Concentrated channel flow and sediment transport; erosion of banks by undercutting and basal sapping	None
Depositional	Tributary Fan (TFD)	Moderate	Depositional surfaces of tributary alluvial fans	Deposition of fine sediments from surface wash from upslope; aeolian accession	Low
	Footslope (FSD)	Moderate	Concave upwards low angled slopes mantled with sediment	Deposition of fine sediments from surface wash from upslope; aeolian accession	Low
	Valley Floor (VFD)	Moderate	Stable surfaces of main valley floor	Minor aeolian accession of sediments around vegetation	Low

Table 1. Geomorphic Units identified and surveyed in the upper Stud Creek catchment.

Data sets of the upper Stud Creek catchment were constructed largely from intensive field surveys using electronic total stations. The location and extent of artefact sampling surveys are indicated in Figure 2. Several survey base stations were established around the margins of the study area using Australian Map Grid (AMG) co-ordinates with a master station's coordinates captured using a hand-held GPS. The GPS was left in place for several hours before co-ordinates were recorded, in order to maximize the stability of the signals being received and hence reduce location errors. Once the master base station was established, all surveys were locked in to that co-ordinate system, and digitized aerial photographs, which form the backdrop for the survey data, were geo-referenced using those co-ordinates.

Geomorphic features were surveyed at two different scales (i.e. meso- and micro-) to reflect the different spatial and temporal scales discussed above. At the meso scale, twelve geomorphic units were identified, based on spatial location, topography and dominant process i.e. whether they were residual, actively eroding, fully lagged or depositional (Figure 3 and Table 1). Exposure of artifacts was expected to be greatest on lagged and actively eroding landforms, and the least on those where deposition dominates, such as channel margins on the valley floors (Table 1).

Table 2. Artifact densities on different Geomorphic Units in the Stud 1 artifact survey area.

Geomorphic Unit	**Area (m^2)**	**Artifact Number (n)**	**Artifact Density ($n\ m^{-2}$)**
EVM	2328	6992	3.0
TFL	2595	5751	2.2
FSL	3225	4626	1.4
VFL	1043	1250	1.2
TFD	5321	3389	0.6
FSD	2515	1213	0.5
VFD	7430	330	0.04

Artifacts appeared to be concentrated around clusters of heat-retainer hearths on the valley floors and tributary alluvial fans, and were most clearly exposed on the severely eroded parts of these landforms, for example on the eroding valley margin unit (EVM) and lagged surfaces on the valley floor and tributary alluvial fans (VFL and TFL). Artifacts were less visible on the vegetated slopes and depositional areas of the valley floor. This pattern is confirmed by analysis of artifact density in relation to geomorphic unit from one of the sampling locations, Stud 1 (Figure 2 and Table 2). In this table, the Stud 1 geomorphic units are listed in order of exposure potential from maximum (fully lagged surfaces) to minimum (depositional surfaces). There is a clear correlation with artifact density (Spearman's rho = 0.89, n = 7, p = 0.007).

Even where erosion is dominant, however, such as on the EVM and VFL units, there are patches of different surface materials which may influence artifact visibility. As discussed above, survey at the level of micromorphology and ground surface condition addresses the problem of differential artifact visibility across the study area at the time of the survey. Features that obscure the ground surface, and hence reduce artifact visibility, include vegetation, plant litter, the presence of topsoil, and sediments of various kinds, especially sand and mud. Other ground surface features both cover artifacts and promote their vertical and lateral dispersal, such as ant nests and animal tracks. On the other hand, ground surface features that promote artifact visibility include bedrock and eroded or lagged surfaces such as subsoil, stone pavements and some kinds of surface crust. Microtopographic features such as rills concentrate surface water flow and hence promote artifact dispersal (Holdaway et al. 1998). Factors that determine the distribution of microtopographic features and ground surface condition within a given area include the operation of contemporary geomorphic processes, local regolith geology, animal behavior, weather and climate, and land use practice. A second (micro-) level of landsurface unit surveying (labeled 'surface condition') was therefore conducted on two portions of the eroding valley margin (EVM) geomorphic unit in the upper Stud Creek catchment. A map of one of these, in the Stud 2 artefact survey area, is shown in Figure 4. As indicated in Table 3, artifact visibility is expected to vary systematically with surface type.

Since artifacts were individually recorded by piece proveniencing over both areas, the relationship between artifact density and ground surface condition could be analyzed. In Table 4, surface condition on the EVM geomorphic unit at Stud 1 and Stud 2 has been listed in order of artifact visibility potential, from highest to lowest. At both Stud 1 and Stud 2, artifact density is positively correlated with surface condition, although this correlation is significant only at Stud 2 (Spearman's rho at Stud 1 = 0.9, n=4, p = 0.14; Spearman's rho at Stud 2 = 0.9, n = 5, p = 0.04).

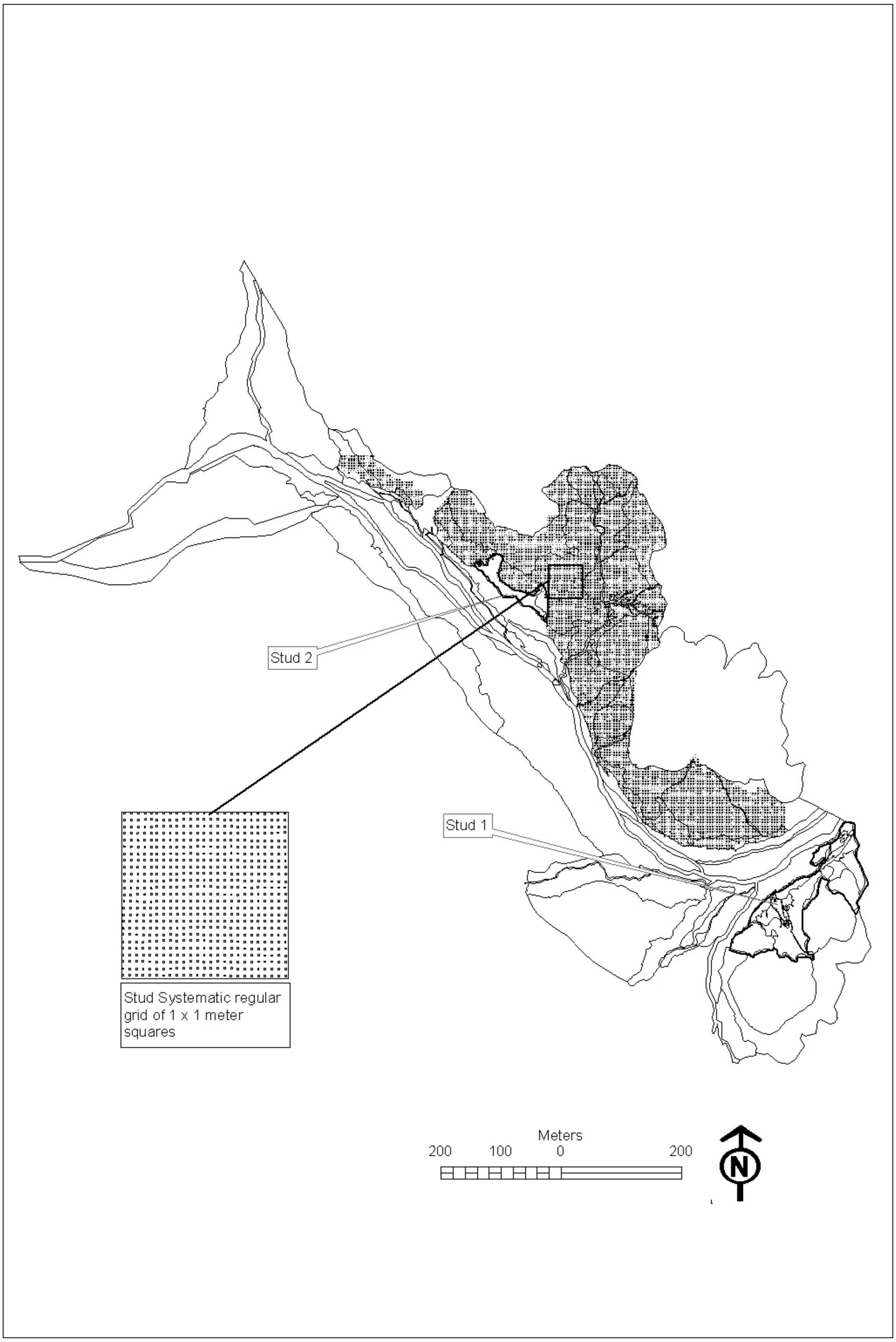

Figure 2: Location of artefact survey areas in the upper Stud Creek catchment.

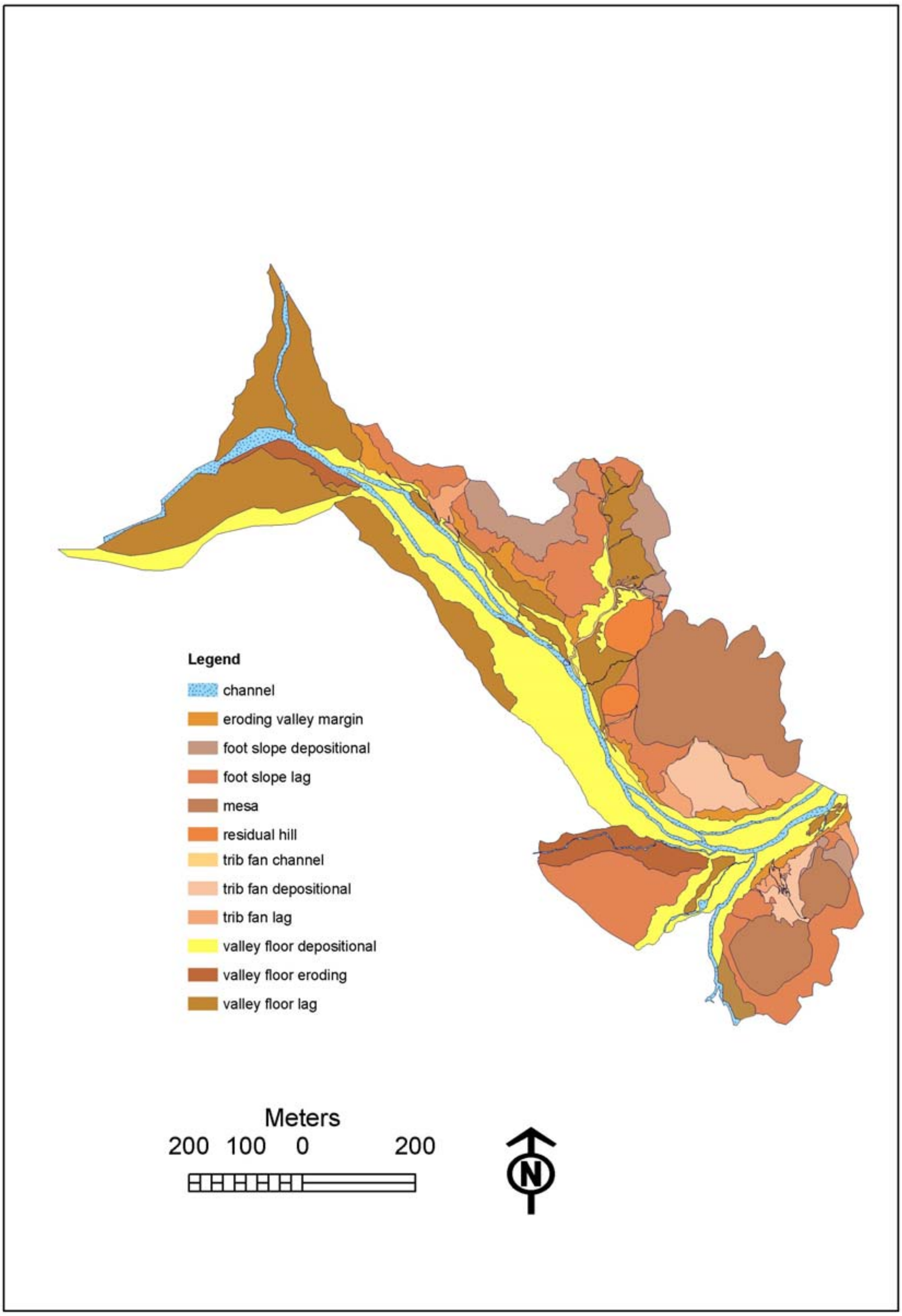

Figure 3: Map of the main valley of the upper Stud Creek catchment, showing the distribution of geomorphic units.

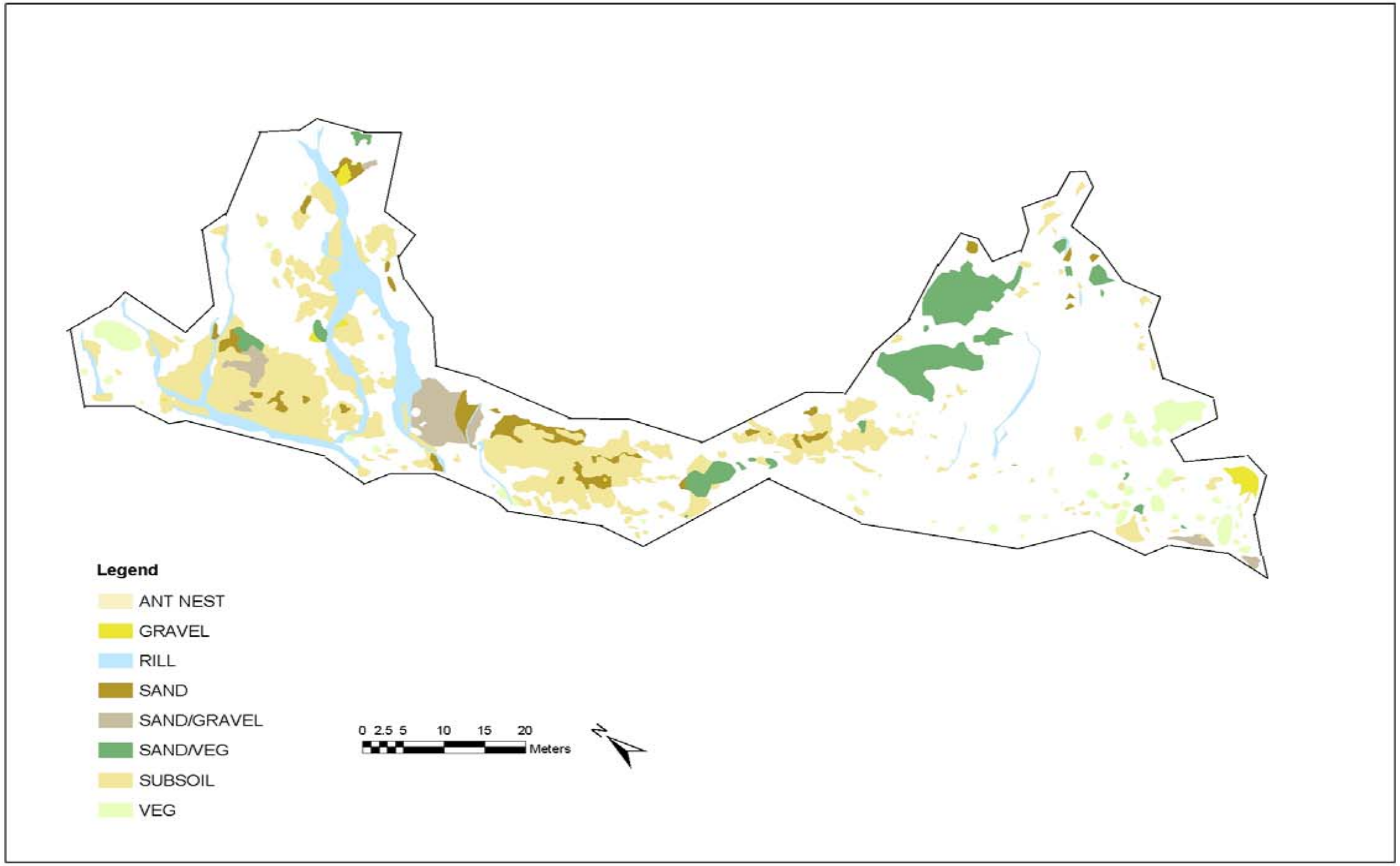

Figure 4: Stud 2 artefact survey location, showing distribution of microtopographic features and surface condition types.

Surface Condition Type	Relative Area	Characteristics	Expected Artifact Visibility
Subsoil	Moderate	Subsoil exposed by erosion	High
Gravel	Moderate	Stony (gibber) pavement	High
Sand/gravel	Extensive	Mixed sand and gravel on lagging surface	Moderate
Sand	Moderate	Medium sediment deposition	Low
Mud	Minor	Fine sediment (silt and clay) deposition	Low
Sand/vegetation	Moderate	Medium sediment deposition around the base of shrubs	Low
Vegetation	Minor	Grasses &/or shrubs often growing out of sediment mounds	Low
Antnest	Minor	Circular sediment mounds, to 5 cm high and to 50 cm diameter, surrounding nest entrance	Low
Rill	Minor	Linear concentrated flow channels across surface	Dispersed

Table 3. Surface condition types and microtopographic features in the Stud 1 and Stud 2 artifact survey areas.

Survey Area	Surface Condition Type	Area (m^2)	Artifact Number (n)	Mean Density ($n\ m^{-2}$)
Stud 1	Gravel	366.56	1725	4.71
	Sand/gravel	338.80	1775	5.24
	Sand	248.29	548	2.21
	Mud	19.99	39	1.95
Stud 2	Gravel	16.45	178	10.82
	Subsoil	560.96	4111	7.33
	Sand/gravel	73.92	441	5.97
	Sand	70.50	344	4.88
	Vegetation	75.13	26	0.35

Table 4. Artifact densities on different surface condition types in the Stud 1 and Stud 2 artifact survey areas.

Accommodating Differential Artifact Discard Behavior

In the Stud Creek catchment, measured artefact densities confirm the expected relationships between the nature of the land surface, as characterized by landform unit, and the degree of exposure of artifacts lying on that surface (Table 2). Similarly, at the micro-scale level, there is a high level of correlation of surface condition type and the density of artifacts visible on those surfaces (Table 4). However, we would like to be able to use these data to develop a quantitative predictive relationship between artifact density and surface condition, such that if the proportion of surface cover types in a survey area is known then a quantitative estimate of the true artifact density, including those obscured from view, can be made. Unfortunately, this is much more difficult to achieve primarily because the influence of human discard behavior on the distribution of artifacts across the land surface needs to be taken into account.

Artifact discard in the past reflects a variety of behavioral activities; sometimes related to artifact function but including such other activities such as caching, refuse disposal, and abandonment (Wandsnider 1996). The result is a clustered, rather than even or random, dispersal of artifacts across the landscape. Assuming equal visibility, areas with few or no artifacts are interspersed with areas with very high artifact counts as a result of variability in the pattern of artifact discard. Thus, a method is needed for correcting for differential visibility that is sensitive to the underlying pattern of differential artifact distribution.

A further complication arises out of our inability to use excavation as a method of comparison of artifacts visible at the surface at the time of the survey with the available archaeological record (surface and sub-surface artifacts). One of the goals of the WNSWAP research in Sturt National Park was to develop a set of techniques for dealing with surface artifact scatters that did not require excavation. Permission to undertake this work was only given by the Aboriginal traditional owners and the NSW National Parks and Wildlife Service, who manage the national park, on the proviso that no disturbances to the archaeological record, through excavation, take place. Thus, we were unable to compare our estimates of artifact density based on the differential visibility factor with the complete record of surface and subsurface artifacts.

One way to overcome these limitations is to limit the spatial sample over which comparison is made to a small subset of the total area, on the assumption that differential artifact abandonment as a result of human behavior is unlikely to systematically occur over small areas. Small samples can be generated in ARCINFO by using the buffering function, where forming a band a fixed distance either side of a line creates a polygon. In this case, defining a region 2 m to either side of the boundary lines separating adjacent geomorphic unit polygons created a buffer. The area represented by the 2 m buffer in each polygon was then calculated and the INTERSECT function of the ARCINFO software was used to determine how many artifacts rested on each buffer. From these data, relative change in artifact density when moving from one geomorphic unit to the next can be calculated. The results are displayed in Figure 5. There is a significant linear relationship between depositional and lagged surfaces ($r^2 = 0.54$, $F= 8.15$, $p = 0.025$) and, as will be shown below, this relationship could be used to predict the influence of differential visibility on changes in artifact density across the upper Stud Creek catchment as a whole.

A similar buffering technique was employed to compare the artifact density of individual surface condition polygons with the density in an area defined by a buffer with a 0.5 m radius from these polygons. The 0.5 m radii reflected the small size of some of the polygons and the desire to limit the area over which comparisons were made so that differential discard behavior could be readily discounted. Where multiple polygons intersected the 0.5 m buffers the CLIP function in ARCINFO was used to remove intersecting areas of the 0.5 m buffer.

At the Stud 2 sampling location the Eroding Valley Margin (EVM) geomorphic unit contains substantial areas of subsoil. On average, the presence of subsoil increases the density of artifacts by 1.73 ± 2.62 artifacts per square meter. As shown in Figure 6, the relationship between the 0.5m buffer artifact density and the subsoil polygon artifact density is linear ($r^2 = 0.77$, $F= 76.67$ $p < 0.001$).

For sand, the next most frequent Stud 2 surface condition type, the change is more dramatic with a mean decrease in density of 7.12 ± 4.91 artifacts per square meter when moving from the 0.5 m buffer to the sand polygon. However, the mean value exhibits considerable variability and a plot of the density values for buffer and polygon does not reflect the clear linear relationship seen for subsoil (Figure 7).

Other surface cover types are rare at Stud 2. For gravel, density increases by 8.48 ± 3.08 artifacts per square meter but there are only two areas of gravel at Stud 2 surrounded by eroding valley margin (EVM). For the combination of sand and gravel, there is a decrease of 2.78 ± 4.56 artifacts per square meter (n = 2), while for sand and vegetation, the mean decrease is 2.86 ± 2.25 artifacts per square meter (n = 4).

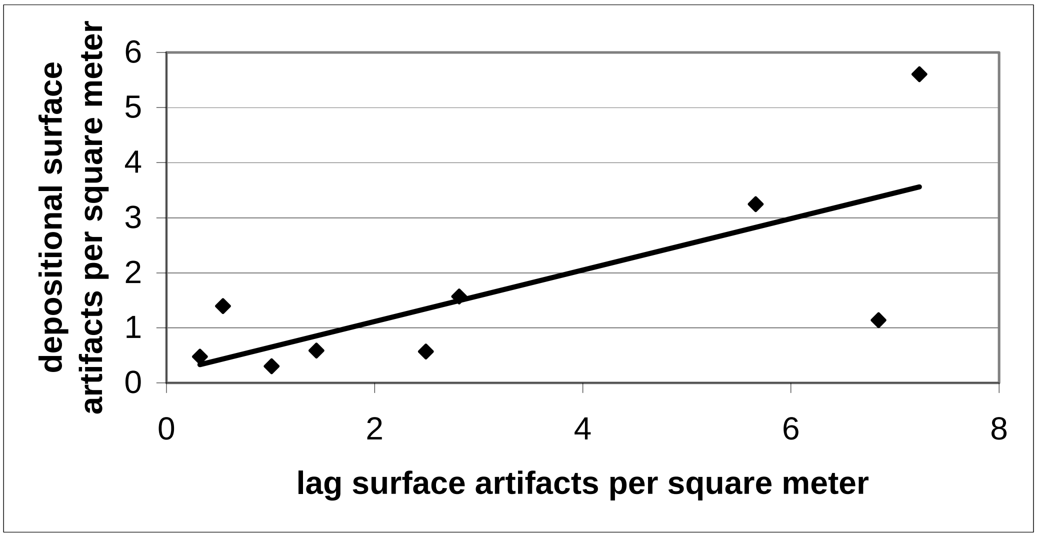

Figure 5. Relationship between densities of artifacts on lagged surfaces compared with densities of artifacts on depositional surfaces at the Stud 1 artifact survey location. The regression line (r^2=0.54, p=0.025) indicates a significant linear increase in density when moving from depositional to lagged surfaces.

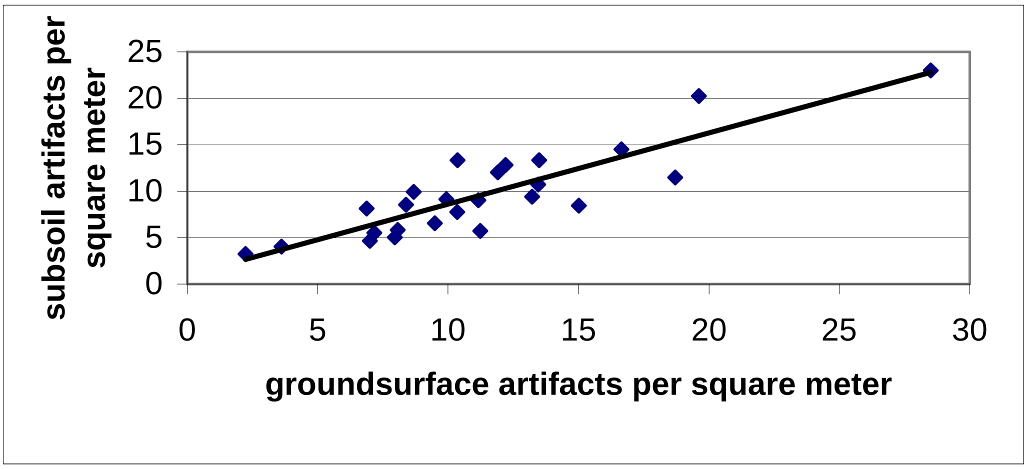

Figure 6. Statistically significant relationship between artifact density on subsoil and on adjacent ground surface in the Stud 2 artifact survey location (r^2=0.77, p<0.001).

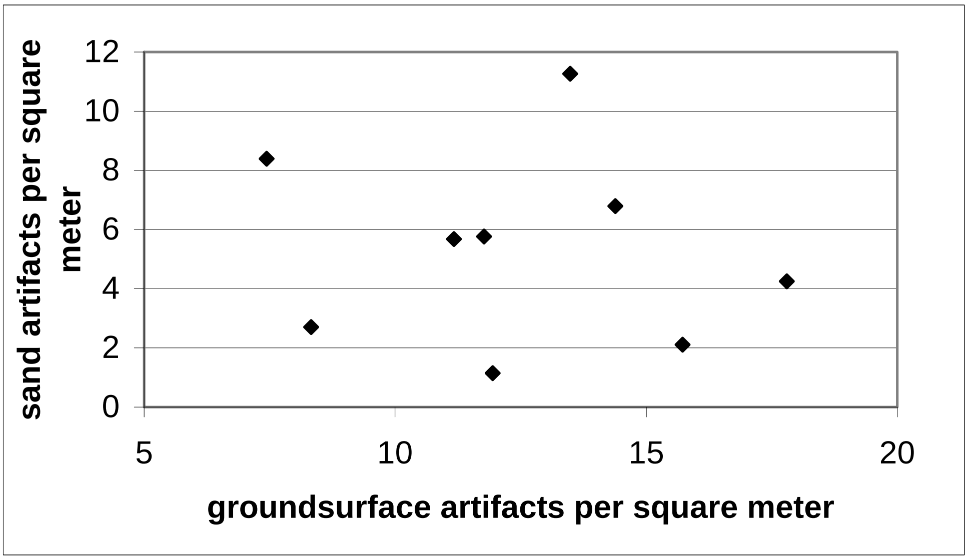

Figure 7. Non-significant relationship between artifact density on sand and on adjacent ground surface in the Stud 2 artifact survey location.

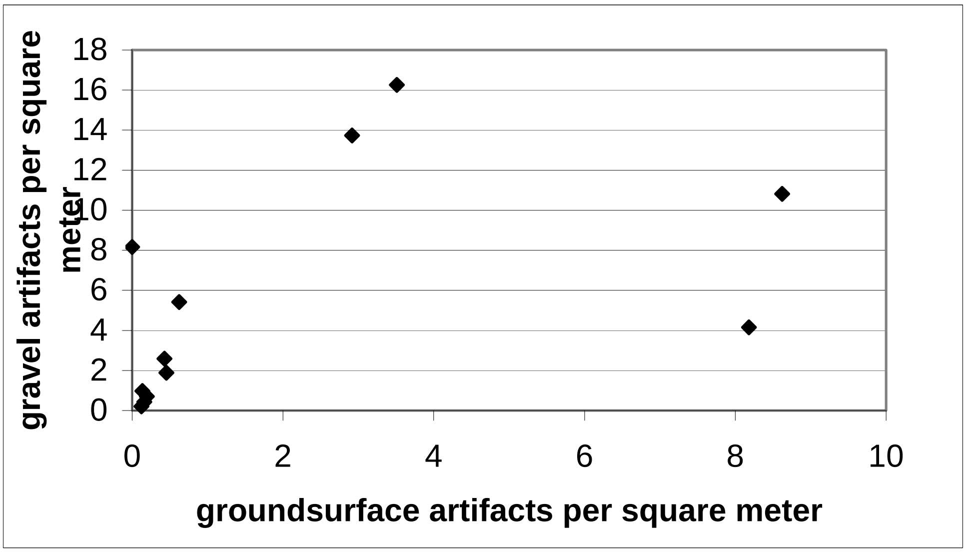

Figure 8. Relationship between artifact density on gravel and on adjacent ground surface at the Stud 1 artifact survey location. Note the two squares with high artifact densities (n = 14 and n = 16 per m^2) that strongly influence the regression equation.

At the Stud 1 sampling location subsoil is much less common. There are, however, several gravel polygons that show a mean increase in artifact density of 3.33 ± 4.91 artifacts per square meter. The high standard deviation reflects the presence of two polygons with high densities of artifacts in the 0.5m buffer (Figure 8). If these polygons are removed, the r^2 increases from 0.23 to 0.81. Sand/gravel also shows an increase in artifact density but the change (1.60 ± 3.10) is smaller and more variable than for gravel and is not linear.

In summary, it appears that, when differential discard behavior is controlled for, the relationships between surface condition and artifact visibility, as measured by mean density, are not so straightforward. Gravel and subsoil both show a positive linear relationship between the density of artifacts within the surface condition polygon and the area immediately adjacent to it. No simple linear relationship exists for the other surface types present in the Stud 1 and 2 sample areas. Sand and vegetation have a variable, but generally negative, effect on artifact density, although the number of cases is very small. Where sand and gravel or sand and vegetation are found together, moving from the lagged eroding valley margin surface onto the surface condition polygon results in a highly variable change in artifact density.

Towards a Survey Protocol for Accommodating Differential Artifact Visibility

The combination of recording by piece proveniencing and a GIS permitted a detailed assessment of differential visibility for the Stud 1 and Stud 2 sampling locations, but the techniques are not practical for survey across large areas. There is no single, widely accepted approach to assessing site or artifact visibility in the archaeological literature, although it is almost universally recognized as an important determinant of the available archaeological record. Surveyors might include estimates of vegetation cover or density, but often only for descriptive purposes (e.g. DuCros 1990, Seaman et al. 1988, Smith 1991). A more detailed approach to assessing "site" visibility was adopted by Dallas et al. (1995) for an archaeological survey of a proposed power line in far western NSW, Australia, 30 km from our study area, which included cover proportion estimates for various surface types. However there was no attempt to quantitatively relate the cover proportion estimates to the surface artifact visibility estimates. Thorley (1998) attempted a quantitative analysis, but was hampered by the relatively low number of recovered artifacts (420 over a surveyed area of 60,000 square meters). The methods used in Australia for site visibility assessment generally lack the quantitative basis required for realistic estimates of true artefact density.

Therefore, we sought an alternative set of methods that could be applied as part of a sampling strategy employed to study the distribution of artifacts across relatively large areas.

At Stud Creek we adopted a method of quantifying surface condition based on an assessment of cover. In vegetation ecology, crown cover is the most commonly used measure of cover. This is the proportion of a known area within the vertical projection of the periphery of the foliage canopy or crowns. It is visually assessed against standard projections to the nearest 10% (McDonald et al. 1990). For the assessment of surface condition, we have adapted this technique in a similar way to that suggested by McDonald et al. (1990) for determination of the abundance of coarse fragments on the land surface. A visual estimate is made of the proportion of a known area containing or covered by each surface type present in that area, to the nearest 10%. Since cover is two-dimensional, the cover types must not overlap and the total of the percentages of cover types must not exceed 100%. However, this necessitates some special treatment of the data generated, as discussed below. Surface condition assessment is made at the same time as artifact survey.

We laid out a systematic grid of 1m x 1m squares oriented north-south and east-west (Figure 2), and recorded all artifacts in every fifth square. This resulted in 7259 squares being included in the database, a 6% sample of a total area in excess of 120,000 m^2. A 6% sampling fraction was selected based on the standard error for the number of tula adzes (Holdaway and Stern, in press) from Stud 1 where all visible artifacts over 20 mm in length were analyzed. The tula was selected for this calculation because it was a relatively rare, yet distinctive, tool type. The 6% sample permitted estimates of the true number of tula at Stud 1 plus or minus 50%. While this error range may seem high, a 6% sample gives estimates of rare types like tula that are of the same order of magnitude as the true number. Estimates of the true number of more common forms are therefore likely to be much more accurate. A systematic, rather than random, sample was applied since the interest was in discovering regions of artifact concentration. Following Wandsnider (1998), the spacing of 1 m squares permits the identification of artifact clusters separated by at least 12 m (i.e. more than 2.5 times the spacing between the squares).

Artifact attributes and surface condition assessment were recorded into palmtop computers in the field using data entry software (McPherron and Holdaway, 1996, 1999) and transferred each night to a relational database and ARCINFO. A unique number assigned to each surveyed square provided a relational link between artifact attributes, surface condition and the count of artifacts in each square. A series of technological and typological variables were described for each artifact, including size measurements (Holdaway, Fanning and Witter 2000). The maximum dimension (a-axis length) of each artifact was measured with calipers to the nearest millimeter. Artifacts shorter than 20 mm were disregarded in order to eliminate the effects of fluvial reworking (Fanning and Holdaway 2001a). Surface condition categories recorded included material types (gravel, sand, mud, topsoil, subsoil, and bedrock), surface crust, vegetation, ant nests, animal tracks and dead wood or fallen timber. Since the method involves subjective assessment of cover percent, maximum consistency was achieved by using just one operator to assess surface condition for the whole of the survey area. Finally, digital images of each square were taken and stored in the database.

Data Analysis: How Mean Artifact Counts Vary With Surface Condition

Using SPSS v.10, mean artefact densities were calculated for squares characterized by increasing proportions of each cover type over 50%, and where there was at least one artefact present. For example, the mean artefact densities for all squares exhibiting 50% gravel, 60% gravel, 70% gravel, 80% gravel, 90% gravel and 100% gravel were calculated. The process was repeated for the other cover types. Figures 9 and 10 summarize the results of these analyses. The two figures separate surface types that show markedly different patterns in the density of artifacts as the proportion of each surface cover increases from 50% to 100%. For crust, sand, and vegetation, there is a significant negative linear relationship between the proportion of the square covered and the density of artifacts (Figure 9). For gravel, subsoil and sand/gravel the plots are bi or even tri-modal (Figure 10). Third order polynomials are needed to bring the r^2 values above 50%.

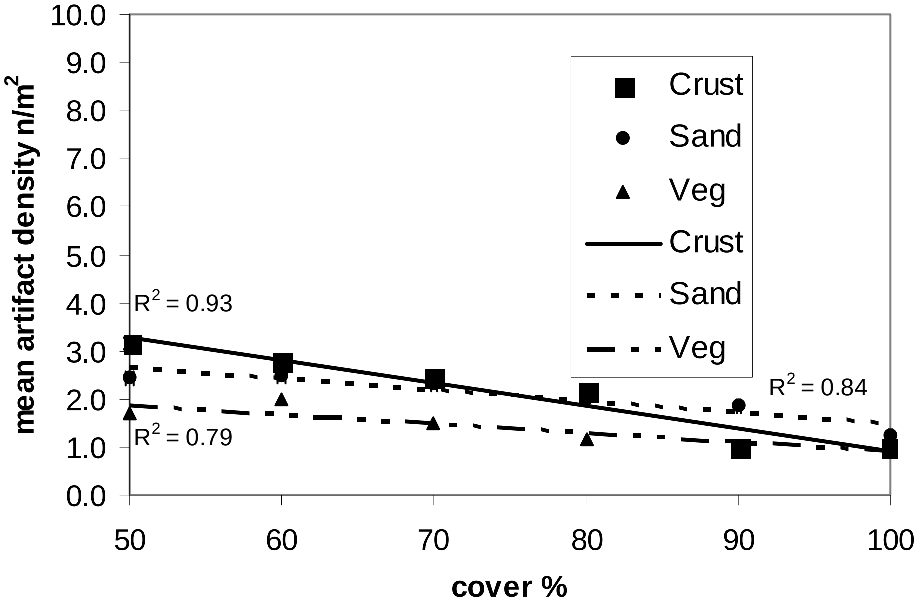

Figure 9. Mean artifact densities for squares characterized by increasing proportions of crust, sand and vegetation (veg) where cover is over 50%, and where there is at least one artefact present. Linear least square regression lines have been added to emphasize the relatively uniform decline in mean artefact count as cover proportion increases.

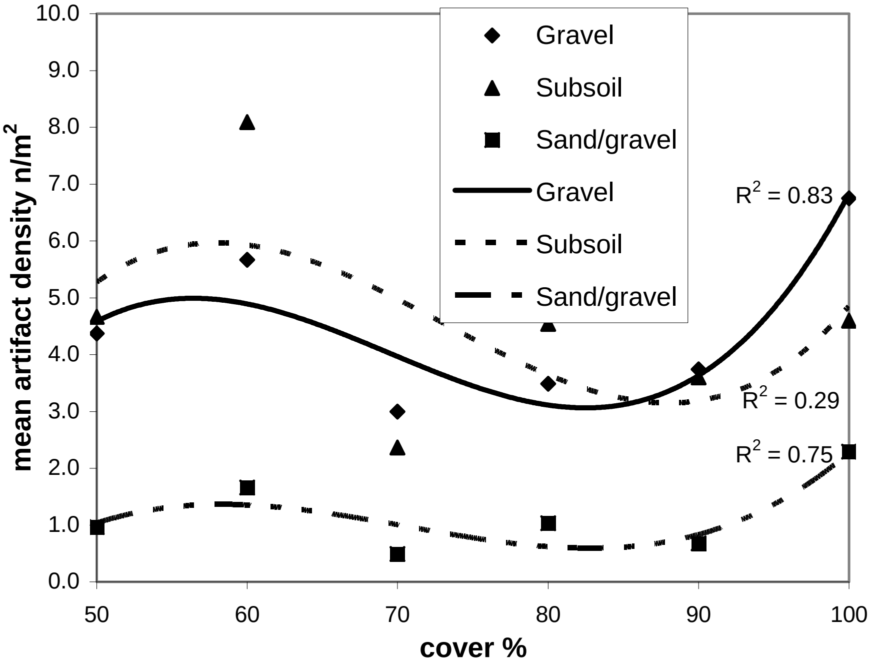

Figure 10. Mean artifact densities for squares characterized by increasing proportions of gravel, subsoil and sand/gravel where cover is over 50%, and where there is at least one artifact present. Third order polynomial lines have been added to emphasize the variable change in mean artifact count as cover proportion increases.

The non-linear pattern for gravel appears to partially reflect the presence of other low visibility cover types that gravel is most often coupled with, such as vegetation or sand. This was confirmed by examination of various combinations of cover types. For example, in 18 of the 19 squares where gravel cover was 90%, it was found in combination with sand or vegetation, both low visibility surface condition types. Similarly, of the 35 squares where gravel cover was 80%, 28 were in combination with sand, thus reducing the artifact visibility as measured by mean artifact density.

Squares dominated by subsoil are relatively few in number, and in most of them, subsoil is found in combination with sand/gravel, with mean artifact densities varying from 1.43 to 5.09. Sand/gravel is most often found in combination with sand and vegetation, with corresponding low mean artifact densities. High mean densities, around five artifacts per square meter, are found when sand/gravel occurs in combination with gravel, and up to seven in combination with bedrock.

Very limited outcrops of bedrock occurred throughout the study area, and there were very few squares with more than 40% cover of bedrock. Nevertheless, mean artifact densities for squares containing bedrock were generally high, probably reflecting the combination of bedrock with other high visibility cover types, like gravel and subsoil.

The variability, or lack thereof, illustrated in Figures 9 and 10 is also apparent if artifact density and proportion of surface cover are related to the geomorphic unit on which the meter squares rest. All squares were located in the field by a single coordinate in the southwest corner obtained with a total station. These coordinates were converted to a point coverage in the GIS and, using the INTERSECT function of ARCINFO, the geomorphic unit on which the squares fall was determined. Results are presented in Table 5.

Table 5. Mean artifact densities (nm^{-2}) for different surface condition types on different geomorphic units in the upper Stud Creek catchment. Geomorphic unit codes are described in Table 1.

Geomorphic Unit	Subsoil	Gravel	Sand/gravel	Sand	Vegetation
RH	None	1.544 ± 1.07	None	1.34 ± 0.60	None
FSL	9.57 ± 7.41	4.531 ± 3.81	4.66 ± 4.84	2.58 ± 2.83	1.6 ± 0.69
VFL	2.13 ± 1.13	None	2.30 ± 2.14	1.71 ± 1.24	1.33 ± 0.58
FSD	None	2.00 ± 1.58	3.05 ± 3.08	1.82 ± 1.65	1.54 ± 1.0
TFD	3.0 ± 0	3.80 ± 3.11	2.66 ± 2.38	2.15 ± 1.83	1.0 ± 0
VFD	None	2.0 ± 0	1.64 ± 0.91	1.57 ± 1.50	1.0 ± 0

All surface types show some variation in artifact density with geomorphic unit, but the variability is highest for subsoil, gravel and sand/gravel. Sand and vegetation show densities that are uniform. Maps of the distribution of the squares help to explain the variability. Squares with sand and vegetation proportions greater than or equal to 50% are distributed in a relatively even manner across the upper Stud Creek catchment. This is not the case for the other surface types. Squares with greater than 50% subsoil are limited to small areas of EVM and VFL. Squares with high proportions of sand/gravel occur differentially on two areas of FSL. Finally, squares with high proportions of gravel are distributed in a complex manner. High proportions of gravel on the residual hill (RH) geomorphic unit show low densities of artifacts, while those on foot slope lag (FSL), particularly the region to the east of the Stud 2 survey location, show high densities of artifacts. Squares located on FSD have intermediate density values. This most likely reflects the fact that stone artifacts were discarded in prehistory in some places in the physical landscape and not in others. The lower footslopes, tributary fans and valley floors were favored locations for the construction of heat retainer hearths, so erosion processes which have exposed subsoil and gravel in these areas are also exposing clusters of discarded artifacts.

In summary, analysis of surface condition on meter squares across a substantial area of the upper Stud Creek catchment indicates variable artifact visibility effects. While there is a consistent decrease in mean artifact density as the proportion of sand and vegetation in the sample squares increases, there is no similar consistent pattern with the other surface condition types encountered in the upper Stud Creek valley. This is because surface cover types like gravel, subsoil and sand/gravel reflect exposure of the original discard pattern via erosion as well as the interaction of surface cover and geomorphic unit. Where samples are relatively small and clustered, as is the case for coarse-grained sediments (gravel, sand/gravel) and subsoil, the result is a complex non-linear pattern. On the other hand, fine-grained sediments (sand, mud) and vegetation obscure the original artifact discard pattern and, if large enough samples over a diverse array of geomorphic units can be obtained, the predicted linear (in these cases inverse) relationship between mean artifact density and visibility (increased cover percent) is apparent.

Discussion

At the beginning of our study we predicted that erosional landforms in the Stud Creek study area (i.e. EVM, FSL, TFL and VFL – Figure 2 and Table 1) would show the highest artifact exposure. The lowest levels of artifact exposure were predicted to occur on depositional landforms (FSD, TFD and VFD – Figure 2 and Table 1). We also expected that gravel and subsoil land surface condition types would promote artifact visibility while sand and vegetation would reduce the number of artifacts observable.

In general these predictions are born out (Tables 2 and 4), but the data are complicated by the differential use of space by people in the past. Despite use of the buffering technique in our analysis to reduce the influence of differential artifact disposal, density changes when moving from lagged to depositional surfaces are variable, although still linear. Greater changes are seen for the smaller surface condition polygons. The general direction of predictions is maintained but on a case-by-case basis there is a great deal of variability, sometimes obscuring the predicted linear relationships.

These results have implications for many of the survey techniques commonly used in Australia and elsewhere. Archaeologists often use narrow transects to sample long linear distances when survey regions are large, or, in the Cultural Resource Management industry, when the development leading to site destruction occurs in a linear form (e.g. pipeline surveys). While our study was not designed to test such survey strategies, our results indicate that differences in artifact visibility caused by relatively localized changes in surface conditions are significant. Even with extensive surveys like ours at Stud Creek, it is difficult to obtain quantitative relationships that would allow the development of a correction factor for differential artifact visibility. This problem is likely to be compounded when samples are taken as long narrow transects. While transects aim to obtain long, linear samples to investigate change in artifact form and density across large regions, the results are dependent on local conditions. As Thorley (1998) remarked on the results of his survey in northern Australia, half the artifacts discovered were found in only 8% of the survey area, a finding largely reflecting differential surface visibility. Despite the desire to sample at a macro scale by using transects, our results suggest that considerable variability will be encountered as a result of changing local conditions. Thus, in some cases, ‘regional level’ differences identified by transect sampling may reflect nothing more than differing local surface conditions between sampling units. Clearly, it is desirable to study the nature of local level variability before assessments of regional significance are made.

Our initial findings based on total artifact provenience (that is, for pieces greater than 20mm in maximum dimension) prompted us to look for a technique that could be applied to the survey of larger areas where piece provenience is impractical. Our solution, the application of surface cover estimates as used in plant ecology surveys, seems feasible in a variety of situations, but our results again emphasize the need for very large samples before interpretations are made. Where sediment and vegetation obscure artifact visibility, we found a linear decrease in artifact density in line with our initial predictions. However, this result may reflect the wide distribution of squares dominated by sand/gravel, sand or vegetation across the upper Stud Creek valley, and their occurrence on a variety of geomorphic unit surfaces. Where the distribution of sampling squares is clustered on separate geomorphic unit surfaces, as is true for gravel and subsoil, the change in density with increasing proportion cover becomes much more complex and is particularly affected by the presence of small areas of depositional materials in sample squares.

This also has implications for survey designs. As noted above, density profiles along transects may be difficult to interpret. The same may be true of density estimates based on sampling units from stratified random designs that seek to correlate artifact disposal patterns with broad environmental zones. While we do not doubt that such correlations exist in many regions, demonstrating the nature of this correlation needs to take into account the difference in artifact density generated by a number of factors operating at different spatial scales. The results from Stud Creek suggest that when large enough samples are taken from one relatively small valley, the predicted relationships hold true. However, smaller samples may be problematic given the level of variability we encountered. We are reluctant to apply our results more generally without additional research. The results of our study suggest that quantifying differential artifact visibility is complex. However, if reproducible, the results from Stud Creek have implications for the Cultural Resource Management industry, where surface assessment of artifact density is a regular practice. We suggest that considerably more effort may be needed to estimate true artifact density where exposure is poor.

Conclusions

Surface visibility has long been recognized as an important factor in assessments of artifact distribution and density. In Australia, where surface artifact scatters dominate the archaeological record, visibility assessment is a regular feature of CRM reports. Increasingly, concerns over visibility as well as other processes that affect the ability to detect a record of past human habitation, have led to the adoption of a geomorphological basis for archaeological survey design. However, despite this approach, there are few instances where artifact visibility is the subject of systematic study.

By considering artifact visibility in the Stud Creek artifact survey area, we are able to demonstrate that erosional surfaces have the highest levels of artifact exposure while artifacts are hardest to find on depositional surfaces. However, our attempts to precisely quantify these relationships reveal that at a local level, there is considerable variation, so much so that at times the predicted relationships between surface condition and visibility are obscured. For the archaeologist interested in studying landscape level relationships in order to reveal the nature of prehistoric settlement patterns, the variability introduced by local differences in visibility needs to be taken into account. Although regional differences in artifact abundance are a common source for behavioral inferences in archaeology, our findings suggest that at times local variation in artifact visibility will obscure these differences or, indeed, create them. Either way, behavioral inferences may be compromised. As Wobst (1983) commented a number of years ago, our ability to understand the past is only as good as our ability to understand the sources of variability that configure the archaeological record.

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